UNITED STATES DEPARTMENT OF COMMERCE
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P.O. Box 1450
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APPLICATION NO.	ISSUE DATE	PATENT NO.	ATTORNEY DOCKET NO.	CONFIRMATION NO.
16/526,281	09/22/2020	RE48221	0079124-000266	9657

21839 7590 09/02/2020

BUCHANAN, INGERSOLL & ROONEY PC
POST OFFICE BOX 1404
ALEXANDRIA, VA 22313-1404

ISSUE NOTIFICATION

The projected patent number and issue date are specified above.

Determination of Patent Term Extension or Adjustment under 35 U.S.C. 154 (b)

A reissue patent is for "the unexpired part of the term of the original patent." See 35 U.S.C. 251. Accordingly, the above-identified reissue application is not eligible for Patent Term Extension or Adjustment under 35 U.S.C. 154(b).

Any questions regarding the Patent Term Extension or Adjustment determination should be directed to the Office of Patent Legal Administration at (571)-272-7702. Questions relating to issue and publication fee payments should be directed to the Application Assistance Unit (AAU) of the Office of Data Management (ODM) at (571)-272-4200.

APPLICANT(s) (Please see PAIR WEB site http://pair.uspto.gov for additional applicants):

Henrik ÖJELUND, Lyngby, DENMARK;
3Shape A/S, Copenhagen K, DENMARK, Assignee (with 37 CFR 1.172 Interest);
David FISCHER, Stenløse, DENMARK;
Karl-Josef HOLLENBECK, København Ø, DENMARK;

PART B - FEE(S) TRANSMITTAL

Complete and send this form, together with applicable fee(s), by mail or fax, or via EFS-Web.

By mail, send to: Mail Stop ISSUE FEE
Commissioner for Patents
P.O. Box 1450
Alexandria, Virginia 22313-1450

By fax, send to: (571)-273-2885

INSTRUCTIONS: This form should be used for transmitting the ISSUE FEE and PUBLICATION FEE (if required). Blocks 1 through 5 should be completed where appropriate. All further correspondence including the Patent, advance orders and notification of maintenance fees will be mailed to the current correspondence address as indicated unless corrected below or directed otherwise in Block 1, by (a) specifying a new correspondence address; and/or (b) indicating a separate "FEE ADDRESS" for maintenance fee notifications.

CURRENT CORRESPONDENCE ADDRESS (Note: Use Block 1 for any change of address)

21839 7590 05/11/2020
BUCHANAN, INGERSOLL & ROONEY PC
POST OFFICE BOX 1404
ALEXANDRIA, VA 22313-1404

Note: A certificate of mailing can only be used for domestic mailings of the Fee(s) Transmittal. This certificate cannot be used for any other accompanying papers. Each additional paper, such as an assignment or formal drawing, must have its own certificate of mailing or transmission.

Certificate of Mailing or Transmission

I hereby certify that this Fee(s) Transmittal is being deposited with the United States Postal Service with sufficient postage for first class mail in an envelope addressed to the Mail Stop ISSUE FEE address above, or being transmitted to the USPTO via EFS-Web or by facsimile to (571) 273-2885, on the date below.

(Typed or printed name)

(Signature)

(Date)

APPLICATION NO.	FILING DATE	FIRST NAMED INVENTOR	ATTORNEY DOCKET NO.	CONFIRMATION NO.
16/526,281	07/30/2019	Henrik ÖJELUND	0079124-000266	9657

TITLE OF INVENTION: SYSTEM WITH 3D USER INTERFACE INTEGRATION

APPLN. TYPE	ENTITY STATUS	ISSUE FEE DUE	PUBLICATION FEE DUE	PREV. PAID ISSUE FEE	TOTAL FEE(S) DUE	DATE DUE
nonprovisional	UNDISCOUNTED	$1000	$0.00	$0.00	$1000	08/11/2020

EXAMINER	ART UNIT	CLASS-SUBCLASS
KE, PENG	3992	345-156000

1. Change of correspondence address or indication of "Fee Address" (37 CFR 1.363).

❑ Change of correspondence address (or Change of Correspondence Address form PTO/SB/122) attached.

❑ "Fee Address" indication (or "Fee Address" Indication form PTO/SB/47; Rev 03-09 or more recent) attached. **Use of a Customer Number is required.**

2. For printing on the patent front page, list
(1) The names of up to 3 registered patent attorneys or agents OR, alternatively,
(2) The name of a single firm (having as a member a registered attorney or agent) and the names of up to 2 registered patent attorneys or agents. If no name is listed, no name will be printed.

1 BUCHANAN INGERSOLL
2 & ROONEY P.C.
3

3. ASSIGNEE NAME AND RESIDENCE DATA TO BE PRINTED ON THE PATENT (print or type)

PLEASE NOTE: Unless an assignee is identified below, no assignee data will appear on the patent. If an assignee is identified below, the document must have been previously recorded, or filed for recordation, as set forth in 37 CFR 3.11 and 37 CFR 3.81(a). Completion of this form is NOT a substitute for filing an assignment.

(A) NAME OF ASSIGNEE: 3SHAPE A/S

(B) RESIDENCE: (CITY and STATE OR COUNTRY): Copenhagen K, Denmark

Please check the appropriate assignee category or categories (will not be printed on the patent) : ❑ Individual ☒ Corporation or other private group entity ❑ Government

4a. Fees submitted: ☒ Issue Fee ❑ Publication Fee (if required) ❑ Advance Order - # of Copies ______

4b. Method of Payment: *(Please first reapply any previously paid fee shown above)*

☒ Electronic Payment via EFS-Web ❑ Enclosed check ❑ Non-electronic payment by credit card (Attach form PTO-2038)

☒ The Director is hereby authorized to charge the required fee(s), any deficiency, or credit any overpayment to Deposit Account No. 02-4800

5. **Change in Entity Status** (from status indicated above)

❑ Applicant certifying micro entity status. See 37 CFR 1.29

❑ Applicant asserting small entity status. See 37 CFR 1.27

❑ Applicant changing to regular undiscounted fee status.

NOTE: Absent a valid certification of Micro Entity Status (see forms PTO/SB/15A and 15B), issue fee payment in the micro entity amount will not be accepted at the risk of application abandonment.
NOTE: If the application was previously under micro entity status, checking this box will be taken to be a notification of loss of entitlement to micro entity status.
NOTE: Checking this box will be taken to be a notification of loss of entitlement to small or micro entity status, as applicable.

NOTE: This form must be signed in accordance with 37 CFR 1.31 and 1.33. See 37 CFR 1.4 for signature requirements and certifications.

Authorized Signature /Travis D. Boone/ Date 11 August 2020

Typed or printed name Travis D. Boone Registration No. 52,635

PTOL-85 Part B (08-18) Approved for use through 01/31/2020 OMB 0651-0033 U.S. Patent and Trademark Office; U.S. DEPARTMENT OF COMMERCE

Electronic Patent Application Fee Transmittal

Application Number:	16526281
Filing Date:	30-Jul-2019
Title of Invention:	SYSTEM WITH 3D USER INTERFACE INTEGRATION
First Named Inventor/Applicant Name:	Henrik ÖJELUND
Filer:	Travis Dean Boone/Denise Miles
Attorney Docket Number:	0079124-000266

Filed as Large Entity

Filing Fees for **Utility under 35 USC 111(a)**

Description	Fee Code	Quantity	Amount	Sub-Total in USD($)
Basic Filing:				
Pages:				
Claims:				
Miscellaneous-Filing:				
Petition:				
Patent-Appeals-and-Interference:				
Post-Allowance-and-Post-Issuance:				
REISSUE ISSUE FEE	1511	1	1000	1000

Description	Fee Code	Quantity	Amount	Sub-Total in USD($)
Extension-of-Time:				
Miscellaneous:				
	Total in USD ($)			**1000**

Electronic Acknowledgement Receipt

EFS ID:	40248234
Application Number:	16526281
International Application Number:	
Confirmation Number:	9657
Title of Invention:	SYSTEM WITH 3D USER INTERFACE INTEGRATION
First Named Inventor/Applicant Name:	Henrik ÖJELUND
Customer Number:	21839
Filer:	Travis Dean Boone/Denise Miles
Filer Authorized By:	Travis Dean Boone
Attorney Docket Number:	0079124-000266
Receipt Date:	11-AUG-2020
Filing Date:	30-JUL-2019
Time Stamp:	11:38:07
Application Type:	Utility under 35 USC 111(a)

Payment information:

Submitted with Payment	yes
Payment Type	CARD
Payment was successfully received in RAM	$1000
RAM confirmation Number	E20208AB38250936
Deposit Account	
Authorized User	

The Director of the USPTO is hereby authorized to charge indicated fees and credit any overpayment as follows:

File Listing:

Document Number	Document Description	File Name	File Size(Bytes)/ Message Digest	Multi Part /.zip	Pages (if appl.)
1	Issue Fee Payment (PTO-85B)	Issue_Fee_Transmittal_-_As_Filed_08112020.pdf	1230594 ab35712de38e08ff33263a028ff079189a43c50e	no	1
Warnings:					
Information:					
2	Fee Worksheet (SB06)	fee-info.pdf	30363 59398c81d384ad285a7a1d2bdc13d4832b65599d	no	2
Warnings:					
Information:					
			Total Files Size (in bytes):	1260957	

This Acknowledgement Receipt evidences receipt on the noted date by the USPTO of the indicated documents, characterized by the applicant, and including page counts, where applicable. It serves as evidence of receipt similar to a Post Card, as described in MPEP 503.

<u>New Applications Under 35 U.S.C. 111</u>
If a new application is being filed and the application includes the necessary components for a filing date (see 37 CFR 1.53(b)-(d) and MPEP 506), a Filing Receipt (37 CFR 1.54) will be issued in due course and the date shown on this Acknowledgement Receipt will establish the filing date of the application.
<u>National Stage of an International Application under 35 U.S.C. 371</u>
If a timely submission to enter the national stage of an international application is compliant with the conditions of 35 U.S.C. 371 and other applicable requirements a Form PCT/DO/EO/903 indicating acceptance of the application as a national stage submission under 35 U.S.C. 371 will be issued in addition to the Filing Receipt, in due course.
<u>New International Application Filed with the USPTO as a Receiving Office</u>
If a new international application is being filed and the international application includes the necessary components for an international filing date (see PCT Article 11 and MPEP 1810), a Notification of the International Application Number and of the International Filing Date (Form PCT/RO/105) will be issued in due course, subject to prescriptions concerning national security, and the date shown on this Acknowledgement Receipt will establish the international filing date of the application.

UNITED STATES PATENT AND TRADEMARK OFFICE

UNITED STATES DEPARTMENT OF COMMERCE
United States Patent and Trademark Office
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Alexandria, Virginia 22313-1450
www.uspto.gov

NOTICE OF ALLOWANCE AND FEE(S) DUE

21839 7590 05/11/2020

BUCHANAN, INGERSOLL & ROONEY PC
POST OFFICE BOX 1404
ALEXANDRIA, VA 22313-1404

EXAMINER	
KE, PENG	
ART UNIT	PAPER NUMBER
3992	

DATE MAILED: 05/11/2020

APPLICATION NO.	FILING DATE	FIRST NAMED INVENTOR	ATTORNEY DOCKET NO.	CONFIRMATION NO.
16/526,281	07/30/2019	Henrik ÖJELUND	0079124-000266	9657

TITLE OF INVENTION: SYSTEM WITH 3D USER INTERFACE INTEGRATION

APPLN. TYPE	ENTITY STATUS	ISSUE FEE DUE	PUBLICATION FEE DUE	PREV. PAID ISSUE FEE	TOTAL FEE(S) DUE	DATE DUE
nonprovisional	UNDISCOUNTED	$1000	$0.00	$0.00	$1000	08/11/2020

THE APPLICATION IDENTIFIED ABOVE HAS BEEN EXAMINED AND IS ALLOWED FOR ISSUANCE AS A PATENT. PROSECUTION ON THE MERITS IS CLOSED. THIS NOTICE OF ALLOWANCE IS NOT A GRANT OF PATENT RIGHTS. THIS APPLICATION IS SUBJECT TO WITHDRAWAL FROM ISSUE AT THE INITIATIVE OF THE OFFICE OR UPON PETITION BY THE APPLICANT. SEE 37 CFR 1.313 AND MPEP 1308.

THE ISSUE FEE AND PUBLICATION FEE (IF REQUIRED) MUST BE PAID WITHIN THREE MONTHS FROM THE MAILING DATE OF THIS NOTICE OR THIS APPLICATION SHALL BE REGARDED AS ABANDONED. THIS STATUTORY PERIOD CANNOT BE EXTENDED. SEE 35 U.S.C. 151. THE ISSUE FEE DUE INDICATED ABOVE DOES NOT REFLECT A CREDIT FOR ANY PREVIOUSLY PAID ISSUE FEE IN THIS APPLICATION. IF AN ISSUE FEE HAS PREVIOUSLY BEEN PAID IN THIS APPLICATION (AS SHOWN ABOVE), THE RETURN OF PART B OF THIS FORM WILL BE CONSIDERED A REQUEST TO REAPPLY THE PREVIOUSLY PAID ISSUE FEE TOWARD THE ISSUE FEE NOW DUE.

HOW TO REPLY TO THIS NOTICE:

I. Review the ENTITY STATUS shown above. If the ENTITY STATUS is shown as SMALL or MICRO, verify whether entitlement to that entity status still applies.

If the ENTITY STATUS is the same as shown above, pay the TOTAL FEE(S) DUE shown above.

If the ENTITY STATUS is changed from that shown above, on PART B - FEE(S) TRANSMITTAL, complete section number 5 titled "Change in Entity Status (from status indicated above)".

For purposes of this notice, small entity fees are 1/2 the amount of undiscounted fees, and micro entity fees are 1/2 the amount of small entity fees.

II. PART B - FEE(S) TRANSMITTAL, or its equivalent, must be completed and returned to the United States Patent and Trademark Office (USPTO) with your ISSUE FEE and PUBLICATION FEE (if required). If you are charging the fee(s) to your deposit account, section "4b" of Part B - Fee(s) Transmittal should be completed and an extra copy of the form should be submitted. If an equivalent of Part B is filed, a request to reapply a previously paid issue fee must be clearly made, and delays in processing may occur due to the difficulty in recognizing the paper as an equivalent of Part B.

III. All communications regarding this application must give the application number. Please direct all communications prior to issuance to Mail Stop ISSUE FEE unless advised to the contrary.

IMPORTANT REMINDER: Maintenance fees are due in utility patents issuing on applications filed on or after Dec. 12, 1980. It is patentee's responsibility to ensure timely payment of maintenance fees when due. More information is available at www.uspto.gov/PatentMaintenanceFees.

PART B - FEE(S) TRANSMITTAL

Complete and send this form, together with applicable fee(s), by mail or fax, or via EFS-Web.

By mail, send to: Mail Stop ISSUE FEE
Commissioner for Patents
P.O. Box 1450
Alexandria, Virginia 22313-1450

By fax, send to: (571)-273-2885

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CURRENT CORRESPONDENCE ADDRESS (Note: Use Block 1 for any change of address)

21839 7590 05/11/2020

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POST OFFICE BOX 1404
ALEXANDRIA, VA 22313-1404

Note: A certificate of mailing can only be used for domestic mailings of the Fee(s) Transmittal. This certificate cannot be used for any other accompanying papers. Each additional paper, such as an assignment or formal drawing, must have its own certificate of mailing or transmission.

Certificate of Mailing or Transmission

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(Typed or printed name)
(Signature)
(Date)

APPLICATION NO.	FILING DATE	FIRST NAMED INVENTOR	ATTORNEY DOCKET NO.	CONFIRMATION NO.
16/526,281	07/30/2019	Henrik ÖJELUND	0079124-000266	9657

TITLE OF INVENTION: SYSTEM WITH 3D USER INTERFACE INTEGRATION

APPLN. TYPE	ENTITY STATUS	ISSUE FEE DUE	PUBLICATION FEE DUE	PREV. PAID ISSUE FEE	TOTAL FEE(S) DUE	DATE DUE
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EXAMINER	ART UNIT	CLASS-SUBCLASS
KE, PENG	3992	345-156000

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❑ Change of correspondence address (or Change of Correspondence Address form PTO/SB/122) attached.

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(1) The names of up to 3 registered patent attorneys or agents OR, alternatively,
(2) The name of a single firm (having as a member a registered attorney or agent) and the names of up to 2 registered patent attorneys or agents. If no name is listed, no name will be printed.

1____________________
2____________________
3____________________

3. ASSIGNEE NAME AND RESIDENCE DATA TO BE PRINTED ON THE PATENT (print or type)

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(A) NAME OF ASSIGNEE

(B) RESIDENCE: (CITY and STATE OR COUNTRY)

Please check the appropriate assignee category or categories (will not be printed on the patent) : ❑ Individual ❑ Corporation or other private group entity ❑ Government

4a. Fees submitted: ❑Issue Fee ❑Publication Fee (if required) ❑Advance Order - # of Copies __________

4b. Method of Payment: *(Please first reapply any previously paid fee shown above)*

❑ Electronic Payment via EFS-Web ❑ Enclosed check ❑ Non-electronic payment by credit card (Attach form PTO-2038)

❑ The Director is hereby authorized to charge the required fee(s), any deficiency, or credit any overpayment to Deposit Account No. __________

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❑ Applicant certifying micro entity status. See 37 CFR 1.29

❑ Applicant asserting small entity status. See 37 CFR 1.27

❑ Applicant changing to regular undiscounted fee status.

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NOTE: This form must be signed in accordance with 37 CFR 1.31 and 1.33. See 37 CFR 1.4 for signature requirements and certifications.

Authorized Signature ____________________ Date ____________________

Typed or printed name ____________________ Registration No. ____________________

PTOL-85 Part B (08-18) Approved for use through 01/31/2020 OMB 0651-0033 U.S. Patent and Trademark Office; U.S. DEPARTMENT OF COMMERCE

UNITED STATES PATENT AND TRADEMARK OFFICE

UNITED STATES DEPARTMENT OF COMMERCE
United States Patent and Trademark Office
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Alexandria, Virginia 22313-1450
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APPLICATION NO.	FILING DATE	FIRST NAMED INVENTOR	ATTORNEY DOCKET NO.	CONFIRMATION NO.
16/526,281	07/30/2019	Henrik ÖJELUND	0079124-000266	9657

21839 7590 05/11/2020

BUCHANAN, INGERSOLL & ROONEY PC
POST OFFICE BOX 1404
ALEXANDRIA, VA 22313-1404

EXAMINER	
KE, PENG	
ART UNIT	**PAPER NUMBER**
3992	

DATE MAILED: 05/11/2020

Determination of Patent Term Extension or Adjustment under 35 U.S.C. 154 (b)

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Any questions regarding the Patent Term Extension or Adjustment determination should be directed to the Office of Patent Legal Administration at (571)-272-7702. Questions relating to issue and publication fee payments should be directed to the Customer Service Center of the Office of Patent Publication at 1-(888)-786-0101 or (571)-272-4200.

PTOL-85 (Rev. 02/11)

OMB Clearance and PRA Burden Statement for PTOL-85 Part B

The Paperwork Reduction Act (PRA) of 1995 requires Federal agencies to obtain Office of Management and Budget approval before requesting most types of information from the public. When OMB approves an agency request to collect information from the public, OMB (i) provides a valid OMB Control Number and expiration date for the agency to display on the instrument that will be used to collect the information and (ii) requires the agency to inform the public about the OMB Control Number's legal significance in accordance with 5 CFR 1320.5(b).

The information collected by PTOL-85 Part B is required by 37 CFR 1.311. The information is required to obtain or retain a benefit by the public which is to file (and by the USPTO to process) an application. Confidentiality is governed by 35 U.S.C. 122 and 37 CFR 1.14. This collection is estimated to take 30 minutes to complete, including gathering, preparing, and submitting the completed application form to the USPTO. Time will vary depending upon the individual case. Any comments on the amount of time you require to complete this form and/or suggestions for reducing this burden, should be sent to the Chief Information Officer, U.S. Patent and Trademark Office, U.S. Department of Commerce, P.O. Box 1450, Alexandria, Virginia 22313-1450. DO NOT SEND FEES OR COMPLETED FORMS TO THIS ADDRESS. SEND TO: Commissioner for Patents, P.O. Box 1450, Alexandria, Virginia 22313-1450. Under the Paperwork Reduction Act of 1995, no persons are required to respond to a collection of information unless it displays a valid OMB control number.

Privacy Act Statement

The Privacy Act of 1974 (P.L. 93-579) requires that you be given certain information in connection with your submission of the attached form related to a patent application or patent. Accordingly, pursuant to the requirements of the Act, please be advised that: (1) the general authority for the collection of this information is 35 U.S.C. 2(b)(2); (2) furnishing of the information solicited is voluntary; and (3) the principal purpose for which the information is used by the U.S. Patent and Trademark Office is to process and/or examine your submission related to a patent application or patent. If you do not furnish the requested information, the U.S. Patent and Trademark Office may not be able to process and/or examine your submission, which may result in termination of proceedings or abandonment of the application or expiration of the patent.

The information provided by you in this form will be subject to the following routine uses:

1. The information on this form will be treated confidentially to the extent allowed under the Freedom of Information Act (5 U.S.C. 552) and the Privacy Act (5 U.S.C 552a). Records from this system of records may be disclosed to the Department of Justice to determine whether disclosure of these records is required by the Freedom of Information Act.
2. A record from this system of records may be disclosed, as a routine use, in the course of presenting evidence to a court, magistrate, or administrative tribunal, including disclosures to opposing counsel in the course of settlement negotiations.
3. A record in this system of records may be disclosed, as a routine use, to a Member of Congress submitting a request involving an individual, to whom the record pertains, when the individual has requested assistance from the Member with respect to the subject matter of the record.
4. A record in this system of records may be disclosed, as a routine use, to a contractor of the Agency having need for the information in order to perform a contract. Recipients of information shall be required to comply with the requirements of the Privacy Act of 1974, as amended, pursuant to 5 U.S.C. 552a(m).
5. A record related to an International Application filed under the Patent Cooperation Treaty in this system of records may be disclosed, as a routine use, to the International Bureau of the World Intellectual Property Organization, pursuant to the Patent Cooperation Treaty.
6. A record in this system of records may be disclosed, as a routine use, to another federal agency for purposes of National Security review (35 U.S.C. 181) and for review pursuant to the Atomic Energy Act (42 U.S.C. 218(c)).
7. A record from this system of records may be disclosed, as a routine use, to the Administrator, General Services, or his/her designee, during an inspection of records conducted by GSA as part of that agency's responsibility to recommend improvements in records management practices and programs, under authority of 44 U.S.C. 2904 and 2906. Such disclosure shall be made in accordance with the GSA regulations governing inspection of records for this purpose, and any other relevant (i.e., GSA or Commerce) directive. Such disclosure shall not be used to make determinations about individuals.
8. A record from this system of records may be disclosed, as a routine use, to the public after either publication of the application pursuant to 35 U.S.C. 122(b) or issuance of a patent pursuant to 35 U.S.C. 151. Further, a record may be disclosed, subject to the limitations of 37 CFR 1.14, as a routine use, to the public if the record was filed in an application which became abandoned or in which the proceedings were terminated and which application is referenced by either a published application, an application open to public inspection or an issued patent.
9. A record from this system of records may be disclosed, as a routine use, to a Federal, State, or local law enforcement agency, if the USPTO becomes aware of a violation or potential violation of law or regulation.

Notice of Allowability	**Application No.** 16/526,281	**Applicant(s)** ÖJELUND et al.	
	Examiner PENG KE	**Art Unit** 3992	**AIA (FITF) Status** No

-- The MAILING DATE of this communication appears on the cover sheet with the correspondence address--

All claims being allowable, PROSECUTION ON THE MERITS IS (OR REMAINS) CLOSED in this application. If not included herewith (or previously mailed), a Notice of Allowance (PTOL-85) or other appropriate communication will be mailed in due course. **THIS NOTICE OF ALLOWABILITY IS NOT A GRANT OF PATENT RIGHTS.** This application is subject to withdrawal from issue at the initiative of the Office or upon petition by the applicant. See 37 CFR 1.313 and MPEP 1308.

1.☑ This communication is responsive to 10/28/19.

☐ A declaration(s)/affidavit(s) under **37 CFR 1.130(b)** was/were filed on _____.

2.☐ An election was made by the applicant in response to a restriction requirement set forth during the interview on _____; the restriction requirement and election have been incorporated into this action.

3.☑ The allowed claim(s) is/are 1-3 and 5-44 . As a result of the allowed claim(s), you may be eligible to benefit from the **Patent Prosecution Highway** program at a participating intellectual property office for the corresponding application. For more information , please see **http://www.uspto.gov/patents/init_events/pph/index.jsp** or send an inquiry to **PPHfeedback@uspto.gov.**

4.☑ Acknowledgment is made of a claim for foreign priority under 35 U.S.C. § 119(a)-(d) or (f).

Certified copies:

a) ☑All b) ☐ Some *c) ☐ None of the:

1. ☐ Certified copies of the priority documents have been received.
2. ☑ Certified copies of the priority documents have been received in Application No. 13/991,513 .
3. ☐ Copies of the certified copies of the priority documents have been received in this national stage application from the International Bureau (PCT Rule 17.2(a)).

* Certified copies not received: _____ .

Applicant has THREE MONTHS FROM THE "MAILING DATE" of this communication to file a reply complying with the requirements noted below. Failure to timely comply will result in ABANDONMENT of this application.
THIS THREE-MONTH PERIOD IS NOT EXTENDABLE.

5.☐ CORRECTED DRAWINGS (as "replacement sheets") must be submitted.

☐ including changes required by the attached Examiner's Amendment / Comment or in the Office action of Paper No./Mail Date _____ .

Identifying indicia such as the application number (see 37 CFR 1.84(c)) should be written on the drawings in the front (not the back) of each sheet. Replacement sheet(s) should be labeled as such in the header according to 37 CFR 1.121(d).

6.☐ DEPOSIT OF and/or INFORMATION about the deposit of BIOLOGICAL MATERIAL must be submitted. Note the attached Examiner's comment regarding REQUIREMENT FOR THE DEPOSIT OF BIOLOGICAL MATERIAL.

Attachment(s)

1.☑ Notice of References Cited (PTO-892)
2.☑ Information Disclosure Statements (PTO/SB/08), Paper No./Mail Date 4/28/20, 10/28/19 and 2/13/20.
3.☐ Examiner's Comment Regarding Requirement for Deposit of Biological Material _____.
4.☐ Interview Summary (PTO-413), Paper No./Mail Date. _____.
5. ☐ Examiner's Amendment/Comment
6. ☑ Examiner's Statement of Reasons for Allowance
7. ☐ Other _____.

/PENG KE/
Primary Examiner, Art Unit 3992

Notice of Pre-AIA or AIA Status

1. The present application is being examined under the pre-AIA first to invent provisions.

Detail Action

2. For reissue applications filed before September 16, 2012, all references to 35 U.S.C. 251 and 37 CFR 1.172, 1.175, and 3.73 are to the law and rules in effect on September 15, 2012. Where specifically designated, these are "pre-AIA" provisions.

3. *For reissue applications filed on or after September 16, 2012, all references to 35 U.S.C. 251 and 37 CFR 1.172, 1.175, and 3.73* are to the current provisions.

4. The application 16/526,281 is a reissue of 9,329,675 patent, which was filed as the application 13/991,513.

5. Claims 1-3, and 5-44 are pending. The preliminary amendment filed on 10/28/19, claims 1-3, and 5-13 were amended, claims 20-44 are added; and claim 4 is cancelled.

Information Disclosure Statement

6. The information disclosure statement (IDS) submitted on 10/28/19 and 2/13/20 are in compliance with the provisions of 37 CFR 1.97. Accordingly, the information disclosure statement is being considered by the examiner to the extend explained in the IDS.

Priority

7. Acknowledgment is made of applicant's claim for foreign priority under 35 U.S.C. 119 (a)-(d). The certified copy has been filed in parent Application No. 13/991,513, filed on 5/4/19.

Allowable Subject Matter

8. Claims 1-3, and 5-44 are allowed.

9. The following is an examiner's statement of reasons for allowance:

10. Kopelman US 2013/0110469, teaches modifying a virtual model of physical structure with additional 3D data obtained from the physical structure to provide a modified virtual model.

11. Dillon US 2012/0062557 teaches generating and displaying intra-oral measurement data.

12. Cinader, Jr US 2007/0031774, teaches registering a three-dimensional coordinate system of a physical model of a patient's tooth structure to a 3D coordinate system of a virtual model of the same tooth structure.

13. The prior arts fail to teach individually or in combination : "a handheld device including an optical scanner, wherein the 3D environment to be scanned is selected by pointing the optical scanner at the 3D environment; and at least one display remotely connected to the handheld device, wherein the handheld device is adapted for performing at least one scanning action in a physical 3D environment, and the at least one display is adopted for visually representing the physical 3D environment; and the handheld device includes a user interface for remotely controlling the display to adjust the view with which the 3D environment is represented on the display."

Any comments considered necessary by applicant must be submitted no later than the payment of the issue fee and, to avoid processing delays, should preferably accompany the issue fee. Such submissions should be clearly labeled "Comments on Statement of Reasons for Allowance."

Contact Information

14. Any inquiry concerning this communication or earlier communications from the examiner should be directed to PENG KE whose telephone number is (571)272-4062. The examiner can normally be reached on M-F 6:30-5:00.

Examiner interviews are available via telephone, in-person, and video conferencing using a USPTO supplied web-based collaboration tool. To schedule an interview, applicant is encouraged to use the USPTO Automated Interview Request (AIR) at http://www.uspto.gov/interviewpractice.

If attempts to reach the examiner by telephone are unsuccessful, the examiner's supervisor, Alexander Kosowski can be reached on 5712723744. The fax phone number for the organization where this application or proceeding is assigned is 571-273-8300.

Information regarding the status of an application may be obtained from the Patent Application Information Retrieval (PAIR) system. Status information for published applications may be obtained from either Private PAIR or Public PAIR. Status information for unpublished applications is available through Private PAIR only. For more information about the PAIR system, see https://ppair-my.uspto.gov/pair/PrivatePair. Should you have questions on access to the Private PAIR system, contact the Electronic Business Center (EBC) at 866-217-9197 (toll-free). If you would like assistance from a USPTO Customer Service Representative or access to the automated information system, call 800-786-9199 (IN USA OR CANADA) or 571-272-1000.

PENG . KE
Examiner
Art Unit 3992

/PENG KE/
Primary Examiner, Art Unit 3992

Conferees:

/RSD/

/ALEXANDER J KOSOWSKI/
Supervisory Patent Examiner, Art Unit 3992

Notice of References Cited	Application/Control No. 16/526,281	Applicant(s)/Patent Under Reexamination ÖJELUND et al.	
	Examiner PENG KE	Art Unit 3992	Page 1 of 1

U.S. PATENT DOCUMENTS

*		Document Number Country Code-Number-Kind Code	Date MM-YYYY	Name	CPC Classification	US Classification
*	A	US-20130110469-A1	05-2013	Kopelman; Avi	G06F30/00	703/1
*	B	US-20120062557-A1	03-2012	Dillon; Robert F.	A61C7/002	345/419
*	C	US-20070031774-A1	02-2007	Cinader; David K. JR.	A61C9/0053	433/24
	D					
	E					
	F					
	G					
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	I					
	J					
	K					
	L					
	M					

FOREIGN PATENT DOCUMENTS

*		Document Number Country Code-Number-Kind Code	Date MM-YYYY	Country	Name	CPC Classification
	N					
	O					
	P					
	Q					
	R					
	S					
	T					

NON-PATENT DOCUMENTS

*		Include as applicable: Author, Title Date, Publisher, Edition or Volume, Pertinent Pages)
	U	
	V	
	W	
	X	

*A copy of this reference is not being furnished with this Office action. (See MPEP § 707.05(a).)
Dates in MM-YYYY format are publication dates. Classifications may be US or foreign.

Index of Claims	Application/Control No. 16/526,281	Applicant(s)/Patent Under Reexamination ÖJELUND et al.
	Examiner PENG KE	Art Unit 3992

✓	Rejected	-	Cancelled	N	Non-Elected	A	Appeal
=	Allowed	÷	Restricted	I	Interference	O	Objected

CLAIMS

☐ Claims renumbered in the same order as presented by applicant ☐ CPA ☐ T.D. ☐ R.1.47

CLAIM		DATE								
Final	Original	04/27/2020								
	1	=								
	2	=								
	3	=								
	4	-								
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	42	=								

Index of Claims	Application/Control No. 16/526,281	Applicant(s)/Patent Under Reexamination ÖJELUND et al.
	Examiner PENG KE	**Art Unit** 3992

CLAIM		DATE								
Final	Original	04/27/2020								
	43	=								
	44	=								

Search Notes	Application/Control No. 16/526,281	Applicant(s)/Patent Under Reexamination ÖJELUND et al.
	Examiner PENG KE	Art Unit 3992

CPC - Searched*		
Symbol	**Date**	**Examiner**
A61B5/0088; A61C9/004; G01B11/24; G06F3/002; G06F3/01; G06F3/011; G06F3/017; G06F3/0346; G06F3/04815	04/27/2020	PK

CPC Combination Sets - Searched*		
Symbol	**Date**	**Examiner**
East Text search	04/27/2020	PK

US Classification - Searched*			
Class	**Subclass**	**Date**	**Examiner**

* See search history printout included with this form or the SEARCH NOTES box below to determine the scope of the search.

Search Notes		
Search Notes	**Date**	**Examiner**
Litigation Search	04/27/2020	PK

Interference Search			
US Class/CPC Symbol	**US Subclass/CPC Group**	**Date**	**Examiner**
	East Text Search	04/27/2020	PK

Issue Classification	**Application/Control No.** 16/526,281	**Applicant(s)/Patent Under Reexamination** ÖJELUND et al.
	Examiner PENG KE	**Art Unit** 3992

CPC						
Symbol					**Type**	**Version**
G06F	/	3	/	01	F	2013-01-01
A61B	/	5	/	0088	I	2013-01-01
A61C	/	9	/	004	I	2013-01-01
G01B	/	11	/	24	I	2013-01-01
G06F	/	3	/	002	I	2013-01-01
G06F	/	3	/	011	I	2013-01-01
G06F	/	3	/	017	I	2013-01-01
G06F	/	3	/	0346	I	2013-01-01
G06F	/	3	/	04815	I	2013-01-01

CPC Combination Sets								
Symbol					**Type**	**Set**	**Ranking**	**Version**
	/		/					

NONE (Assistant Examiner) (Date)	**Total Claims Allowed:** 43	
/PENG KE/ 27 April 2020 Primary Examiner, Art Unit 3992 (Primary Examiner) (Date)	O.G. Print Claim(s) 1	O.G. Print Figure 1

Issue Classification	Application/Control No.	Applicant(s)/Patent Under Reexamination
	16/526,281	ÖJELUND et al.
	Examiner	**Art Unit**
	PENG KE	3992

INTERNATIONAL CLASSIFICATION				
CLAIMED				
G06F3/01	/	3	/	01
A61B5/00	/	5	/	00
A61C9/00	/	9	/	00
G01B11/24	/	11	/	24
G06F3/00	/	3	/	00
G06F3/0346	/	3	/	0346
G06F3/0481	/	3	/	0481

NON-CLAIMED				
	/		/	

US ORIGINAL CLASSIFICATION	
CLASS	**SUBCLASS**

CROSS REFERENCES(S)						
CLASS	**SUBCLASS (ONE SUBCLASS PER BLOCK)**					

NONE (Assistant Examiner) (Date)	**Total Claims Allowed:** 43	
/PENG KE/ Primary Examiner, Art Unit 3992 (Primary Examiner) 27 April 2020 (Date)	O.G. Print Claim(s) 1	O.G. Print Figure 1

Issue Classification	**Application/Control No.** 16/526,281	**Applicant(s)/Patent Under Reexamination** ÖJELUND et al.
	Examiner PENG KE	**Art Unit** 3992

☑ Claims renumbered in the same order as presented by applicant ☐ CPA ☐ T.D. ☐ R.1.47

CLAIMS

Final	Original	Final	Original	Final	Original	Final	Original	Final	Original	Final	Original	Final	Original	Final	Original

NONE (Assistant Examiner)	(Date)	**Total Claims Allowed:** 43	
/PENG KE/ Primary Examiner, Art Unit 3992 (Primary Examiner)	27 April 2020 (Date)	O.G. Print Claim(s) 1	O.G. Print Figure 1

United States Patent And Trademark Office **Reissue Terminal Disclaimer Review Form**	**Application No.** 16/526,281	**Art Unit** 3992
	Examiner PENG KE	**AIA Status** No

Original Patent Number of Patent to be Reissued is: 9,329,675

The Maintenance fee status is:
- (●) up to date
- ( ) not up to date (Consult with SPRS)

Is there a terminal disclaimer filed and accepted during the prosecution of (i) the current reissue application, (ii) the underlying patent, and/or (iii) reexamination proceeding(s) of the underlying patent?

- (●) NO
- ( ) YES (Complete the rest of the form)

The reissue patent is subject to Terminal Disclaimer(s) that was/were:

☐ filed and accepted (DISQ or DISQ.E.FILE) during the prosecution of the current reissue application. (Enter terminal disclaimer(s) filing date(s) below).

1. _____ 2. _____ 3. _____

The underlying patent of the current reissue application is subject to Terminal DIsclaimer(s) that was/were:

☐ accepted (DISQ or DISQ.E.FILE) and of record in the prosecution of the underlying patent and/or reexamination procceeding(s) of the underlying patent. (Enter application/control no(s) and terminal disclaimer(s) filing date(s) below).

1. _____ _____ 2. _____ _____ 3. _____ _____

Bibliographic Data

Application No: 16/526,281

Foreign Priority claimed: (•) Yes ( ) No

35 USC 119 (a-d) conditions met: ☑ Yes ☐ No | ☐ Met After Allowance

Verified and Acknowledged: /PENG KE/ |

Examiner's Signature | Initials

Title: SYSTEM WITH 3D USER INTERFACE INTEGRATION

FILING or 371(c) DATE	CLASS	GROUP ART UNIT	ATTORNEY DOCKET NO.
07/30/2019	345	3992	
RULE			

APPLICANTS

3Shape A/S, Copenhagen K, DENMARK

INVENTORS

Henrik ÖJELUND Lyngby, DENMARK

David FISCHER Stenløse, DENMARK

Karl-Josef HOLLENBECK København Ø, DENMARK

CONTINUING DATA

This application is a REI of 13991513 06/04/2013 PAT 9329675

13991513 is a 371 of PCT/DK2011/050461 12/05/2011

PCT/DK2011/050461 has PRO of 61420138 12/06/2010

FOREIGN APPLICATIONS

DENMARK PA 2010 01104 12/06/2010

IF REQUIRED, FOREIGN LICENSE GRANTED**

08/14/2019

STATE OR COUNTRY

DENMARK

ADDRESS

FILING FEE RECEIVED

$4,960

ALL REFERENCES CONSIDERED EXCEPT WHERE LINED THROUGH. /P.K/

Doc code: IDS
Doc description: Information Disclosure Statement (IDS) Filed

PTO/SB/08a (01-10)
Approved for use through 07/31/2012. OMB 0651-0031
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INFORMATION DISCLOSURE STATEMENT BY APPLICANT (Not for submission under 37 CFR 1.99)		
	Application Number	16526281
	Filing Date	2019-07-30
	First Named Inventor	Henrik ÖJELUND et al.
	Art Unit	3992
	Examiner Name	Peng KE
	Attorney Docket Number	0079124-000266

U.S.PATENTS Remove

Examiner Initial*	Cite No	Patent Number	Kind Code[1]	Issue Date	Name of Patentee or Applicant of cited Document	Pages,Columns,Lines where Relevant Passages or Relevant Figures Appear
	1	6361489	B1	2002-03-26	Jory Tsai	

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Examiner Initial*	Cite No	Publication Number	Kind Code[1]	Publication Date	Name of Patentee or Applicant of cited Document	Pages,Columns,Lines where Relevant Passages or Relevant Figures Appear
	1	20070078340	A1	2007-04-05	Stephen D. Wilcox et al.	
	2	20100231509	A1	2010-09-16	Marc Ballot et al.	
	3	20080063998	A1	2008-03-13	Rongguang Liang et al.	

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Examiner Initial*	Cite No	Foreign Document Number[3]	Country Code[2] i	Kind Code[4]	Publication Date	Name of Patentee or Applicant of cited Document	Pages,Columns,Lines where Relevant Passages or Relevant Figures Appear	T[5]
	1	2011/011193	WO	A1	2011-01-27	DIMENSIONAL PHOTONICS INTERNATIONAL, INC.		

ALL REFERENCES CONSIDERED EXCEPT WHERE LINED THROUGH. /P.K/

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	Examiner Name	Peng KE
	Attorney Docket Number	0079124-000266

	2	2012/076013	WO	A1	2012-06-14	3SHAPE A/S		

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Examiner Initials*	Cite No	Include name of the author (in CAPITAL LETTERS), title of the article (when appropriate), title of the item (book, magazine, journal, serial, symposium, catalog, etc), date, pages(s), volume-issue number(s), publisher, city and/or country where published.	T[5]
	1		

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EXAMINER SIGNATURE

Examiner Signature	/PENG KE/	Date Considered	04/27/2020

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[1] See Kind Codes of USPTO Patent Documents at www.USPTO.GOV or MPEP 901.04. [2] Enter office that issued the document, by the two-letter code (WIPO Standard ST.3). [3] For Japanese patent documents, the indication of the year of the reign of the Emperor must precede the serial number of the patent document. [4] Kind of document by the appropriate symbols as indicated on the document under WIPO Standard ST.16 if possible. [5] Applicant is to place a check mark here if English language translation is attached.

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	First Named Inventor	Henrik ÖJELUND et al.
	Art Unit	3992
	Examiner Name	Peng KE
	Attorney Docket Number	0079124-000266

CERTIFICATION STATEMENT

Please see 37 CFR 1.97 and 1.98 to make the appropriate selection(s):

That each item of information contained in the information disclosure statement was first cited in any communication from a foreign patent office in a counterpart foreign application not more than three months prior to the filing of the information disclosure statement. See 37 CFR 1.97(e)(1).

OR

☐ That no item of information contained in the information disclosure statement was cited in a communication from a foreign patent office in a counterpart foreign application, and, to the knowledge of the person signing the certification after making reasonable inquiry, no item of information contained in the information disclosure statement was known to any individual designated in 37 CFR 1.56(c) more than three months prior to the filing of the information disclosure statement. See 37 CFR 1.97(e)(2).

See attached certification statement.

The fee set forth in 37 CFR 1.17 (p) has been submitted herewith.

☒ A certification statement is not submitted herewith.

SIGNATURE

A signature of the applicant or representative is required in accordance with CFR 1.33, 10.18. Please see CFR 1.4(d) for the form of the signature.

Signature	/Stephany G. Small/	Date (YYYY-MM-DD)	2020-02-13
Name/Print	Stephany G. Small	Registration Number	69,532

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The information provided by you in this form will be subject to the following routine uses:

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2. A record from this system of records may be disclosed, as a routine use, in the course of presenting evidence to a court, magistrate, or administrative tribunal, including disclosures to opposing counsel in the course of settlement negotiations.

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5. A record related to an International Application filed under the Patent Cooperation Treaty in this system of records may be disclosed, as a routine use, to the International Bureau of the World Intellectual Property Organization, pursuant to the Patent Cooperation Treaty.

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7. A record from this system of records may be disclosed, as a routine use, to the Administrator, General Services, or his/her designee, during an inspection of records conducted by GSA as part of that agency's responsibility to recommend improvements in records management practices and programs, under authority of 44 U.S.C. 2904 and 2906. Such disclosure shall be made in accordance with the GSA regulations governing inspection of records for this purpose, and any other relevant (i.e., GSA or Commerce) directive. Such disclosure shall not be used to make determinations about individuals.

8. A record from this system of records may be disclosed, as a routine use, to the public after either publication of the application pursuant to 35 U.S.C. 122(b) or issuance of a patent pursuant to 35 U.S.C. 151. Further, a record may be disclosed, subject to the limitations of 37 CFR 1.14, as a routine use, to the public if the record was filed in an application which became abandoned or in which the proceedings were terminated and which application is referenced by either a published application, an application open to public inspections or an issued patent.

9. A record from this system of records may be disclosed, as a routine use, to a Federal, State, or local law enforcement agency, if the USPTO becomes aware of a violation or potential violation of law or regulation.

ALL REFERENCES CONSIDERED EXCEPT WHERE LINED THROUGH. /P.K/

Doc code: IDS
Doc description: Information Disclosure Statement (IDS) Filed

PTO/SB/08a (02-18)
Approved for use through 11/30/2020. OMB 0651-0031
U.S. Patent and Trademark Office; U.S. DEPARTMENT OF COMMERCE
Under the Paperwork Reduction Act of 1995, no persons are required to respond to a collection of information unless it contains a valid OMB control number.

INFORMATION DISCLOSURE STATEMENT BY APPLICANT (**Not for submission under 37 CFR 1.99)**		
	Application Number	16526281
	Filing Date	2019-07-30
	First Named Inventor	Henrik Öjelund
	Art Unit	3992
	Examiner Name	KE, PENG
	Attorney Docket Number	0079124-000266

U.S.PATENTS Remove

Examiner Initial*	Cite No	Patent Number	Kind Code[1]	Issue Date	Name of Patentee or Applicant of cited Document	Pages,Columns,Lines where Relevant Passages or Relevant Figures Appear
	1					

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Examiner Initial*	Cite No	Foreign Document Number[3]	Country Code[2] i	Kind Code[4]	Publication Date	Name of Patentee or Applicant of cited Document	Pages,Columns,Lines where Relevant Passages or Relevant Figures Appear	T[5]
/P.K/	1	2664272	EP	A1	2013-11-20	ADVANCE KK		

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NON-PATENT LITERATURE DOCUMENTS Remove

Examiner Initials*	Cite No	Include name of the author (in CAPITAL LETTERS), title of the article (when appropriate), title of the item (book, magazine, journal, serial, symposium, catalog, etc), date, pages(s), volume-issue number(s), publisher, city and/or country where published.	T[5]

ALL REFERENCES CONSIDERED EXCEPT WHERE LINED THROUGH. /P.K/

INFORMATION DISCLOSURE STATEMENT BY APPLICANT (**Not for submission under 37 CFR 1.99)**		
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	Filing Date	2019-07-30
	First Named Inventor	Henrik Öjelund
	Art Unit	3992
	Examiner Name	KE, PENG
	Attorney Docket Number	0079124-000266

	1		
If you wish to add additional non-patent literature document citation information please click the Add button Add			

EXAMINER SIGNATURE

Examiner Signature	/PENG KE/	Date Considered	05/01/2020

*EXAMINER: Initial if reference considered, whether or not citation is in conformance with MPEP 609. Draw line through a citation if not in conformance and not considered. Include copy of this form with next communication to applicant.

[1] See Kind Codes of USPTO Patent Documents at www.USPTO.GOV or MPEP 901.04. [2] Enter office that issued the document, by the two-letter code (WIPO Standard ST.3). [3] For Japanese patent documents, the indication of the year of the reign of the Emperor must precede the serial number of the patent document. [4] Kind of document by the appropriate symbols as indicated on the document under WIPO Standard ST.16 if possible. [5] Applicant is to place a check mark here if English language translation is attached.

INFORMATION DISCLOSURE STATEMENT BY APPLICANT (Not for submission under 37 CFR 1.99)		
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	Filing Date	2019-07-30
	First Named Inventor	Henrik Öjelund
	Art Unit	3992
	Examiner Name	KE, PENG
	Attorney Docket Number	0079124-000266

CERTIFICATION STATEMENT

Please see 37 CFR 1.97 and 1.98 to make the appropriate selection(s):

That each item of information contained in the information disclosure statement was first cited in any communication from a foreign patent office in a counterpart foreign application not more than three months prior to the filing of the information disclosure statement. See 37 CFR 1.97(e)(1).

OR

☐ That no item of information contained in the information disclosure statement was cited in a communication from a foreign patent office in a counterpart foreign application, and, to the knowledge of the person signing the certification after making reasonable inquiry, no item of information contained in the information disclosure statement was known to any individual designated in 37 CFR 1.56(c) more than three months prior to the filing of the information disclosure statement. See 37 CFR 1.97(e)(2).

See attached certification statement.

The fee set forth in 37 CFR 1.17 (p) has been submitted herewith.

✓ A certification statement is not submitted herewith.

SIGNATURE

A signature of the applicant or representative is required in accordance with CFR 1.33, 10.18. Please see CFR 1.4(d) for the form of the signature.

Signature	/Travis D. Boone/	Date (YYYY-MM-DD)	2020-04-28
Name/Print	Travis D. Boone	Registration Number	52,635

This collection of information is required by 37 CFR 1.97 and 1.98. The information is required to obtain or retain a benefit by the public which is to file (and by the USPTO to process) an application. Confidentiality is governed by 35 U.S.C. 122 and 37 CFR 1.14. This collection is estimated to take 1 hour to complete, including gathering, preparing and submitting the completed application form to the USPTO. Time will vary depending upon the individual case. Any comments on the amount of time you require to complete this form and/or suggestions for reducing this burden, should be sent to the Chief Information Officer, U.S. Patent and Trademark Office, U.S. Department of Commerce, P.O. Box 1450, Alexandria, VA 22313-1450. DO NOT SEND FEES OR COMPLETED FORMS TO THIS ADDRESS. **SEND TO: Commissioner for Patents, P.O. Box 1450, Alexandria, VA 22313-1450.**

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EAST Search History

EAST Search History (Prior Art)

Ref #	Hits	Search Query	DBs	Default Operator	Plurals	Time Stamp
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S2	0	("20060459602").PN.	US-PGPUB; USPAT; DERWENT	OR	OFF	2020/04/10 13:55
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S6	2	"20090174679"	US-PGPUB; USPAT; DERWENT	OR	OFF	2020/04/10 14:01
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S8	2	("9329675").pn.	US-PGPUB; USPAT; DERWENT	OR	OFF	2020/04/27 09:08
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S10	5289	S9 and (3d).ab,ti.	US-PGPUB; USPAT; DERWENT	OR	OFF	2020/04/27 09:11
S11	1040	S10 and scan	US-PGPUB; USPAT; DERWENT	OR	OFF	2020/04/27 09:12
S12	615	S11 and environment$3	US-PGPUB; USPAT; DERWENT	OR	OFF	2020/04/27 09:12
S13	96	S12 and oral$3	US-PGPUB; USPAT; DERWENT	OR	OFF	2020/04/27 09:16
S18	86140	((A61B5/0088 OR A61C9/004 OR G01B11/24 OR G06F3/002 OR G06F3/01 OR G06F3/011 OR G06F3/017 OR G06F3/0346 OR G06F3/04815).CPC.)	US-PGPUB; USPAT; DERWENT	OR	OFF	2020/04/27 09:19
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S20	1040	S19 and scan	US-PGPUB; USPAT; DERWENT	OR	OFF	2020/04/27 09:19
S21	615	S20 and environment$3	US-PGPUB; USPAT; DERWENT	OR	OFF	2020/04/27 09:19
S22	96	S21 and oral$3	US-PGPUB; USPAT; DERWENT	OR	OFF	2020/04/27 09:19

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FIRST INFORMATION DISCLOSURE STATEMENT BY APPLICANT	**Application Number**	16/526,281
	Filing Date	July 30, 2019
	First Named Inventor	Henrik ÖJELUND
(use as many sheets as necessary)	**Examiner Name**	Peng KE
Sheet 1 of 4	**Attorney Docket Number**	0079124-000266

U.S. PATENTS

Examiner Initials	Item No.	Patent Number	Kind Code (if known)	Name of Patentee or Applicant of Cited Document	Issue Date (MM-DD-YYYY)
	1.	9,329,675	B2	Öjelund *et al.* (IPR2018-00197, Ex. 1001) (IPR2018-00198, Ex. 1001)	05-03-2016
	2.	8,903,746	B2	Brennan *et al.* (IPR2018-00197, Ex. 1007) (IPR2018-00198, Ex. 1007)	12-02-2014
	3.	7,221,332	B2	Miller *et al.* (IPR2018-00197, Ex. 1013) (IPR2018-00198, Ex. 1013)	05-22-2007
	4.	5,377,011	A	Koch (IPR2018-00197, Ex. 1014) (IPR2018-00198, Ex. 1014)	12-27-1994
	5.	6,485,413	B1	Boppart *et al.* (IPR2018-00197, Ex. 1015) (IPR2018-00198, Ex. 1015)	11-26-2002
	6.	5,131,844	A	Marinaccio *et al.* (IPR2018-00197, Ex. 1020) (IPR2018-00198, Ex. 1020)	07-21-1992
	7.	6,592,371	B2	Durbin *et al.* (IPR2018-00197, Ex. 1021) (IPR2018-00198, Ex. 1021)	07-15-2003
	8.	5,722,412	A	Pflugrath *et al.* (IPR2018-00197, Ex. 1024) (IPR2018-00198, Ex. 1024)	03-03-1998
	9.	6,645,148	B2	Nguyen-Dinh *et al.* (IPR2018-00197, Ex. 1025) (IPR2018-00198, Ex. 1025)	11-11-2003
	10.	5,181,181	A	Glynn (IPR2018-00197, Ex. 1027) (IPR2018-00198, Ex. 1027)	01-19-1993
	11.	6,227,850	B1	Chishti *et al.* (IPR2018-00197, Ex. 1030) (IPR2018-00198, Ex. 1030)	05-08-2001
	12.	7,213,214	B2	Baar *et al.* (IPR2018-00197, Ex. 1032) (IPR2018-00198, Ex. 1032)	05-01-2007
	13.	7,551,353	B2	Kim *et al.* (IPR2018-00197, Ex. 1034) (IPR2018-00198, Ex. 1034)	06-23-2009
	14.	7,813,591	B2	Paley *et al.* (IPR2018-00198, Ex. 2001)	10-12-2010
	15.	7,141,020	B2	Poland *et al.*	11-28-2006
	16.	6,967,644	B1	Kobayashi	11-22-2005
	17.	7,831,292	B2	Quaid *et al.*	11-09-2010
	18.	8,035,637	B2	Kriveshko	10-11-2011
	19.	8,384,665	B1	Powers *et al.*	02-26-2013
	20.	6,135,961	A	Pflugrath *et al.*	10-24-2000

U.S. PATENT APPLICATION PUBLICATIONS

Examiner Initials	Item No.	Document Number	Kind Code (if known)	Name of Patentee or Applicant of Cited Document	Publication Date (MM-DD-YYYY)
	21.	2007/0171220	A1	Kriveshko (IPR2018-00197, Ex. 1005) (IPR2018-00198, Ex. 1005)	07-26-2007
	22.	2006/0020204	A1	Serra *et al.* (IPR2018-00197, Ex. 1006) (IPR2018-00198, Ex. 1006)	01-26-2006
	23.	2006/0212260	A1	Kopelman *et al.* (IPR2018-00197, Ex. 1008) (IPR2018-00198, Ex. 1008)	09-21-2006

Examiner Signature	/PENG KE/	Date Considered	04/27/2020

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FIRST INFORMATION DISCLOSURE STATEMENT BY APPLICANT (use as many sheets as necessary)	**Application Number**	16/526,281
	Filing Date	July 30, 2019
	First Named Inventor	Henrik ÖJELUND
	Examiner Name	Peng KE
Sheet 2 of 4	**Attorney Docket Number**	0079124-000266

	24.	2007/0172112	A1	Paley *et al.* (IPR2018-00197, Ex. 1009) (IPR2018-00198, Ex. 1009)	07-26-2007
	25.	2012/0179035	A1	Boudier (IPR2018-00197, Ex. 1010) (IPR2018-00198, Ex. 1010)	07-12-2012
	26.	2009/0322676	A1	Kerr *et al.* (IPR2018-00197, Ex. 1011) (IPR2018-00198, Ex. 1011)	12-31-2009
	27.	2005/0237581	A1	Knighton *et al.* (IPR2018-00197, Ex. 1026) (IPR2018-00198, Ex. 1026)	10-27-2005
	28.	2006/0092133	A1	Touma *et al.* (IPR2018-00197, Ex. 1028) (IPR2018-00198, Ex. 1028)	05-04-2006
	29.	2010/0009308	A1	Wen *et al.* (IPR2018-00197, Ex. 1031) (IPR2018-00198, Ex. 1031)	01-14-2010
	30.	2003/0164952	A1	Deichmann *et al.* (IPR2018-00197, Ex. 1033) (IPR2018-00198, Ex. 1033)	09-04-2003
	31.	2009/0040175	A1	Xu *et al.* (IPR2018-00197, Ex. 2001) (IPR2018-00198, Ex. 2003)	02-12-2009
	32.	2009/0217207	A1	Kagermeier *et al.*	08-27-2009
	33.	2003/0158482	A1	Poland *et al.*	08-21-2003
	34.	2009/0061381	A1	Durbin *et al.*	03-05-2009
	35.	2006/0146009	A1	Syrbe *et al.*	07-06-2006
	36.	2004/0204787	A1	Kopelman *et al.*	10-14-2004
	37.	2005/0057745	A1	Bontje	03-17-2005
	38.	2006/0025684	A1	Quistgaard *et al.*	02-02-2006
	39.	2014/0022352	A1	Fisker *et al* (IPR2018-00197, Ex. 1039)	01-23-2014

FOREIGN PATENT DOCUMENTS

Examiner Initials	Item No.	Country Code[1], Number, Kind Code	Publication Date (MM-DD-YYYY)	Name of Patentee or Applicant of Cited Document
	40.	WO 2010/064156 A1 (IPR2018-00197, Ex. 1012) (IPR2018-00198, Ex. 1012)	06-10-2010	Poland *et al.*
	41.	EP 2200332 A1 (IPR2018-00197 Ex. 1019) (IPR2018-00198, Ex. 1019)	06-23-2010	Thominet
	42.	WO 00/08415 A1 (IPR2018-00198, Ex. 1037)	02-17-2000	Babayoff *et al.*
	43.	WO 2010/145669 A1	12-23-2010	3Shape A/S *et al.*
	44.	WO 2011/120526 A1	10-06-2011	3Shape A/S *et al.*
	45.	WO 2004/066615 A1	08-05-2004	Nokia Corporation
	46.	CN 101513350 A with English Abstract	08-26-2009	Siemans AG
	47.	WO 2009/089126 A1	07-16-2009	3M Innovative Properties Company
	48.	WO 2001/011193 A1	01-27-2011	Dimensional Photonics International, Inc.
	49.	WO 2007/084727 A1	07-26-2007	3M Innovative Properties Company
	50.	WO 2013/010910 A1 (IPR2018-00197, Ex. 1040)	01-24-2013	3Shape A/S *et al.*

NON-PATENT LITERATURE DOCUMENTS

Examiner Initials	Item No.	Include name of the author (in CAPITAL LETTERS), title of the article (when appropriate), title of the item (book, magazine, journal, serial, symposium, catalog, etc.), date, page(s), volume-issue number(s), publisher, city and/or country where published.

Examiner Signature	/PENG KE/	Date Considered	04/27/2020

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Substitute for form PTO/SB/08a and PTO/SB/08b				Complete if Known	
FIRST INFORMATION DISCLOSURE STATEMENT BY APPLICANT (use as many sheets as necessary)				**Application Number**	16/526,281
				Filing Date	July 30, 2019
				First Named Inventor	Henrik ÖJELUND
				Examiner Name	Peng KE
Sheet	3	of	4	**Attorney Docket Number**	0079124-000266

	51.	Petition for Inter Partes Review of U.S. Patent 9,329,675, filed November 22, 2017 in IPR2018-00197.
	52.	Patent Owner's Preliminary Response to the Petition for Inter Partes Review of U.S. Patent No. 9,329,675, filed March 3, 2018 in IPR2018-00197.
	53.	Institution Decision entered May 30, 2018 in IPR20198-00197.
	54.	Patent Owner's Response to the Petition for Inter Partes Review of U.S. Patent No. 9,329,675, filed August 20, 2018 in IPR2018-00197.
	55.	Petitioner's Reply to Patent Owner's Response, filed November 14, 2018, in IPR2018-00197.
	56.	Petitioner's Demonstratives filed January 31, 2019, in IPR2018-00197.
	57.	Patent Owner's Submission of Demonstratives for Oral Argument filed January 31, 2019, in IPR2018-00197.
	58.	Petition for Inter Partes Review of U.S. Patent No. 9,329,675, filed November 22, 2017 in IPR2018-00198.
	59.	Patent Owner's Preliminary Response to the Petition for Inter Partes Review of U.S. Patent No. 9,329,675, filed March 3, 2018 in IPR2018-00198.
	60.	Decision Denying Institution entered May 30, 2018 in IPR20198-00198.
	61.	Petitioner's Request for Rehearing of Institution Decision, filed June 29, 2018 in IPR20198-00198.
	62.	Decision Denying Petitioner's Request for Rehearing, entered December 4, 2018 in IPR20198-00198.
	63.	U.S. Patent No. 9,329,675 File History (IPR2018-00197, Ex. 1002) (IPR2018-00198, Ex. 1002)
	64.	Declaration of Dr. Chandrajit L. Bajaj (IPR2018-00197, Ex. 1003)
	65.	Declaration of Dr. Chandrajit L. Bajaj (IPR2018-00198, Ex. 1003)
	66.	Dr. Chandrajit L. Bajaj Curriculum Vitae (IPR2018-00197, Ex. 1004) (IPR2018-00198, Ex. 1004)
	67.	Karatas *et al.*, "Three-dimensional imaging techniques: A literature review," European Journal of Dentistry , Vol. 8, Issue 1, 2014; pp. 132-140. (IPR2018-00197, Ex. 1016) (IPR2018-00198, Ex. 1016)
	68.	Broadbent H.B., "A New X-Ray Technique and Its Application to Orthodontia," The Angle Orthodontist, Vol. I, No. 2, February 4, 1931; pp. 45-66. (IPR2018-00197, Ex. 1017) (IPR2018-00198, Ex. 1017)
	69.	Birnbaum *et al.*, "Dental Impressions Using 3D Digital Scanners: Virtual Becomes Reality," (IPR2018-00197, Ex. 1018) (IPR2018-00198, Ex. 1018)
	70.	Ireland *et al.*, "3D surface imaging in dentistry what we are looking at," British Dental Journal, Vol. 205, No. 7, October 11, 2008; pp. 387-392. (IPR2018-00197, Ex. 1022) (IPR2018-00198, Ex. 1022)
	71.	Hajeer *et al.*, "Current Products and Practices Applications of 3D imaging in orthodontics: Part II," Journal of Orthodontics, Vol. 31, 2004; pp. 154-162. (IPR2018-00197, Ex. 1023) (IPR2018-00198, Ex. 1023)
	72.	Bornik *et al.*, "A Hybrid User Interface for Manipulation of Volumetric Medical Data," 3D User Interfaces, 2006; 8 pages. (IPR2018-00197, Ex. 1029) (IPR2018-00198, Ex. 1029)
	73.	Giammanco, et. al., "Using 3D Laser Scanning Technology to Create Digital Models of Hailstones," American Meteorological Society, July 2017; pp. 1341-1347. (IPR2018-00197, Ex. 1036) (IPR2018-00198, Ex. 1036)
	74.	D. A. Bowman et al., "Theory and Practice" 3D User Interfaces, 4:96-101, July 2004. (IPR2018-00197, Ex. 1038)
	75.	EPO Prosecution History of European Patent Application No. 11847582.1, filed June 19, 2013. (IPR2018-00198, Ex. 1038)
	76.	Yoshida, Hiroshi *et al.*, "Intraoral Ultrasonic Scanning as a Diagnostic Aid," J. CRANIO-MAX.-FAC. SURG. 15 (1987), pp. 306-311. (IPR2018-00197, Ex. 2002) (IPR2018-00198, Ex. 2004)
	77.	Moran, Carmel M *et al.*, "A Comparison of the Imaging Performance of High Resolution Ultrasound Scanners for Preclinical Imaging," ULTRASOUND IN MED. & BIOL., Vol. 37, No. 3 (2011), pp. 493-501. (IPR2018-00197, Ex. 2003) (IPR2018-00198, Ex. 2005)

Examiner Signature	/PENG KE/	Date Considered	04/27/2020

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FIRST INFORMATION DISCLOSURE STATEMENT BY APPLICANT	**Application Number**	16/526,281
	Filing Date	July 30, 2019
	First Named Inventor	Henrik ÖJELUND
(use as many sheets as necessary)	**Examiner Name**	Peng KE
Sheet 4 of 4	**Attorney Docket Number**	0079124-000266

	78.	Ahn, Jae Sung, *et al.*, "Development of Three-Dimensional Dental Scanning Apparatus Using Structured Illumination," Sensors, 17, 1634 (2017), 9 pages. (IPR2018-00197, Ex. 2004) (IPR2018-00198, Ex. 2002)
	79.	U.S. Patent Application Serial No. 10/744,869. (IPR2018-00197, Ex. 2005)
	80.	B.C. Chua *et al.*, "SonoDEX: 3D space management and visualization of ultrasound data," INTERNATIONAL CONGRESS SERIES 1281:143-148 (2005). (IPR2018-00197, Ex. 2006)
	81.	Deposition Transcript of Chandrajit Bajaj, Ph.D. on July 25, 2018 with Errata Sheet. (IPR2018-00197, Ex. 2008)
	82.	J. Mackinlay *et al.*, "A Semantic Analysis of the Design Space of Input Devices," HUMAN-COMPUTER INTERACTION 5:145-190 (1990). (IPR2018-00197, Ex. 2009)
	83.	"Taxonomies of Input" in DEVELOPING A TAXONOMY OF INPUT 4.1-4.16 (Jan. 4, 2009) available at https://www.billbuxton.com/input04.Taxonomies.pdf. (IPR2018-00197, Ex. 2010)
	84.	Declaration of Ravin Balakrishnan, Ph.D. (IPR2018-00197, Ex. 2011)
	85.	*Curriculum Vitae* of Ravin Balakrishnan, Ph.D. (IPR2018-00197, Ex. 2012)
	86.	D. Bowman, *et al., 3D User Interfaces Theory and Practice* § 4.1.1 "Input Device Characteristics" pp 88-89; § 4.2.2 "2D Mice and Trackballs" pp 91-92; § 4.8.2 "Input Device Taxonomies" pp 128-132 (2005). (IPR2018-00197, Ex. 2013)
	87.	J. Jerald, *The VR Book: Human-Centered Design for Virtual Reality* § 27.1.3 (2016). (IPR2018-00197, Ex. 2014)
	88.	International Search Report (PCT/ISA/210) issued on February 22, 2012 in International Application No. PCT/DK2011/050461.
	89.	C. Graetzel, *et al.*, A Non-Contact Mouse for Surgeon-Computer Interaction, Technology and Helath Care, 12(3):1-19, 2004.
	90.	S. Vogt *et al.*, An AR System With Intuitive User Interface For Manipulation And Visualization of 3D Medical Data, Stud. Health Technol. Inform., Medicine Meets Virtual Reality, 12(98):397-403, 2004.
	91.	Xia *et al.*, Three-Dimensional Virtual Reality, IEEE Transactions on Information Technology in Biomedicine, 5(2):97-107, June 2001.
	92.	First Office Action issued April 3, 2015 in corresponding Chinese Patent Application No. 201180066956.6 (13 pages).
	93.	Second Office Acton issued in corresponding Chinese Patent Application No. 201180066956.6 dated November 18, 2015, with English translation (27 pages).
	94.	Deposition Transcript of Dr. Ravin Balakrishnan.
	95.	Record of Oral Hearing held February 4, 2019 from IPR2018-00197
	96.	Final Written Decision, entered May 29, 2019- Termination Decision Document from IPR2018-00197 [Paper 22]

Examiner Signature	/PENG KE/	Date Considered	04/27/2020

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INFORMATION DISCLOSURE STATEMENT BY APPLICANT (Not for submission under 37 CFR 1.99)		
	Application Number	16526281
	Filing Date	2019-07-30
	First Named Inventor	Henrik Öjelund
	Art Unit	3992
	Examiner Name	KE, PENG
	Attorney Docket Number	0079124-000266

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INFORMATION DISCLOSURE STATEMENT BY APPLICANT (Not for submission under 37 CFR 1.99)	Application Number	16526281
	Filing Date	2019-07-30
	First Named Inventor	Henrik Öjelund
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INFORMATION DISCLOSURE STATEMENT BY APPLICANT (Not for submission under 37 CFR 1.99)		
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	Examiner Name	KE, PENG
	Attorney Docket Number	0079124-000266

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Please see 37 CFR 1.97 and 1.98 to make the appropriate selection(s):

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The fee set forth in 37 CFR 1.17 (p) has been submitted herewith.

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A signature of the applicant or representative is required in accordance with CFR 1.33, 10.18. Please see CFR 1.4(d) for the form of the signature.

Signature	/Travis D. Boone/	Date (YYYY-MM-DD)	2020-04-28
Name/Print	Travis D. Boone	Registration Number	52,635

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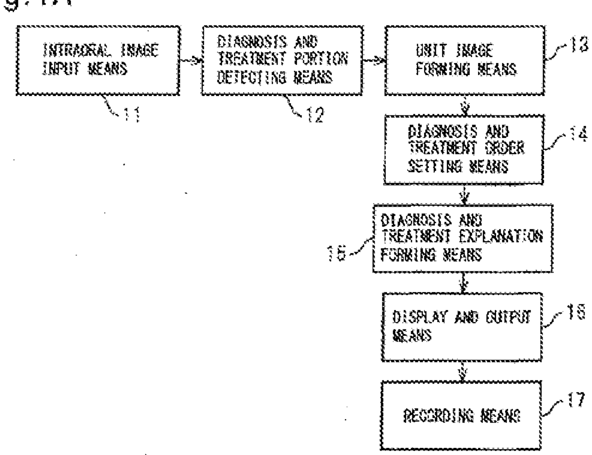
(54) **ORAL IMAGING AND DISPLAY SYSTEM**

(57) A system configured provided with a continuously captured image sequence forming means for continuously capturing side surfaces of rows of teeth to form an image sequence, a side surface tooth row image forming means for combining sequences of images which were formed by the continuously captured image sequence forming means as partial tooth row images from an image forming the center of the overall composite so as to form a plurality of partial tooth row images, and a side surface tooth row image combining means for linking and combining a plurality of partial tooth row images which were formed by the side surface tooth row image forming means based on images forming the centers of the overall composite so as to form overall rows of teeth. By configuring the system in this way, it is possible to use a handheld type intraoral video camera to form a panoramic image of the side surface tooth rows for display on a computer monitor and propose a broad range of dental diagnosis and treatment to a patient and to secure participation of the patient in proactive dental diagnosis and treatment.

Fig.1A



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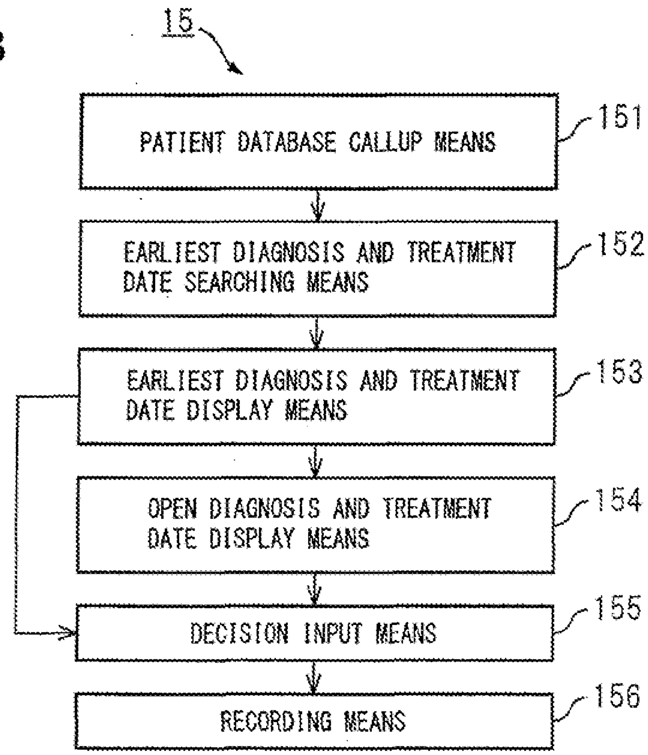
(Cont. next page)

Fig.1B


15
PATIENT DATABASE CALLUP MEANS
151
EARLIEST DIAGNOSIS AND TREATMENT DATE SEARCHING MEANS
152
EARLIEST DIAGNOSIS AND TREATMENT DATE DISPLAY MEANS
153
OPEN DIAGNOSIS AND TREATMENT DATE DISPLAY MEANS
154
DECISION INPUT MEANS
155
RECORDING MEANS
156

Description

Technical Field

[0001] The present invention relates to a system which captures an image of the entire oral cavity and displays a panoramic image.

Background Art

[0002] In the treatment of tooth cavities and other intraoral diseases, when the target treatment ends, the visits to the clinic usually also end. Treatment of tooth decay usually starts when the patient becomes aware of tooth pain, discomfort, or other symptoms. When the treatment ends, the visits to the clinic also end. This is the usual pattern. Therefore, even if there is other tooth decay, if there are no noticeable symptoms, in many cases it is left alone - the clinic is visited only after the tooth decay advances. Further, with such one-time visits to the clinic, a healthy oral cavity is not secured. Staining, swelling, loss, tartar, wear, salivary calculus, mismatch, and other issues for which there are no subjective symptoms, but which can be seen from the outside after often unnoticed by the person in question.

[0003] For the business operations of a dental practice as well, one-time treatment sometimes cannot by any means be said to be good in terms of profitability, but there were no means found which were suitable for dealing with this. For example, PLT 1 discloses a configuration of an electronic patient chart in which the entire rows of teeth are displayed on a computer monitor and which the individual teeth are colored so as to enable easy viewing from the patient side. Ease of viewing the rows of teeth is a requirement which is sought in informed consent, but even if parts of the entire rows of teeth are easy to view, for use for explanations of treatment, greater enlargement and configuration for enabling understanding of the purpose of treatment are required.

[0004] Further, PLT 2 describes a configuration in which a plurality of sets of intraoral image data which is captured in advance are displayed on a monitor screen of a computer. Furthermore, PLT 3 discloses a method of presentation by display of moving images and still images using a computer to as to improve the understanding of specialized terminology etc. as a tool for obtaining informed consent. Further, it is described that such a presentation method may be used for educational purposes in elementary schools, junior high schools, various businesses, retirement homes, etc. Furthermore, PLT 4 discloses fluorescent film which enables visualization of an X-ray image and a configuration which reflects an image rendered visible by a prism for capture by a camera.

[0005] As other patent literature relating to dental medicine, for example, the following such literature may be mentioned: PLT 5: Oral Cavity Washer Fitted With Videoscope; PLT 6: Intraoral Camera Apparatus and Method; PLT 7: Handpiece for Dental Examination and Diagnosis; PLT 8: Hand Switch for Intraoral Camera, PLT 9: Intraoral Camera With Built-in Display; PLT 10: Intraoral Camera Apparatus and Dental Mirror; PLT 11: Dental Camera Apparatus; PLT 12: Instrument for Periodontal Examination Use; PLT 13: Regular Examination Method and System; PLT 14: Apparatus Used in Dental Medicine Environment; and, further, PLT 15: X-Ray Image Detection System for Medical Use.

Citations List

Patent Literature

[0006]

PLT 1: Japanese Patent Publication No. 10-97404A
PLT 2: Japanese Patent Publication No. 2005-334426A
PLT 3: Japanese Patent Publication No. 10-97405A
PLT 4: Japanese Patent Publication No. 10-201757A
PLT 5: Japanese Patent Publication No. 2001-212161A
PLT 6: Japanese Patent Publication No. 2005-144171A
PLT 7: Japanese Patent Publication No. 62-246347A
PLT 8: Japanese Patent Publication No. 2001-29315A
PLT 9: Japanese Patent Publication No. 2002-355262A
PLT 10: Japanese Patent Publication No. 2005-304600A
PLT 11: Japanese Utility Model Publication No. 5-30402U
PLT 12: Japanese Utility Model Registration No. 3131408U
PLT 13: U.S. Patent No. 5752827
PLT 14: Japanese Patent Publication No. 2009-516555A
PLT 15: Japanese Patent Publication No. 5-130991A

Summary of Invention

Technical Problem

[0007] Numerous proposals have been made for examination of the oral cavity by using image displays. In the final analysis, these just provide information to patients by conventional one-time local treatment systems. They do not reach the level of systems designed for ensuring health of the teeth in the oral cavity as a whole.

[0008] Further, when a dentist explains treatment to a patient, sometimes he or she will use an intraoral image or X-ray image obtained by a dental camera, but the image itself is hard to interpret.

[0009] Furthermore, images and data easily understandable by the patient can be expected to help the dentist explain diagnosis and treatment to the patient, increase interest of the patient in intraoral health, and provide incentive for self health management, but such equipment, image displays, etc. fulfilling this promise have still not been proposed.

[0010] The dental practice has had to pay more attention to business operations along with the increase in the number of clinics. In order to stabilize business operations, entry into new dental diagnosis and treatment areas, reduction of costs, securing patients who regularly visit the clinics, and streamlining of the dental field have become necessary. For example, a handheld terminal such as described in the previously cited Japanese Utility Model Registration No. 3131408U has also been proposed.

Solution to Problem

[0011] In consideration of the above, the present invention proposes to provide a continuously captured image sequence forming means for continuously capturing side surfaces of rows of teeth to form an image sequence, a side surface tooth row image forming means for combining sequences of images which were formed by the continuously captured image sequence forming means as partial tooth row images from images forming the centers of overall composites so as to form a plurality of partial tooth row images, and a side surface tooth row image combining means for linking and combining a plurality of partial tooth row images which were formed by the side surface tooth row image forming means based on an image forming the center of the overall composite so as to form overall rows of teeth. By configuration in this way, according to the present invention, it is possible to use a handheld type of intraoral camera to form a clear panoramic image of the rows of teeth. Furthermore, it is possible to display an X-ray panoramic image of the rows of teeth and a panoramic image of the rows of teeth which have been virtual straightened or virtually beautified and colored side by side or display them superposed so as to broaden the range of diagnosis and treatment in the dental practice.

[0012] Furthermore, the present invention proposes a combination comprised of a unit image forming means for forming an image of the oral cavity for each diagnosis and treatment and care unit, a setting means for setting diagnosis and treatment and care order information for images captured by unit image formation by the unit image forming means, a display means for displaying images, with the diagnosis and treatment and care order information attached, based on the diagnosis and treatment and care order information so as to be able to be displayed in a list form, and a display medium which displays and records display information which is obtained by the display means. By configuration in this way, according to the present invention, it becomes possible to raise self awareness of the patient about treatment so as to promote intraoral health and encourage regular visits by patients and thereby realize an improvement of the efficiency of business operations of the dental field.

[0013] Furthermore, in addition, the present invention proposes preparing data for using a monitor of a computer etc. to explain details of treatment using the above-mentioned method etc. to the patient, manage attendance of dental employees, manage fees for diagnosis and treatment, and otherwise have a dental employee process data using a computer by a compact mobile terminal which is provided with a processor, memory, communicating means, inputting means, and display means. By using such a compact mobile terminal, in the present invention, greater efficiency in the dental practice is realized.

[0014] The image which is referred to in the present invention in the final analysis indicates a digital image. Either a moving image or a still image may be used. Further, the "image forming the center of the overall composite" in the present invention refers to for example an image common to two partial panoramic images when combining the two. "Overall" does not refer to only the final overall panoramic image of rows of teeth. For example, it also includes the case of a panoramic image of rows of teeth in the process of combination which is obtained by first combining two partial panoramic images of rows of teeth when forming three or more partial images of rows of teeth. "Combining ... from an image forming the center of the overall composites" means, for example, combining a plurality of still images which were obtained by continuously capturing rows of teeth in the back tooth direction from images where part of teeth at the center of the surface of the front teeth becomes the center so as to form a left side partial tooth row panoramic image and a right side partial tooth row panoramic image. "Linking and combining" means, for example, combining a left side partial tooth row panoramic image and a right side partial tooth row panoramic image at portions common to both or combining them by connection based on linkable portions.

[0015] The present invention sometimes sets a mark at an image including a part forming the center of combination. This "mark" indicates, for example, one which will not easily dissolve in saliva, water, etc. and which has an elongated rectangular shape or a seal which has a short rectangular shape and, for example, is coated on its back surface with a binder, adhesive, etc. and can be peeled off or another such deposit. Further, the invention is not limited to a deposit. It is also possible to draw a mark on the teeth by a pen which can give a removable color which can be clearly captured such as green, red, etc.

[0016] The portion where the mark is made is preferably arranged so as to span an upper tooth and lower tooth, but, for example, when capturing the image of only one of the upper jaw or lower jaw, it may be arranged at only the one to be captured. Further, the "predetermined position on the rows of teeth for making a mark" indicates, for example, an image becoming the center of combination at a position where a change in the capturing direction of the camera, the way it is held, etc. would cause the image capture to stop and the movement to stop.

[0017] The mark may be formed by a color (green, blue, etc.) and shape which can be easily discerned in the captured image. The material and color are suitably selected. Further, when obtaining a 3D image, it is possible to use a mark with provides a characteristic 3D property. The mark need only be one which is shown on the surface of the teeth and which clearly displays a position in the captured image, so for example it is also possible to provide a means which fires a laser sighting beam giving a shape of known dimensions on the tooth surface or to arrange a means such as a spotlight where there is correspondence between the lighting distance and area of the emitted light so as to enable light to be shone from the intraoral camera toward the teeth.

[0018] The mark need only be one enabling start of combination from the image where the mark is captured at a predetermined position. The capturing direction need not always be from the back teeth. The capturing direction and the combining direction need not be opposite. At the time of combination, sometimes the parts are combined from an image where a mark is displayed at a predetermined position to the left and right and finally the images are combined as a whole based on an image at which the mark is displayed at a predetermined position. The "predetermined position of the mark for starting combination" includes the illustrated case where, for example, the mark is at the center of the captured image, but the invention is not limited to this. It may be at any portion where combination is easy in partial combination and overall combination.

[0019] Sometimes, for example, in the case of partial combination of the three right, center, and left side surfaces of the rows of teeth such as the back side surfaces of the teeth, marks are required at the tooth between the right side surface and the center side surface and two teeth at the center side surface and right side surface, that is, sometimes a plurality of marks may be provided. The "side surface of the rows of teeth" referred to in the present invention is not limited to the front side. The back side and bite surfaces are sometimes also included. "Continuous capture" indicates automatic image capture at a rate of up to 30 images per second or less.

[0020] "Combine" is the method of combination of the panoramic images. For the method at the time of combination, existing methods may be selectively used. Simple combination, simple alignment, block matching, the Lucas-Kanade method and other optical flow estimation methods and other automatic or manual methods of combination can be utilized, but it is preferable to use an affine transform or other image adjusting means in advance and use the common parts between images as the basis to adjust the slant, magnification, etc.

[0021] The characterizing portion in the present invention is a line shape, dot shape, graphic shape, or 3D shape when combining panoramic images of partial rows of teeth, for example, when combining two side panoramic images, the center front teeth and the boundary lines of the front teeth, but the invention is not limited to this. One of the characterizing teeth of the front teeth or front end of the gums or other portions are also included.

[0022] The "oral cavity" in the unit image forming means for forming an image of the oral cavity for each unit of diagnosis and treatment and care indicates the teeth, rows of teeth, gums, alveolar bone, lips, hard palate, soft palate, uvula, and other regions.

[0023] "Diagnosis and treatment" includes diagnosis and treatment together and diagnosis by a dentist and treatment by a specialized medical institution.

[0024] The "diagnosis and treatment and care unit" indicates the range of one diagnosis and treatment procedure of tooth decay, periodontal disease, tongue cancer, gum cancer, etc. and sometimes also indicates stain removal, straightening, or other care, preventive treatment, and quasi-diagnosis and treatment.

[0025] "Care" indicates something of the extent which can be handled by brushing or application of fluorine or a mouthwash etc. and preventive care such as coating the teeth with fluorine, cleaning, coating with a preventive agent against periodontal disease, and other actions.

[0026] "Image forming" indicates conversion to image data which can be output to and displayed on a computer monitor (display) device or mobile phone display and also a state printed on paper or other state displayed two-dimensionally or three-dimensionally.

[0027] The diagnosis and treatment and care order information of the setting means for setting diagnosis and treatment and care order information for an image processed by unit image-forming by the unit image forming means includes symbols, codes, numerals, etc. indicating the order of diagnosis and treatment, prevention, and care and, in addition, includes the date and time of diagnosis and treatment, the state of advance of disease, predictions on the advance of disease, and other data. It need only be enough to enable determination of the order of diagnosis and treatment and care for at least a plurality of unit images. It may be content which can be directly visually confirmed and may be parameters for computation which can be confirmed after computer processing.

[0028] "Displayed in a list form" means at least a list of the order of diagnosis and treatment and care which, if in a state able to be easily viewed as a whole, is printed on several sheets of paper or is displayed as several images able to be changed by scrolling.

[0029] The "display medium" which displays and records the display information which is obtained at the display means indicates a state displayed by being printed on one or more sheets of paper or booklets or a state of image data of the JPEG, GIF, BMP, or other format displayed in a portable manner. The "display medium" includes a sheet or booklet of paper, a USB memory, SD card, memory, or other recording device provided in a display device, mobile phone, etc., but indicates at least printed matter or an electronic image etc. which a patient can carry and use to view his or her oral cavity. Alternatively, it includes the case of viewing one's own intraoral data on a homepage on the Internet. Therefore, the display medium includes a desktop type or notebook type of personal computer.

[0030] The present invention utilizes a reflecting mirror, so the path of the sighting beam is relatively long. By using an LED or other sighting beam source with a spread based on the directional angle, it is possible to clarify the image capture position and the image capture range.

[0031] Further, the present invention provides an intraoral camera which utilizes a reflecting mirror wherein the dentist etc. can clearly understand the image capturing position even with an image which is captured through this reflecting mirror.

[0032] Furthermore, the present invention measures the posture of an intraoral camera which moves vertically and horizontally by a gyro sensor so as to obtain angle information of the body, derives the angle of the mirror from the angle of this body, and obtains a grasp of what kind of state the camera is in. By adjusting the posture of the image from the captured state, regardless of the state of the vertically and horizontally moving camera, it is possible to realize display of an image in a readily viewable state at all times.

[0033] In the present invention, an angular acceleration sensor (gyro sensor), acceleration sensor, or other position sensor is used. Specifically, rate gyros which output angular acceleration, rate integrating gyros which output angle, posture gyros, MEMS (micro electro mechanical systems) type and other mechanical type, optical type, and other angular acceleration sensors, piezoresistance type, electrostatic capacity type, and heat sensing type MEMS sensors, and other acceleration sensors can be mentioned.

[0034] The color of the sighting beam in the present invention may be any color which can be discriminated from the color of illumination light. If the illumination light is white, the sighting beam may be red, green, etc. Alternatively, as the timing of firing the sighting beam, a timing right before the user starts an image capture operation is preferable, but the beam may also be fired in a short time during the image capture as well in some cases.

[0035] Furthermore, the present invention provides a mobile terminal which can be worn on the body. By arranging inside it a storing means, computer, modulating and demodulating means for communication with the outside, and display means and enabling input and output for the dental practice as a whole, it is possible to manage dental employees, access electronic patient charts, calculate diagnosis and treatment fees, etc. at one's fingertips and to share, display, and synchronize this information so that even a handful of people can administer the dental office work and perform administrative processing for diagnosis and treatment in a dispersed manner. This enables the work of the dental practice to be streamlined.

[0036] The present invention preferably arranges an operating interface at a position which can be operated at the time of treatment, but depending on the operator, the method of operation will differ or the fingers will not reach the interface. Due to such physical factors, an adjusting means is provided for giving a time lag by the method of operation of the interface between operation of the operating interface and the actual operation performed in accordance with the state of inability of operation or the state of explanation to the patient (for example, when an interval is necessary between the oral explanation and screen display).

[0037] For example, when the operating interface is a switch, if the switch is successively pressed twice, the operation is performed after 2 seconds. In this way, it is possible to adjust the delay time by the number of times pressed or adjust the timing of display by the display means by the number of times pressed, the pressed time, etc. for a GUI-like operation.

[0038] Furthermore, the present invention provides a means for fetching an X-ray image and superposing it over an actual image or, for example, splicing together X-ray images for the different teeth to form a panoramic image and superposing it over an actual image obtained by capturing and combining images in the same way so as to enable a panoramic comparison from the side surfaces of the rows of teeth. By superposing, aligning, etc. this actual image and X-ray images on a display means, much greater understanding of treatment by the patient is realized.

[0039] Furthermore, the present invention forms a terminal which connects with a computer terminal wirelessly or by cable, is sometimes provided with a liquid crystal display, tenkeys, etc., and can be worn at the user arm, leg, or other part so as to enable input and output of patient information etc. with the computer terminal at one's fingertips, enable the dentist to obtain past data necessary for treatment and background information for when explaining treatment to individual patients in a manner not visible to the patients, and enable accurate diagnosis and treatment and explanation of treatment to the patients.

[0040] That is, a dental diagnosis and treatment system may be formed comprised of a mobile terminal which is provided with an input part for inputting dental related information and a display part for displaying dental related information, a host terminal which is provided with a recording means for temporarily or continuously recording dental related information and a processing means for processing dental related information based on a predetermined algorithm, and an information transmitting means for transmitting information between the mobile terminal and a center terminal wirelessly or by cable. In this case, the mobile terminal may be carried by being worn by the dental employee on his arm, leg, upper torso, lower torso, or other part of the body. All or part of the dental employees can therefore share the information which is displayed.

[0041] The present system may be configured to be portable as explained above and may be used as a tablet type or a desktop type PC. In this case as well, centralized management of dental information is possible.

[0042] A mobile terminal is a terminal which enables input and output and enables information processing, so enables centralized management of intraoral information, dental diagnosis and treatment information, dental office information, dental employee information, and other dental practice related information. Specifically, it displays information from corresponding software, an intraoral camera or other peripheral device, etc., adds new data, corrects data, deletes it, and otherwise processes input and stores data, shares data with other mobile terminals and host terminals and displays and processes input in synchronization with the same, but the invention is not limited to this. It is sufficient that the required dental information can be displayed, recorded, input, and processed from the mobile terminal.

[0043] On the computer monitor screen, for example, on the screen of the mobile terminal, a menu is displayed. In addition, various information is displayed by switching of the screen each time the user selects it by a mouse etc. Alternatively, a single screen displays all information of a specific patient as an individual window screen.

[0044] The user follows the displayed content of the screen to select, newly add, correct, delete, and otherwise input information. Input is performed by using the attached tenkeys or virtual tenkeys or by selecting preset input text by a mouse, tenkeys, etc.

[0045] Further, attendance of the dental employees can, for example, be input by the individual employees using their own mobile terminals and the host terminal or an attendance-keeping staff can newly add, correct, delete, or otherwise process input from his or her own mobile terminal or the host terminal. If the dental employees have their own mobile terminals and only the staff concerned should perform processing through them, it is also possible to set passwords for the staff concerned.

[0046] "Centralized management" means, for example, the case where a single terminal is used for input, output, and display of intraoral information, dental diagnosis and treatment information, dental office information, dental employee information, and other information related to the dental practice, but the invention is not limited to this. Even only part of that information is included if sufficient for the intended management.

[0047] The present invention further forms a dental treatment menu by combining partial subdivided images obtained by subdivision in advance and enables formation of still images, slide like moving images, moving images, or other explanatory images in accordance with the treatment for the individual patients.

[0048] The subdivided images are, for example, preferably images of tooth extraction, images of bridging actions of facing teeth, images explaining dental work, etc. prepared in advance as CG images and moving images. These are selected and combined by the dentist, dental hygienist, etc. based on the patient or are selected and combined by the patient from a display of a treatment menu including treatment by implants, treatment by prosthetics, etc.

[0049] The selection may be performed by selecting the individual subdivided images and running them consecutively on a computer. Further, it is also possible to prepare several existing moving images selected in advance to enable the dental employee or patient to view them as combined moving images for explanation of treatment and see the states before treatment, after treatment, and sometimes during treatment.

[0050] These linked images can be formed to content tailored to the state of treatment of the patient himself or herself, so the effect of greater understanding and promotion of efforts for prevention of tooth decay etc. can be expected. Such partial moving images and images of the patient captured by camera means may be converted to the same image format for use. A treatment system which is easy for the patient to understand and which is easy for the dentist or other user to use is therefore provided.

Advantageous Effects of Invention

[0051] The present invention enables the display of part or all of rows of teeth by a clear panoramic image using the actual image and further, sometimes, enables display of an X-ray image superposed or in parallel, so that display can be used to explain to a patient the diagnosis and treatment in an easily understandable manner.

[0052] Further, the present invention enables the image capturing position of an intraoral camera which uses a reflecting mirror to be accurately displayed and enables the capturing posture of the camera unit being moved up and down in the oral cavity to be learned and adjusted to a state facilitating viewing of the captured image.

[0053] A patient can constantly check the situation in his or her own oral cavity and the necessity of diagnosis and treatment by a portable display means by which these are displayed on paper or in a recording medium in a list format. Due to this, the possibility of on-going diagnosis and treatment and care for maintaining intraoral health becomes higher and the profits in the dental practice can be increased and other facets of business can be improved.

[0054] The present invention further enables all processing in the dental practice to be handled using a mobile terminal able to process digital data and therefore enables rationalization of work and reduction of costs.

Brief Description of Drawings

[0055]

[FIG. 1] FIG. 1 is a block diagram for showing an embodiment of the present invention.
[FIG. 2] FIG. 2 is a schematic view for explaining an embodiment.
[FIG. 3] FIG. 3 is a schematic view for explaining an embodiment.
[FIG. 4] FIG. 4 is a schematic view for explaining an embodiment.
[FIG. 5] FIG. 5 is a block diagram for showing another embodiment of the present invention.
[FIG. 6] FIG. 6 is a schematic view for explaining an embodiment.
[FIG. 7] FIG. 7 is a schematic view for explaining an embodiment.
[FIG. 8] FIG. 8 is a schematic view for explaining an embodiment.
[FIG. 9] FIG. 9 is a schematic view for explaining an embodiment of the present invention.
[FIG. 10] FIG. 10 is a schematic view for explaining an embodiment.
[FIG. 11] FIG. 11 is a schematic view for explaining an embodiment.
[FIG. 12] FIG. 12 is a schematic view for explaining an embodiment.
[FIG. 13] FIG. 13 is a block diagram for showing another embodiment of the present invention.
[FIG. 14] FIG. 14 is a schematic view for explaining an embodiment.
[FIG. 15] FIG. 15 is a schematic view for explaining an embodiment.
[FIG. 16] FIG. 16 is a schematic view for explaining an embodiment.
[FIG. 17] FIG. 17 is a schematic view for explaining an embodiment.
[FIG. 18] FIG. 18 is a block diagram for showing an embodiment of the present invention.
[FIG. 19] FIG. 19 is a schematic view for explaining an embodiment of the present invention.
[FIG. 20] FIG. 20 is a block diagram for explaining an embodiment of the present invention.
[FIG. 21] FIG. 21 is a block diagram for explaining an embodiment of the present invention.
[FIG. 22] FIG. 22 is a schematic view for explaining an embodiment of the present invention.
[FIG. 23] FIG. 23 is a schematic view for explaining an embodiment of the present invention.
[FIG. 24] FIG. 24 is a block diagram for explaining an embodiment of the present invention.
[FIG. 25] FIG. 25 is a block diagram for explaining an embodiment of the present invention.
[FIG. 26] FIG. 26 is a block diagram for explaining an embodiment of the present invention.
[FIG. 27] FIG. 27 is a schematic view for explaining an embodiment of the present invention.
[FIG. 28] FIG. 28 is a schematic view for explaining an embodiment of the present invention.
[FIG. 29] FIG. 29 is a block diagram for explaining an embodiment of the present invention.

Description of Embodiments

[0056] Next, various aspects and embodiments for working the present invention will be explained in detail while referring to the drawings. However, the present invention is not limited to only the aspects described below. It should be understood that various changes and improvements may be made within the scope of the present invention.

[0057] The present invention continuously captures images of rows of teeth, uses panoramic image combination to form partial panoramic images, and combines these partial panoramic images to form an overall panoramic image of the rows of teeth. Preferably, marks are provided at the combined parts. By doing this, it is possible to easily form a panoramic image of rows of teeth by a handheld camera.

[0058] The present invention acquires a unit image corresponding to diagnosis and treatment or care from intraoral images which are captured at the time of dental diagnosis and treatment or examination and diagnosis by using an intraoral camera or X-ray camera system and intraoral images captured at the home. This unit image is for example shown on a computer monitor (display) device which enables viewing together with the patient. The patient views the state inside the oral cavity. While doing this, he or she works with the dentist to enter the order of diagnosis and treatment, the period of start of treatment, the degree of necessity of diagnosis and treatment, etc. The obtained diagnosis and treatment and care order information and unit image are printed out on a single sheet of paper or stored in a mobile phone which is provided with a storage medium and displayed on the monitor of the mobile phone. Alternatively, it is uploaded to a homepage of the dentist and displayed on an individual's own screen.

[0059] The present invention provides a portable, wearable mobile terminal which includes inside it a storing means, computer, modem means for communication with the outside, and display means so as to enable input/output and data processing for the dental practice as a whole. Using this, it is possible to manage attendance of dental employees, make entries into electronic patient charts, calculate diagnosis and treatment fees, and have dental employees perform other work at their handheld terminals and share this information. The mobile terminal is connected with a host terminal wirelessly by infrared, light, or other media or is connected by a cable. Alternatively, the mobile terminal may be connected through a wireless LAN, wired LAN, etc. to a cloud computing computer network by designing it to have computer specifications.

(First Embodiment)

[0060] FIG. 1A is a view which shows an embodiment of the present invention. In the figure, reference numeral 11 indicates an intraoral image inputting means, for example, a device which uses a camera for capturing images of all teeth of the upper jaw and lower jaw so as to obtain digital image data.

[0061] The intraoral image inputting means 11 is, for example, a reflection type of dental camera which uses a convex mirror such as shown in FIG. 3C or another camera for capturing an image of the oral cavity using a fisheye's lens and outputs a digital image of all teeth. Alternatively, as shown in FIGS. 6A and 6B, it is possible to use an ordinary intraoral camera to capture images of the individual teeth, extract contours from the individually captured images, connect the contours at the shared parts, and combine the images to obtain an overall image of the teeth.

[0062] Reference numeral 12 indicates a diagnosis and treatment portion detecting means. This, for example, is for setting a tooth for diagnosis and treatment or for care and a predetermined range of that tooth. This cuts out and extracts a tooth from a broad range intraoral image, which has been input by an intraoral image inputting means 11, by visual inspection while using graphics software. Further, it extracts and finds the contour of the tooth by software processing, assumes the extracted contour to be a circle and finds its center, and extracts an image of a radius 10% to 20% larger than the radius of the contour from that center.

[0063] Reference numeral 13 indicates a unit image forming means. This processes the image for diagnosis and treatment, which was obtained by the diagnosis and treatment portion detecting means 12, for display use. This is for forming an image with a region for entry of the diagnosis and treatment order and comments. The unit image forming means 13 automatically creates and displays templates by designation of the diagnosis and treatment portion by the above-mentioned diagnosis and treatment portion detecting means 12 by operating icons by software.

[0064] The image which is shown is sometimes just a designated range of the image which was input by the intraoral image inputting means 11. It may also be a separately prepared template for unit image display which the user himself or herself designates. The image may further be one which is displayed after being captured by a suitable camera which uses a reflecting mirror which is shown in FIG. 3 at the time when the unit image is displayed. The image may also be initially displayed as a moving image in the unit image area and then confirmed and displayed as a still image by pressing a confirmation button.

[0065] Reference numeral 14 is a diagnosis and treatment order setting means. For example, the state of advance of tooth decay or the degree of diagnosis and treatment and care may be used as the basis for the dentist to determine the order on his or her own or in consultation with the patient or by automatic measurement of the state of advance of tooth decay or degree of deformation of shape. For automatic determination of the order, it is possible to convert the difference in color of the teeth to a numerical value for comparison with a certain threshold value or determine when a degree of deformation has exceeded a basic shape of a tooth by a certain extent or more or when the size of a spectral component based on the wavelength to an illumination light source of the tooth decay detection wavelength is a predetermined value or more so as to determine the order. The order of the images may be changed on the screen of the monitor (display) device.

[0066] The above mentioned changes are talked over with the patient, then the order of treatment and diagnosis is determined, so by pushing the confirmation button after determining the order, the order of unit images which are placed on the screen is automatically changed and the result printed out for patient use, so the diagnosis and treatment time can be streamlined.

[0067] Reference numeral 15 indicates a diagnosis explanation forming means. In the same way as the diagnosis and treatment order setting means 14, this is a means for entering the time of start of diagnosis and treatment, the urgency of diagnosis and treatment, the diagnosis and treatment technique, and other content which the patient believes necessary as data. This may be entered by input from a keyboard of a computer (for example, 315 of FIG. 3), selection of set explanations by operation using a mouse (for example, 316 of FIG. 3), or input by connecting operating buttons of the intraoral camera which is shown in FIG. 3 with the input interface of the computer and in that state operating the buttons attached to the camera body.

[0068] The diagnosis explanation forming means 15 has the date of start of diagnosis and treatment or scheduled date of diagnosis and treatment entered from the cells 21b to 23b which are shown in FIG. 2C to FIG. 2E, but it is also possible that the earliest date enabling diagnosis and treatment be automatically displayed for that date.

[0069] The earliest date enabling start of diagnosis and treatment may also be set by a function of calling up the diagnosis and treatment scheduled start date entry fields from the database of patients recorded and stored in the recording means 17 and displaying the earliest date among the dates with no entries.

[0070] The specific configuration is shown in FIG. 1B. This is part of the configuration of the diagnosis explanation forming means. The rest is omitted. Reference numeral 151 indicates a patient database callup means. This is a database in which the image data which is shown in FIG. 2, the order data, data on the date of start of treatment (including time), and explanatory data are recorded. This is managed as is general practice, so related data is recorded in a temporary recording region. This may be configured so that when the stored data is voluminous, data is called up to the database for each examination.

[0071] The earliest diagnosis and treatment date searching means 152 calls up the diagnosis and treatment start date data from this and searches for a date where no diagnosis and treatment start date is entered from this starting from the search start date. When there is data which does not match it, this is output as the earliest diagnosis and treatment date.

[0072] Reference numeral 153 indicates an earliest diagnosis and treatment date display means which displays a date searched for and detected by the earliest diagnosis and treatment date searching means 152 on the display part of the unit image.

[0073] Reference numeral 154 indicates an open diagnosis and treatment date display means which displays the open dates and times of diagnosis and treatment in an easily understandable format. For example, an analog clock and calendar can be schematically displayed or otherwise a computer monitor can be made to display units of months, units of several months, or units of years.

[0074] Reference numeral 155 indicates a decision input means for input of the consent of the patient and recordal of it in the database.

[0075] Reference numeral 156 is a recording means for recording to a database. This recording means 156 is the same as the recording means 17. Input may be recorded as finalized in the recording means 17, but the date and time of diagnosis and treatment have to be quickly recorded in the database since there is a possibility of another dentist simultaneously setting up a schedule like that of the patient. Therefore, as soon as the decision is made, it is preferably recorded in the database.

[0076] Returning again to FIG. 1A, 16 is a display and output means for editing and displaying images comprised of unit images, diagnosis and treatment orders, and diagnosis and treatment explanations on a screen of a computer monitor (display) device or using a printer (for example, 317 of FIG. 3) to print edited images on paper.

[0077] Reference numeral 17 is a recording means for recording the edited image data. It records it as part of an electronic patient chart stored by the dentist or records it in a patient mobile phone or computer through a storage medium. The recording means 17 includes a database which stores data of all of the patients from data of the individual patients.

[0078] Next, one example of an intraoral camera will be shown by FIG. 3 and explained.

[0079] Reference numeral 301 is a housing for holding use. It is shaped as a tube so as to form a pencil type intraoral camera. Inside, a circuit board, a USB connection circuit for connection with the outside, and a USB socket are contained.

[0080] At the front end, a camera unit 309 is integrally connected. For example, as shown in FIG. 3E, the camera unit 309 has for example a CCD camera arranged at its center and has white LEDs and other color LEDs and other illumination devices 312 arranged around it in a concentric circle at equal intervals.

[0081] Reference numeral 302 is a reflecting mirror unit. At its front end, a flat mirror 303 which is arranged at a for example 45 degree angle is connected. At its back end, a tubular part 305 is formed in a state enabling insertion into the outer circumference of the camera unit 309 and enabling replacement. The outer shape of the camera unit 309 and the inner shape of the tubular part 305 of the reflecting mirror unit 302 are preferably made elliptical so that the parts will not rotate when fastened by insertion with each other.

[0082] The reflecting mirror unit 302 can be suitably replaced. FIG. 3B shows the state where a reflecting mirror unit provided with a flat mirror 303 is attached, while FIG. 3C shows the state where a reflecting mirror unit 310 where a spherical surface shape convex mirror 308 is attached is inserted into and joined with the camera unit 309.

[0083] When capturing all of the teeth in this way, the reflecting mirror unit 310 which has the convex mirror 308 of FIG. 3C connected to it is used. The convex reflected video of the convex mirror 308 is captured by the camera 313 of the camera unit 309. The output light of the illumination device 312 is reflected through the convex mirror 308 to light up the observed portion of the oral cavity. The camera 313 is illustrated as a CCD type, C-MOS type, etc. For the resolution, a higher image quality is preferable, but when mainly capturing a moving image, the image quality may be kept low in use.

[0084] In the case of normal image capture, the tubular part 305 of the reflecting mirror unit to which the flat mirror 303 which is shown in FIG. 3B is attached is inserted into the outer circumference of the camera unit 309 to join it for use.
[0085] Reference numeral 304 is a lead line such as a dedicated electrical lead line or a general use USB cable etc.
[0086] Reference numerals 306 and 307 are operating buttons. These are one or more push type, rotary type, composite type, or other buttons. In the present embodiment, two are shown. In addition to turning the power on or off or otherwise operating the camera, sometimes a selection and operation use display window which is displayed on a monitor 314A of a computer 314 which is connected through a lead line 304 is operated by pressing this operating button 307 in a GUI (graphical unit interface) function. For example, the operating buttons 306 and 307 can be operated when automatically rearranging the unit images in order after the order has been determined.
[0087] For example, reference numeral 306 may be made a button corresponding to the left click function of a mouse and 307 may be made a button corresponding to the right click function.
[0088] Reference numeral 314 indicates a computer which is formed integrally with a monitor (display) 314A as one example. In addition, it may also be combined as a dedicated device.
[0089] Reference numeral 315 indicates a keyboard, while 316 indicates a mouse for a computer. Both are used for operating the computer. Furthermore, they may also double as switches for operating the intraoral camera.
[0090] Reference numeral 317 indicates a printer. It is formed by an ink jet type or laser type color printer etc. and is used when printing out a patient's own intraoral image to give to the patient.
[0091] FIG. 3D shows a reflecting mirror unit 318 which uses a concave mirror 311 as a reflecting mirror. For example, this is used when an enlarged image is required. Alternatively, in the case of an oral cavity, when capturing enlarged only the inside of the rows of teeth, sometimes the curvature of the concave mirror 311 is adjusted to a direction close to a flat mirror and the rows of teeth are captured from a location somewhat separated from it so as to obtain a wide range image shown in the present invention.
[0092] In the present invention, sometimes not just the rows of teeth but also the tongue, lips, gums, etc. included in a wide range image are handled as a unit image. For example, the present invention can be suitably utilized in the case of displaying a polyp, which can be a manifestation of tongue cancer, as a unit image and explaining diagnosis and treatment.
[0093] Next, the present invention will be explained while referring to FIG. 6 which shows one example for forming an overall tooth image. The camera which is used is one using the reflecting mirror unit 302 using a flat mirror 303 such as shown in FIG. 3B. Alternatively, the image may be captured as a still digital or may be captured as a digital moving image. Furthermore, when obtaining a plurality of still images from a digital moving image, since this is for capturing a moving image, the number of pixels becomes relatively small, therefore it is preferable to capture still images by an auto catcher while moving.
[0094] All of the teeth of the lower jaw 600 which is shown in FIG. 6A are captured while making the flat mirror 303 of the reflecting mirror unit 302 move in the direction from the capture planes 601 to 612. When capturing a digital moving image, the result is similar to the case of inputting still images at a rate of about 30/sec, so if the reflecting mirror part of an intraoral camera for capturing a digital moving image is made to move along a path from the image capture planes 601 to 612 of FIG. 6A, a large number of still images can be found. Further, continuous capture of still images gives a greater number of pixels and a higher resolution than acquisition of still images by capture of a moving image, so this is a preferable mode when acquiring images of individual teeth from this overall tooth image.
[0095] FIG. 6B shows parts of the individual images when performing a capture operation which is shown in FIG. 6A. Reference numeral 613 indicates an image of a common part of the images 601 and 602, 614 indicates an image of a common part of the images 602 and 603, and 615 indicates an image of a common part of the images 603 and 604. In addition, the capture operation is performed so that images of common parts are obtained for 604 and 605, 605 and 606, 606 and 607, 607 and 608, 608 and 609, 609 and 610, 610 and 611, and 611 and 612.
[0096] For example, these images are digitalized to obtain the contours, then are superposed so that the contours of the common parts match between images. Furthermore, the images 605, 606, 607, 608, 609, 610, 611, and 612 are successively captured and these images are linked based on their mutually common parts to obtain an overall tooth image. A panoramic type image of the bite plane can be formed by known panoramic image combining software, but when there is the effect of shaking due to holding the camera by the hand, the images are corrected before combination, so sometimes processing by affine transformation is preferable.
[0097] Next, the operation of the above embodiment will be explained in detail while referring to FIG. 2.
[0098] The intraoral image inputting means 11 is used to capture an image of for example the entire teeth of the upper jaw in the oral cavity. The position of the captured image is shown in FIG. 2A. The intraoral image inputting means 11 need only obtain an image which includes the tooth which the dentist is diagnosing and treating and which enables to which part in the oral cavity this corresponds to be understood.
[0099] The image which is shown in FIG. 2A, for example, is captured by the intraoral camera unit which is shown in FIG. 3C which is shown in FIG. 3C. Furthermore, it is possible to calibrate this so as to correct for distortion. Alternatively, the intraoral image inputting means 11 does not necessarily capture all of the teeth. It may also capture part of the teeth

or a single tooth. FIG. 2A shows the upper jaw 20 and captures all of the teeth and the hard palate part. This portion is sometimes both diagnosed and treated.

[0100] Next, the diagnosis and treatment portion detecting means 12 is used to automatically or manually extract a portion requiring diagnosis and treatment or care. If extracting it manually, in the same way as graphic software, a mouse is used to designate this portion by a circle or square, then the portion is copied, cut, etc. and furthermore pasted. In FIG. 2A, 20a, 20b, and 20c indicate the state of using graphic software to manually or automatically designate and display a tooth to be covered by a conspicuous color circle.

[0101] "Manually designate and display" is to operate a mouse or keyboard which is for example attached to a computer so as to draw a circle, square, or other contour etc. and process the inside, while "automatically designate and display" is to for example use a mouse to move a point to a designated portion on the screen and press a button so as to display a circle of a predetermined radius or a square of a predetermined area and process the inside.

[0102] Next, the unit image forming means 13 adjusts the designated tooth 20a which is shown in FIG. 2C to a unit image 21. At that time, for example, an order field 21a in which the order of treatment is entered after the order is determined, a diagnosis and treatment start date field 21b in which for example the start of treatment is entered after it is determined, and an explanatory field 21c in which what kind of diagnosis and treatment are to be performed is entered are additionally set. This earliest diagnosis and treatment date is, for example, displayed in the diagnosis and treatment start date field 21b of the unit image earliest in order in FIG. 2. If the patient consents to this date, the operation shifts to the decision input means 155 which decides on this date and records it in the patient database by the recording means 156.

[0103] If the patient does not consent, the open diagnosis and treatment date display means 154 displays the open diagnosis and treatment dates in a 2D form like a calendar format. This display may be of a list type, a page flipping type, or other type employing display of a schedule. It is sufficient that it at least be a display which the patient can easily understand.

[0104] Note that, not only the date, but also the time is required, so the time is also preferably displayed simultaneously. If agreement is reached on the date of start of diagnosis and treatment based on this display, the decision input means 155 is used to input that date and time and the recording means 156 is used to record them in the database.

[0105] The next unit image in order is shifted to and a similar date of start of diagnosis and treatment is decided and entered.

[0106] This scheduling operation of the diagnosis and treatment date is effective for clarification of the schedule since when the present invention sets a plurality of scheduled diagnosis and treatment dates, it is necessary to avoid conflicts with schedules of other patients - which does not occur with singe-instance diagnosis and treatment.

[0107] Note that, the ID number may be entered in any field for each tooth. This field is for example an input use box display used in the database. The diagnosis and treatment date can be automatically determined as a date which is open in view of the diagnosis and treatment schedules of other patients, so when a unit image is displayed, the open time slots may also be displayed from the data of patients. The content which is displayed in a window may be the image before treatment with fields in which at least the order of treatment is displayed or in which ID codes are attached.

[0108] FIG. 2D shows a unit image 22 which shows a tooth 20b for diagnosis and treatment of FIG. 2A, while FIG. 2E shows a unit image 23 which shows a tooth 20c for diagnosis and treatment of FIG. 2A.

[0109] The unit image 22 displays an order field 22a, diagnosis and treatment start date field 22b, and explanation field 22c all together. FIG. 2E similarly shows a unit image 23 which shows an order field 23a, diagnosis and treatment start date field 23b, and explanation field 23c all together. Note that, when finalized, a confirm button (including a virtual button which is displayed on the screen) is pressed. By pressing the confirm button, the display may be rearranged along the numbers in the order entry fields. By automating this work, in the final analysis, the time for preparing the paperwork to be handed over to the patient can be shortened.

[0110] The view which is shown in FIG. 2 sometimes is shown in its entirety on a single computer monitor. In this case, this sometimes doubles as the operating range of the display and output means 16.

[0111] In the diagnosis and treatment order setting means 14, the order in the order field 22a is determined and entered by the dentist alone or by the dentist and patient in consultation. Similarly, the diagnosis explanation forming means 15 is used to make entries into the diagnosis and treatment start date field 22b and the explanation field 22c. These entries include considerable specialized matter, so sometimes are made by the dentist alone in advance.

[0112] The display and output means 16 forms and displays on the computer screen the finalized plurality of unit images and state including all tooth images. The display and output means 16 preferably displays any dental diagnosis and treatment which are performed on the same screen when they are performed.

[0113] However, when there are many unit images, they may be displayed by scrolling or may, if necessary, be reduced in size or shown by thumbnails. Furthermore, the finalized image at the display and output means 16 may be printed by a printer on paper to be given to the patient. The patient can keep the image of his or her own oral cavity. This is expected to lead to regular visits to the clinic to maintain oral cavity health. Further, after diagnosis and treatment end, the image of the oral cavity is again captured as shown in FIG. 1.

[0114] The tooth 20a of the same portion is displayed as a unit image 24 as shown in FIG. 2B. Reference numeral 24d indicates the diagnosis and treatment portion, while 24a displays the order when, for example, the diagnosis and treatment order setting means 14 is used to search for the same image data from image data for which the diagnosis and treatment order has been set in advance and that order is shown. For example, the diagnosis explanation forming means 15 is used to describe the recorded matter etc. in advance at the time of diagnosis and treatment.

[0115] Further, the unit images after diagnosis and treatment which are shown in FIG. 2A can be displayed at locations adjoining the same unit images before diagnosis and treatment so as to increase the trust in the dentist and keep the patient aware of the timing for visits to the clinic for maintenance of the diagnosed and treated teeth. Reference numeral 24c indicates the explanation field for example after diagnosis and treatment. This is more preferably an explanatory field for consultation with the patient over the start of the next diagnosis and treatment.

[0116] Further, the display and output means 16 uses a printer to print out on a single sheet of paper for example the four images which are shown in 400 of FIG. 4. This is handled to the patient to impress on the patient the need for continuous diagnosis and treatment. Note that, 400 does not show the intraoral wide range image which is shown in FIG. 2A, but preferably shows the wide range image so as to clarify the diagnosis and treatment portion and thereby obtain the further understanding of the patient.

[0117] The display fields of FIG. 2 and FIG. 4 are an example. The number of display fields per unit image and the displayed content are suitably selected in accordance with the purpose of the treatment, schedule, etc.

(Second Embodiment)

[0118] Next, another embodiment will be shown in FIG. 5 and explained. In the figure, reference numeral 51 indicates a wide range image inputting means. This is a means for capturing an image of all teeth of the upper jaw and all teeth of the lower jaw of the oral cavity. For example, it is possible to capture all teeth which are reflected in the convex mirror which is shown in FIG. 3C by a camera so as to obtain a wide range image or to continuously capture images shown in FIG. 6 and combine common parts from the still images forming the digital moving image so as to form a complete tooth image.

[0119] Reference numeral 52 indicates a tooth detecting means which extracts image data of respective teeth from the rows of teeth obtained by the wide range image inputting means 51. The extraction may, for example, be performed by a means using a contour extraction program to extract the peripheral sides in just a predetermined range to form an image of a single tooth and also by a means which uses the flat mirror which is shown in FIG. 3B to capture the individual teeth and form a single image, but the method of cutting out unit images from the overall tooth image and intraoral wide range image so as to form images of single teeth is both rational and preferable in some cases.

[0120] Reference numeral 53 indicates a unit image forming means which adds to the individual images obtained by the tooth detecting means 52 the respective order entry fields, diagnosis and treatment explanation entry fields, etc. to form the display use images. Furthermore, it is preferable to form a tooth database and attach unique codes to manage the teeth.

[0121] Reference numeral 54 indicates a diagnosis and treatment image selecting means for selecting a tooth for diagnosis and treatment of tooth decay, loss, etc. The dentist can visually, or through a comparison with previously registered data which is read out, select a tooth for diagnosis and treatment based on the differences in color, shape, etc.

[0122] Reference numeral 55 indicates a diagnosis and treatment order setting means by which the dentist decides on the order of the teeth for diagnosis and treatment on his or her own or by which the dentist and patient decide on this by discussion based on images displayed on a computer monitor (for example, monitor 314A of FIG. 3A) or printed images.

[0123] Reference numeral 56 indicates a diagnosis explanation forming means by which the period of diagnosis and treatment, date of start, and details of the diagnosis and treatment and the necessity of care etc. may be entered by the dentist alone or by consultation with the patient and by which explanations recorded in advance based on comparison with previous data may be displayed according to the magnitude of the differences.

[0124] Reference numeral 57 indicates a display and output means by which the display image for diagnosis and treatment may be displayed on a single sheet of paper or may be displayed on a computer monitor (for example, 314A of FIG. 3A) for use for explanations for obtaining patient consent and understanding. Alternatively, an image which is printed out on paper may be provided to the patient and used for scheduling future diagnosis and treatment so as to realize on-going dental diagnosis and treatment.

[0125] Reference numeral 58 indicates a recording means by which information may be recorded as a patient chart or database or by which information is uploaded to a storage area exclusively for the patient in a server. Tooth image data may also be recorded at the recording part of a mobile phone of a patient.

[0126] Next, the operation of the embodiment which is shown in FIG. 5 will be explained with reference to FIG. 7. In the present embodiment, a wide range image inputting means 51 is used to capture an image of all of the teeth from the oral cavity of a patient so as to form image data 700 of all teeth comprised of a single or multiple images (see FIG. 7A). The image data 700 which shows all teeth can be formed by linking the still images which are shown in FIG. 6 as one example. From the obtained wide range image data 700, the tooth detecting means 52 manually or automatically forms tooth images.

[0127] As the technique for automatically detecting teeth, the intraoral image data may be processed by a contour extraction program to extract contours and detect the contours of the teeth. In this case, if the contours are incomplete, several points are detected and a virtual circle which passes through these points is formed. This virtual circle can be deemed as the position of one tooth, so the radius from the envisioned center can be enlarged by exactly a predetermined value and a square surface can be extracted as an image of one tooth.

[0128] The extracted images become, for example, as shown in FIG. 7B, the tooth image 701 for the tooth 71, the tooth image 702 for the tooth 72, and the tooth image 703 for the tooth 73.

[0129] Next, the unit image forming means 53 is used to link the images of these teeth with identifiers and other patient information for unit image foration (see FIG. 7C). A unit image 74 includes a tooth image 701 and a display field 704 for entering the diagnosis and treatment order etc. The unit image 75 includes a tooth image 702 and a display field 705, while the unit image 76 includes a tooth image 703 and a display field 706. These unit images are recorded in a preset patient database and form an upper and lower intraoral data list of the patient.

[0130] The diagnosis and treatment image selecting means 54 visually or automatically extracts from the unit images a unit image 77 which shows an image of a tooth for diagnosis and treatment or care (see FIG. 7D).

[0131] In the diagnosis and treatment order setting means 55 and diagnosis explanation forming means 56, which have configurations similar to FIG. 1 and perform similar operations, the dentist enters the diagnosis and treatment order etc. alone or preferably while viewing the unit tooth images displayed on a computer monitor together with the patient.

[0132] Further, when the diagnosis and treatment order has been determined and the date of start of diagnosis and treatment etc. has been entered, the display and output means 57 may also display on the computer monitor 78, for example, an array of unit images displayed in sequence as shown in FIG. 7E or, as shown in FIG. 7F, a wide range image further included in an edited state. It is therefore possible to create a situation where the patient confirms diagnosis and treatment and gives consent for on-going diagnosis and treatment.

[0133] The unit images 707, 708, 709, and 710 are preferably arranged in order of start of treatment. FIG. 7F shows, for example, a screen display including the entire tooth image data 711 or tooth data 79 printed out to enable the patient to carry it.

[0134] The recording means 58 records these unit images in the database and is suitably used for adjusting the schedule with other patients.

[0135] Further, the present invention may form a single image by combining the technique of using a convex mirror shown in FIG. 3 when obtaining a wide area image or the technique of making the reflecting mirror move along the rows of teeth and combining the still images. That is, by making only the rows of teeth a still image, capturing the tongue portion by using a convex reflecting mirror, and combining the images, an intraoral wide area image provided with distortion-free rows of teeth is obtained.

[0136] Furthermore, one example of a panoramic tooth row image forming technique which combines panoramic images of rows of teeth in a state with the teeth engaged so as to form a clear image is shown from FIG. 8 to FIG. 12.

[0137] As shown in FIG. 8, the technique is adopted of using a camera to capture images from the left back up to near the center, then changing the orientation of the intraoral camera to then capture images from the right back to near the center. In this case, the direction of the camera is changed once, so the capture operation is interrupted. Therefore, the left and right tooth row images often cannot be accurately combined and end up deviating from each other.

[0138] Further, when manually moving and operating a camera, for example, when capturing an image of the back teeth, the intraoral camera is made to move in a state arranged between the cheek at the inside of the oral cavity and the side surfaces of the teeth and pushing aside the cheek or a state of contact is formed with the side surfaces of the teeth. Therefore, the cheek and the side surfaces of the teeth are in a state where they support the reflecting mirror of the intraoral camera or the image capturing portion of the camera, but if the intraoral camera is made to move in the direction of the front teeth, the camera is released from the pinched state with the cheek etc. and becomes held only by the hand whereby the operating camera becomes unstable in position and the images easily become disturbed. In particular, the distance between the camera and the captured object, that is, the side surfaces of the teeth, fluctuates and shaking occurs in the image capturing direction whereby the captured objects, that is, the teeth, fluctuate in size or the images become distorted.

[0139] The intraoral camera 901 which uses the reflecting mirror which is shown in FIG. 8 is configured as shown in FIG. 3 as one example, that is, is configured by a modular CCD camera or CMOS camera around which a plurality of light source LEDs are arranged. The oral cavity is lighted by the light source LEDs through the reflecting mirror and images of the rows of teeth in the oral cavity etc. are continuously captured. Stable capture is possible from the back teeth, but the invention is not limited to this. It may also use a camera for direct image capture not using a reflecting mirror in some cases.

[0140] The intraoral camera 901 which is used here is illustrated as one which is configured with a reflecting mirror unit 903 (302 of FIG. 3) which is provided with a flat type reflecting mirror 902 (303 of FIG. 3) attached interchangeably at the front end of a body 904 (301 of FIG. 3). The body 904 is provided at its front end with a camera unit 905 (309 of FIG. 3) which combines a CCD camera, CMOS camera, or other camera and four to eight light emitting diodes arranged around the camera.

[0141] The camera unit 905 is illustrated as one which outputs still digital images by using the continuous capture technique so as to obtain a range of for example 10 to 30 still images per second.

[0142] Before starting the continuous capture, first a mark ML is attached near the center of the rows of teeth 900a in the state with the upper and lower teeth engaged with each other. The mark ML is preferably made by temporary adhesion of a colored seal, marking by a colored pen giving a color that can be removed, or use of another means giving a mark which can be clearly displayed in the image captured by the camera. "Near the center" when attaching the mark ML for example near the center of the rows of teeth indicates a location serving as a reference when continuously capturing the left and right tooth rows, then combining the images. In addition, it is also possible to detect a characterizing portion in image processing near the center of a captured image and set that portion as the mark in the image. The mark ML is preferably arranged so as to span an upper tooth and lower tooth.

[0143] This continuous capture operation is performed from the back tooth position, for example, the state of 906a, along the tooth surfaces like 906b and 906c, preferably separated by the same distance from the surfaces of the rows of teeth, while the body 904 is held by the hand and the reflecting mirror 902 is moved.

[0144] "IG" indicates a correction use indicator. This is comprised of an adhesive member which is attached to a tooth surface in a manner enabling it to be peeled off later. On this, a graphic for image correction use such as a box, square, triangle, or checkerboard may be displayed to enable correction of distortion of the image or correction of the relative size of images based on the distance between the camera and tooth side surfaces. Alternatively, the correction use indicator IG may be colored green or another color which can be discerned in image processing, but it is not limited to green.

[0145] This adhesive member may be attached at the center of a tooth such as shown in, for example, FIG. 8 and FIG. 10, at the surface of the tooth where the mark ML is made. Alternatively, the tooth attached to is not limited to a single tooth. A plurality of teeth may have the adhesive member attached for image capture. The adhesive member may sometimes also be attached to another tooth in the oral cavity where the teeth are to be captured by hand with no other support.

[0146] The means for attaching the correction use indicator IG to a tooth surface may utilize a similar technique to that of the mark ML. An indicator which will not dissolve and will not run in saliva etc. may be used as an example. This is preferable when correcting for distortion and size of and combining a partial panoramic image of the left rows of teeth and a partial panoramic image of the right rows of teeth based on the correction use indicator IG which is captured in common to the two. Note that, when combining three partial panoramic images of the left rows of teeth, the center rows of teeth, and the right rows of teeth, the teeth common to the partial panoramic images may be provided with auxiliary use indicators IG.

[0147] Individual captured still images may also be corrected. For example, based on a reference auxiliary use indicator IG in the continuously obtained images or using as a reference one of the auxiliary use indicators IG captured in a group of images and detected by the block matching method or the template matching method etc., the auxiliary use indicator IG captured in another image is detected, then compared with the reference image to detect distortion, tilt, and differences in size, then correction is performed using affine transformation which performs enlargement, reduction, rotation, and adjustment of movement. At the time of image capture by hand where shaking is unavoidable, the auxiliary use indicator IG may be attached to a tooth so as to enable stable combination for forming a panoramic tooth row image.

[0148] The above-mentioned such correction of an image using the correction use indicator IG may, for example, be performed by the method of Zhang (IEEE Transactions on Pattern Analysis and Machine Intelligence, 22(11); 1330-1334, 2000) and other techniques used in calibration of camera images. Further, the correction use indicator IG sometimes is not essential depending on the captured state, affine transformation, or other processing.

[0149] FIG. 8B schematically shows one image capture range when continuously capturing images from the back teeth. The reflecting mirror part of the intraoral camera is made to move along with the elapse of time such as by 906a→906b→906c→906d→906e→906f→906g while obtaining continuously captured images as still images.

[0150] The intraoral camera 901 is configured provided with a reflecting mirror 902 at the front end at a predetermined angle, so if capturing the surfaces of the row of teeth from the left back teeth in the figure, the direction of the body 904 is changed near the center and then the surfaces are captured in order from the right back teeth in the figure. Therefore, the surfaces of 906e to 906g shown in FIG. 8 are captured, then the intraoral camera 901 is reversed and starts to capture images from the right back teeth.

[0151] The speed of continuous capture is made capture of a slightly great 20 to 30 images per second since the body 904 is moved by hand and therefore the effects of hand shaking and other shaking should be considered. Continuous capture with enough extra leeway to delete images which are out of focus due to hand shaking is preferable.

[0152] This continuous capture is preferably performed until the mark ML reaches the center of the capture screen or the reflecting mirror, but sometimes it is performed until a portion exceeding that by a certain extent. After that, the captured images may be picked and discarded.

[0153] Since the camera is operated manually, before combination, sometimes, the common portions of the images are used as the basis for affine transformation so as to match the images in state. For example, using the image first becoming the center of combination as a reference, block matching is performed with a comparative image to detect a plurality of common points. Based on this plurality of common points, the next image is processed by affine transformation. For example, a plurality of pixel coordinates (xb, yb) of the next image corresponding to the pixel coordinates (xa, ya) of the reference image at the common part are selected and entered into the following formula to obtain the coefficient values "a" to "f". In the state entering the coefficient values into the following formula, the next image is processed by affine transformation to straighten out the images or the images are straightened out while combining panoramic images.

[0154]

[Formula 1]

$$\begin{pmatrix} x_a \\ y_a \end{pmatrix} = \begin{pmatrix} a & b \\ c & d \end{pmatrix} \begin{pmatrix} x_b \\ y_b \end{pmatrix} + \begin{pmatrix} e \\ f \end{pmatrix}$$

[0155] Part of the images which are obtained by continuous capture from the left back to near the front surface in the figure in the rows of teeth 900a are shown in FIG. 9. Jointly using FIG. 8, the capture operation of an intraoral camera based on this embodiment will be explained.

[0156] FIG. 9A to FIG. 9E show one example of the sequence of captured image data when performing continuous capture near the centers 907c to 907e in the captured image data of the rows of teeth which are shown in FIG. 8B. Note that, the intraoral camera utilizes the reflecting mirror 902 to obtain a tooth row image, so the captured image is inverted left to right, but is shown in FIG. 9 and FIG. 11 in a non-inverted state so as to facilitate understanding.

[0157] FIG. 9A is an image which captures the area near 906c of FIG. 8B, FIG. 9B is an image which captures the area near 906d, FIG. 9C is an image which captures the area near 906e, FIG. 9D is an image which captures the area near 906f, and further FIG. 9E is an image which captures the area near 906g. Note that, since the capture is performed manually, the captured images often cannot be captured in the same state at all times. Therefore, when the images are tilted etc., it is preferable to perform correction for matching states using affine transformation at parts for example overlapping with the states of other teeth. FIG. 9 shows the view after correction. At the time of correction, as portions serving as reference, in addition to the mark ML, the vertical centerline CL and horizontal centerline HL which are set in advance at the reflecting mirror surface at which the reflecting mirror 902 is captured may be used.

[0158] The vertical centerline CL and the horizontal centerline HL are not necessarily displayed at the image. Further, at the edges of the reflecting mirror, it is also possible to provide projections or other marks at portions corresponding to the starting points and end points of the vertical centerline and horizontal centerline. These marks are sometimes used as the basis for virtual display.

[0159] Further, it is also possible to simultaneously perform processing for correcting distortion caused by a CCD camera lens by software.

[0160] RM is the contour of a mirror. The actually captured image becomes a circular image in the contour RM, but is displayed as a square image so as to facilitate the explanation of the range.

[0161] The captured image sometimes differs in the distance between the teeth and camera since the camera is held by the hand. In this case, an image where the mark ML and the vertical centerline CL approximately match may be used as a reference to correct the size of another captured image. Note that, sometimes the front end of the reflecting mirror 902 is made to lightly contact the tooth surface while continuously capturing images so it is possible to stabilize the obtained images.

[0162] As shown in FIG. 8, the reflecting mirror 902 of the body 904 is arranged from the front surface to the back teeth of the left side and then is made to move in the direction of the front surface for continuous capture so as to obtain, for example, the images of FIG. 9A to FIG. 9E. In this case, the images which are obtained by capture at timings where the mark ML matches the vertical centerline (CL) of the reflecting mirror 902 (up to FIG. 9C) are supposedly employed as images for combination. If using FIG. 9D on, at the time of combination, sometimes these will cause deviation, so it is preferable not to use these for combination.

[0163] The image which is shown in FIG. 9C is corrected for tilt of the image etc. in accordance with need with reference to the mark ML used as the reference image. That is, the image may be corrected based on the long sides and short sides of the mark ML to obtain the reference image. One example of the combination operation will be explained below.

[0164] The images which are used for combination are shown in FIG. 9F on. FIG. 9F corresponds to the image which is shown in FIG. 9C, FIG. 9G corresponds to FIG. 9B, and FIG. 9E corresponds to FIG. 9A.

[0165] The image 906e which is shown in FIG. 9F and the image 906d which is shown in FIG. 9G are combined by superposition based on common parts where the shape of the image of the image 906d matches or approximates the image 906e as a reference.

[0166] The part which sticks out in the left direction of FIG. 9G when superposed based on FIG. 9F is shown by 1001a. 1001a becomes the image in the back tooth direction.

[0167] Next, the combined image which is shown in FIG. 9G and the image 906c which is shown in FIG. 9A are superposed visually or by an image processing technique at parts of common shape etc. with reference to the combined image of FIG. 9G. In the superposed image, the part protruding in the left direction from FIG. 9G is indicated by 1001b. 1001b is an image in the back tooth direction.

[0168] The above operation is next performed between the next adjoining images. Furthermore, the next adjoining images are superposed at the common part. Due to this, the images from the image where the mark is at a predetermined position to the deep tooth direction are combined panoramically to form the left side rows of teeth.

[0169] In addition, the technique of splicing together the parts 1001a, 1001b... which protrude from the center image shown in FIG. 9F to form a left half panoramic image may be illustrated.

[0170] Further, the protruding parts are detected by, for example, extracting the protruding parts between 906e of FIG. 9C and 906d of FIG. 9B, extracting the protruding parts between 906d of FIG. 9B and 906c of FIG. 9A, furthermore collecting the protruding parts between the next adjoining images, and finally making the reference image the image shown in FIG. 9F and splicing together the protruding parts to form a panoramic image. The images of the protruding parts are sometimes preferably obtained by using an image from the center as a reference and superposing the adjoining images from it.

[0171] Note that, even when not completely superposed and matching or approximate, if the marker part is present in common, that part may be superposed for similar combination. Further, since the operation is manual, there is a proximity feeling in the obtained still images and the tilt sometimes differs. In this case, it is preferable to use affine transformation etc. for automatic correction to enlarge or reduce the image for adjustment.

[0172] The combined state is shown in FIG. 12A. As shown in FIG. 12A, it is possible to form the left half of the panoramic image of the rows of teeth.

[0173] Next, as shown in FIG. 10A, the reflecting mirror 104 of the body 103d is arranged at the right back of the rows of teeth 900a in the state with the top and bottom engaged. In that state, while holding a certain distance from the surface of the rows of teeth 900a as much as possible, continuous capture is performed by still images at 1101a→1101b→1101c in a direction approaching the center. FIG. 10B schematically shows the positional relationship between the captured still images and the rows of teeth 900a.

[0174] The user holds the intraoral camera 901 in his or her hand while making it move in the direction of 1102a→1102b→1102c→1102d→1102e→1102f to capture images and obtain continuously captured still images. The present example is of a handheld type, so the captured image will tilt or shift to the left or right and in the back direction, but a step may be provided which utilizes affine transformation to rotate or move the image based on the common parts present between adjoining images obtained by continuous capture so as to adjust the image.

[0175] The intraoral camera 901 which is shown in FIG. 10A is the one of FIG. 8 used as it is, so the same reference notations are assigned and explanations are omitted.

[0176] In FIG. 11A to FIG. 11E, typical images are shown in the range of 1102a to 1102f of FIG. 10B. Configurations which are common to FIG. 11 and FIG. 9 are assigned the same the same reference numerals as the reference numerals which are shown in FIG. 9.

[0177] In FIGS. 11, FIG. 11A shows the area near the image of 1102d of FIG. 10B, FIG. 11B shows the area near the image of 1102e of FIG. 10B, and FIG. 11C shows the area near the image of 1102f of FIG. 10B. Further, FIG. 11D shows the area near the image of 1102g of FIG. 10B, and FIG. 11E shows the area near the image of 1102h of FIG. 10B.

[0178] Note that, FIG. 11D and FIG. 11E are images of photos when the vertical centerline CL and the mark ML match, then the reflecting mirror 104 is made to move further in the left direction. If employing these images, the superposed parts of the images captured from the left and right directions will become greater and the images will deviate, so these are not employed. FIG. 11A to FIG. 11C are employed.

[0179] In the above images, the one using the image where the mark ML and the vertical centerline CL match (1102f of FIG. 11C) as a reference is shown in FIG. 11F. Next, the common portions of the images 1102e and 1102f shown in FIG. 11B are superposed.

[0180] In the state where the image 1102f is used as a reference and the image 1102e is superposed from above in a matching or similar range of shape, the protruding part is 1201a.

[0181] Next, this superposed image and the image 1201b which is shown in FIG. 11B are superposed with reference to the superposed image using pattern matching etc. at portions matching or substantially matching in shape.

[0182] The part which protrudes in the superposed state is 1201b. In this way, the adjoining images are superposed to form the right side rows of teeth. As another method of combination, the reference image 906e and images 1201a and 1201b may be combined as shown in FIG. 12B in some cases. Note that, when superposing front and back images, if there is some deviation, it is sometimes also possible to delete one of the superposed locations.

[0183] By using the above routine to combine continuously captured still images and superposing the center image 906e when combining the images of the left rows of teeth and the center image 1102f when combining the images of the right rows of teeth to make them match or substantially match, the panoramic image of the rows of teeth which is shown in FIG. 12C is formed.

[0184] The superposition is, for example, preferably performed by connecting and combining the left and right panoramic images of the rows of teeth based on the boundary part (KL) of teeth at the center. Note that, to deal with the case where the boundaries of teeth differ between the upper jaw and the lower jaw, the boundary part of teeth of the upper jaw or lower jaw may be used as the boundary for the combination. The combination at that time may also consist of respectively combining the panoramic image of the row of teeth of only the upper jaw and the panoramic image of the row of teeth of the lower jaw and finally combining the upper jaw and the lower jaw. At this time as well, when there is some deviation between the center images, it is also possible to delete one of the images in the superposed range.

[0185] Further, it is not necessarily required to superpose the center image 906e and the center image 1102f in advance. In some cases it is possible to employ one of the center images 1301. In this case, when for example employing the center image 906e, sometimes the sizes of 1201a and 1201b are corrected somewhat. When employing the center image 1102f, sometimes the sizes of 1001a and 1001b are corrected. In this way, in addition to the technique of splicing together the protruding parts between images, when not extracting the protruding parts and superposing images as they are at the common parts, sometimes the center images are superposed while adjusting them in size.

[0186] By, in this way, combining the left and right rows of teeth from the center images to form left side combined rows of teeth and right side combined rows of teeth and combining these based on their respective center images, it is possible to form a panoramic image of rows of teeth kept down in deviation.

[0187] For combination based on the center images, for example, it is preferable to use the contact line (edge) between teeth at the center so as to combine the left side combined rows of teeth and the right side combined rows of teeth. Furthermore, the mark does not necessarily have to be provided at the center teeth. It may sometimes be a portion of a tooth which is captured at a timing when changing the direction of the camera at the time of capture. In addition, the position of the mark is suitably selected based on the objective etc.

[0188] The characterizing portion is also not particularly limited so long as a portion which, in the same way as a mark, enables positioning at the time of combining images. Further, by applying a mark to the rows of teeth being captured in advance or providing a portion corresponding to a mark from the images, more accurate combination becomes possible.

[0189] Note that, the above explanation of operation is for the case of using graphic software to perform operations on a plurality of images which are displayed on a computer monitor such as copying and pasting them, dragging and dropping them, enlarging or reducing images, or correcting tilt visually and by mouse operation. Sometimes the known automatic panoramic image photo composing software such as Photoshop Elements 7® (made by Adobe), Photo Stitch® (made by Canon), etc. may be utilized.

[Preparation of 3D Panoramic Tooth Row Image]

[0190] A row of teeth is shaped bent into a bow in the bite plane. When trying to obtain a realistic grasp of it as a whole, with a 2D panoramic image display, the state of the individual teeth can be understood, but since the teeth are displayed in a state arranged in a flat shape, they are insufficiently grasped in three dimensions. Therefore, a technique able to display them in three dimensions is preferable.

[0191] The technique for obtaining a panoramic image by the actual image of an oral cavity, as described in for example WO2007/063980, is to form a frame which has a shape approximating an imaginary curve resembling the outline of an arch form of a row of teeth, arrange the camera device at its side surface, capture the rows of teeth as a whole, and convert the result to a 3D format so as to obtain a 3D panoramic image. True, it is possible to capture an image of rows of teeth in a 3D state, but it is hard to say this is a simple measurement technique due to the need for forming a frame provided with an imaginary curve resembling the outline of an arch form.

[0192] Next, an example of forming a 3D panoramic image by actual images will be explained with reference to FIG. 13. FIG. 13 is a block diagram for explaining a 3D panoramic tooth row image forming means.

[0193] Reference numeral 1401 indicates a camera data input means. This connects a stereo image capturing camera which is provided with a plurality of cameras such as shown in FIG. 14 and simultaneously forms the same number of images as the number of cameras.

[0194] The camera data inputting means 1401 is of a type where the shutter is operated for each image or a type where the shutter is operated once to enable continuous capture of a plurality of photographs. Sometimes a plurality of pairs of still images are continuously output.

[0195] Reference numeral 1402 indicates a calibrating means. This corrects distortion due to the lens shape, hand-shaking, etc. and corrects the perspective distance etc. It is configured using the known technique of calibration.

[0196] The calibrating means 1402 calibrates the simultaneously captured images and deletes the peripheral parts where distortion is large.

[0197] Reference numeral 1403 indicates a common point detecting means. This for example detects common points of a pair of images. The common point detecting means 1403 uses the luminance of one pixel or one group of pixels of one image as the reference luminance, uses the luminance of one pixel or one group of pixels of the other image to obtain, for example, the sum of absolute difference (SAD) of luminance and the sum of squared difference (SSD) of luminance, and outputs the parts which match by the minimum values or maximum values or the parts estimated by subpixel estimation as common points.

[0198] More specifically, for example, it is possible to utilize the configuration shown by Motoki Arai et al., Optimization of Correlation Functions and Subpixel Designation Formula in Block Matching of Images, Research Reports of Information Processing Society of Japan, 2004, P33-40 and other known techniques.

[0199] Reference numeral 1404 indicates a world coordinate converting means. This converts the coordinates of images of the common points obtained to 3D coordinates common to them all.

[0200] The world coordinate converting means 1404, for example, performs computer processing by the triangle method, 8-point algorithm method, triangulation method, or other arithmetic technique. It forms and outputs parallax values from coordinate values of photographic images of common points obtained by the common point detecting means 1403 and world coordinates (X, Y, Z) from characteristics of the camera (internal parameters of focal distance of lens, image center, and pixel size and external parameters of positions and postures of two cameras).

[0201] For example, the world coordinates (X, Y, Z) are found based on the generally known following formula (1) from the perspective projection matrixes P1 and P2 comprised of the internal parameters and external parameters of the different cameras and the local coordinates (u1, v1) and (u2, v2) of the common points M of the captured images:

[0202]

[Formula 2]

$$\omega i \begin{bmatrix} ui \\ vi \\ 1 \end{bmatrix} = Pi \begin{bmatrix} X \\ Y \\ Z \\ 1 \end{bmatrix} (i = 1,\ 2) \cdots\cdots (1)$$

[0203] For the method of using the internal parameters and external parameters of the cameras to find perspective projection matrixes or finding the perspective projection matrixes P_1, P_2 and ω1, ω2 from the local coordinates of a plurality of common points obtained from still images and obtaining world coordinates based on the above formula (1), for example, the technique described in the Journal of the IEICE, Vol. 92, No. 6, 2009, 463-468 and other known techniques may be suitably used.

[0204] Another technique for obtaining 3D coordinates is described together with the closeup technique in, for example, Dental Materials and Equipment, Vol. 19, No. 3, 333-338 (2000) etc., but the invention is not limited to this. Other general techniques can be employed.

[0205] Reference numeral 1405 indicates a 3D image forming means which, for example, can display this world coordinate data in a 3D coordinate space virtually formed on a computer and connect this coordinate data by lines or curves to form a wire frame model and which, furthermore, can attach virtual surface data to parts surrounded by the lines so as to obtain more realistic panoramic 3D data. By making the 3D panoramic tooth row data three-dimensional on 3D coordinates, curved rows of teeth can be displayed.

[0206] Reference numeral 1406 indicates a display means which may be formed by a computer monitor, printer, etc. and may display a virtual 3D image on a usual computer monitor. Furthermore, it may display a curved panoramic tooth row image by projection to two dimensions.

[0207] FIG. 14 shows one example of a probe-shaped 3D measurement probe 1500 which is provided with two cameras at its tip end. Reference numeral 1501 indicates a camera part A. This has a lens 1501a at its center and has the form of a so-called "camera module". Reference numeral 1502 indicates a camera part B. This has a lens 1503a at its center and has the form of a so-called "camera module".

[0208] Reference numeral 1503 indicates a lighting beam emitter. This is preferably provided around the camera part A1501 and the camera part B1502. Light which is emitted by the light emitting means 1505 which is formed inside of the support member 1506 is guided through the light guide 1504 and fired from the lighting beam emitter 1503 to the surface of the tooth being captured. The lighting beam emitter 1503 is preferably shaped so that more uniform lighting is performed. It is not specified as being the shape which is shown in FIG. 14.

[0209] Reference numeral 1503a indicates a light source for instruction use and shows the captured surface. It provides output in a spotlight like manner. Red, blue, white, and other LEDs covered around them by a black tube are used. Since the light is of a spotlight nature, the area of the surface struck will differ depending on the distance. Therefore, the probe 1500 can be moved while maintaining this constant.

[0210] Reference numeral 1504 indicates a light guide which is formed inside of the support member 1506 and is preferably covered at its surface by a light reflecting member made of aluminum, silver, or other thin film. The light guide 1504 is connected with a lighting beam emitter 1503.

[0211] Reference numeral 1505 indicates a light emitting means which is attached inside of the support member 1506. A white LED or other light source may be illustrated. In the present embodiment, an intermittent flash drive like a strobe or continuous illumination drive etc. may also be used.

[0212] Reference numeral 1506 indicates a support member which, for example, is molded from a light weight, hard plastic material, has a camera part etc. at its front end, is rod shaped, and has a shape enabling it to be easily inserted to the back of the oral cavity.

[0213] Reference numeral 1507 indicates an operating switch which performs a shutter operation etc. The switches may be freely set in number in accordance with the operating specifications and objectives and may be configured in any way. A specification may also be employed where, when used as a shutter, the shutter is driven continuously at predetermined intervals while pressed.

[0214] Reference numeral 1508 indicates a holding part which is preferably configured integrally with the support member 1506 and is molded by a light weight, tough plastic material.

[0215] Reference numeral 1509 indicates an electric lead line which is connected to an outside power supply and connects with an outside data processing system etc. A cable utilizing a USB connector may be utilized. Note that, when the light source is a strobe-type light emitter and the continuous shooting data can be temporarily stored inside of the camera, if Zigbee® wireless communication front end circuit is used for wireless connection etc., sometimes a connecting means becomes unnecessary.

[0216] Next, the operation of the present embodiment which is shown in FIG. 13 and FIG. 14 will be explained.

[0217] In the camera data inputting means 1401 of FIG. 13, the user holds the holding part 1508 shown in FIG. 14 and, in the state such as shown in FIG. 8 where the upper and lower teeth are engaged with each other, brings the camera part A1501 and the camera part B1502 at the front end of the support member 1506 close to the captured portion, and, while viewing the size and position of the spotlight emitted by the instruction use light source 1503a, presses the operating switch 1507 to start the continuous capture operation.

[0218] Sometimes rather than a continuous capture operation, it is better to press the shutter use operating switch 1507 for every capture operation, but to prevent hand shaking etc., continuous capture where the number of times the switch is depressed is reduced is preferable. In this pressed state, images are captured up to the same position as in FIG. 8A, then images are captured up to the same position in the same state as FIG. 10A.

[0219] FIG. 15 shows images forming pairs in the group of images which were obtained by a single continuous image capture operation. Note that, when more precisely measuring the surface shapes of the teeth in the oral cavity, it is preferable to capture the images in the proximity state. The focal distance of the camera is also preferably set at a state which enables close-up photography. These captured images are calibrated against distortion due to the curvature of the lens, tilt, etc. by the calibrating means 1402 of FIG. 13 and are output to the common point detecting means 1403.

[0220] At the time of 3D processing, as shown in FIG. 9 and FIG. 11, the combination is preferably performed from the center in consideration of the combination from near the center to the left-right direction, but the invention is not particularly limited to this technique.

[0221] FIG. 15A is a front view of teeth and shows an image capturing a location near the center. This is also data which is obtained by capture by the camera data inputting means 1401 which has the probe 1500 of FIG. 14 as a constituent requirement.

[0222] Reference numeral 1701a indicates the image of the camera part B1502, while 1701b indicates the image of the camera part A1501. These images are assigned coordinates having center points of the same part. For example, any point A (x1, y1) of the image 1701a of FIG. 15A captured by the camera part B1502 is set and the point A' (x2, y2) showing the same position as this is searched for. The average luminance is found using the point A as for example one pixel block. From near the position envisioned as the point A' of the image data 1702a of FIG. 15A, a pixel block of the same size as the point A is found. The sum of the difference of luminance of the two or the squared sum is obtained and gradually similar operations are performed in the direction of the point A' along with movement to form a match evaluation curve.

[0223] The subpixel estimation technique which sets the part where the sum of the differences or the squared sum of the differences becomes the smallest or becomes the largest on the match evaluation curve as the point A' is preferable, but the invention is not particularly limited to this so long as a technique obtaining common points.

[0224] Next, a similar operation is performed on the pixel block next to the point A of 1701a to detect the common points from the image 1702a. This operation is performed repeatedly to find the coordinates of common points in the common range 1703a minus the range of occlusion of the images 1701a and 1702a. In this case as well, formation of common point coordinates centered at the position of the newly added mark ML enables high precision common points to be obtained. Further, by making this block smaller, common points can be detected in a state of a high precision, but the processing time becomes long, so the size of the block etc. are suitably selected.

[0225] Next, the world coordinate converting means 1404 of FIG. 13 converts, for example, the coordinate values measured by taking several of the above-mentioned common points to a 3D word coordinate system based on the parallax, focal distance, and other parameters inherent to the camera and formula 1. For this specific technique, the usual methods shown in the above-mentioned literature etc. may be suitably employed.

[0226] It finds the common points from a pair of images of FIG. 15A, then uses the image pair 1701b and 1702b shown in the next FIG. 15B to convert the common range 1703b minus the range of occlusion to 3D world coordinates A (X, Y, Z). In the state of 3D world coordinates, it prepares, for example, an image formed into the wire frame shown in FIG. 15D.

[0227] Furthermore, it finds the 3D world coordinates of common points of the common range 1703c minus the range of occlusion of the image pair 1701c and 1702c shown in FIG. 15C.

[0228] Next, the 3D image forming means 1405 which is shown in FIG. 13 superposes the 3D coordinates which were converted to world coordinates and found from FIG. 15A with FIG. 15B not by planar superposition, but in a virtual 3D coordinate space. It further superposes the 3D world coordinates shown in FIG. 15C with this superposed image. If this superposition is superposition in a virtual 3D space, it is possible to use the data converted to 3D world coordinates as the basis to virtually display wire frame like rows of teeth such as for example shown in FIG. 15D on a computer monitor and possible to try to superpose them visually while operating a mouse or other computer interface, but to raise the precision of the superposition, sometimes it is preferable to use either of the 3D values for comparison as a reference and use differential comparison etc. so that the difference becomes the smallest in the combination. The subpixel estimation technique using block matching may also be used to obtain common points.

[0229] FIG. 15A to FIG. 15C show the formation of rows of teeth based on data obtained by converting the right side rows of teeth to 3D world coordinates toward the front surface, but next the left side rows of teeth are converted to 3D world coordinates. The conversion to world coordinates may be performed using the above-mentioned known technique. For example, it is possible to obtain 3D coordinates based on the two images, the convert them to common coordinates, that is, world coordinates.

[0230] After obtaining the 3D world coordinates of the left and right rows of teeth, it is sometimes sufficient to combine the rows by 3D virtual display on a computer or by approximate match by numerical superposition of the coordinate values. In this case, it is preferable to superpose them based on the 3D coordinate data of the mark part. According to this technique, not only with 2D, but also with 3D coordinates, panoramic display of the rows of teeth without offset becomes possible by the display means 1406 shown in FIG. 13.

[0231] The superposition is performed by the technique of superposing numerical values of data of the same shape parts and, when they do not match, taking the average of two coordinate values while performing superposition, the method of superposing images on the screen by the manual technique of dragging and dropping them while operating the computer mouse, then finding the coordinate values, etc.

[0232] Note that, even if images which have mutually common portions, if images with poor degrees of superposition due to the image capture circumstances even after calibration, it is sometimes sufficient to select one of the common images. Sometimes it is possible to use the image of the not superposed part as required for preparing the panoramic image.

[0233] By combination by conversion to three dimensions based on world coordinates, it bcomes possible for the entire rows of teeth to be displayed in a so-called "denture" state.

[0234] A 2D display of a panoramic digital image of the side surfaces of the teeth and a 3D display of a panoramic digital image of the side surfaces of the teeth enable a patient to easily understand the state of his or her entire rows of teeth, so, for example, the 2D panoramic image tooth row data and 3D panoramic image tooth row data may respectively be processed for simulation of straightening and virtual whitening to as to form virtual rows of teeth. The image of this state may be displayed together on the computer monitor to form a state impressing upon the patient the effect of treatment etc.

[0235] "Simulation of straightening" indicates for example, in the case of a 2D panoramic tooth row image, preparing a database of various shapes of single teeth in advance in accordance with the portion, processing the images of the teeth on the 2D panoramic tooth row image by having an orthodontist operate a computer mouse in graphic software to copy and paste images, and thereby forming a virtual straightened panoramic image of the rows of teeth.

[0236] In the case of a panoramic 3D tooth row image, since the 3D coordinates have already been set, existing CAD software may be used by an orthodontist etc. to adjust the 3D coordinates of the panoramic 3D tooth row image so as to form a virtual straightened 3D panoramic image of the rows of teeth. The technique of displaying such a straightened panoramic image is an illustration. Other techniques may also be employed.

[0237] A virtual display after virtual whitening of one's own panoramic 2D and 3D tooth row images or display of these images after being adjusted in color by the dentist in graphic software are also possible alongside. By providing a display of a panoramic image of a patient's own rows of teeth after treatment for virtual straightening and virtual coloring in this way alongside on the screen, it is possible to increase the depth of the patient's understanding of treatment.

[Means for Firing Sighting Beam]

[0238] FIG. 16 is a view which shows one embodiment of the present invention. In the figure, A10 indicates a reflecting mirror unit. This is formed by a hard plastic etc. At the front end, a reflecting mirror A10K set at a predetermined angle (for example 45 degrees) is provided. At the back end, a tubular mounting part A10S able to be connected to the outer circumference of the camera unit A14 is formed. The shape between them is opened.

[0239] The mounting part A10S and the camera unit A14 are connected by being shaped to allow one to be pushed into the other. They can be detached by just pulling them apart as well. To prevent rotation, the two may be provided with relief shapes or may be formed in elliptical shapes or other asymmetric shapes.

[0240] A11 indicates a housing. This is formed by a plastic or resin and is shaped as a tube like a ball pen which has a large caliber and is easy to grip by the hand. At the front end, the camera unit A14 is arranged sticking out. At the back end, a cable A15 for connection with an outside processing system is connected.

[0241] A12 is the direction of observation when a dentist, dental hygienist, etc. directly views the reflecting mirror A10K which is arranged at the front end of the reflecting mirror unit A10 at a predetermined angle.

[0242] A13 indicates a surface struck by the sighting beam. This is one example of the surface struck by the sighting beam when the sighting beam which is output from the sighting use light source A142 is reflected at the reflecting mirror A10K and strikes the tooth surface.

[0243] The sighting use light source A142 (see FIG. 16C) may be positioned at any location. So long as a position enabling the range of the captured image to be determined, it may be another position as well. That portion may be, for example, the front end of the reflecting mirror unit A10 at a portion lighting up the image capture range. In this case, the light path becomes short, so sometimes even if the directional angle is somewhat wide, the range of the captured image can be lighted up.

[0244] FIG. 16C shows the state of the camera unit A14 enlarged. In the figure, A141 is the illumination use light source. An LED with a wide directional angle or a combination of a lens and an LED may be illustrated as an example. A plurality of illumination use light sources A141 are arranged in the vicinity of the camera member A143.

[0245] A142 indicates a sighting use light source. An LED with a small directional angle or a combination of a lens and an LED may be used to output light to give a predetermined spread on the illuminated surface as an example. Alternatively, in the case of a light source with a small directional angle, arrangement of a plurality at predetermined intervals is preferable.

[0246] A143 indicates a camera member. This is formed by a CCD or CMOS camera. One with a larger number of pixels is preferable.

[0247] Returning again to FIG. 16A, A15 indicates a cable for connection with an external image display device. It may be formed by a general use cable such as a USB cable or also by a dedicated cable.

[0248] A16a and A16b respectively indicate operating buttons A and B. These are configured by push types, pull types, turn types, etc. If pushing the operating button A16a among these buttons, the sighting use light source A142 emits light for a predetermined time and lights up important parts for exactly a certain time through the reflecting mirror A10K. The "certain time" is at least the time by which the user can recognize the sighting beam as it strikes a key part in the oral cavity and is preferably until the timing of image capture, for example, when the operating button A16a is pressed.

[0249] At the time of image capture, a lighted part with a different color arrangement is formed in the still image. This is not preferable from the viewpoint of obstructing observation. If not obstructing observation, there is no particular need to erase the sighting beam. This may also be turned on and off to draw the attention of the user.

[0250] Next, the operation of the embodiment which is shown in FIG. 16 will be explained.

[0251] The light output of the illumination use light source A141 which is attached around the camera member A143 of the camera unit A14 lights up the tooth AH1 of the oral cavity through the reflecting mirror A10K. A14L is the light path of the sighting beam. In addition, the illumination use light source also emits light through the reflecting mirror A10K. In this state, the surface A13 struck by the sighting beam is formed in part of the surface which is lighted up.

[0252] The camera member A143 captures the portion of the oral cavity which is lighted up through the reflecting mirror A10K and displays it through the cable A15 at an external monitor device.

[0253] The dentist or other user can obtain a grasp of the image capturing position by the image which is displayed on an external monitor device, but when shortening the diagnosis and treatment time, when treatment is included, etc., this is often used in the same way as a dental mirror. Sometimes the observation direction differs from the captured image such as shown by A12. At this time, for example, the operating button A16a is pressed. If the operating button A16a is pressed, the sighting use light source A142 emits light. The light is emitted for a predetermined time, preferably until before starting to capture the image, and is of an extent enabling the observer to confirm the observed position and image capturing position. The observer moves the reflecting mirror A10K to match the capture position and the observation position and again presses the operating button A16a so as to adjust the capture position and the observation position.

[0254] When the positioning ends, the operating button A16a or operating button B16b is depressed again to record the still image or moving image. The contents of the operations of the above-mentioned operating button A16a and operating button B16b are illustrations and are suitably selected according to the case. One example is shown in FIG. 16B.

[0255] A17 indicates an example of an image. A tooth AH1 targeted for capture is captured. The range of firing of the sighting beam is the range of the circle shown by the surface A13 struck by the sighting beam. Almost the entirety of the key part targeted for capture is included.

[0256] The range of the surface A13 struck by the sighting beam changes depending on movement of the combination of the housing A11 and reflecting mirror unit A10 up and down with respect to the tooth H1, so the user may adjust this by moving the housing A11 and reflecting mirror unit A10 up and down. The surface becomes larger than or smaller than the image capture range, but never becomes offset from the key part of the image capture range. Further, the key part of the image capture range is sufficiently shown compared with a point light source.

[0257] Due to the above operation, the captured surface and the observed surface are adjusted and an accurate still image or moving image is recorded.

[0258] The housing A11 which is shown in FIG. 16A is held and the reflecting mirror A10K is made to move up and down with respect to the observed portion of the oral cavity so as to observe and capture the target portion.

[0259] The intraoral camera is inserted to the narrow back portion of the upper jaw or lower jaw of the oral cavity. The image capture range of the reflecting mirror extends over a wide range. At the same time, the oral cavity can be captured with the reflecting mirror in the inverted state. Capture is also possible in the tilted state or laid flat state etc. Therefore, the captured image also becomes tilted or inverted. Accordingly, the present invention is provided with an image correcting means for detecting the image capture state by position sensors and correcting images in an up-down inverted state or tilted state to a horizontal state.

[Means for Correcting Captured Image]

[0260] FIG. 17 shows an example of an intraoral camera which is used for explaining one embodiment of the present invention. It is shown as a partial cross-sectional view. In the figure, A21 indicates a housing for holding use. This has a cylindrical shape which is provided with an internal space. At the front end, an elliptical tubular shaped camera unit A23 which is comprised of a camera and illumination use light sources formed around the camera is connected in a state sticking out from the housing A21. At the back end, a cable A26 for connection with an external display device is connected.

[0261] One example of the illumination unit is shown in FIG. 17. In the figure, A22 indicates a reflecting mirror unit. At its front end, a reflecting mirror A22H which is arranged at a predetermined angle is attached. At the back end, a tubular mounting part A22S which can be attached to cover the circumference of the camera unit A23 is formed. The rest is open in state.

[0262] A24 indicates a circuit board. This is mounted inside of the housing A21 and mounts an image processing use IC etc. A25a and A25b indicate position sensors. These have IC chips etc. which are mounted on the circuit board. The numbers and mounting portions of the position sensors are examples. Depending on the types of the sensors, they are sometimes not mounted.

[0263] The position sensors A25a and A25b employed are acceleration sensors, angular acceleration sensors, or other sensor devices which can sense the state of movement of the intraoral camera over a wide range and therefore will not be disabled from measurement due to the angle. The number of the position sensors is shown here as two, but this is an illustration. The number of chips changes depending on the number of axes. If a unit for three axes, sometimes a single one is sufficient. The acceleration sensors and angular acceleration sensors are illustrated as three-axis sensors. The number of the position sensors also may be adjusted by the number of axes. The x-axis, y-axis, and z-axis of the position sensors A25a, A25b... are for example the axes which are shown in FIG. 19.

[0264] When the position sensors A25a and A25b are made angular acceleration sensors (gyro sensors), the angular acceleration sensors, for example, respectively output the amount of change of the angle due to movement about the x-axis, the amount of change of the angle due to movement about the y-axis, and the amount of change of the angle due to movement about the z-axis. In the case of angular acceleration sensors, the initial states of the x-axis, y-axis, and z-axis are freely set, then the amounts of change along these axes are added to thereby detect the image capture state of the camera.

[0265] As opposed to this, the acceleration sensors respectively output the x-axis direction acceleration component, y-axis direction acceleration component, and z-axis direction acceleration component. Furthermore, the combined vector of these acceleration components gives a posture vector. In the still state, the respective gravity acceleration vectors are shown. The image capturing state of the camera can be obtained from this posture vector.

[0266] For example, an acceleration sensor outputs the state of the gravity acceleration vector A451 as the posture vector when still, so it is possible to use the x-axis direction, y-axis direction, and z-axis direction vectors in this state as the reference posture and then use the angular acceleration sensors to add the amounts of change by rotation of these axes and perform other operations, so

[0267] It is also possible to combine both acceleration sensors and angular acceleration sensors to detect various states of a camera.

[0268] FIG. 18 is a block diagram which shows an example of means for using position sensors to correct the image display state. The configuration which is shown by the block diagram may have parts which are realizable by a program if involving computer processing. In the figure, A31 indicates a camera means which uses a camera which is arranged at the center of the camera unit A23 of FIG. 17 to capture a moving image or still image.

[0269] A32 indicates an image correcting means which is comprised of an image recording memory, CPU, etc. It temporarily records an image which is obtained by the camera means A31 and uses the camera angle information of the position detecting means A34 as the basis to rotate the image and form image data in a state which can be easily viewed.

[0270] For example, when the camera unit A23 captures an image, the reference posture of the image displayed on the monitor is determined, the housing is moved with respect to that reference posture, and thereby the reference posture image rotates, for example, the angular acceleration sensors etc. detect the amounts of change of the rotational angles from the angular accelerations of the respective axes to enable display of the images rotated by exactly the angles minus the amounts of change of the rotational angles whereby an easily viewable image can be formed.

[0271] Note that, sometimes the image can be corrected by just rotation about the y-axis which is shown in FIG. 19. When capturing an image of the oral cavity which is reflected by the reflecting mirror, since the camera of the camera unit A23 is constantly facing the reflecting mirror direction, the image rotates mainly due to rotation accompanying rotation of the housing about the y-axis coordinate shown in FIG. 19. Therefore, at the very least, in the state where the housing A11 and reflecting mirror unit A10 are changed in the x-axis, y-axis, and z-axis directions, it is sometimes preferable that the image which is displayed at the xz plane be corrected to a state facing a certain direction at the image display unit.

[0272] Reference numeral 33 indicates an image display means. This shows a computer monitor or other dedicated monitor. It is sufficient that it be one which displays the output image of the image correcting means A32.

[0273] Reference numeral 34 indicates a position detecting means. This is comprised of the position sensors A25a, A25b, etc. of FIG. 17. Specifically, rate gyros which output angular acceleration, rate integrating gyros which output angle, posture gyros, MEMS type and other mechanical type, optical type, and other angular acceleration sensors, piezoresistance type, electrostatic capacity type, and heat sensing type MEMS sensors, and other acceleration sensors can be utilized.

[0274] Next, the operation of FIG. 18 will be explained with reference to FIG. 17 and FIG. 19.

[0275] The coordinate axes which are shown in FIG. 19 indicate the case where a single position sensor deals with three axes. When the position sensors respectively deal with single axes, two axes, etc., coordinate axes are set corresponding to the individual portions of the position sensors.

[0276] The housing A21 which is shown in FIG. 17 is held and the reflecting mirror A22H is inserted into the oral cavity to capture an image of the target portion. At this time, a switch which is attached on the housing A21 is operated to record the initial posture state. One example of the coordinates at the initial posture state is shown by A410 of FIG. 19.

[0277] By installing the position sensors, coordinate axes are formed. In the present embodiment, A421 is designated as the x-axis, A431 as the y-axis, and A441 as the z-axis. Note that, A451 indicates a gravity acceleration vector. This is one example of a posture vector obtained by combination when the acceleration sensor is stationary. Therefore, the gravity acceleration vector sometimes cannot be utilized when not using an acceleration sensor.

[0278] The coordinates are shown in a state where the intraoral camera is in a state close to vertical for capturing the side surfaces of for example the back teeth. A422 is the x-axis, A432 is the y-axis, and A442 is the z-axis. When using an acceleration sensor, A452 can indicate a gravity acceleration vector.

[0279] The reflecting mirror 22H is made to move the target portion of the oral cavity. One example of the method of movement is shown in FIG. 19. The intraoral camera which is comprised of the reflecting mirror 22H and the housing is moved to the positions such as shown by A411, A412, and A413. The camera means A31 captures the intraoral images in those states as still images or moving images and outputs them to the image correcting means A32.

[0280] The position detecting means A34, for example, outputs the initial posture information to the image correcting means A32 for the x-, y-, and z-directions. Further, when, as in the present embodiment, configuring the system to display the image of the reflecting mirror, the camera faces the reflecting mirror direction, so the camera image inverts and becomes hard to view in state usually due to rotation about the y-axis, so sometimes it is also possible to use only single-axis type position sensors. The image correcting means A32 links this initial posture information and image for output to and display at the image display means A33.

[0281] As shown in FIG. 19, when moving the intraoral camera like A411, A412, and A413 to capture an image of the oral cavity, the camera means A31 outputs images corresponding to those postures. If the camera rotates about the y-axis, the image is captured upside down and an image corresponding to the captured state is output.

[0282] The position detecting means A34 detects the angular accelerations about the x-axis, y-axis, and z-axis from the position sensors A25a and A25b (for example in the case of gyro sensors) and detects the amount of change of the angle about the x-axis ($\Delta\theta yz$), the amount of change of the angle about the y-axis ($\Delta\theta xz$), and the amount of change of the angle about the z-axis ($\Delta\theta xy$) from the angular accelerations.

[0283] These amounts of change are output to the image correcting means A32. The image correcting means A32 uses the image data which was input from the camera means A31 and the position information which was output from the position detecting means 34 as the basis, for example, uses the amounts of change of the angles as the basis, to make the image rotate and return it to the initial state of the image.

[0284] Therefore, in the image display means A33, even if capturing the same intraoral object as a moving image or still images while rotating the camera, images can constantly be displayed as in the initial set state with the images of the displayed content changed.

[0285] Note that, when using a convex mirror to capture all teeth of the upper jaw and lower jaw, it is also possible to use the fisheye lens correcting means of the technique described in the Literature (Design Wave Magazine, 2008 December, P113-115).

[Means for Adjusting Capture Operation Timing]

[0286] The present invention adjusts the time until the actual capture operation by the method of pressing the switch which is operated when obtaining an actual image, for example, by the number of times pressed in a certain time like the "double click" performed when operating a computer, and therefore help stabilize camera operation when the dentist performs treatment, performs diagnosis, or provides an explanation to the patient. Alternatively, it is possible to adjust the capture operation timing by operating a camera switch on the monitor image and designating an icon showing the timing of display (for example, for two operations in two seconds and then continuous capture of several images) so as to determine the timing.

[0287] Further, when displaying coordinates etc. on the screen, by adjusting the number of times the operating button is depressed, the way it is depressed, etc., it is possible to adjust the timing of the display and therefore provide an explanation while inserting the camera into the oral cavity or otherwise adjust the timing of display of the image. The specifications of the specific timing may be input and adjusted from the screen of a mobile terminal.

[0288] One example of the timing adjusting means will be explained in detail with reference to FIG. 20. In FIG. 20, B7001 indicates an inputting means. For example, it shows pushbuttons 101d and 101e forming the operating interface of FIG. 1.

[0289] B7002 indicates an input count detecting means. This is comprised of a counter, flipflop, etc. and counts the number of times a pushbutton is depressed. This count is preferably counted within a predetermined time interval.

[0290] B7003 indicates a delaying means. This is for setting a delay time by multiplying the number of times the pushbutton is depressed with the delay time for each time. After the elapse of the delay time, a single pulse is output.

[0291] B7004 is an image capture output setting means. At the rising and trailing edges of the delay pulse of the delaying means B7003, a signal for starting the capture operation is output to the camera means B7005.

[0292] The camera means B7005 uses the signal of the start of capture as the basis to continuously capture several to several dozen still images or capture a moving image. The images obtained by this capture operation are input to the image inputting means B7006. Furthermore, the image selecting means B7007 selects the focused images and stores them at the storage and display means B7008 or displays them on the display 104 shown in FIG. 1.

[0293] The image inputting means B7006 is for fetching an image obtained by the camera means B7005 as digital data and outputting it to the image selecting means B7007. Further, the image selecting means B7007 is, for example, a means for selecting only focused images.

[0294] B7009 indicates a display means which shows the time from when a button of the inputting means B7001 is pressed to when the operation is performed in a visual manner while changing the position of blinking. The display means B7009 is set at a location highly visible to the dentist at time of treatment and shows how many seconds after the operating button is pressed the operation will be started. It is sometimes displayed on the monitor of a computer constituting one of the display means B7009.

[0295] Further, by providing an LED which gives off a red color during the delay time and which changes to a white color when the delay time ends or a light source which continuously emits light or intermittently emits light only during the delay time or other indicator by which the user can discern that the delay time is in progress, relaxed button operation becomes possible and the extent of intraoral work can be expanded.

[Means for Capturing X-Ray Image]

[0296] FIG. 21A is a block diagram which shows an embodiment of the present invention. In the figure, B8011 indicates an X-ray image capturing means. A combination of an X-ray output device and an X-ray CCD sensor or a combination of an X-ray output device and X-ray phosphor plate and CMOS or CCD camera are illustrated. Specifically, FIG. 21B shows one example.

[0297] The X-ray image capturing means B8011 includes the existing panoramic image X-ray camera device, X-ray CT, digital X-ray device, etc. It is sufficient that it enable data to be displayed on a computer monitor. When X-ray image data cannot be directly obtained, it is also possible to obtain visualized data of the X-ray image on the computer, hard copy data of the screen, data in a shared state on the monitor screen, data obtained by capturing an X-ray image on the monitor by an intraoral camera, or other X-ray image data. Furthermore, sometimes the configuration of FIG. 21B is also included.

[0298] B8012 indicates an actual image capturing means. For example, a reflection type intraoral camera is preferably used. The actual image capturing means B8012 sometimes further includes the configuration which is shown in FIG. 21C.

[0299] B8013 is a comparison portion extracting means. It is formed by the block matching technique and subpixel estimation technique and extracts parts matching with the image captured by the X-ray image capturing means B8011 and extracts comparison portions. For example, it extracts contours of the captured image, extracts a plurality of pixel values, and outputs the X-ray image extracted data.

[0300] B8014 indicates a comparison portion extracting means. It is formed by the block matching technique, subpixel estimation technique, etc. and extracts parts matching with the image captured by the actual image capturing means B8012 and extracts comparison portions. For example, it extracts contours of the captured image, extracts a plurality of pixel values, and outputs the actual extracted data.

[0301] B8015 indicates a comparing means. It compares extracted data which is output from the comparison portion extracting means and outputs portions which match, substantially match, or are estimated as matching as matched parts. At the time of comparison, the images are sometimes enlarged or reduced, but for example the actual image and X-ray image data need only be enlarged or reduced by general use graphic software after conversion to the BMP, JPEG, GIF, or other general formats.

[0302] B8016 indicates a matched part recording means. This records the matched portions, substantially matched portions, or estimated matched portions and transmits them to the display means B8017.

[0303] The display means B8017 may be a computer monitor (display) device, mobile phone display part, etc., but it is sufficient if it be of a size of an extent enabling side-by-side display of an X-ray image and an actual image and superposed display and have a resolution of an extent whereby the X-ray image can be displayed clearly.

[0304] The present embodiment is realized by computer software, but may also be formed by hardware.

[0305] The X-ray camera means and the actual image capturing means may be separate devices, but preferably they are a single device with parts changed and shared.

[0306] Next, the operation of the present embodiment will be explained.

[0307] The X-ray camera means B8011 is used to capture a measured portion by a moving image or still images. The portion which is measured by the X-ray camera means B8011 may be selected as a single tooth, a plurality of teeth, or all teeth of the upper jaw and lower jaw.

[0308] Next, the actual image capturing means B8012 is used to capture the portion captured by the X-ray camera means B8011 as a moving image or still images. In capture, the same portion may be accurately positioned to for capture, but it may also be used as a general measure for capture.

[0309] Distortion of the image obtained from the two is corrected. As the technique for the correction, for example, the calibration technique may be used. A grid serving as a reference is captured in advance to calculate the distortion value due to the lens and to correct the data.

[0310] Next, the comparison portion extracting means B8013 and B8014 calculate the characterizing portions. The characterizing portions are, for example, contours. Part or all of the contours of teeth in the case of X-rays and the contours of teeth in the case of actual images are extracted.

[0311] Next, the contours of the two are compared. At that time, the X-ray image and the actual image have parts of the contours matched in state or substantially matched in state and the superposed portions of the two images are taken out.

[0312] The comparing means B8015 outputs the two superposed images to the matching part recording means B8016, whereupon the matching part recording means B8016 records the two images. The display means B8017 displays the two images in accordance with the selection of the user to superpose them in a transparent state or place them side by side.

[0313] FIG. 23 shows one example of images captured by the X-ray image capturing means and the actual image capturing means. FIG. 23A indicates an X-ray image which shows a tooth b101 captured by X-rays. FIG. 23B shows an actual image of a tooth b101 captured at the same portion as FIG. 23A. FIG. 23C shows a superposed image b103 displaying these superposed. The comparison of the X-ray image and the actual image can be used to facilitate understanding of the X-ray image. In particular, the display of the actual image enables the color and any swelling or inflammation of the gums to be displayed, so comparison with the X-ray image enables the degree of advance of any periodontal disease or tooth decay to be displayed in a manner easily understandable by the patient.

[0314] Next, a specific example of the X-ray camera means will be shown in FIG. 22 and explained in detail. In FIG. 22, B9101 indicates a housing for gripping use. This is preferably molded from a plastic material etc. containing lead to make it impenetrable to X-rays.

[0315] B9102 indicates an X-ray output device. An existing device of a portable type for general dental use is preferable, but the invention is not particularly limited to this. Any X-ray output device which is used in dental diagnosis and treatment can be used if sufficient functionally, but a portable type is effective for home diagnosis and treatment etc. as well and is suitable for use for X-ray images used with actual images. Even if a portable type, use mounted on a stand is possible.

[0316] B9103 indicates an electrical lead line. A general use USB cable may be used. In addition, a dedicated cable etc. may be utilized.

[0317] B9104 indicates an X-ray phosphor member. One comprised of a glass substrate which is coated with a crystal of a phosphor material such as CsI, CaWO, $Gd_2O_2S:Tb^{3+}$, 549nm(f-f), and (Zn, Cd)s:Ag is used.

[0318] B9105 indicates a member passing visible light. This is formed by a transparent member which contains lead and passes only visible light.

[0319] B9106 indicates a camera unit. In this case, this need only be a camera. A higher resolution one is preferably used.

[0320] B9107 indicates a support member for X-ray capture. This is formed by a member including lead and impenetrable by X-rays. At the front end, a reflecting mirror B9108, an X-ray phosphor member B9104, etc. are mounted. The other end is formed into an open tubular shape which is inserted over the camera unit B9106 for fastening.

[0321] The reflecting mirror B9108 is, for example, formed in a state tilted 45 degrees. It is formed by a flat type mirror. It is for reflecting a visualized image after removing the X-rays and transferring it to the camera unit B9106.

[0322] In FIG. 22A, the X-rays which are output from the X-ray output device are converted to visible light by the X-ray phosphor member B9104, then the X-ray component is removed, then the light is reflected at the reflecting mirror B9108, then input to the camera unit. B9109 is a schematic view of a row of teeth in the oral cavity at the portion captured.

[0323] FIG. 22B shows an example of combination of an X-ray photographic image which is obtained by an X-ray sensor and an actual image which is obtained by a reflecting mirror. B9110 is a support member for capturing X-rays and is formed by an X-ray impermeable member in the same way as the support member B9107 for capturing X-rays which is shown in FIG. 2A.

[0324] B9111 indicates a visible light passing member which is comprised of a filter which is formed from a light transmitting member containing lead, which removes X-rays, and which transmits the visible light to the camera unit B9106.

[0325] B9112 indicates a reflecting mirror comprised of a flat mirror, while B9113 is an X-ray sensor which is formed by an existing X-ray CCD (CMOS) sensor or imaging plate. B9114 is a lead line which transmits a sensor signal of the X-ray sensor to the outside. This is also preferably covered by a resin containing lead.

[0326] The present embodiment is configured to use only an X-ray sensor B9113 and also jointly use a combination of a reflecting mirror unit and a camera unit B9106 so as to output an X-ray visible image and an actual image at the same timing.

[0327] The configuration combining the reflecting mirror B9112 and the X-ray sensor B9113 enables the actual image to show the back side of the teeth, but comparison against an image separately capturing the front of the teeth becomes easy. The same portion can be simultaneously obtained at the actual image and the X-ray image, so this is preferable from the viewpoint of easy acquisition without image processing for finding the range of match.

[0328] An X-ray image of the oral cavity is difficult for a patient to understand, but displaying the actual image of the same captured portion on a computer monitor, paper, etc. side-by-side or superposed transparently enables the X-ray image to be more easily understood and facilitates the explanation to the patient.

[0329] In an X-ray image, in the case of a dental X-ray, several teeth are captured as a single image or single set of data by a single shot. In this case, X-ray sensor and the X-ray output device are shifted while for example continuously capturing images so as to obtain a plurality of X-ray images of the entire jaw, then the contours are extracted as digital data. Further, it is possible to detect the common parts of the images with little distortion at the adjoining X-ray images, detect the points of match and estimated match by the block matching method or superposition, and form a panoramic image. Furthermore, a panoramic image is formed in the same way by the actual images. These images can be displayed on the monitor screen or printed out on paper to form data easy for comparison.

[0330] One example of the data is shown in FIG. 23D and FIG. 23E. FIG. 23D shows the state where the actual image data is spliced together by digital processing. b104 is the upper jaw data, while b105 is the lower jaw data. The upper jaw data b104 is obtained, for example, by continuous capture by the intraoral camera which is shown in FIG. 1 while shifting the position bit by bit and splicing together the common parts of the images by superposition. The lower jaw data b105 is also similarly prepared. The method of forming a single image is shown, but it is also possible to simultaneously capture the upper jaw and lower jaw and splice the common parts together by superposition. With continuous capture, the images are displayed continuously. They are also continuous in terms of size. Therefore, it is easy to find the connecting portions. Sometimes, little size adjustment is required.

[0331] When obtaining such a panoramic actual image, the intermediate luminance method, block matching method, optical flow method, etc. may be used.

[0332] FIG. 23E shows the upper jaw X-ray data b106 and the lower jaw X-ray data b107 which are prepared by splicing together X-ray images in the same way, Furthermore, at the lower jaw, lower jaw data b108 obtained from the actual image is superposed to facilitate viewing by the patient.

[0333] The present embodiment enables comparison of the intraoral actual image, X-ray image Y, virtual corrected panoramic tooth row image, virtual colored panoramic tooth row image, etc. by display on a computer monitor or printing on paper to make the oral cavity "visible" to the patient and therefore promote on-going treatment, effective preventive care, and proactive treatment for increasing the ratio of care at the patient's own cost.

[0334] Further, it is possible to display portions at the gums and jawbone where care is required by X-ray and actual images and combine the state of the jawbones as conditions for implanting an artificial root and the state of a virtual prosthetic shown by actual image based on the X-ray image and possible to display areas for regeneration by bone regenerating means.

[0335] An actual image, X-ray image, and microscope image can be summarized for easy viewing in a multiperspective image list. By editing this and displaying or printing out the result, it is possible to show the patient the order of treatment and prevention based on the intraoral situation in an easily understandable manner.

[0336] An actual image can be captured by, for example, coloring the plaque by phloxine etc. to enable the state of deposition of plaque to be visually observed, then forming the image shown in FIG. 23D, recording it at the recording device, then observing the state of deposition of plaque and state of the gums. Furthermore, based on the state of the gums, the plaque may be sampled and a microscope used to form an image of periodontal bacteria and edit the image in a state related to the sampled portion.

[0337] Furthermore, together with use of the X-ray image, an intraoral map which easily shows the state of periodontal disease in five rankings may be formed as image data and print data to enable suitable prevention of periodontal disease and prevention of tooth decay.

[0338] By using an actual image forming means which obtains a photographic image of all or part of the teeth by the above-mentioned panoramic image specification, it is possible to use a red color dye to show the plaque in the image data obtained.

[0339] The degree of depth of the red color of this image data is detected as a depth value by a software-based detecting means using for example the luminance detection technique. When this depth value exceeds a certain value, for example, when the value of the deepness based on the thickness in the state where the plaque has accumulated to an extent where periodontal bacteria can easily proliferate exceeds a value converted to luminance, a caution mark (symbol formed on the screen etc.) is attached to that portion of the image data. By providing this means, if outputting the image after dyeing the oral cavity to a computer monitor or printer, the parts with large amounts of deposition of plaque can be automatically displayed. This output display and the state of the gums can be viewed from the images and therefore periodontal disease can be efficiently discovered, prevented, and treated.

[Virtual Prosthesis Treatment Display of Oral Cavity]

[0340] The present invention can combine an X-ray image and an actual image side by side to form an easily understandable image, but it is further possible to superpose the virtual shape or color information of a prosthesis on this image and display the virtual state after treatment in a readily understandable form.

[0341] As one example, the X-ray camera means B8011 which is shown in FIG. 21A is given a means for displaying in combination the virtual shape which is shown in FIG. 21B, while the actual image capturing means B8012 which is shown in FIG. 21A is given a means for displaying in combination the virtual shape which is shown in FIG. 21C.

[0342] Furthermore, it is preferable to provide a virtual shape etc. storing means B8022 for storing virtual shapes in advance to enable them to be called up for use when displaying the virtual shapes in combination. As the virtual shapes etc., shape information of dentures, bridges, clasps, nonclasps, implants, inlays, crowns, and other prosthetic and orthodontic devices are included. Further, the virtual shapes include color information. For example, shade guides comprised of color samples providing a large number of tooth shapes used when deciding on the hue are stored in advance or converted to data at the time of use. Ones storing color information of all teeth or single teeth are also included. This data may be successively stored when taking X-ray images or actual images of the oral cavities of patients while adding corrective and management data to the images as required.

[0343] In FIG. 21B, B8018 indicates a virtual shape adjusting means for X-ray image use. In the X-ray image capturing means B8011, this adjusts the virtual shape which is called up from the virtual shape etc. storing means B8022 by designation by the user or automatically to the size of the X-ray image captured or adjusts it to a color which is easily recognizable on the X-ray image but not disturbing so as to adjust it to a state enabling combination. B8019 indicates a combined display means for the X-ray image which combines the X-ray image and virtual state for display on the monitor screen.

[0344] FIG. 21B and FIG. 21C added virtual combined display means as ancillary members to the respective camera means, but these are not limited to ancillary members. They may also be set as main components in accordance with the objective. Alternatively, it is not necessary to superpose the actual image and X-ray image of FIG. 21. It is also possible to combine respectively independent virtual displays of the actual image and X-ray image. This combination may be performed by converting the images to the BMP, JPEG, GIF, or other general format and, in the same way as a grid display etc., using the superimposition technique or using the transparency technique or superposition technique used in general graphic software.

[0345] In FIG. 21C, B8020 is a virtual shape adjusting means for real image use. This has a configuration the same as the virtual shape adjusting means for X-ray image use. B8021 indicates a combined display means. This has a function and configuration similar to the combined display means for X-ray image use.

[0346] Next, the configuration for combination of virtual displays shown in FIG. 21 will be explained in detail.

[0347] In FIG. 21A, the X-ray camera means B8011 captures and forms a full tooth X-ray image b201 shown in FIG. 28A. This is, for example, a panoramic image which is obtained from an existing X-ray panoramic image camera system or all teeth captured several at a time by X-rays to obtain images, converting these to digital images, then processing these images to for example extract contours, then detect the common parts.

[0348] It is also possible to connect individual images at common parts to form a panoramic image of all teeth. Similarly, the actual image capturing means B8012 forms a panoramic actual image b202 of all teeth shown in FIG. 28B. Further, this full tooth image is not limited to this technique. It is also possible to use the technique of continuously capturing images then selecting and splicing together suitable images.

[0349] The treatment portions are found from the image. For example, in the image b201, there are a lost back tooth part b219a and lost back tooth part b219b and a lost part b219c of the front teeth and a gap b219d of the front teeth. The same is true in the panoramic actual image b202.

[0350] Each lost part is studied as to what kind of prosthetic is necessary. For example, if a front tooth prosthetic, the virtual shape adjusting means B8018 searches through the virtual shape etc. storing means B8022 to select a candidate for the front tooth of a shape enabling prosthesis. After selection, the selected image is read out and is displayed on the display monitor combined at the combined display means B8019 while selecting the size and color on the screen. FIG. 28C shows the image b203 which is obtained by for example combining virtual configurations. In the combined image b203, when artificial roots are deemed suitable for the lost back tooth parts b291a and b219b of the back tooth lower jaw, if bridging several artificial tooth roots b213 and superstructures b215, the bridge use implant b212 and bridge superstructure b214 are selected from the virtual shape etc. storing means B8022. The virtual shape adjusting means B8018 adjusts the size and color and combines the images at the combined display means B8019 for display on the monitor screen or mobile terminal monitor screen.

[0351] In the same way for the panoramic actual image b202 which is obtained by the actual image capturing means, the actual image use prosthetic teeth, inlay data, etc. are called up from the virtual shape etc. storing means B8022. The virtual shape adjusting means B8020 adjusts the size and color for display at the combined display means B8021.

[0352] In FIG. 28, b216 indicates the bridge superstructure b214 of FIG. 28C, while b219 indicates the superstructure b215 of FIG. 28C. b217 indicates a crown for a front tooth and corresponds to b210 of FIG. 28C. b218 indicates a gap prosthetic part b211 of FIG. 28C.

[0353] For formation of the gap prosthetic part b211, for example, if the teeth are crowns, formation is possible by enlarging the sizes of the crowns and making the two crowns contact in state. In the case of natural teeth, the technique is shown of grinding away some of the two teeth for insertion of the prosthetic.

[0354] In the combined images b203 and b204, the prosthetics are shown by hatching. For example, in the bridge use implant b212 and bridge use superstructure b214 in the combined image b203, when strength etc. is not preferable, three artificial roots and superstructures similar to the lower jaw right side are read out from the virtual shape etc. storing means B8022 and displayed replaced to allow adjustment of the state of the one at the lost part and the possible range of an implant while viewing the image.

[0355] Further, it is possible to call up tooth color data from the virtual shape etc. storing means and compare and adjust the relationship of color with the adjoining teeth to make a decision. For example, for the front tooth prosthetic b210, it is possible to refer to general use models and adjust the shape and color with the adjoining teeth for combination and decision.

[0356] As the method of treating a gap b219d as well, it is possible to select the type of prosthetic which can be used, such as an inlay, crown, etc., from the virtual shape etc. storing means B8022, apply it to the image while adjusting it by the virtual shape adjusting means B8018, view the extent of combination by the combined display means B8019, and study the virtual shape as well. When this virtual shape is formed as a 3D shape, the virtual shape is made to rotate on the screen and a more realistic combined image can be obtained even with a planar intraoral image.

[0357] There is sufficient information for study even in the state giving the images of FIG. 28C and FIG. 28D, but the comparison portion detecting means B8013 of FIG. 21A designates a characterizing portion in the portions before combination out of the combined image shown in FIG. 28C, the comparison portion extracting means B8014 designates a characterizing portion in the portions before combination out of the image shown in FIG. 28D, and the comparing means B8015 compares the two comparison portions and temporarily records and displays the matched state.

[0358] An image showing this displayed state is shown in FIG. 28E. The combined image b205 consists of the actual image and the X-ray image superposed. The number is the prosthetic state shown by the combined images b203 and b204. An X-ray image is hard to view. In particular, the gum portion is hard to view, but with such a combined image, the gum part of the X-ray image is displayed in an easily understandable manner. Further, the superstructures or teeth and the balance of the root parts can be displayed to be easily understood.

[0359] By virtually attaching the prosthetic on the screen, it is possible to display to the patient the oral cavity in a manner enabling the actual results of treatment to be imagined. Alternatively, it is attempted to realize a prosthesis suitable for the patient by presenting the patient with a virtual lineup of suitable colored or silver teeth or ceramic or other teeth. At the time of treatment, the virtual attachment to the X-ray image also becomes of reference in treatment to the dentist. For the virtual data, it is possible to use already available data as it is or enlarged or reduced for combination. In addition, after combination, it is possible to convert the actual distance to prosthetic data and obtain color information and whitening and corrective data.

[0360] By combining a virtual shape with a prosthetic portion, it is possible to find part of the size of the actual prosthetic, so the virtual shape or other data can sometimes be used as is as data for prosthetic production.

[0361] Further, this technique is performed by a computer. Part of the size of an actual prosthetic is quickly learned. This can sometimes be used as production data as is for the prosthetic.

[Mobile Terminal Type Information Inputting/Outputting Means]

[0362] Next, an embodiment of the present invention will be explained in detail with reference to FIG. 24. In the figure, 1a01 indicates a small sized battery of a button type, tube type, sheet type, pin type, etc. Further, either a primary cell or a secondary cell may be used. 1a02 indicates a voltage boosting means such as a DC-DC converter, chopper, or switching regulator which, for example, has the function of boosting a voltage of 1.5V to around 3V. 1a03 indicates a control means such as a one-chip type computer or ASIC or other control chip. 1a04 indicates a display means formed by a liquid crystal panel etc. which can display a 2D image.

[0363] 1a05 indicates a terminal side communicating means which is suitably provided by the type of the wireless medium 1a0C. If a radio wave, a circuit which includes a carrier wave output means for use up to several GHz, an FM, AM, PCM, or other modulating means, and a transmission and reception antenna is used. If light, a combination of an LED, laser, and CDS or other light receiving element is used. Among these, Zigbee Module (brand name) using radio waves etc. can be suitably used. In addition, sometimes a USB connection or other general use cable, dedicated cable, or other cable communicating means is also possible.

[0364] 1a06 indicates an inputting means such as a keypad, touchpad, or other means which is depressed, touched, etc. to convert the portion intended by the user to an electrical signal. Sometimes a liquid crystal panel which has a touch panel function or other device which doubles as the display means 1a04 and the inputting means 1a06 is used.

[0365] 1a07 indicates a storing means which stores a program for editing patient data and displaying it on a display. The patient data is mainly recorded at the host device side, so temporary storage is also possible. It need only be stored up to the capacity. 1a08 indicates an electrical line which directly connects the inputting means 1a06 and the terminal side communicating means 1a05. This exhibits the function of direct transmission of a signal through the terminal side communicating means 1a05 if a key is pushed and may be configured in the same way as a circuit line between a keyboard and computer. When a control means 1a03 acts in its stead, it is sometimes unnecessary.

[0366] 1a08 indicates a host device which is configured by a combination of a recording means 1a11 which stores patient data, patient intraoral data, patient health data, attendance records and other dental employee related data, dental diagnosis and treatment data, electronic patient chart data, patient reservation data, etc. in a database and all other data relating to the dental practice, a host computer 1a10, and a communicating means 1a09.

[0367] 1a09 indicates a host side communicating means which is configured paired with the mobile terminal side terminal side communicating means 1a05. It is not uncommon for a plurality of mobile terminals to be utilized for a plurality of patients, so the mobile terminals or communicating means 1a09 preferably can be set to multiple channels and input from only specific mobile terminals can be made to be accepted.

[0368] 1a10 indicates a host computer which is configured by a combination of a display device for display use, a keyboard, mouse, printer, and other peripheral devices. 1a11 indicates a recording means such as a hard disk, SD, DVD, USB memory, or other recording medium which can be housed in the host computer 1a10. The communicating means 1a09 may be similarly connected at the outside and may be built in. 1a12 indicates a communication network such as the Internet, an in-house LAN, Intranet, etc. 1a13 indicates another host device which is configured in the same way as the host computer 1a10 of the host device 1a0B and may store patient data etc. which the host device 1a0B does not hold. Further, for example, by sending treatment data from a distant location to a mobile terminal, it becomes possible to assist the diagnosis and treatment of a dentist operating it.

[0369] Next, the operation of the embodiment which is shown in FIG. 24 will be explained.

[0370] The voltage of the battery 1a01 is boosted by the voltage boosting means 1a02 and supplied to the different means. This voltage boosting means 1a02 is used to, for example, boost the battery voltage of 1.5V to 3V or more to enable the C-MOS control device etc. to be driven.

[0371] The control means 1a03 may call up, run, and display on the display means 1a04 a diagnostic data processing program at the time of dental diagnosis and treatment from the storing means 1a07. Otherwise, data which is sent from the host computer 1a10 may be displayed as it is on the display means 1a04.

[0372] Since a wireless communicating means is used, first, or in the middle of operation, the state of communications is examined and the communication situation is confirmed. Further, even if the wireless connection is broken in the middle, the control means 1a03 may be configured to enable provisional input and output while it is broken.

[0373] In accordance with the display of the display means 1a04, the operator pushes, touches, or otherwise operates the input buttons of the inputting means 1a06. In this case, for example, if pushing the key "1" of the inputting means 1a06, "1" is output and displayed through the control means 1a03 on the display means 1a04 and is sent through the terminal side communicating means 1a05, wireless medium 1a0C, and communicating means 1a09 to the host computer 1a10. If the executed button signals reach the host computer 1a10, for example, when the patient name is sent from the inputting means 1a06 to the host computer 1a10, a search is conducted in the database in the host computer 1a10 receiving it and the data is sent to the mobile terminal 1a0A. The sent data is adjusted for display use at the control means 1a03 through the terminal side communicating means 1a05 and is displayed at the display means 1a04.

[0374] Further, the system may be configured so that the data which is transmitted from the host computer 1a10 to the mobile terminal is displayed as is at the display means 1a04 of the mobile terminal 1a0A. Alternatively, the controlling means 1a03 may call up and run a program from the storing means 1a07, process data which is sent from the host computer 1a10 by the program, and display the results on the display means 1a04.

[0375] As the data which is transferred by a wire communication means, sign data, numeric data, symbol data, and other text data and image data are sent. When the host computer 1a10 does not have the required content, sometimes the data is acquired from another host device 1a13 through the communication network 1a12.

[0376] The input from the inputting means 1a06 is further recorded at a host device side recording means 1a11. For example, when a periodontal pocket depth value is obtained and is manually input from the inputting means 1a06, it is recorded as is through the host computer 1a10 in the recording means 1a11, but to confirm the input value, the display means 1a04 may also be provided with a circuit for displaying it.

[0377] Next, the operation of an embodiment of the present invention will be explained in more detail while referring to FIG. 24 and FIG. 25.

[0378] At the time of start of use, as shown by step 1b01 shown in FIG. 25, an automatic communication test is run. If the communication test fails (NO) (step 1b02 shown in FIG. 25), an error message is displayed (step 1b03 shown in FIG. 25) and an automatic communication test is run again at step 1b01 shown in FIG. 25.

[0379] If the automatic communication test succeeds (YES), the host computer 1a10 which is shown in FIG. 24 outputs the patient selection menu display data through the communicating means 1a09, wireless medium 1a0C, and terminal side communicating means 1a05 to the control means 1a03. The control means 1a03 to which this data is input outputs this to the display means 1a04. In this case, what the host computer 1a10 outputs is display use data. When displaying this display use data at the display means 1a04, a display use program which is read out from the storing means 1a07 is run by the control means 1a03 to form this in this illustration.

[0380] Note that, the patient selection menu may also be recorded as a program in the storing means 1a07 of the mobile terminal. Alternatively, the data may sometimes be directly displayed at the display means 1a04 without going through the control means 1a03.

[0381] The display means 1a04 shown in FIG. 24 displays the patient/user selection menu (step 1b04 shown in FIG. 25).

[0382] The case where, at step 1b05 shown in FIG. 25, the patient selection menu number is input by depressing the keypad (yes) will be explained. If something else is selected (no), the operation shifts to the terminal 1b05a. There, a similar operation is repeated, so illustration and explanation will be omitted.

[0383] The patient selection (for example, depression of "1" on the keypad) and the signal of "1" are sent as they are through the wireless communicating means to the host computer 1a10 where a program operates which displays a patient name input box on the display means 1a04. At step 1b06 shown in FIG. 25, if a patient name or patient code is input by depressing the keypad, each time depressed, a code and text data corresponding to the depressed key of the keypad are sent to the host computer 1a10. If the enter key is depressed, the stored data in the recording means 1a11 of the host computer 1a10 is searched.

[0384] For this search, in addition to a full match search for the entire name, a partial match search where only the surname and first name are input etc. may be utilized, so a list of patients obtained in the case of a partial match search is displayed.

[0385] Whether or not there is a patient candidate is displayed. If there is, a key showing that there is is pressed. The pressed information is sent directly to the host computer 1a10. The host computer 1a10 then calls up the patient data from the database and sends it to the mobile terminal 1a0A.

[0386] This patient data is displayed on the display means 1a04. In this case, the control means 1a03 lists the data for display as it is for each paragraph code.

[0387] Furthermore, when displaying patient data, the control means 1a03 may read out a display use program from the storing means 1a07 and run it so that the display means 1a04 displays an array in accordance with the program.

[0388] If there is a patient candidate (yes) at step 1b07 shown in FIG. 25, the host computer 1a10 shown in FIG. 24 sends the patient data to the mobile terminal 1a0A (step 1b08 shown in FIG. 25). If there is no patient candidate (no) at step 1b07 which is shown in FIG. 25, the patient is registered as new or a search is conducted again, but display of the routine for the repeated search is omitted. Only the step for new registration of a patient (step 1b09 shown in FIG. 25) is shown.

[0389] In the case of new patient registration, if operating the keypad of the inputting means 1a06 to input data, the keypad input is sent as is to the host computer 1a10 where it is registered in the database of the recording means 1a11. Further, in the case of registering a new patient, in addition to input from the inputting means 1a06, input from the host computer 1a10 is also possible. Whatever the input, the patient is newly added to the patient information which is recorded in the recording means 1a11 of the host computer 1a10 (step 1b09 shown in FIG. 25).

[0390] If the patient is identified and the records are displayed, next, at step 1b10 which is shown in FIG. 25, a menu for examination is displayed at the display means 1a04 of the mobile terminal 1a0A. This menu display shows the data which the host computer 1a10 outputs and displays or the data which is processed by running a program which is called up from the storing means 1a07 and is displayed by the display means 1a04 by the control means 1a03 as an example.

[0391] When the examination menu related information is displayed as text sentences, it is displayed from host device 1a0B through the wireless medium 1a0C and the control means 1a03 as is. In the case of a display having a pattern of arrangement distinctive to the database, an application program may be read out from the storing means 1a07 and run (step 1b10 shown in FIG. 25).

[0392] FIG. 25 shows the case where plaque examination is designated. Other options (1b11a) are omitted. If designating plaque examination at step 1b11 which is shown in FIG. 25, the signal which is obtained by pressing the inputting means 1a06 to designate input is directly sent to the host computer 1a10. The host computer then outputs the past plaque data.

[0393] The past plaque data which the host computer 1a10 calls up from the recording means 1a11 and outputs to the mobile terminal 1a0A is data of numerical values, symbols, text, moving images, still images, etc. The control means 1a03 runs a plaque display program which was called up from the storing means 1a07 and uses the data which is output from the host computer 1a10 as the basis for display.

[0394] Data as what stage of plaque to add at what side surface of what tooth is sent to the host computer 1a10 shown in FIG. 24 by operation of the keypad at the mobile terminal side. The host computer 1a10 records data to this effect in the recording means 1a11.

[0395] If, at step 1b12 shown in FIG. 25, the plaque of the patient is displayed, the routine proceeds to step 1b13 shown in FIG. 25 for determination of whether to make corrections or additions to the same. If making corrections or additions, the above-mentioned corrections or additions (step 1b14 shown in FIG. 25) are performed.

[0396] When the modifications and corrections or additions are completed, at step 1b15 shown in FIG. 25, it is judged whether to perform another examination. If performing another examination, an examination menu of step 1b10 shown in FIG. 25 is displayed. If not performing another examination, whether to return to the initial menu is displayed (step 1b16 shown in FIG. 25). If returning to the initial menu, the patient and user selection menu of step 1b04 shown in FIG. 25 is displayed and the processing is continued. If not returning to the initial menu, for example, the routine may be ended.

[0397] Note that the above configuration is only one example. For example, smart phones and mobile phones may sometimes also be used as they are as mobile terminals for managing dental information. At the very least, the dental employee can carry the device and operate it to input, display, and record intraoral information, dental office information, dental employee information, and other related information. If necessary, he or she can read out information from the host terminal and record information there. The devices need only be ones by which dental employees can display and input necessary information in a shared manner. They may be configured in accordance with the purpose of use.

[0398] The above operation enables wireless communication of keypad codes and numerical values, text, symbols, text data, images, moving images, and other data. Real time display is possible, so even if using the terminal at the same time as diagnosis and treatment, stress-free use is possible. Alternatively, when wearing the host device on the waist or back or when there is no problem even if connecting the host device and the mobile terminal by cables, sometimes wireless communication is not necessary and communication by cables is possible.

[0399] The present invention enables centralized management of dental information by the above-mentioned mobile terminal. As the information to be managed, for example, dental office information, patient information, patient chart information, account information, diagnosis and treatment fee information, etc. handled by reservation management systems for dental diagnosis/treatment, electronic patient chart systems, reception computer systems for preparing reception data from accounting information and diagnosis and treatment information, recall management systems relating to repeat patients, etc. can be input. For example, dental office information which is handled by a business management system which is provided with the function of preparing and displaying graphed reports, digital X-ray information, dental microscope information, dental CT information, intraoral camera and other examination information, treatment use dental unit information, patient chair and other data information, probes for periodontal pocket examination use, and intraoral information from other devices, and attendance and other information on dental employees such as dentists, dental hygienists, dental staff, reception and administration staff, dental technicians, and other employees may be shown. In addition, toothpaste information, plaque related information , periodontal bacteria information, etc., preventive information, lifestyle disease related information, and other such information which is not limited to the oral cavity, but relates to diseases relating to periodontal diseases and other indirect diseases, for example, blood pressure and blood information etc. is sometimes also included.

[0400] Further, useful information about the clinic, useful information about the patients, questionnaire information, business information, etc. may be centrally managed, but the centralized management may not only cover all information related to the dental practice, but also just the required part of the information.

[0401] For example, when, like in the case of an analog X-ray camera device, data can only be obtained by analog photographs or images or in the case of handwritten data, an image scanner, digital camera, hard copy of the computer screen, or other digital converting means is preferably used to convert this to a digital signal for management.

[0402] The data may be centrally managed by the above mobile terminal, but a tablet type, notebook type, desktop type, or other dental computer may also be used for centralized management. In particular, a network specification terminal used primarily for the Internet or a mobile terminal may be utilized. A mobile terminal which is connected to the Internet by a wireless LAN may also be utilized.

[0403] Further, the present invention can provided centralized information and can provide data processing etc. using the cloud computing technique. For example, a mobile terminal or host terminal may use application software which is provided by one or more center organizations through the Internet and input and output data by dedicated or general use browser software at the terminal side. The terminal side need not install the centralized management application software. By just installing Internet Explorer®, Firefox®, or other browser software and using this browser software to run software for centralized management of dental information of a center, it can input and output data. It is therefore possible not to worry about the capacity of the recording device at the terminal side and provide both small size and simple design.

[0404] Note that, rather than a general use browser, it is also possible to use dedicated software for starting up software for centralized management of dental information. Further, the terminal side may sometimes store all information at the cloud side resources and sometimes store part of the information requiring secure management such as personal information at the terminal side.

[0405] As the type of the cloud, for example, a system which is constructed as a private cloud of just an in-house system, just a center organization, or a group of participating dentists where leakage of information would be a problem is preferred, but so long as security is reliable, it may be configured by a public cloud which is constructed by outside computer information service organizations. Sometimes, the entire part may be made a private cloud or a public cloud.

[0406] This mobile terminal may be carried for use by not only dentists, but also dental hygienists, dental reception and administrative staff, dental technicians, and other related staff and sometimes patients. Data can therefore be shared with other staff. Alternatively, by providing a function of switching IC cards or other carriers for identifying individuals, a single terminal may be alternately used exclusively.

[0407] For centralized management of the data, it is preferable that there be compatibility between the data which the different systems handle, but compatibility is not necessarily required. For example, when using hard copy data of the screen etc., it is sufficient that the data be displayed on the mobile terminal and be able to be operated there.

[0408] In the present embodiment, use in real time where the server provided with the external database and mobile terminal can communicate is preferable, but the invention is not limited to this. The operation may be temporarily recorded in the mobile terminal and, when communication with the server is enabled, the temporarily recorded data may be automatically transferred to the database by the batch method.

[0409] For example, when operating a patient reservation system on a mobile terminal, when determining the schedule of visits to the clinic for patient treatment and preventive care, if inputting a candidate reservation date from the terminal, the reservation status data is read out from the database and compared. It is possible to display overlapping scheduled dates on the screen of the mobile terminal and prompt change. Alternatively, it becomes possible to enter the schedule into a plurality of treatment and preventive care screens in an input display field of the mobile terminal screen and send a print command from the mobile terminal so as to print out the schedule of treatment and preventive care by a related printer. This can be then given to the patient.

[0410] The mobile terminal may be connected with a host device wirelessly or by cable and also may be connected with an intraoral camera by cable or wirelessly. In this case, it is possible to perform suitable positioning for capturing a tooth or tooth surroundings which require treatment or preventive care.

[0411] Not only is it possible to centralize information between a mobile terminal and host terminal, but also when using a host terminal as a server when providing each dental diagnosis and treatment chair with a terminal as a dental computer, it is possible to achieve centralized management of information between the host terminal and the computers of the individual chairs.

[0412] For input of data to the mobile terminal, in the above-mentioned way, use may be made of operating buttons or rotary dials of the pressing type, sliding type, or type which are operated by bringing a finger or pen or other such object into contact with screen. In addition, virtual buttons or virtual keyboards on the screen and, when an intraoral camera or other peripheral device, is connected, the above mentioned buttons or dials on the peripheral devices may be used. In addition, audio input and recording by an integrally provided microphone or a scanning and recording function by a camera which is integrally or separately provided may be provided to facilitate free input. Further, the scanning and recording function may use a dental camera to record a photographic image.

[0413] When inputting text or a handwriting image by an electromagnetic induction type pen or resistance film pen when inputting information onto the screen of a tablet type computer, mobile terminal, etc., it is also possible to fetch handwritten input data. For example, when providing an explanation to the patient, when explaining a treatment technique to a dental hygienist, and when otherwise display on the screen by handwriting is suitable, if inputting information directly from a mobile terminal by handwriting, it is possible to have this displayed as it is or have it displayed synchronously on the monitor screen of the host terminal to allow explanation to the patient or explanation to another employee or to have it recorded as is and used later. In particular, when entering information into the intraoral image by handwriting, the information can be used as is as patient data.

[0414] Furthermore, it is also possible to input and output audio data to obtain an accurate grasp of the intraoral situation. With the audio data, for example, when talking with a user of another mobile terminal, it is possible to designate a window on the mobile terminal screen and simultaneously display the audio and image. Alternatively, the audio data is converted as is to text data or the handwriting text is converted to text data so as to reduce the required storage capacity. In particular, when diagnosing the oral cavity, specialized terms relating to the state of tooth decay etc. can be recorded in advance as audio data and compared against audio which is input through the mobile terminal for conversion to text data. This enables data which had been previously entered to automatically be made electronic data.

[0415] By recording prerecorded audio samples and text data of specialized terms as tables in a recording device, comparing the input audio data and audio sample data, and converting the matching or substantially matching audio sample data to corresponding text data, it is possible to record accurate dental information.

[0416] The present embodiment enables input of electronic patient charts and other patient information, input of diagnosis and treatment fee information, and input and output of information relating to other dental administration under centralized management, but in this case, the host terminal and the mobile terminal may be synchronized in at least the input state. That is, if there is input from the host terminal, that input is displayed on the mobile terminal. The output display is also performed synchronously in the same way. The screen synchronization software can be run by a mobile terminal which has a built-in general use computer by utilizing the commercially available software Sync+®. Alternatively, the mobile terminal is one shown in a state which utilizes a function built in in advance or connects with a USB terminal which is provided with a LAN function to as to be able to utilize a wireless LAN. This enables sharing not only between the host terminal and mobile terminal but also with another mobile terminal through the host terminal or direct sharing between host terminals. The "direct sharing" may be sharing utilizing electromagnetic waves, infrared rays, and other wireless media and also through relay terminals.

[0417] In the case of home dental treatment, if the storage capacity and processing ability of the mobile terminal are low and data cannot be recorded, it is also possible to use a separate storage device or e-mail etc. to clean up the part which cannot be stored as data and use a dedicated or public line to transmit it to the host terminal sequentially or every certain stored amount.

[0418] Such synchronization of display between terminals enables input from a host terminal provided with a keyboard, mouse, or other input interface and thereby enables quick input since when dental diagnosis and treatment is for example performed on a common room, complicated input from the mobile terminals takes time.

[0419] Further, in centralized management of dental information using a mobile terminal or other terminal, it is also possible to automatically process time series data. For example, the date and time of the end of treatment or suspension of treatment of a patient after treatment is read out from a database and compared with the current date and time. When a preset time period has elapsed after treatment, that fact is displayed on the mobile terminal or host terminal. Alternatively, it is also possible to automatically print out e-mails directly.

[0420] The host terminal may automatically notify the mobile terminal when the time for preparing diagnosis and treatment fees and may automatically notify and adjust attendance figures for days where there are no reports etc.

[0421] The mobile terminal may connect with an X-ray image capturing system, intraoral camera, microscope, or other peripheral devices directly or through a host terminal so as to, for example, display the camera outputs by these peripheral devices in real time on the mobile terminal and record them in patient data folders identified by the patient names etc. These peripheral devices and dental chairs, lighting equipment, etc. may also be controlled in operation from the mobile terminal. At that time, records of the control operation may be logged into the patient chart.

[0422] The patient data folder is preferably recorded mainly in the host terminal in a nonredundant state and can be read by a search from individual terminals. There may be several copies of patient data folders such as at the individual terminals in the case of temporary use, but when recording it continuously, presence in a single storage area is preferable. This storage area may be not only the host terminal, but also a distant location through a network.

[0423] The mobile terminal may further be able to swap audio, image, or text information with the patient. In particular, as use of mobile terminals becomes generalized, the patient may also carry such a mobile terminal. If the patient carries one, preferably he or she can only view information required for himself or herself as a patient. This is because, for example, if developing application software for using smart phones and other mobile phones as the above-mentioned dental management terminal, a patient need only install a specialized application to enable such use.

[Dental Explaining Means]

[0424] The present embodiment explains dental diagnosis and treatment by for example displaying a panoramic image of the entire row of teeth of a patient and an image of the treatment portion on a computer monitor (display) screen and combines subdivided moving images in accordance with the objective for reproduction as a combined moving image so as to enable individual patients to easily understand explanations of treatment. The dentist may use an existing sequence of moving images obtained by combining the subdivided moving images in advance or may select, edit, and combine images in advance.

[0425] For the technique by which the dentist selects and edits images in advance, a semicustom or existing combined moving image sequence is selected for use, but an example of combining all explanatory data to prepare at least one moving image sequence will be explained in detail with reference to FIG. 26.

[0426] FIG. 26 is a view for explaining the operation in the case where the dentist sets one combined moving image in advance. In the figure, 1c01 is the display of the initial menu. A list which shows the existing moving image sequences, a list enabling semicustom connection and editing, and a list of individually subdivided moving images are displayed and are selected in accordance with the objective.

[0427] 1c02 is the step of selecting one of the initial menu displays.

[0428] 1c03 is the step where the steps to be executed are branched according to which is selected. In the case of NO, the routine proceeds to selection of another combined moving image (not shown) through the terminal 1c03a. In the case of YES, the routine proceeds to the step (1c04) of judging whether an image is already registered among the combined moving images by the technique of searching through the names of moving images or searching for combinations of distinctive codes assigned to the subdivided moving image data. If provisionally registered (YES), the routine proceeds to selection of another combined moving image through the terminal 1c03a.

[0429] When not registered, a list of the subdivided data is displayed and furthermore editing regions are displayed. The list of the subdivided data may be broken down by objectives or may be formed into an array or formed into a tree.

[0430] In the selection 1c05 of the subdivided moving image data, the data is moved from the list to the editing region by the copy and paste or drag and drop technique to edit the time-series explanatory data.

[0431] In FIG. 26, when selection of the subdivided moving images has ended (1c06), the selected combined moving image sequence is reproduced on a test basis (1c07).

[0432] FIG. 27 shows an example of combination of the combined moving image. In the figure, 1d01 indicates a moving image of recovery of the gums after tooth extraction, 1d02 indicates a slanted moving image of the adjoining teeth, 1d03 indicates a moving image of elongation of a facing tooth, 1d04 indicates a moving image of formation of a support tooth, and 1d05 indicates a moving image explaining the dental work shown in FIG. 1 and a moving image showing the setting of the dental work. These individual moving images are preferably not single, but a plurality of moving images.

[0433] The series of moving images from 1d01 to 1d05 are made the combined moving image 1d00 which is named and is recorded in a recording device. Code sequences assigned to the individual subdivided moving image data in advance are recorded by the recording device, then the combined moving image 1d00 is displayed on the computer screen as a single icon.

[0434] The combined moving image 1d00 is comprised of moving images which are successively combined to form one moving image which can be continuously reproduced. The individual moving images are subdivided. They are preferably respectively set with patient capacities and dentist capacities. The individual moving images are, for example, the WMV, AVI, or MPEG format. They may be selected and successively combined by existing moving image editing software.

[0435] Furthermore, at step 1c08, the dentist side data and patient side data are displayed, and the time and cost are displayed. Preferably, the use of another technique for lower cost, shorter time, and higher profit is explained in the display as an alternative.

[0436] At step 1c09, even if the combined moving image has already been prepared, if desiring to reselect it, the routine is made to proceed to selection of the subdivided moving image data. 1c10 is the step of selecting whether to store this menu list. If storing it (YES), at step 1c11, the name of the combined moving image is input and registered for storage. When not storing it, the routine returns to the end step it is selected whether to perform editing or to end the routine as it is (1c12).

[0437] FIG. 26 explains the operation when a dentist prepares a combined moving image, but there is a large number of actual subdivided data, so depending on the selected data, sometimes time is taken. Therefore, it is also possible to form samples in the manner of an editing box for each type of explanation in advance. This embodiment may further register the intraoral image of the patient itself in the subdivided moving image for utilization as part of an explanation of treatment, prevention, etc. unique to the patient.

[0438] The present embodiment is mainly utilized for obtaining informed consent. From the viewpoint of shortening the treatment time for the patient and for making the explanation more efficient, more efficient viewing is preferable, but in this case, subdivided moving images of durations of several seconds to several minutes are presented by the dentist while explaining them to the patient. An auxiliary screen which explains terms used by the dentist may also be displayed to make the explanation easier for the patient to understand.

[0439] For example, a list of the subdivided data is displayed on a computer screen by icons, tables, etc. The data is given simple titles easy for the patient to understand. This list is edited by displaying it on the above-mentioned mobile terminal and having the dentist select from it. The selected state is displayed on the screen which is viewed by the patient.

[0440] Further, it is also possible to discuss treatment with a patient while using a simple mobile terminal to prepare a combined sequence of moving images selected for the patient and display this to the patient on an immediate basis. That is, a mobile terminal provided with a display unit and input interface which is mainly carried by a dental employee and a terminal provided with a display monitor by which a patient or person desiring preventive treatment (referred to as "patient etc.") can view the information is used by the dental employee to search for and edit moving images, subdivided moving images, or combined moving images which include content to be informed to the patient etc. on the mobile terminal. When the editing ends, the image is transmitted to the patient viewing terminal. Further, in this case, moving image data may also be transmitted, but it is also possible to transmit identification data attached to the moving image data, have the terminal for patient viewing receive this identification data, and process the moving image based on this identification data sequence in real time for display on a screen.

[0441] Furthermore, the dentist etc. can carry a mobile terminal and in that state play back a moving image on the screen display of the terminal which the patient etc. views, stop it, display or not display the patient data, and perform other remote operations.

[0442] Further, the image and data which the patient is viewing can be synchronously displayed on a mobile terminal which a dental employee carries. In particular, when using the intraoral camera which is shown in FIG. 1 to display and explain the oral cavity of a patient, the explanation and case studies match and become easier to understand.

[0443] Furthermore, in the present embodiment, the mobile terminal which is shown in FIG. 24 may be used to edit the moving image data and to output and display the edited image on a computer monitor which the patient can view.

[0444] Further, the mobile terminal may be used to enable operation of display of a moving image on a monitor which is connected to a dental computer which a patient can view.

[Gum and Tooth Boundary Detecting Means]

[0445] The present invention includes a configuration for enabling the boundary between teeth and the gums to be clearly set.

[0446] The image of an intraoral camera is usually captured while lighting up a dark narrow space, so, for example, in the means for forming a panoramic image by computer image processing which is shown in FIG. 8 and FIG. 10, if detecting the common parts between images, when explaining dental treatment to the patient, etc., it is sometimes difficult to discern the boundary between the gums and teeth and the like due to the close color and the effects of saliva etc.

[0447] Therefore, a combination configuration which is comprised of a contour extracting means for extracting contours of teeth in an actual image, a color component image converting means for converting an actual image to component colors to clarify the shapes of the teeth and the gums, and a combined image forming means for combining the image which was converted by the color component image converting means and the contour extracted image is used to enable extraction of the contours of the teeth and gums even at locations of staining of the teeth or poor illumination.

[0448] The contour extracting means is for example comprised of a means for applying a 3D Fourier transform to an image and a means for detecting only a phase signal in a frequency region which shows changes in contrast of a image after the Fourier transform and applying an inverse Fourier transform. In addition, a Z-transform system and Laplace transform system etc. may also be utilized in some cases.

[0449] The color component image converting means, for example, is a means for forming images broken down into component colors shown by the RGB color system, La*b* color system, HSV color system, XYZ color system, xyY color system, L*u*v* color system, Munsell color system, Ostwald color system, NCS (Natural Color System), DIN color system, or other color system, selecting from among these a component color by which the shape can be clearly seen, and forming an image based on this component color or a means for combining component colors without regard to the color system to form a component color by which the shape can be more clearly seen and form an image based on that component color. This selection is preferably performed by measuring and determining a component color suitable for the intraoral image, but, for example, combination of any one of the L component image, a* component image, or b* component image of the La*b* color system and any one of the H (hue) component image, S (saturation chroma) component image, and V (brightness lightness value) component image of the HSV color system is shown. Combination of component colors of different color systems is sometimes preferable. The component colors need only be selected and combined for conversion to a component color by which the shape can be clearly seen or for combination of a plurality of component colors. Further, a "component image" includes an image which enhances the component obtained by adjusting the values showing the component values in for example a program.

[0450] Further, in addition to selecting a component image by which the shape can be clearly recognized, a combination of colors by which a person can recognize the boundaries more is used for coloring. For example, application of a R (red) component image to the gums and application of a G (green) component image to the teeth is shown.

[0451] Further, the component colors which are shown here not only include ones which are detected from an image, but also ones obtained by newly coloring while using colors which clarify the boundaries.

[0452] Further, the combined image forming means combines the contour image which was obtained by the contour extracting means and the image which was obtained by the color component image converting means and, for example, like the chroma key technique, makes the parts of the contour image other than the contour part the same color system and makes the color component image transparent etc. for combination. Alternatively, after that combination, to further enhance the color component image, means may be employed to change the color of the gum parts or more deeply enhance them to a red color system and to change the color of the teeth or more deeply enhance them to green so that the boundaries become more differentiated visually to people or mechanically. Further, depending on the color component, if converting the gum color to red and the tooth color to green, those color component images may be converted to. These means are preferably all realized by computer software, but sometimes are comprised of gate arrays and PLD (Programmable Logic Devices) and other custom and semicustom ICs.

[0453] Next, the embodiment which is shown in FIG. 29 will be explained. In the figure, reference numeral 2901 is an image inputting means. For example, it is a means for inputting a still image which was captured by an intraoral camera. The still image which was input by the image inputting means is output to a filtering means 2902. The filtering means 2902 is shown as an unsharp filter or other edge enhancement filter, but in addition sometimes a filter which enhances the contrast of the image may also be used.

[0454] The image which is filtered by the filtering means 2902 is output to the contour extracting means 2903 and the component color image converting means 2904. The contour extracting means 2903 is a comprised of a 2D Fourier transform means, a phase signal detecting means, and an inverse Fourier transform means, but these means are for example realized by combining program modules in a software library such as the "open-CV" (made by Intel).

[0455] Reference numeral 2904 is a component color image converting means. In the same way as explained above, it is comprised of a means for forming an image which is converted to the a* component color or b* component color or the H component color, S component color, or V component color of the La*b* color system or the HSV color system and a component color combining means for combining these component colors. The colors change, but an image with clear shapes of the teeth and the gums is formed. Furthermore, the changes in the color sometimes allow staining of teeth and tooth cavities to be found.

[0456] The contour image which is obtained by the contour extracting means 2903 and the images converted to component color images by the component color image converting means 2904 are output to the combined display means 2905. The combined display means 2905 combines the contour image which was output from the contour extracting means 2903 and the component color images which were output from the component color image converting means. This combination, for example, makes parts of the image other than the contours the same color system, makes the system of color transparent, and combines this with the component color image forming the background image. The combined image is displayed on a computer monitor.

[0457] Sometimes this series of processing for composition can give an image with a clear boundary between the gums and teeth. Alternatively, the present embodiment is suitably used when detecting the boundary KL of two teeth at for example the center as a general measure for when combining images (for example, image 906e and image 1102f) where the mark ML becomes the center of the image in the left and right rows of teeth shown in FIG. 12. Alternatively, a contour image which is obtained by detecting the phase signal by a Fourier transform and the actual image can be combined as they are. Further, even if using only component color images, images of clear shapes can be obtained, so even with only the images obtained by the component color image detecting means, an image with a clear boundary of the gums and teeth is obtained. Such an image with a clear boundary between the teeth and the gums can be utilized as mark for various types of combining operations or may be used for explanations to the patient and for dental treatment.

Industrial Applicability

[0458] The present invention provides a dental system which promote intraoral health in dental diagnosis and treatment by providing a patient with intraoral information in a readily understandable format and thereby enabling patient intraoral information to be refreshed. It is effectively utilized in the field of dental medicine.

Reference Notations List

[0459]

11 intraoral image inputting means
12 diagnosis and treatment portion detecting means
13 unit image forming means
14 diagnosis and treatment order setting means
15 diagnosis explanation forming means
16 display and output means
17 recording means

Claims

1. An intraoral video camera and display system which is provided with a continuously captured image sequence forming means for continuously capturing side surfaces of rows of teeth to form an image sequence, a side surface tooth row image forming means for combining sequences of images which were formed by the continuously captured image sequence forming means as partial tooth row images from an image forming the center of the overall composite so as to form a plurality of partial tooth row images, and a side surface tooth row image combining means for linking and combining a plurality of partial tooth row images which were formed by the side surface tooth row image forming means based on images forming the centers of the overall composite so as to form overall rows of teeth.

2. The intraoral video camera and display system as set forth in claim 1, further provided with
a mark setting means for setting a mark which is recognizable on the captured image at a predetermined position on rows of teeth,
a continuously captured image sequence forming means for forming continuously captured image sequences for one side surface and another side surface of the rows of teeth,
a side surface tooth row image forming means for combining the continuously captured image sequence of said one side surface and the continuously captured image sequence of said other side surface from images with marks at the predetermined positions so as to form one side surface tooth row image and another side surface tooth row image, and
a side surface tooth row image combining means for linking and combining said one side surface tooth row image and said other side surface tooth row image based on characterizing portions on the rows of teeth in still images where said marks are at the predetermined positions.

3. The intraoral video camera and display system as set forth in claim 1, further having X-ray image display means for displaying X-ray images of teeth corresponding to said side surface tooth row images and a virtual tooth row display means for displaying rows of teeth obtained by virtually correcting or virtually beautifying and coloring teeth corresponding to said side surface tooth row images.

4. The intraoral video camera and display system as set forth in claim 1, comprising a tooth row display means for displaying a tooth row image which is obtained by said side tooth row image combining means, a unit image forming means for forming an image of the oral cavity for each unit of diagnosis and treatment or care, a setting means for setting diagnosis and treatment and care order information for images formed by unit image formation by said unit image forming means, a display means for displaying images, with said diagnosis and treatment and care order information attached, based on said diagnosis and treatment and care order information so as to be able to be displayed in a list form, and a display medium which displays and records display information which is obtained by said display means.

5. The intraoral video camera and display system as set forth in claim 1, further provided with a small sized portable data processing terminal which has an input part enabling input and adjustment of data relating to the dental practice, a communicating means which can communicate data with an external data processing terminal and a server which manages work attendance or dental diagnosis and treatment, and a display means for displaying a tooth row image combined by said side surface tooth row image combining means and said data relating to the dental practice.

6. The intraoral video camera and display system as set forth in claim 1, further having a dental treatment explanatory data forming means for storing, in a storage means, subdivided moving image data which is formed as moving images which have been prepared in advance and subdivide dental treatment and selecting and linking and connecting said subdivided moving image data from said storage means so as to form data for explaining dental treatment and display it by said display means.

7. The intraoral video camera and display system as set forth in claim 1, further having a handheld type camera means which captures an image of said oral cavity and a sighting means which is provided at said camera means and emits a sighting beam which indicates an image capture portion.

Fig.1A

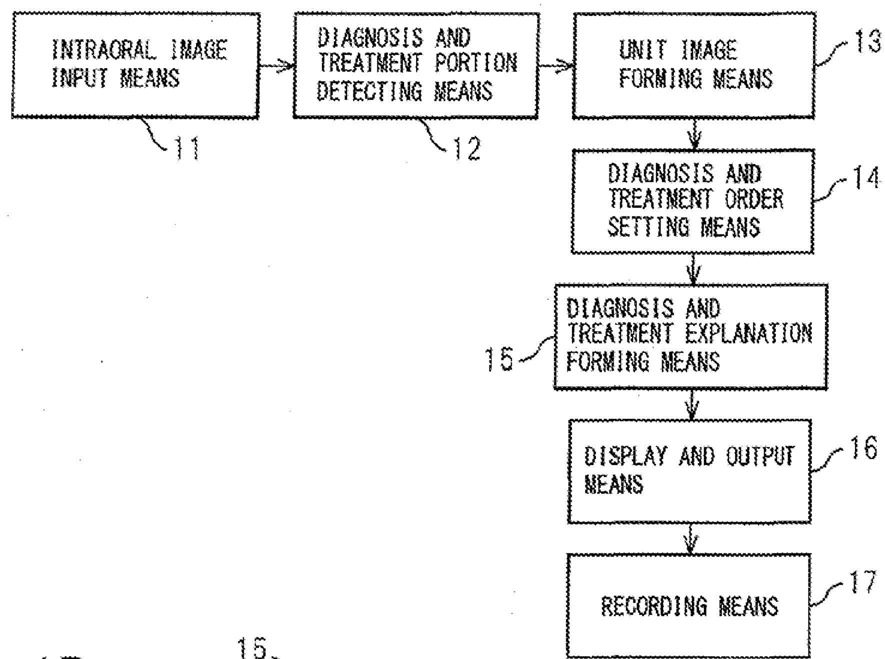

INTRAORAL IMAGE INPUT MEANS
11
DIAGNOSIS AND TREATMENT PORTION DETECTING MEANS
12
UNIT IMAGE FORMING MEANS
13
DIAGNOSIS AND TREATMENT ORDER SETTING MEANS
14
DIAGNOSIS AND TREATMENT EXPLANATION FORMING MEANS
15
DISPLAY AND OUTPUT MEANS
16
RECORDING MEANS
17

Fig.1B

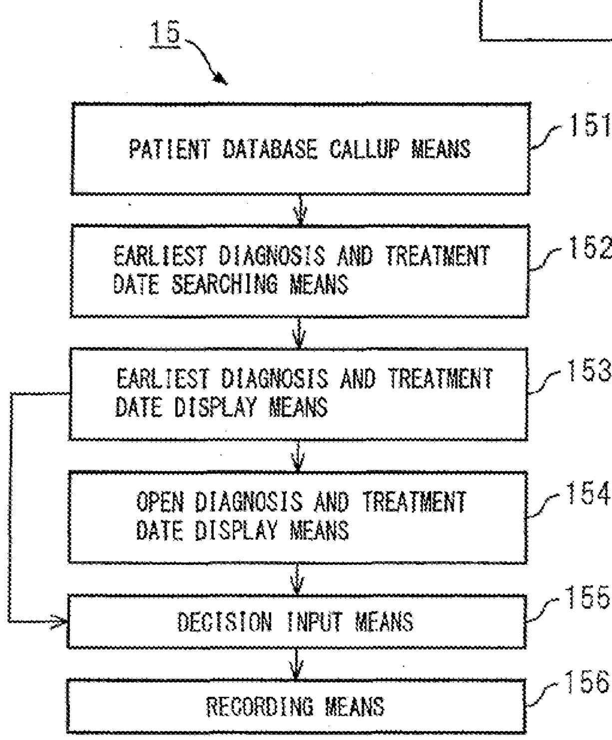

15
PATIENT DATABASE CALLUP MEANS
151
EARLIEST DIAGNOSIS AND TREATMENT DATE SEARCHING MEANS
152
EARLIEST DIAGNOSIS AND TREATMENT DATE DISPLAY MEANS
153
OPEN DIAGNOSIS AND TREATMENT DATE DISPLAY MEANS
154
DECISION INPUT MEANS
155
RECORDING MEANS
156

Fig.2A

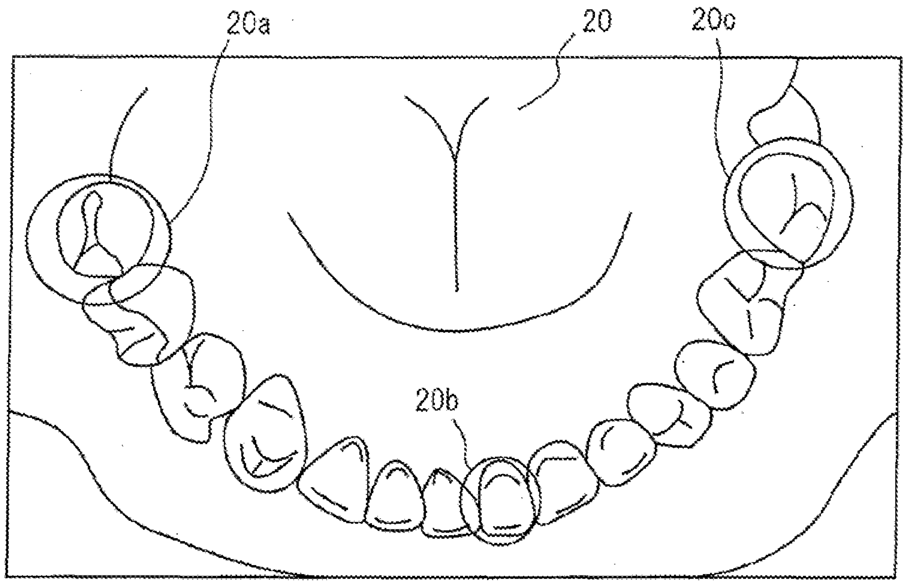


Fig.2B

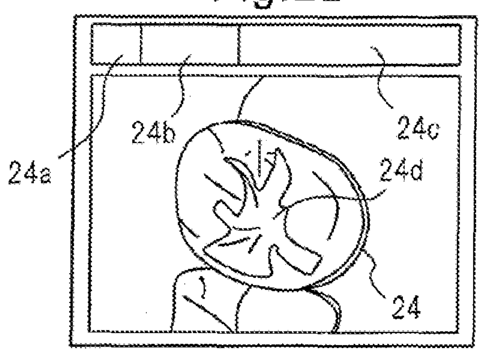
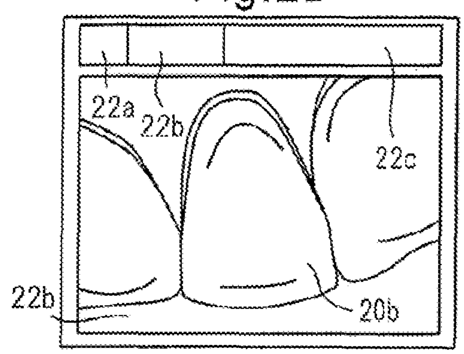


Fig.2D



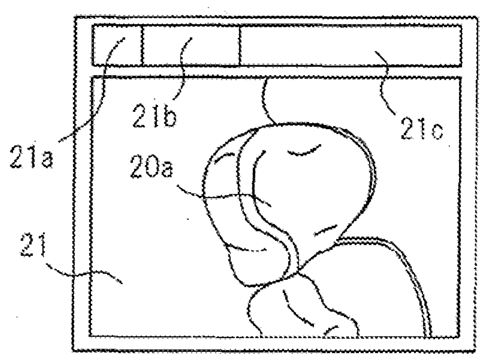


Fig.2C

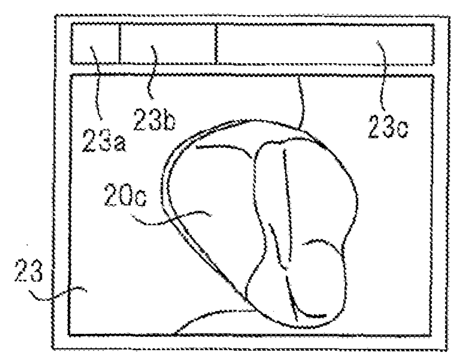


Fig.2E

Fig.3A

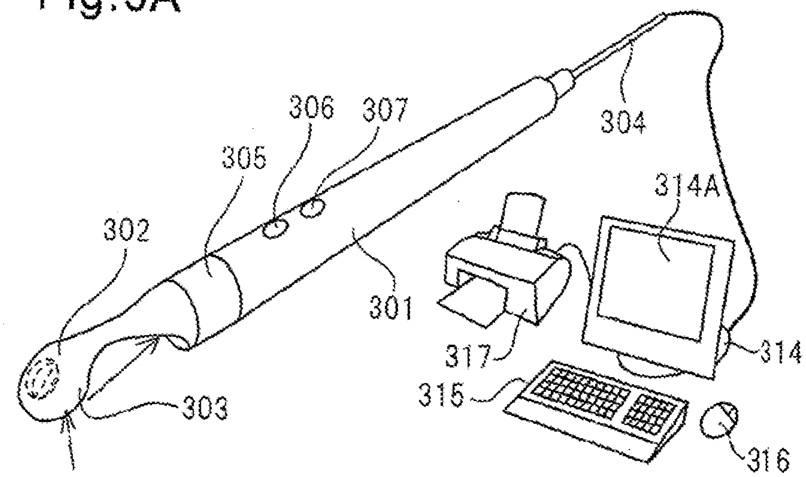


Fig.3B

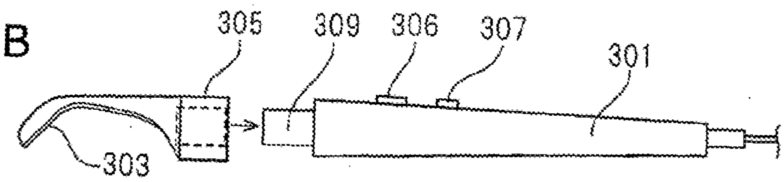


Fig.3C

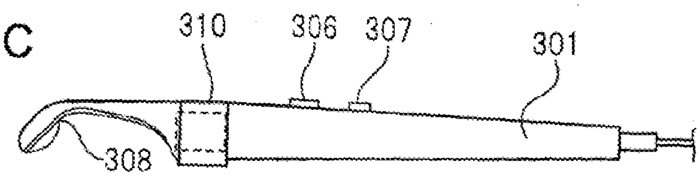


Fig.3D

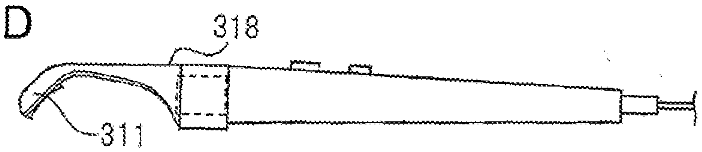


Fig.3E

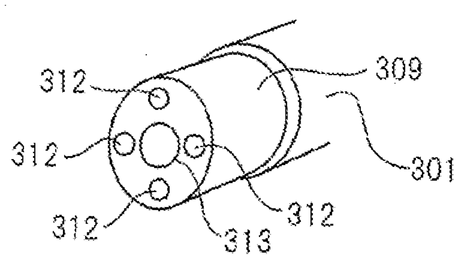
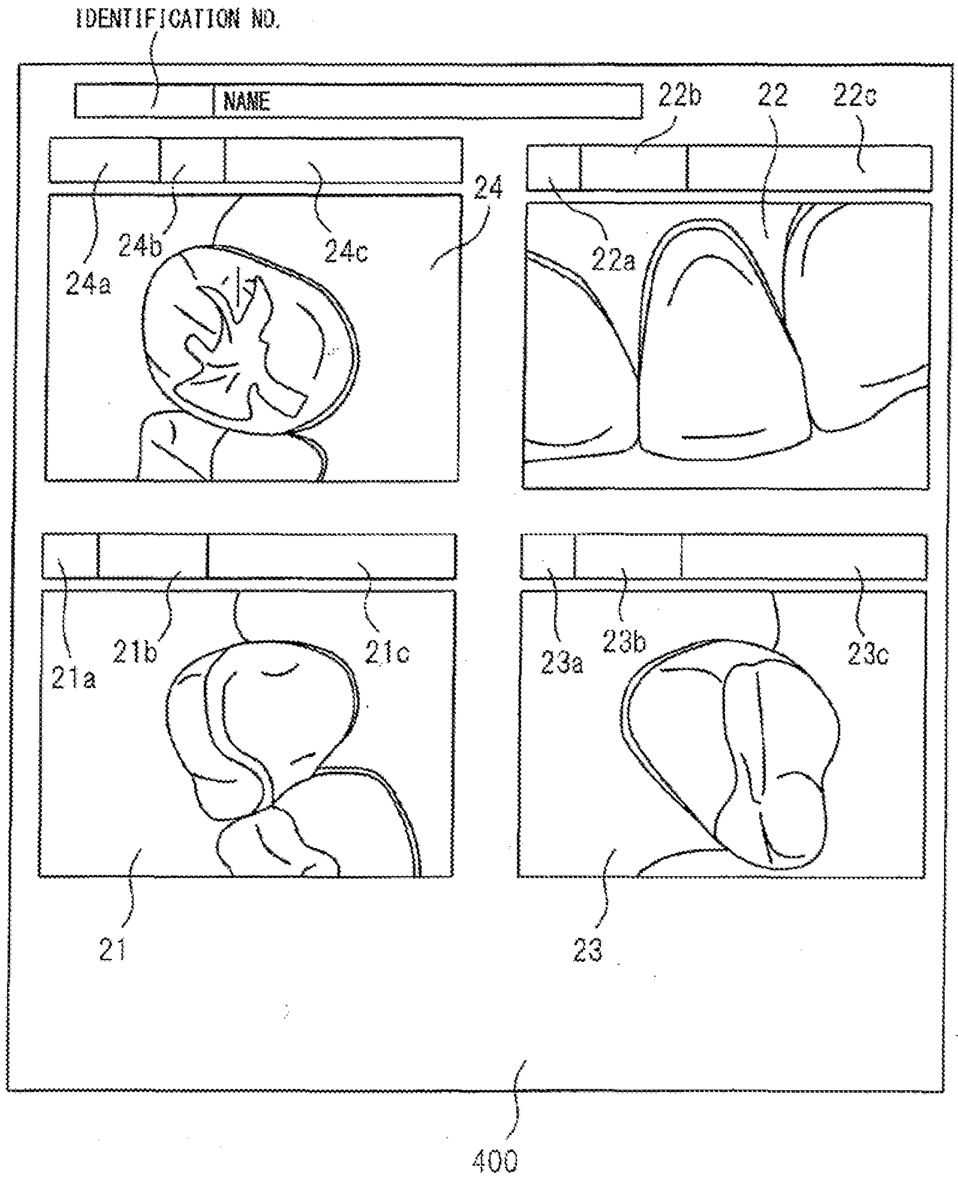


Fig.4


IDENTIFICATION NO.
NAME
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24a
24b
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23a
23b
23c
21
23
400

Fig.5

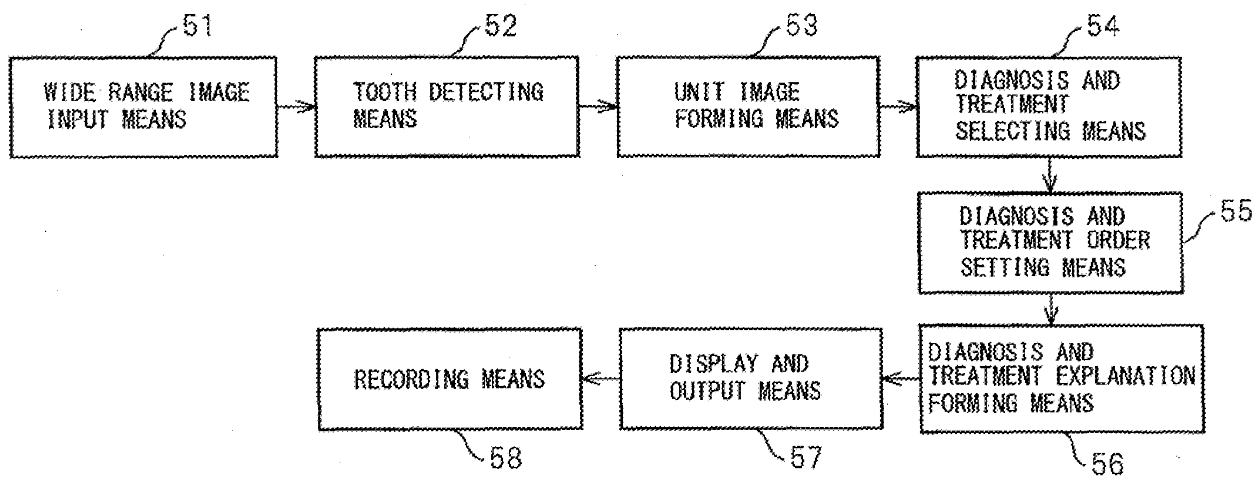
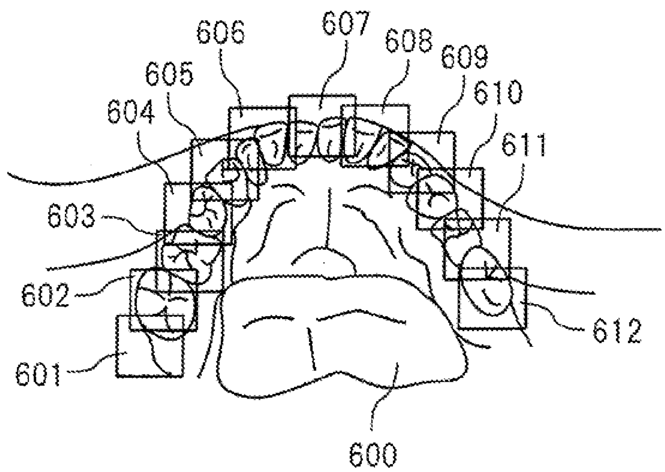

51
WIDE RANGE IMAGE INPUT MEANS
52
TOOTH DETECTING MEANS
53
UNIT IMAGE FORMING MEANS
54
DIAGNOSIS AND TREATMENT SELECTING MEANS
55
DIAGNOSIS AND TREATMENT ORDER SETTING MEANS
56
DIAGNOSIS AND TREATMENT EXPLANATION FORMING MEANS
57
DISPLAY AND OUTPUT MEANS
58
RECORDING MEANS

Fig.6A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600

Fig.6B

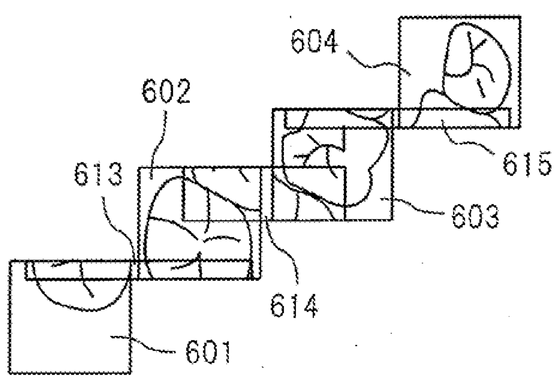
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Fig.7A

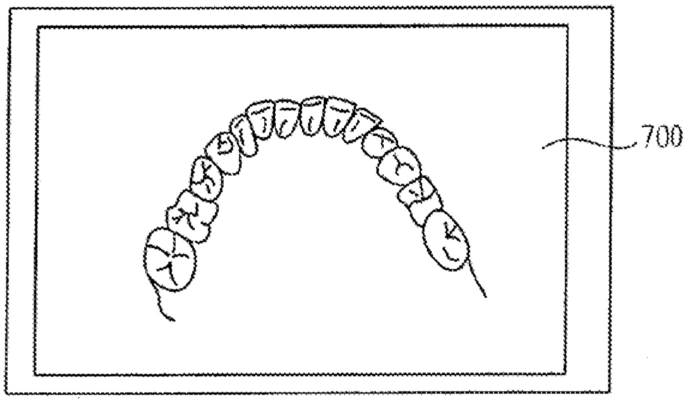


Fig.7B

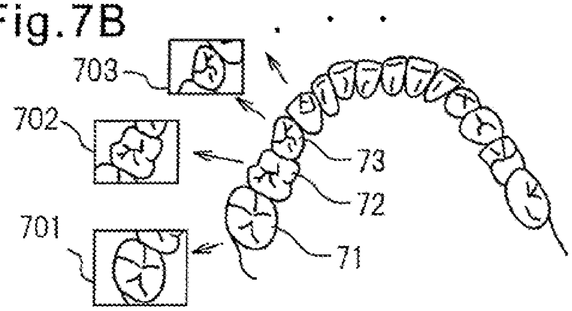


Fig.7D

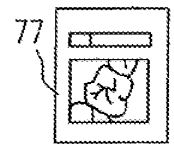
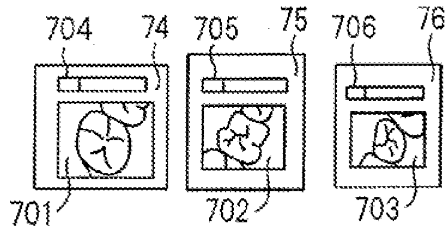


Fig.7C



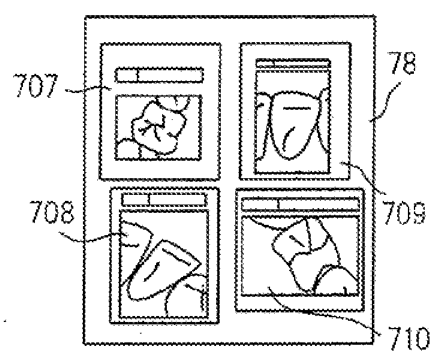


Fig.7E

Fig.7F

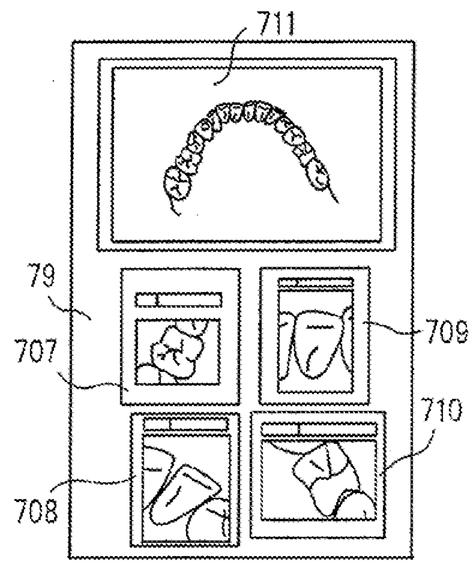


Fig.8A

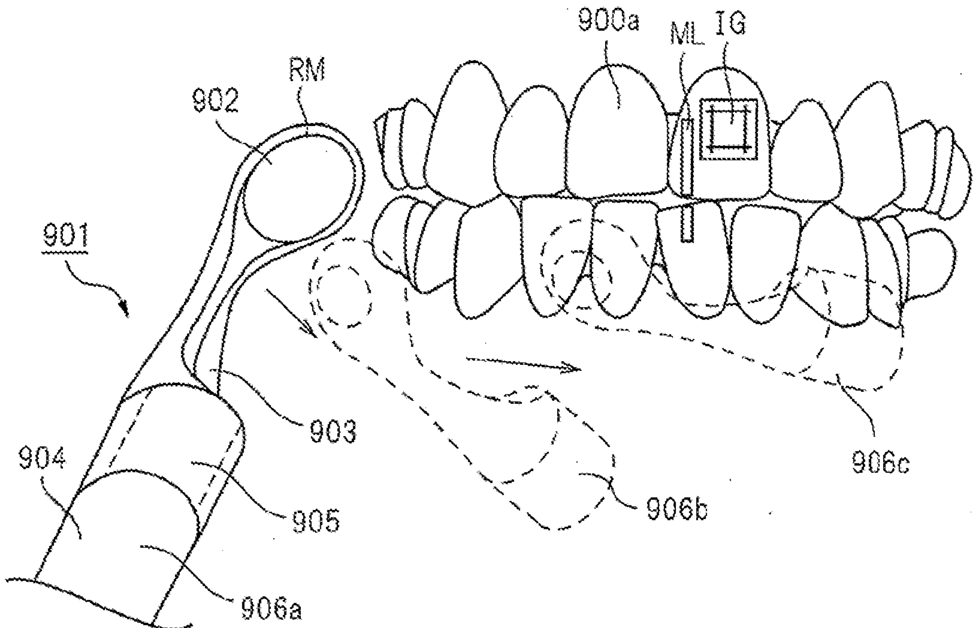

900a
ML
IG
RM
902
901
903
904
905
906a
906b
906c

Fig.8B

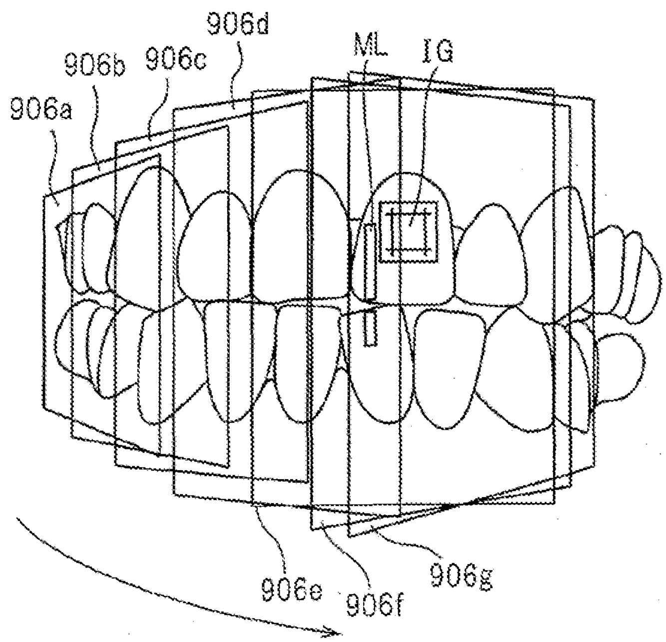

906d
906b
906c
ML
IG
906a
906e
906f
906g

Fig.9A

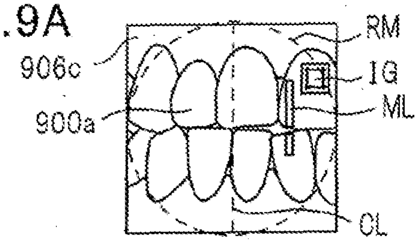


Fig.9B

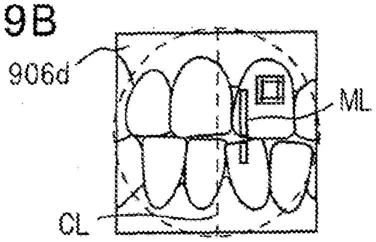


Fig.9C

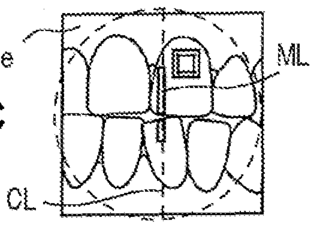


Fig.9D

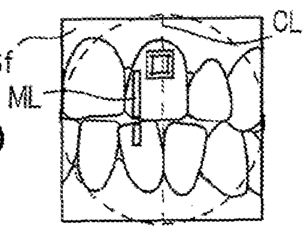


Fig.9E

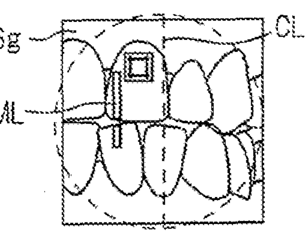


Fig.9F

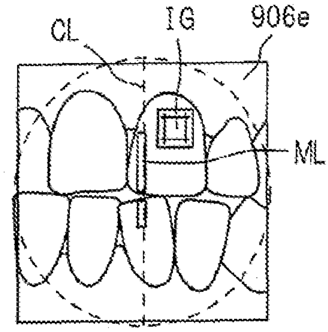


Fig.9G

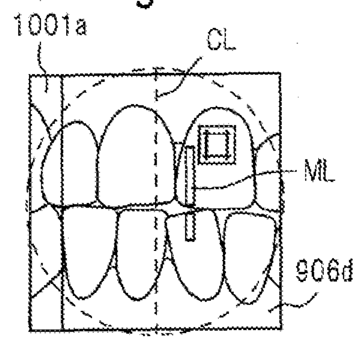


Fig.9H

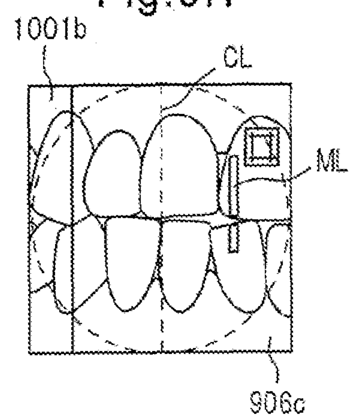


Fig.10A

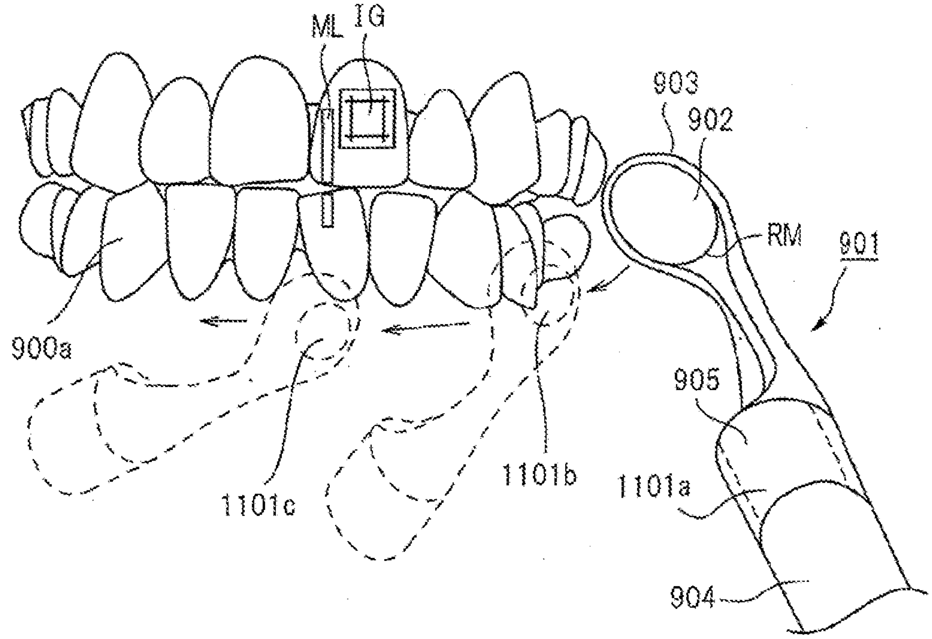


Fig.10B

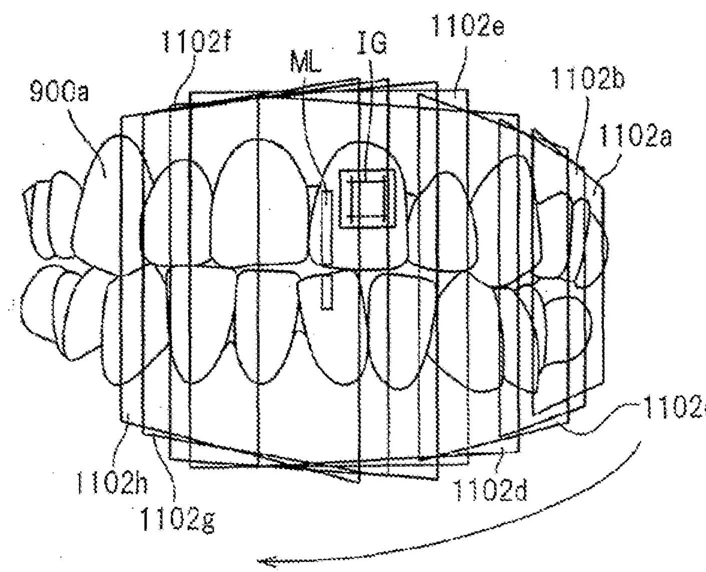


Fig.11A

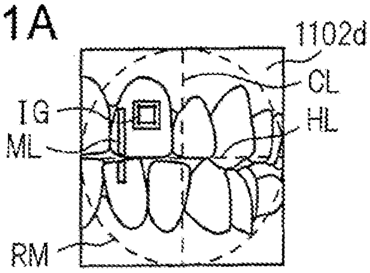


Fig.11B

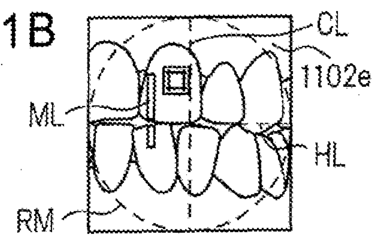


Fig.11C

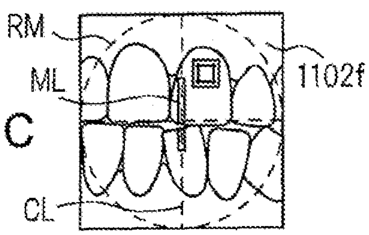


Fig.11D

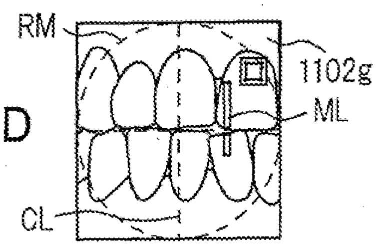


Fig.11E

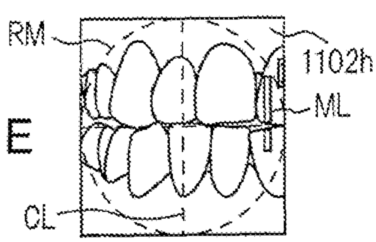


Fig.11F

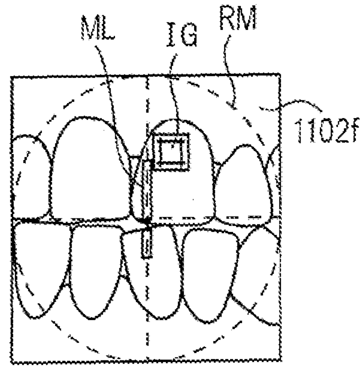


Fig.11G

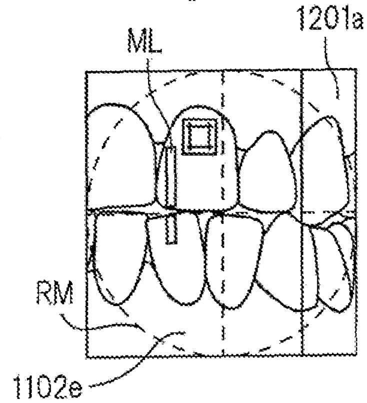


Fig.11H

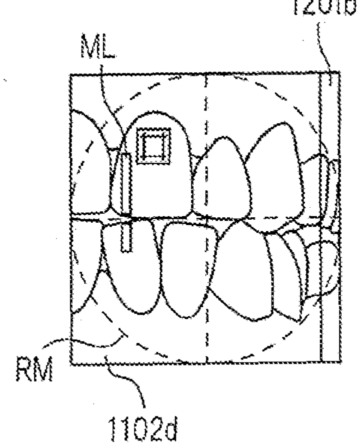


Fig.12A

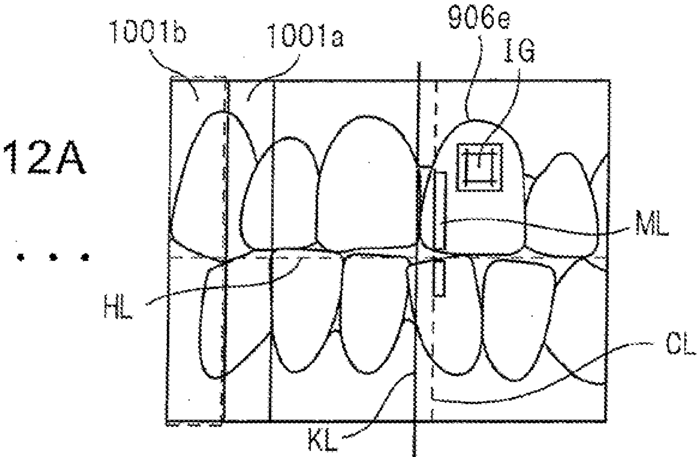


Fig.12B

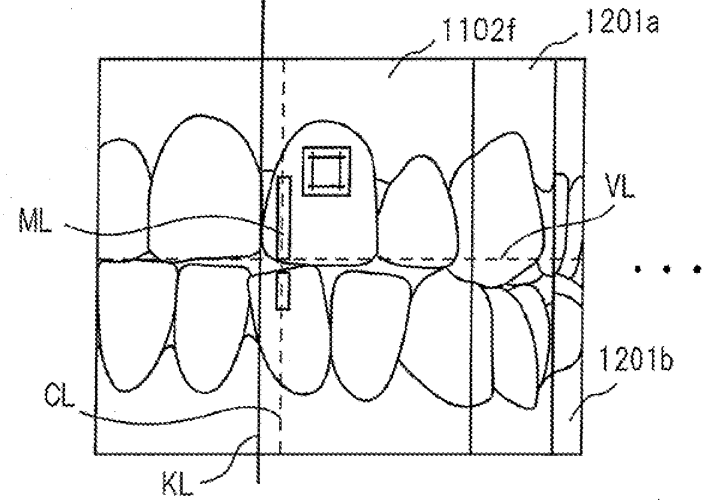


Fig.12C

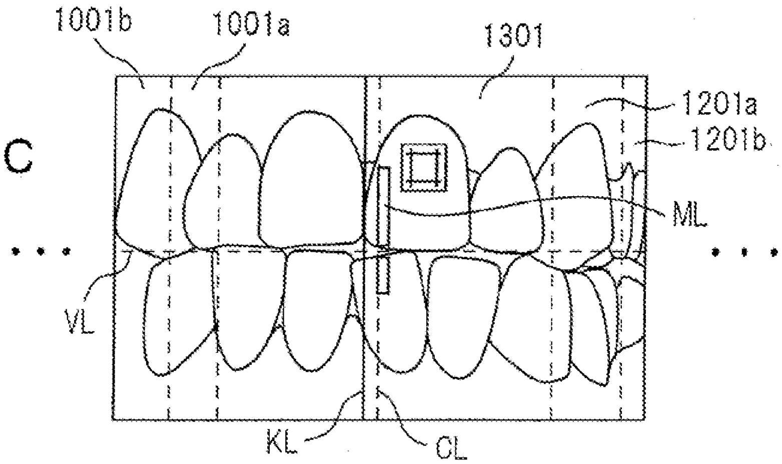


Fig.13

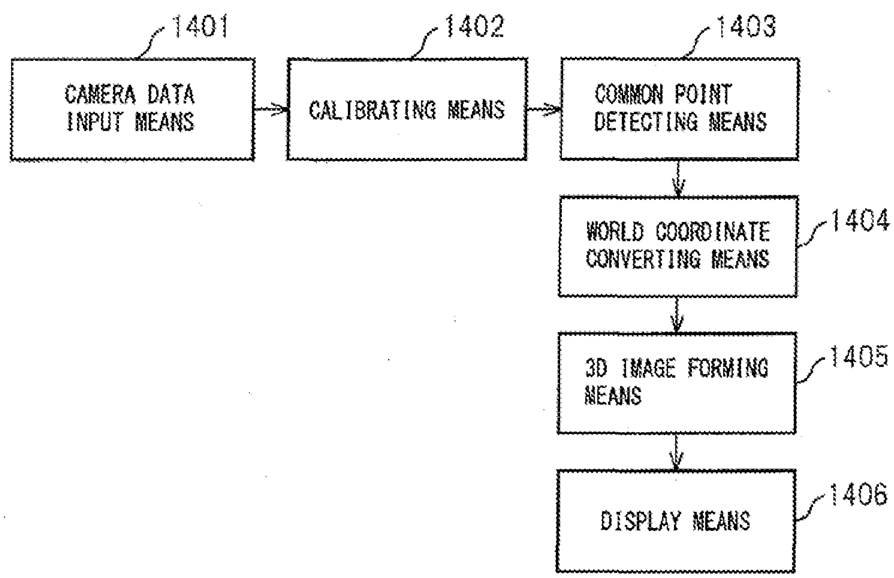

1401
CAMERA DATA INPUT MEANS
1402
CALIBRATING MEANS
1403
COMMON POINT DETECTING MEANS
1404
WORLD COORDINATE CONVERTING MEANS
1405
3D IMAGE FORMING MEANS
1406
DISPLAY MEANS

Fig.14

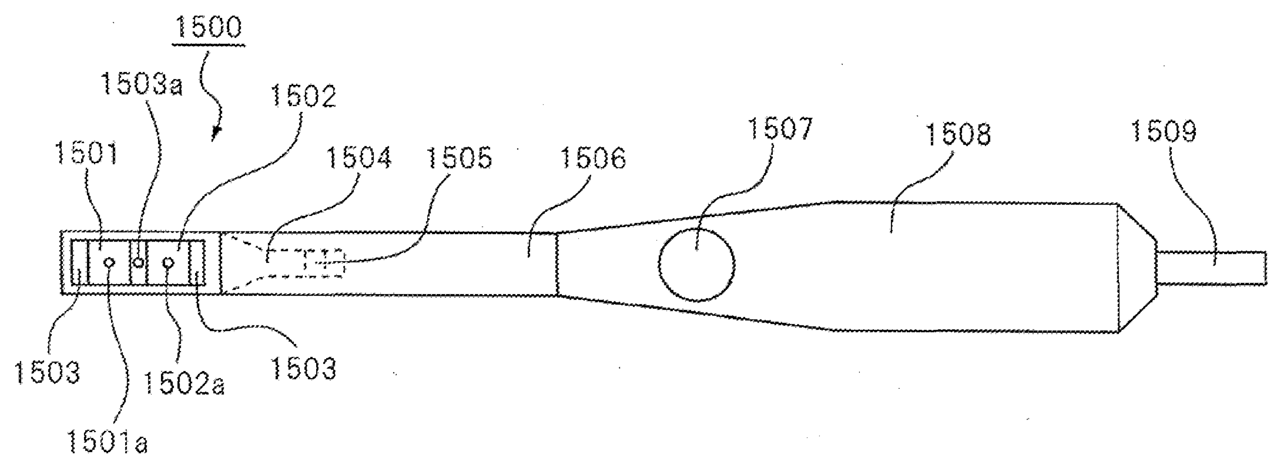

1500
1503a
1502
1501
1504
1505
1506
1507
1508
1509
1503
1502a
1503
1501a

Fig.15A

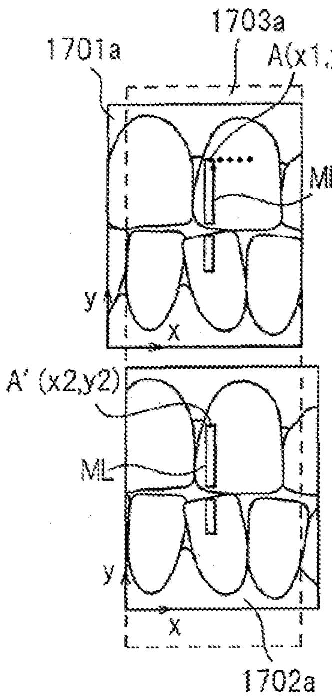


Fig.15B

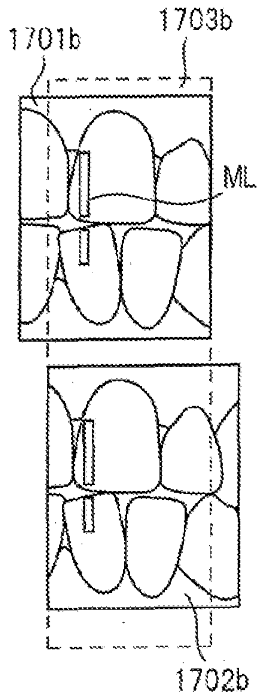


Fig.15C

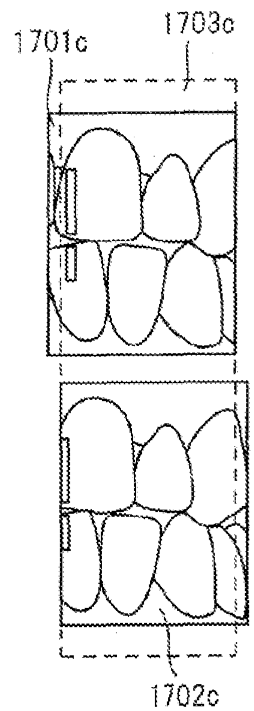


Fig.15D

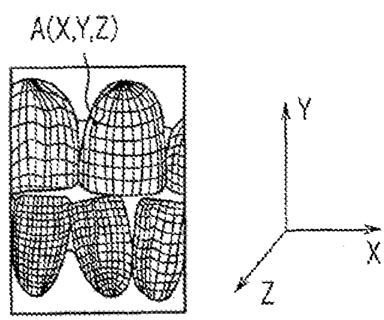


Fig.16A

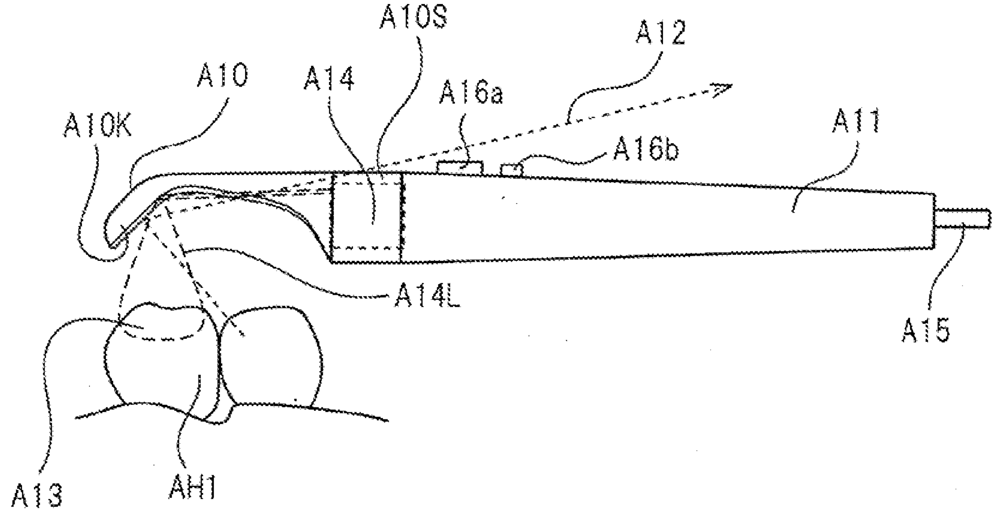


Fig.16B

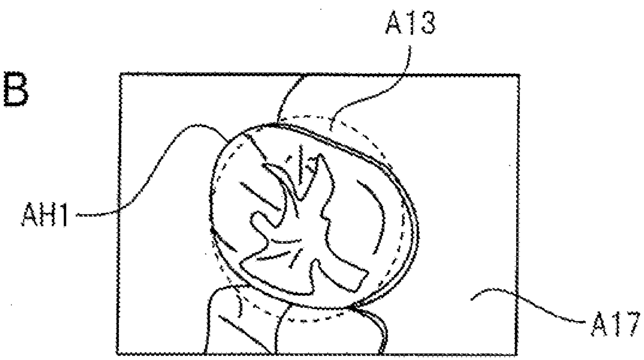


Fig.16C

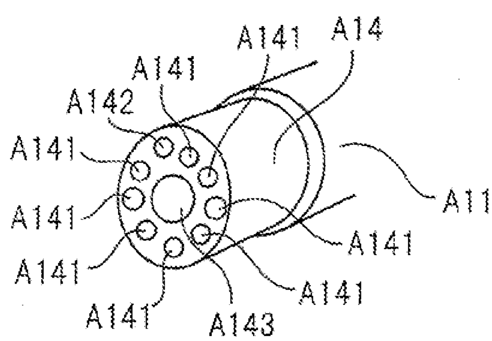


Fig.17

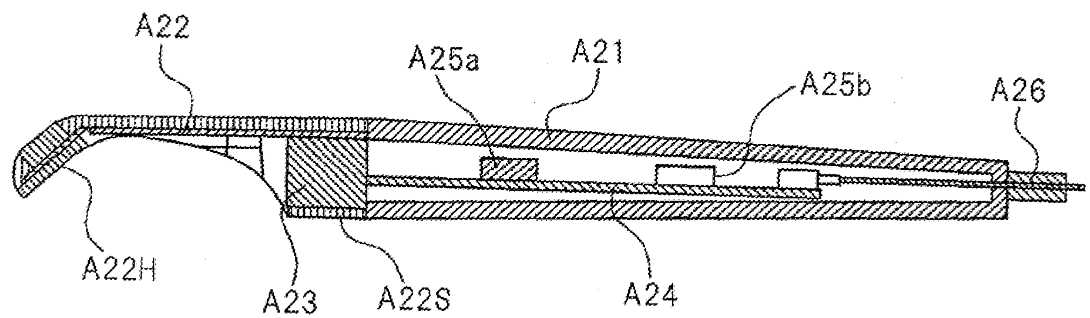


Fig.18

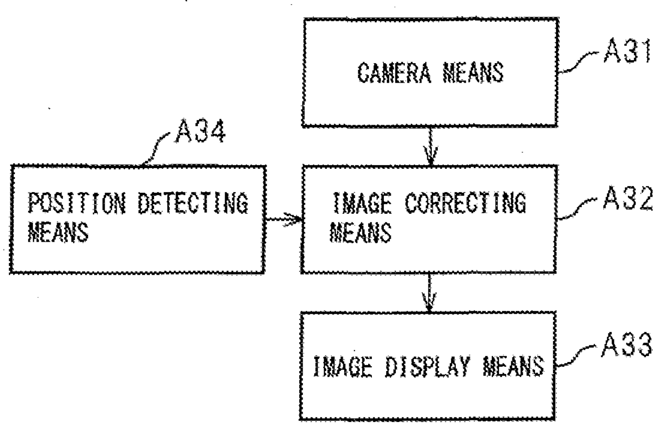

CAMERA MEANS
A31
A34
POSITION DETECTING MEANS
IMAGE CORRECTING MEANS
A32
IMAGE DISPLAY MEANS
A33

Fig.19

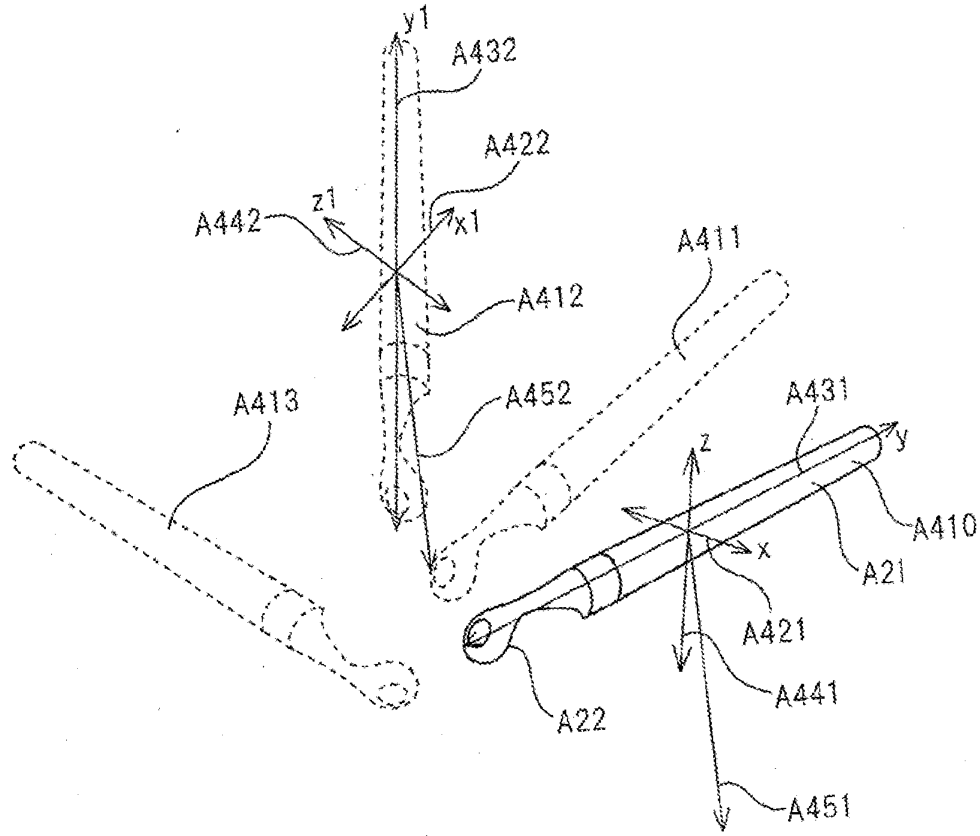

y1
A432
A422
z1
A442
x1
A411
A412
A413
A452
A431
z
y
x
A410
A21
A421
A22
A441
A451

Fig.20

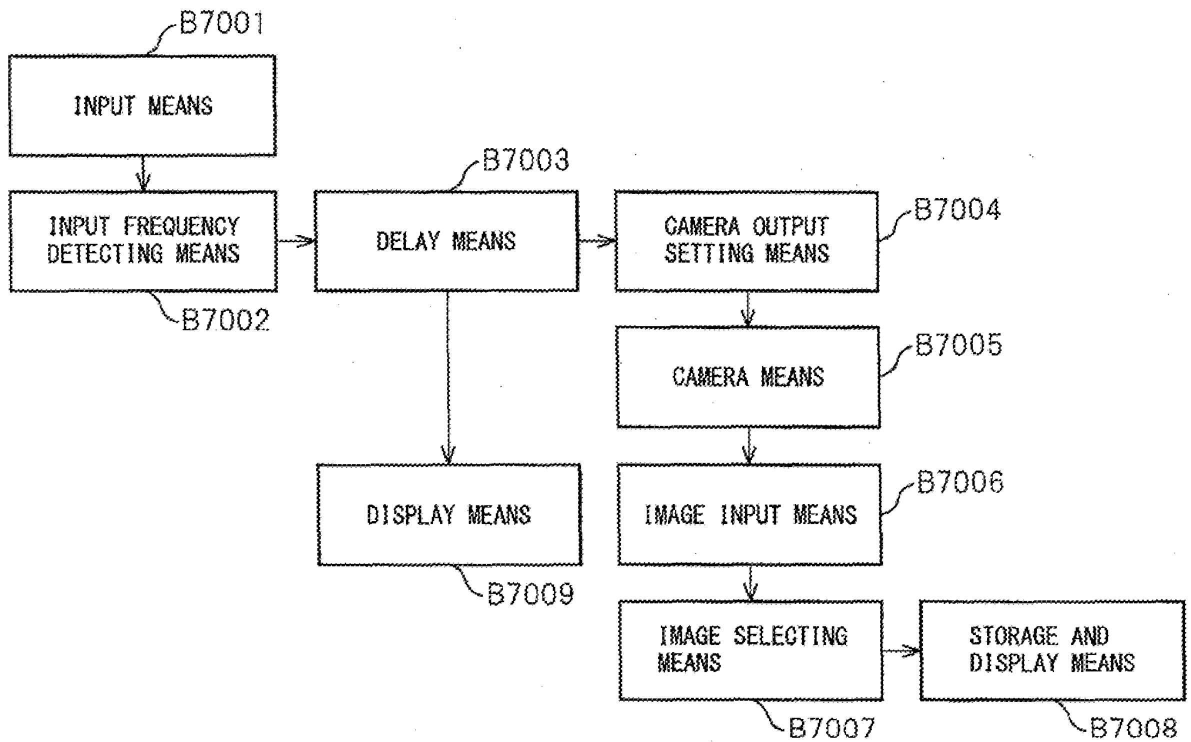

B7001
INPUT MEANS
INPUT FREQUENCY DETECTING MEANS
B7002
B7003
DELAY MEANS
CAMERA OUTPUT SETTING MEANS
B7004
CAMERA MEANS
B7005
IMAGE INPUT MEANS
B7006
DISPLAY MEANS
B7009
IMAGE SELECTING MEANS
B7007
STORAGE AND DISPLAY MEANS
B7008

Fig.21A

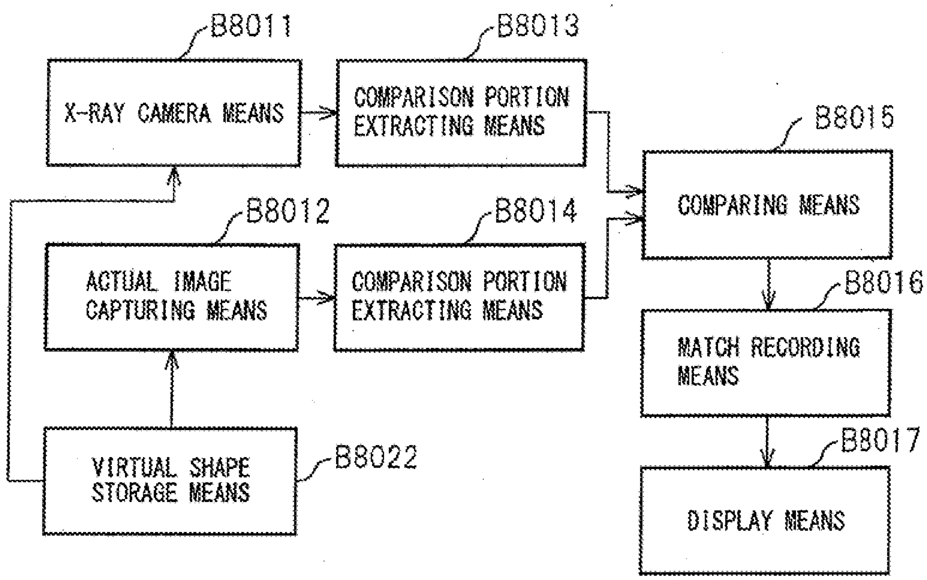


Fig.21B

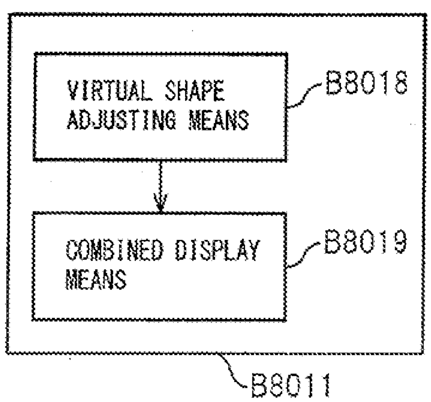


Fig.21C

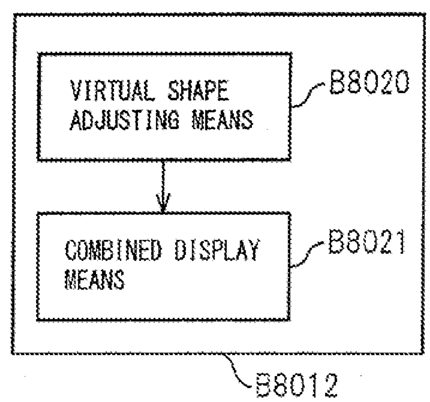


Fig.22A

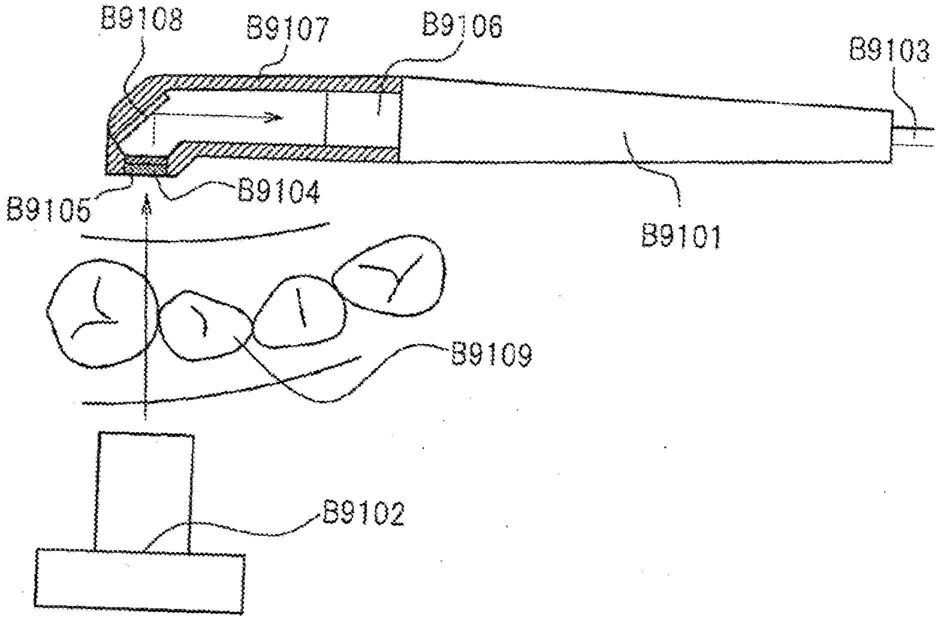


Fig.22B

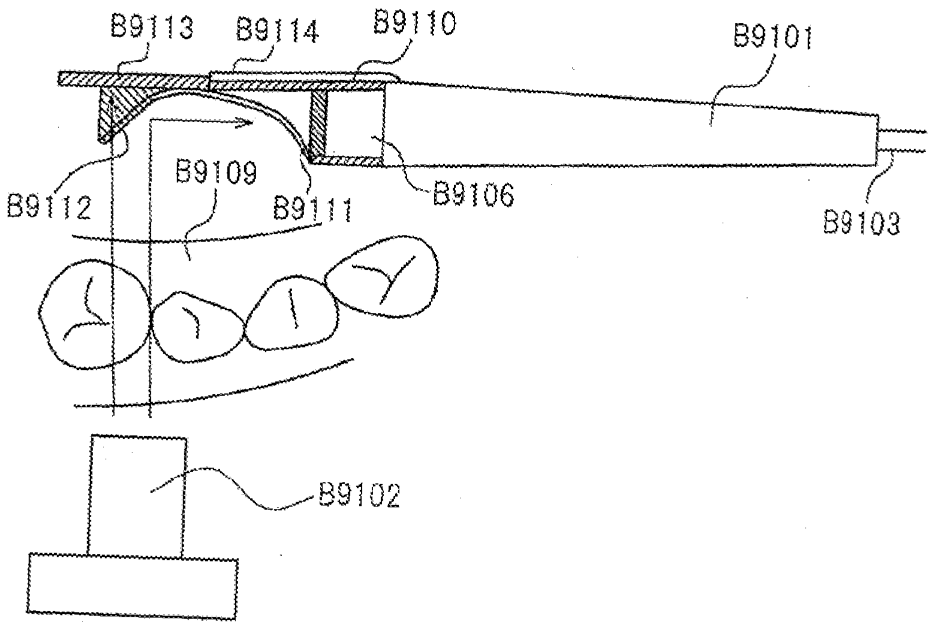


Fig.23A

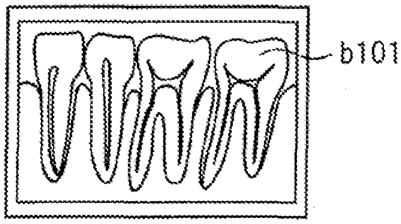


Fig.23B

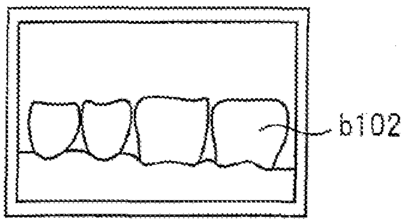


Fig.23C

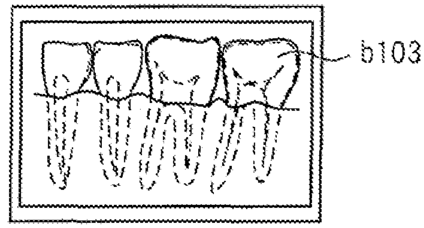


Fig.23D

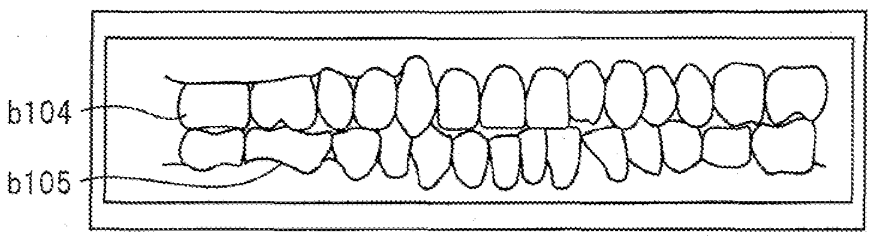


Fig.23E

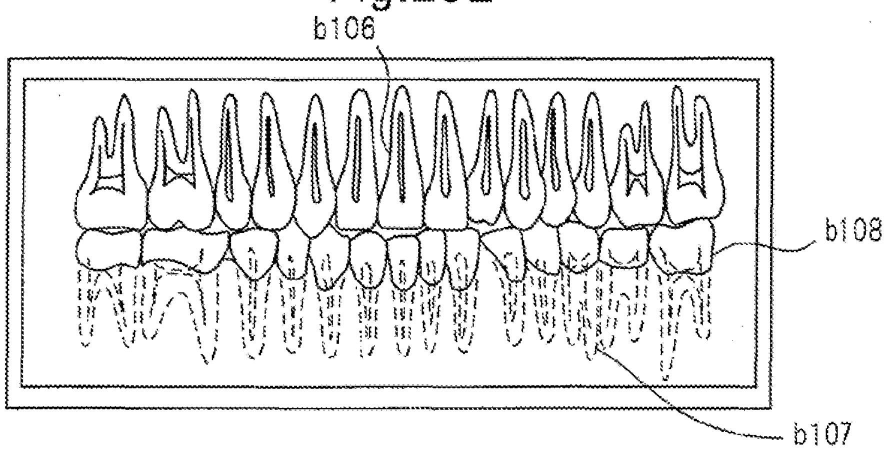


Fig.24

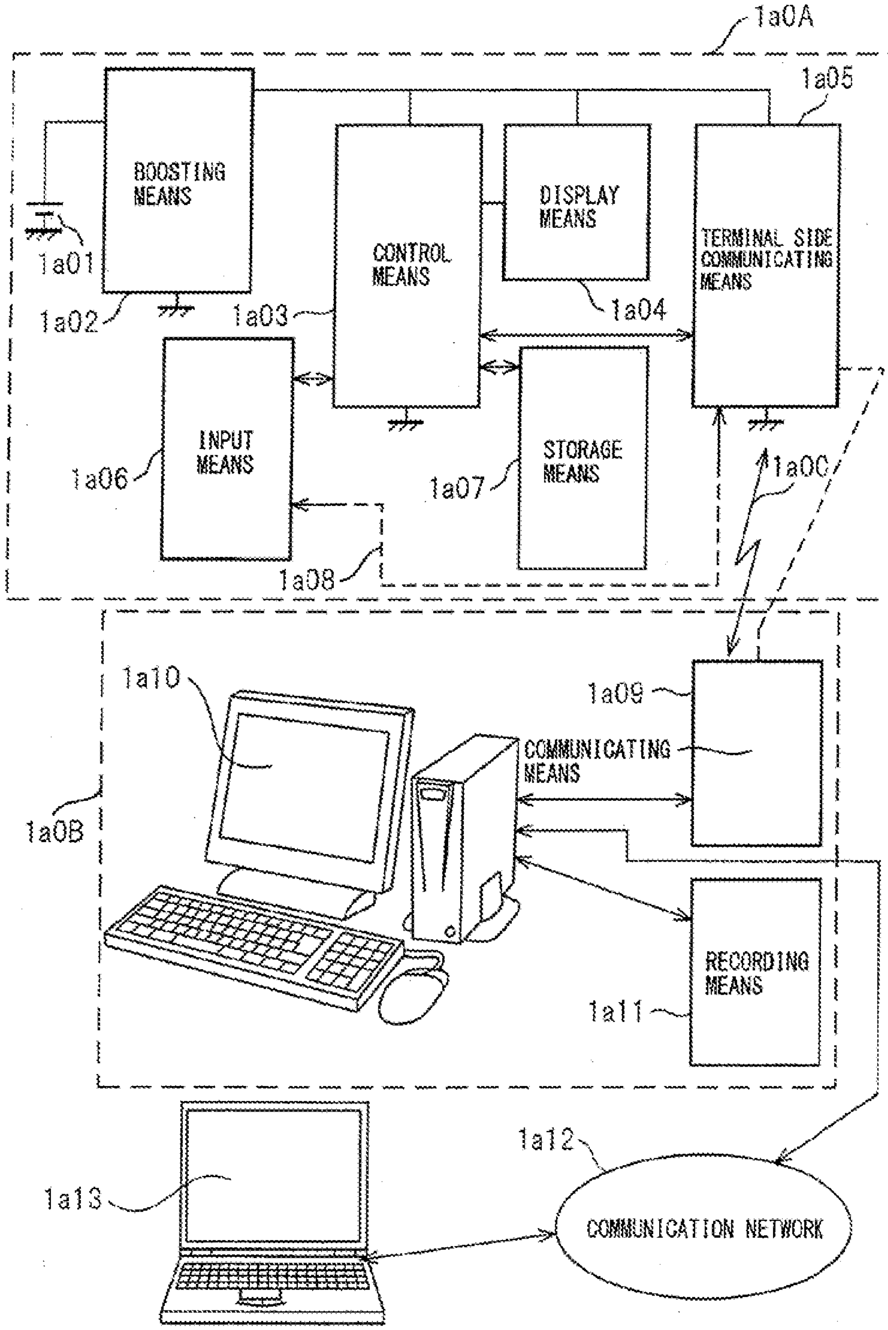
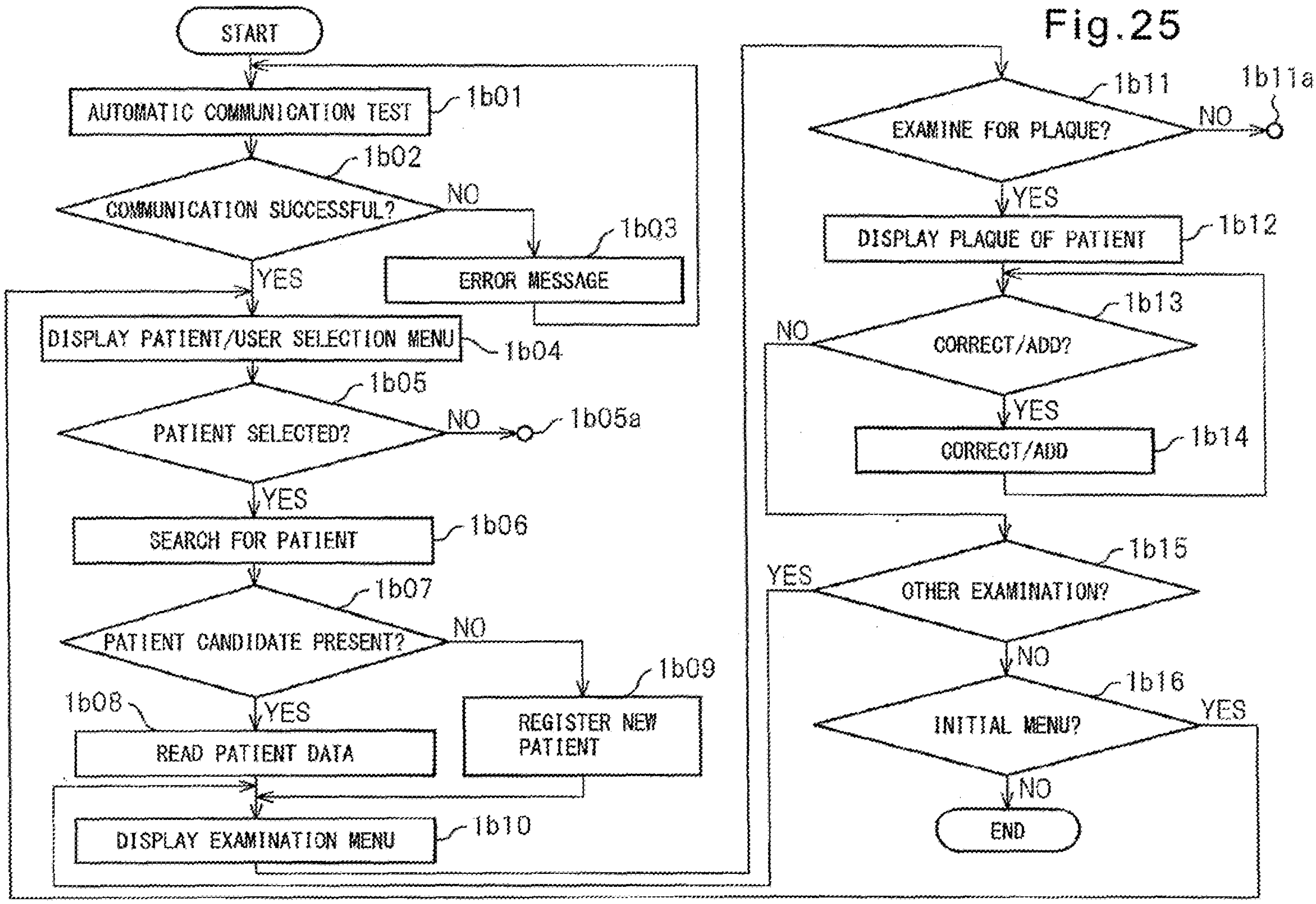

1a0A
1a05
BOOSTING MEANS
DISPLAY MEANS
TERMINAL SIDE COMMUNICATING MEANS
CONTROL MEANS
1a01
1a02
1a03
1a04
INPUT MEANS
STORAGE MEANS
1a06
1a07
1a0C
1a08
1a10
1a09
COMMUNICATING MEANS
1a0B
RECORDING MEANS
1a11
1a12
1a13
COMMUNICATION NETWORK

Fig.25



START
AUTOMATIC COMMUNICATION TEST
1b01
COMMUNICATION SUCCESSFUL?
1b02
NO
ERROR MESSAGE
1b03
YES
DISPLAY PATIENT/USER SELECTION MENU
1b04
PATIENT SELECTED?
1b05
NO
1b05a
YES
SEARCH FOR PATIENT
1b06
PATIENT CANDIDATE PRESENT?
1b07
NO
YES
1b08
READ PATIENT DATA
REGISTER NEW PATIENT
1b09
DISPLAY EXAMINATION MENU
1b10
EXAMINE FOR PLAQUE?
1b11
NO
1b11a
YES
DISPLAY PLAQUE OF PATIENT
1b12
CORRECT/ADD?
1b13
NO
YES
CORRECT/ADD
1b14
OTHER EXAMINATION?
1b15
YES
NO
INITIAL MENU?
1b16
YES
NO
END

Fig.26

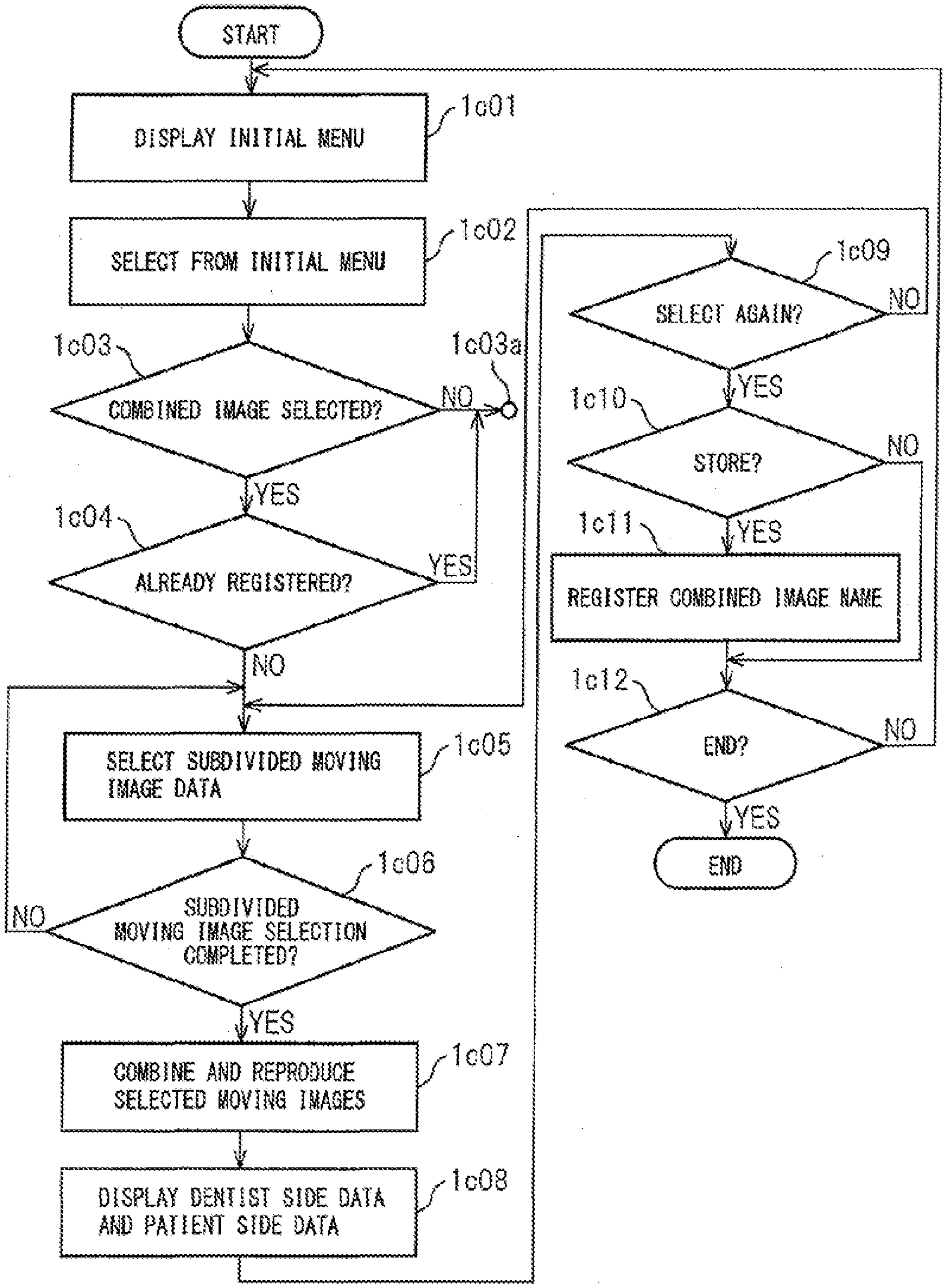

START
DISPLAY INITIAL MENU
1c01
SELECT FROM INITIAL MENU
1c02
1c03
COMBINED IMAGE SELECTED?
NO
1c03a
YES
1c04
ALREADY REGISTERED?
YES
NO
SELECT SUBDIVIDED MOVING IMAGE DATA
1c05
1c06
SUBDIVIDED MOVING IMAGE SELECTION COMPLETED?
NO
YES
COMBINE AND REPRODUCE SELECTED MOVING IMAGES
1c07
DISPLAY DENTIST SIDE DATA AND PATIENT SIDE DATA
1c08
1c09
SELECT AGAIN?
NO
YES
1c10
STORE?
NO
1c11
YES
REGISTER COMBINED IMAGE NAME
1c12
END?
NO
YES
END

Fig.27

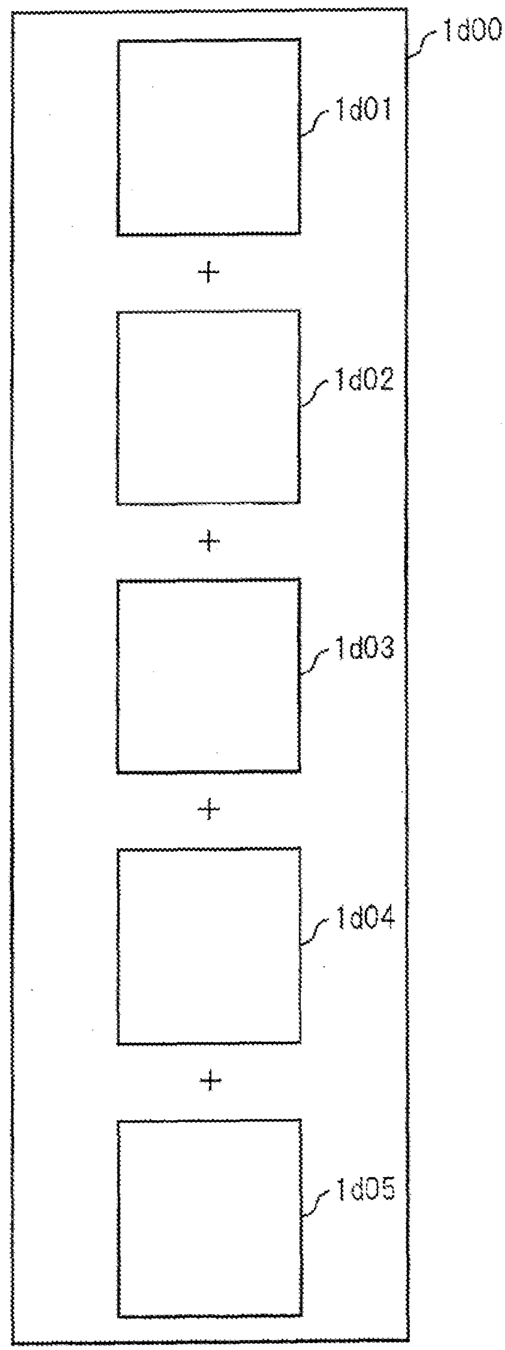


Fig.28A

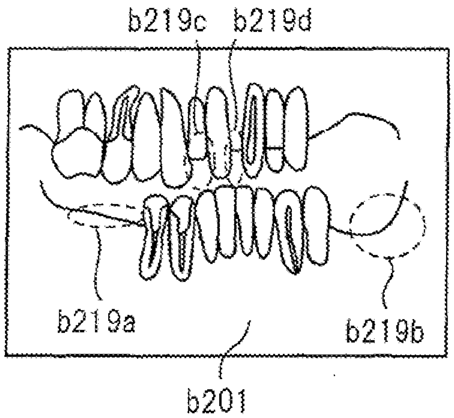


Fig.28B

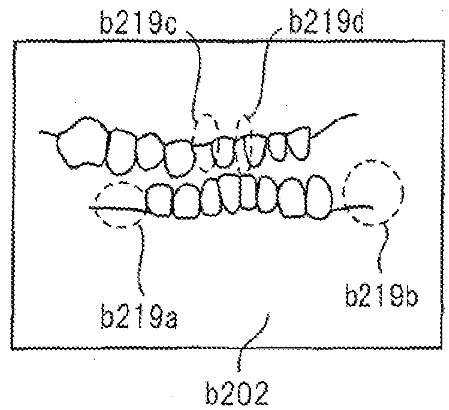


Fig.28C

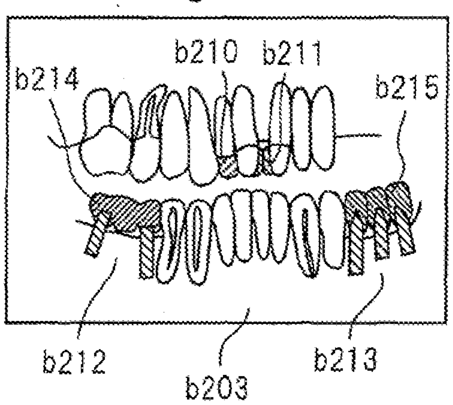


Fig.28D

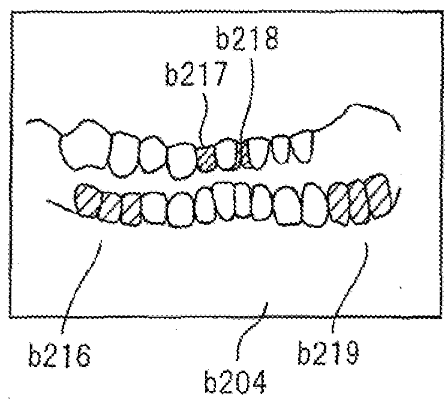


Fig.28E

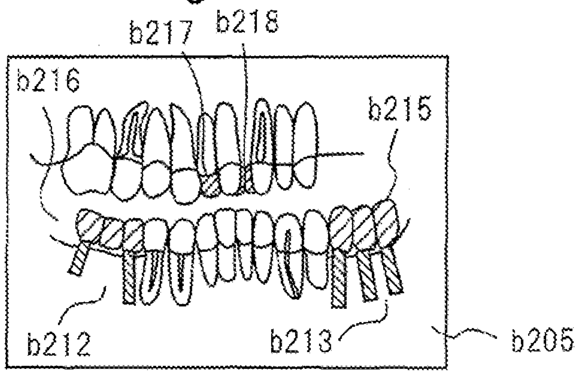
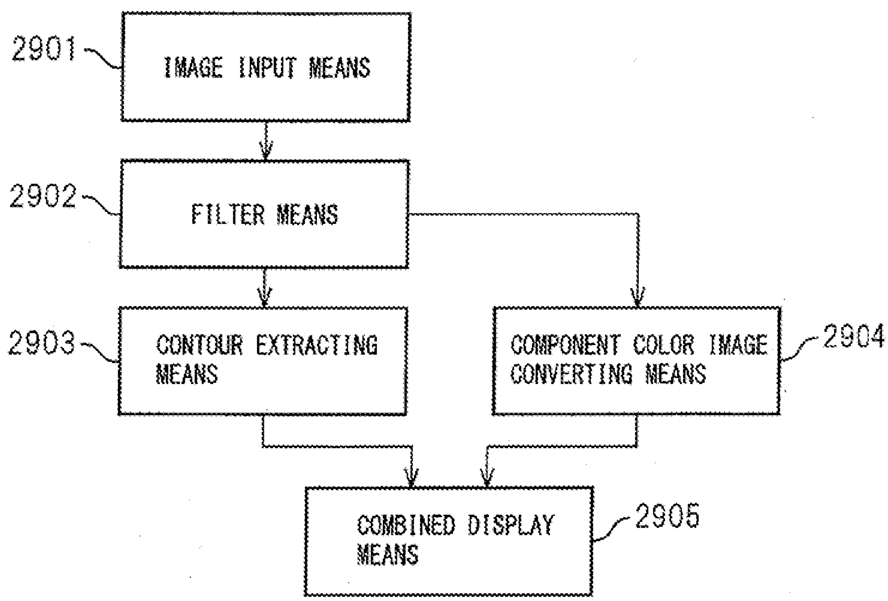


Fig.29


2901
IMAGE INPUT MEANS
2902
FILTER MEANS
2903
CONTOUR EXTRACTING MEANS
COMPONENT COLOR IMAGE CONVERTING MEANS
2904
COMBINED DISPLAY MEANS
2905

INTERNATIONAL SEARCH REPORT

International application No.
PCT/JP2012/050394

A. CLASSIFICATION OF SUBJECT MATTER
A61B1/24(2006.01)i, *G02B23/24*(2006.01)i

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
A61B1/24, G02B23/24

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Jitsuyo Shinan Koho	1922-1996	Jitsuyo Shinan Toroku Koho	1996-2012
Kokai Jitsuyo Shinan Koho	1971-2012	Toroku Jitsuyo Shinan Koho	1994-2012

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X Y A	JP 2004-202069 A (Mitsutoyo Corp.), 22 July 2004 (22.07.2004), paragraph [0027]; fig. 6 & US 2004/0136580 A1 & EP 1434028 A1	1,7 2,3,5,6 4
Y	JP 2008-125719 A (Shimadzu Corp.), 05 June 2008 (05.06.2008), paragraph [0008]; fig. 1, 2 (Family: none)	2
Y	JP 2001-333898 A (J. Morita Manufacturing Corp.), 04 December 2001 (04.12.2001), paragraphs [0043] to [0049]; fig. 1 (Family: none)	3

[X] Further documents are listed in the continuation of Box C. [ ] See patent family annex.

* Special categories of cited documents:
"A" document defining the general state of the art which is not considered to be of particular relevance
"E" earlier application or patent but published on or after the international filing date
"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)
"O" document referring to an oral disclosure, use, exhibition or other means
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"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone
"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art
"&" document member of the same patent family

Date of the actual completion of the international search 10 April, 2012 (10.04.12)	Date of mailing of the international search report 24 April, 2012 (24.04.12)
Name and mailing address of the ISA/ Japanese Patent Office Facsimile No.	Authorized officer Telephone No.

Form PCT/ISA/210 (second sheet) (July 2009)

INTERNATIONAL SEARCH REPORT

International application No.
PCT/JP2012/050394

C (Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	JP 2010-214055 A (South Coast Dental Kabushiki Kaisha), 30 September 2010 (30.09.2010), paragraphs [0042] to [0045]; fig. 11 (Family: none)	3
Y	Rikiya KIKUMOTO, "The mobile type teleradiology system contributes to a medical scene", Gekkan Shin Iryo, The August issue, 23 July 2010 (23.07.2010), (received date), pages 58 to 61	5
Y	JP 2003-299677 A (Shoichi TAKAMINE), 21 October 2003 (21.10.2003), paragraphs [0032] to [0033], [0038] (Family: none)	6
A	JP 2008-132336 A (Degudent GmbH), 12 June 2008 (12.06.2008), paragraph [0023]; fig. 1 to 4 & US 2008/0124677 A1 & EP 1927326 A1 & DE 502006005266 D & AT 446723 T	1

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REFERENCES CITED IN THE DESCRIPTION

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Patent documents cited in the description

- JP 10097404 A **[0006]**
- JP 2005334426 A **[0006]**
- JP 10097405 A **[0006]**
- JP 10201757 A **[0006]**
- JP 2001212161 A **[0006]**
- JP 2005144171 A **[0006]**
- JP 62246347 A **[0006]**
- JP 2001029315 A **[0006]**
- JP 2002355262 A **[0006]**
- JP 2005304600 A **[0006]**
- JP 5030402 U **[0006]**
- JP 3131408 U **[0006] [0010]**
- US 5752827 A **[0006]**
- JP 2009516555 A **[0006]**
- JP 5130991 A **[0006]**
- WO 2007063980 A **[0191]**

Non-patent literature cited in the description

- **ZHANG.** *IEEE Transactions on Pattern Analysis and Machine Intelligence,* 2000, vol. 22 (11), 1330-1334 **[0148]**
- **MOTOKI ARAI et al.** Optimization of Correlation Functions and Subpixel Designation Formula in Block Matching of Images. *Research Reports of Information Processing Society of Japan,* 2004, 33-40 **[0198]**
- *Journal of the IEICE,* 2009, vol. 92 (6), 463-468 **[0203]**
- *Dental Materials and Equipment,* 2000, vol. 19 (3), 333-338 **[0204]**
- *Design Wave Magazine,* December 2008, 113-115 **[0285]**

Electronic Acknowledgement Receipt

EFS ID:	39288270
Application Number:	16526281
International Application Number:	
Confirmation Number:	9657
Title of Invention:	SYSTEM WITH 3D USER INTERFACE INTEGRATION
First Named Inventor/Applicant Name:	Henrik ÖJELUND
Customer Number:	21839
Filer:	Travis Dean Boone/Snjezana Gvozderac
Filer Authorized By:	Travis Dean Boone
Attorney Docket Number:	0079124-000266
Receipt Date:	28-APR-2020
Filing Date:	30-JUL-2019
Time Stamp:	14:46:55
Application Type:	Utility under 35 USC 111(a)

Payment information:

Submitted with Payment	no

File Listing:

Document Number	Document Description	File Name	File Size(Bytes)/ Message Digest	Multi Part /.zip	Pages (if appl.)
1	Information Disclosure Statement (IDS) Form (SB08)	PTO_SB_08.pdf	1034860 612cd63207594e7f48d5304e9b5040c8701844e6	no	4

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2	Foreign Reference	F1_EP2664272A1.pdf	16545270 ce1762359017bc20b29b163e521bd1ff35d82136	no	71

Warnings:

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If a timely submission to enter the national stage of an international application is compliant with the conditions of 35 U.S.C. 371 and other applicable requirements a Form PCT/DO/EO/903 indicating acceptance of the application as a national stage submission under 35 U.S.C. 371 will be issued in addition to the Filing Receipt, in due course.
<u>New International Application Filed with the USPTO as a Receiving Office</u>
If a new international application is being filed and the international application includes the necessary components for an international filing date (see PCT Article 11 and MPEP 1810), a Notification of the International Application Number and of the International Filing Date (Form PCT/RO/105) will be issued in due course, subject to prescriptions concerning national security, and the date shown on this Acknowledgement Receipt will establish the international filing date of the application.

INFORMATION DISCLOSURE STATEMENT BY APPLICANT (Not for submission under 37 CFR 1.99)		
	Application Number	16526281
	Filing Date	2019-07-30
	First Named Inventor	Henrik ÖJELUND et al.
	Art Unit	3992
	Examiner Name	Peng KE
	Attorney Docket Number	0079124-000266

U.S.PATENTS

Remove

Examiner Initial*	Cite No	Patent Number	Kind Code[1]	Issue Date	Name of Patentee or Applicant of cited Document	Pages,Columns,Lines where Relevant Passages or Relevant Figures Appear
	1	6361489	B1	2002-03-26	Jory Tsai	

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	2	20100231509	A1	2010-09-16	Marc Ballot et al.	
	3	20080063998	A1	2008-03-13	Rongguang Liang et al.	

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	1	2011/011193	WO	A1	2011-01-27	DIMENSIONAL PHOTONICS INTERNATIONAL, INC.		

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	Application Number	16526281
	Filing Date	2019-07-30
	First Named Inventor	Henrik ÖJELUND et al.
	Art Unit	3992
	Examiner Name	Peng KE
	Attorney Docket Number	0079124-000266

	2	2012/076013	WO	A1	2012-06-14	3SHAPE A/S		

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NON-PATENT LITERATURE DOCUMENTS Remove

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	1		

If you wish to add additional non-patent literature document citation information please click the Add button Add

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Examiner Signature		Date Considered	

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[1] See Kind Codes of USPTO Patent Documents at www.USPTO.GOV or MPEP 901.04. [2] Enter office that issued the document, by the two-letter code (WIPO Standard ST.3). [3] For Japanese patent documents, the indication of the year of the reign of the Emperor must precede the serial number of the patent document. [4] Kind of document by the appropriate symbols as indicated on the document under WIPO Standard ST.16 if possible. [5] Applicant is to place a check mark here if English language translation is attached.

INFORMATION DISCLOSURE STATEMENT BY APPLICANT (Not for submission under 37 CFR 1.99)	Application Number		16526281
	Filing Date		2019-07-30
	First Named Inventor	Henrik ÖJELUND et al.	
	Art Unit		3992
	Examiner Name	Peng KE	
	Attorney Docket Number		0079124-000266

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Please see 37 CFR 1.97 and 1.98 to make the appropriate selection(s):

That each item of information contained in the information disclosure statement was first cited in any communication from a foreign patent office in a counterpart foreign application not more than three months prior to the filing of the information disclosure statement. See 37 CFR 1.97(e)(1).

OR

☐ That no item of information contained in the information disclosure statement was cited in a communication from a foreign patent office in a counterpart foreign application, and, to the knowledge of the person signing the certification after making reasonable inquiry, no item of information contained in the information disclosure statement was known to any individual designated in 37 CFR 1.56(c) more than three months prior to the filing of the information disclosure statement. See 37 CFR 1.97(e)(2).

See attached certification statement.

The fee set forth in 37 CFR 1.17 (p) has been submitted herewith.

☒ A certification statement is not submitted herewith.

SIGNATURE

A signature of the applicant or representative is required in accordance with CFR 1.33, 10.18. Please see CFR 1.4(d) for the form of the signature.

Signature	/Stephany G. Small/	Date (YYYY-MM-DD)	2020-02-13
Name/Print	Stephany G. Small	Registration Number	69,532

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5. A record related to an International Application filed under the Patent Cooperation Treaty in this system of records may be disclosed, as a routine use, to the International Bureau of the World Intellectual Property Organization, pursuant to the Patent Cooperation Treaty.
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9. A record from this system of records may be disclosed, as a routine use, to a Federal, State, or local law enforcement agency, if the USPTO becomes aware of a violation or potential violation of law or regulation.

US006361489B1

(12) United States Patent
Tsai

(10) **Patent No.: US 6,361,489 B1**
(45) **Date of Patent: *Mar. 26, 2002**

(54) **MEDICAL INSPECTION DEVICE**

(76) Inventor: **Jory Tsai**, 14 Orchard Dr., Hudson, MA (US) 01749

(*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 0 days.

This patent is subject to a terminal disclaimer.

(21) Appl. No.: **09/409,127**

(22) Filed: **Sep. 30, 1999**

Related U.S. Application Data

(63) Continuation-in-part of application No. 09/199,963, filed on Nov. 25, 1998, now Pat. No. 6,186,944.

(51) **Int. Cl.**[7] **A61B 1/227**
(52) **U.S. Cl.** **600/109**; 600/200; 600/130; 600/167; 600/179
(58) **Field of Search** 600/199, 200, 600/129, 130, 131, 109, 167, 179; 348/65, 66; 433/29

(56) **References Cited**

U.S. PATENT DOCUMENTS

4,604,992 A	*	8/1986	Sato	600/108
4,633,304 A	*	12/1986	Nagasaki	348/69
4,742,819 A	*	5/1988	George	600/109
4,884,133 A	*	11/1989	Kanno et al.	348/65
5,363,838 A		11/1994	George	
5,373,317 A	*	12/1994	Salvatti et al.	348/65
5,527,261 A		6/1996	Monroe et al.	
5,634,790 A		6/1997	Pathmanabhan et al.	
5,658,235 A		8/1997	Priest et al.	
5,701,155 A		12/1997	Wood et al.	
5,701,904 A		12/1997	Simmons et al.	
5,702,345 A		12/1997	Wood et al.	
5,733,029 A	*	3/1998	Monroe	362/572
5,751,341 A		5/1998	Chaleki et al.	
5,762,605 A		6/1998	Cane et al.	
5,873,814 A	*	2/1999	Adair	600/109
5,879,289 A	*	3/1999	Yarush et al.	600/179
5,885,214 A	*	3/1999	Monroe et al.	600/407
5,919,130 A	*	7/1999	Monroe et al.	600/200
6,106,457 A		8/2000	Perkins et al.	

FOREIGN PATENT DOCUMENTS

WO	WO-93/15648 A1	*	8/1993	600/112
WO	WO-97/15144 A1	*	4/1997	600/112

OTHER PUBLICATIONS

Website http://www.rfsystem.co.jp/rinfo.html, printed Jul. 30, 2001 (1 sheet).

Website http://www.rsystem.co.jp/kjibissm21.html, printed Jul. 30, 2001 (3 sheets).

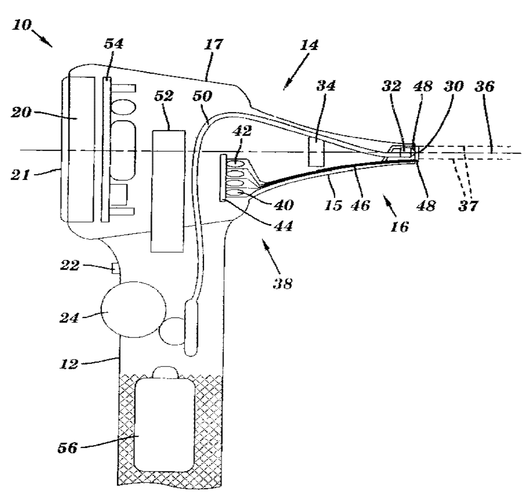
* cited by examiner

Primary Examiner—John P. Leubecker
(74) *Attorney, Agent, or Firm*—Sampson & Associates, P.C.

(57) **ABSTRACT**

A dental/medical instrument is provided for use in diagnostic and related patient inspection/examination. The device includes a body having an integral speculum with a video image capture device or camera, a power supply and a video display. These components, in addition to user actuatable controls, are disposed integrally with the body. The body is adapted for convenient engagement and manipulation by a user's hand to provide a unitary, hand-held device capable of illuminating and capturing an image of a patient, and displaying the image. The video display is disposed on a display portion of the speculum, while components of the image capture device, such as a lens and light emitter, are disposed on a nose portion of the speculum. The nose portion is modularly replaceable with alternate nose portions sized and shaped to facilitate various discrete medical/dental examination procedures.

30 Claims, 5 Drawing Sheets



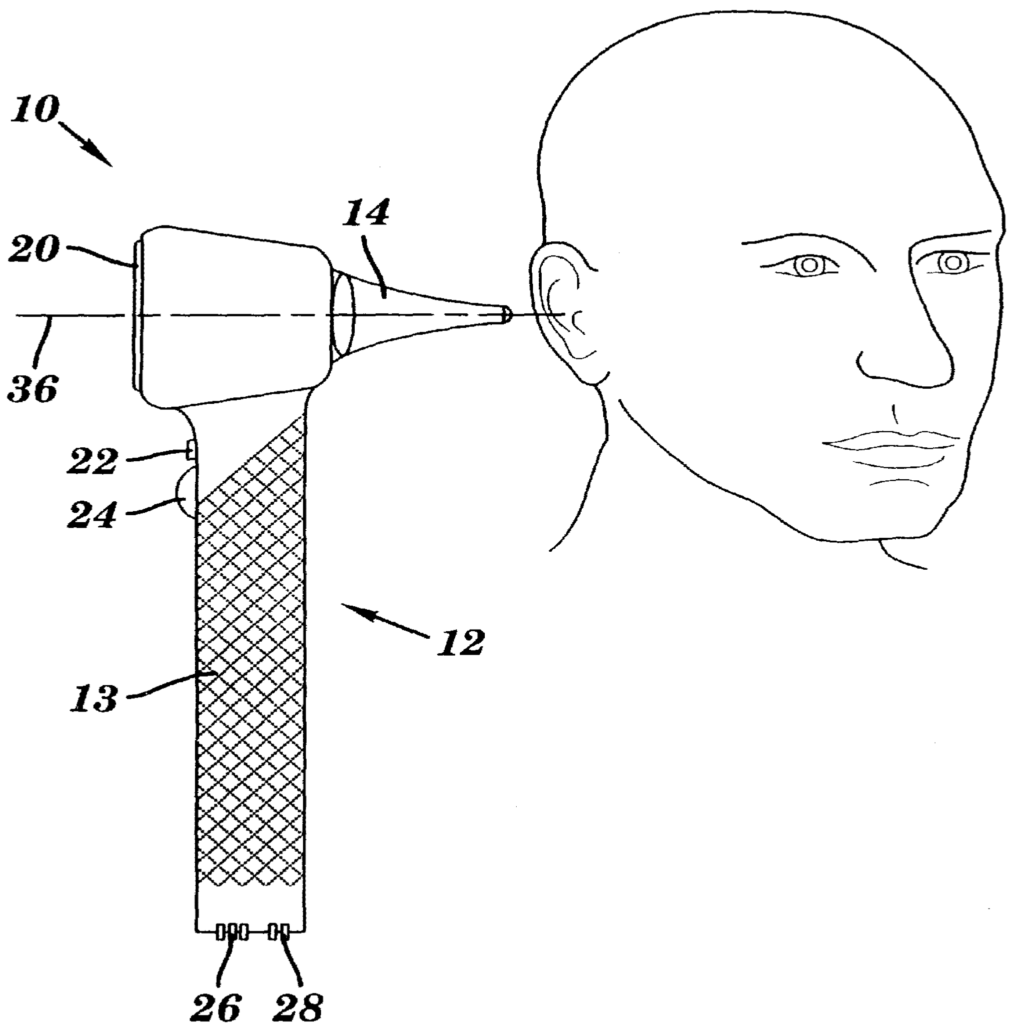
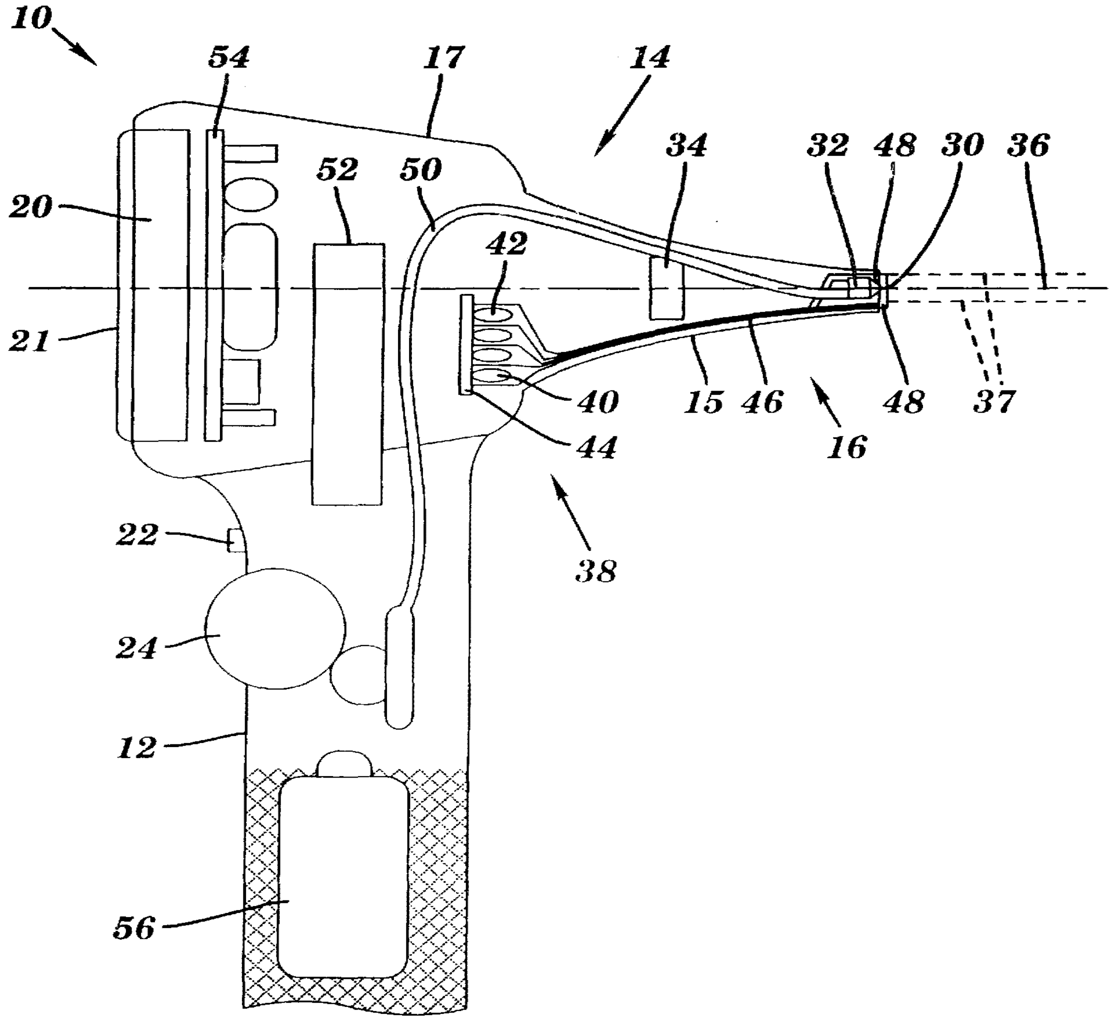


FIG. 1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34
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16
22
38
24
12
56

FIG. 2

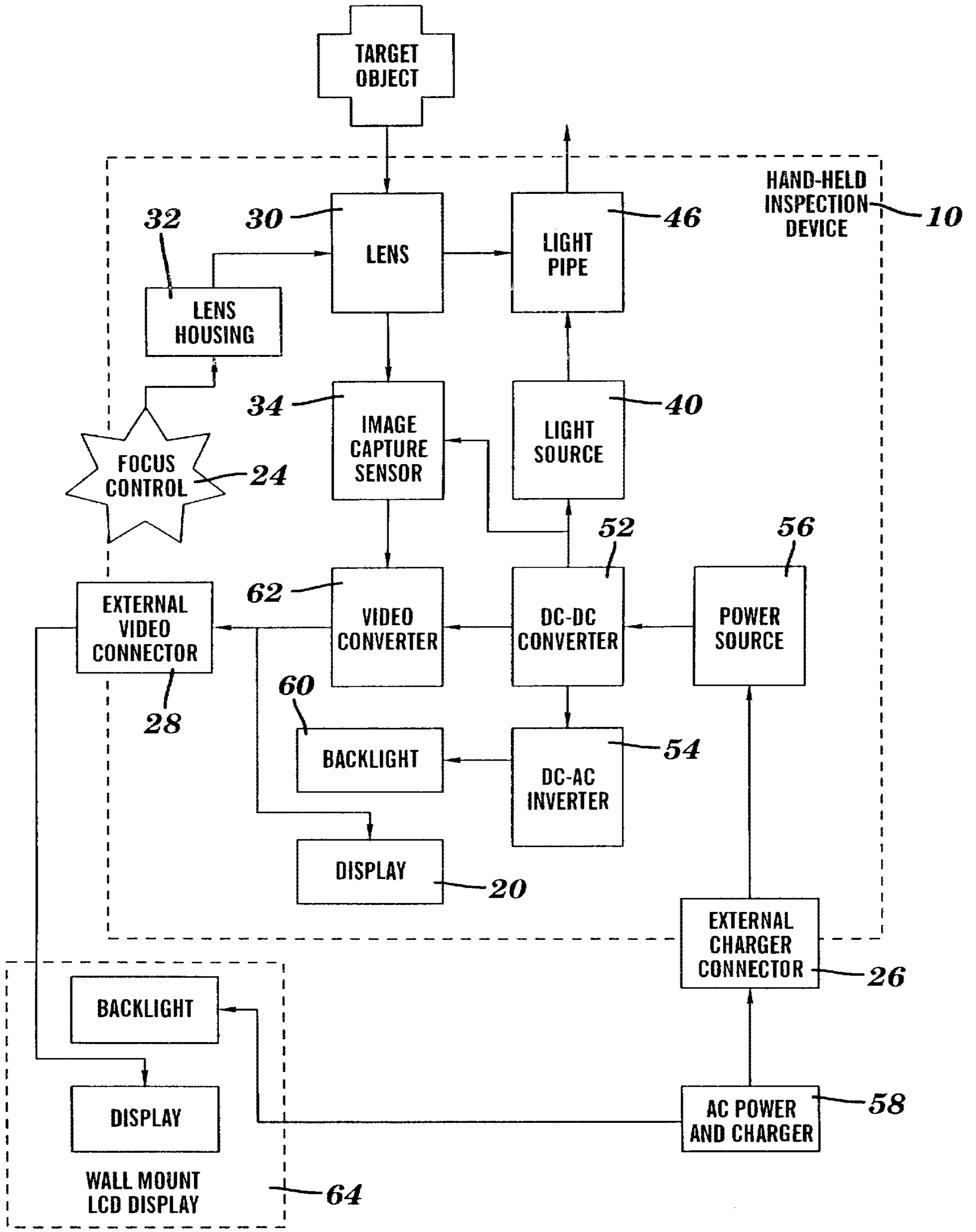
TARGET OBJECT
HAND-HELD INSPECTION DEVICE
10
32
30
LENS
LIGHT PIPE
46
LENS HOUSING
34
IMAGE CAPTURE SENSOR
LIGHT SOURCE
40
FOCUS CONTROL
24
52
56
62
EXTERNAL VIDEO CONNECTOR
VIDEO CONVERTER
DC-DC CONVERTER
POWER SOURCE
60
28
BACKLIGHT
DC-AC INVERTER
54
DISPLAY
20
EXTERNAL CHARGER CONNECTOR
26
BACKLIGHT
DISPLAY
AC POWER AND CHARGER
58
WALL MOUNT LCD DISPLAY
64

FIG. 3

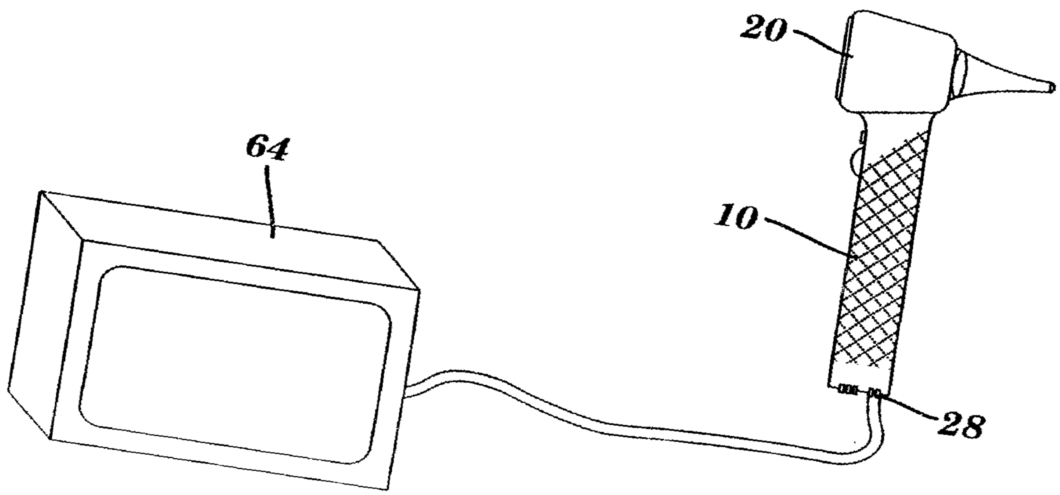

FIG. 4

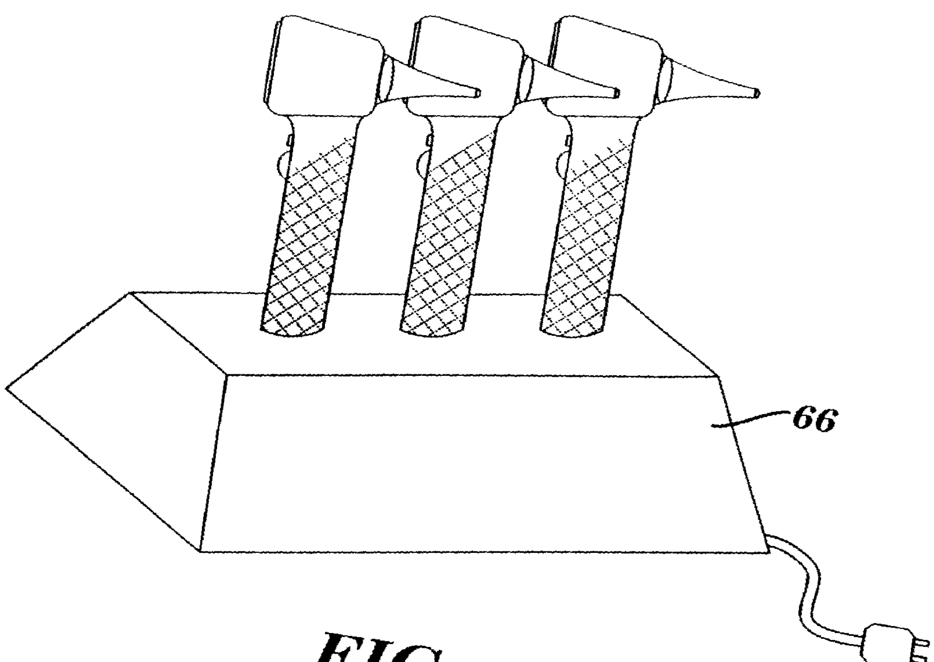

FIG. 5

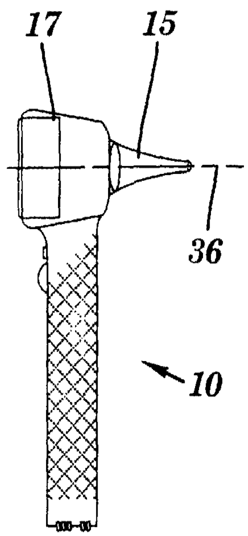

FIG. 6A

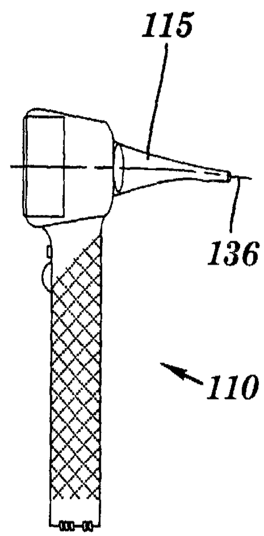

FIG. 6B

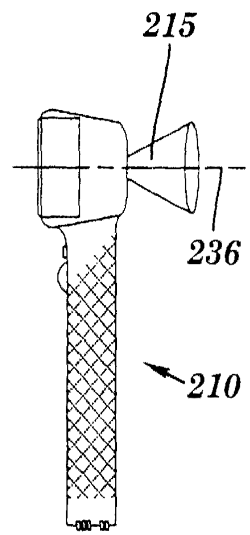

FIG. 6C

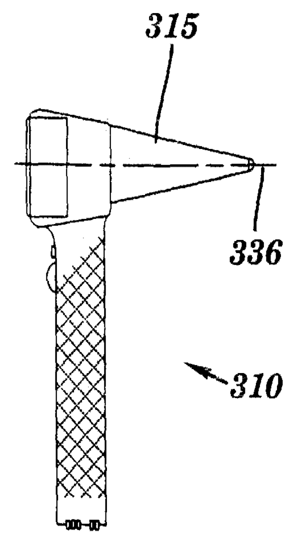

FIG. 6D

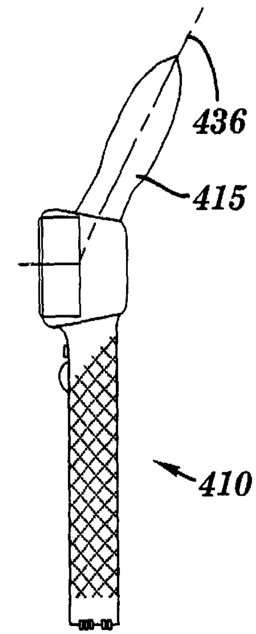

FIG. 6E

MEDICAL INSPECTION DEVICE

BACKGROUND OF THE INVENTION

This application is a Continuation-in-part of U.S. patent application Ser. No. 09/199,963, filed on Nov. 25, 1998, entitled "Medical Inspection Device", now U.S. Pat. No. 6,186,944.

1. Field of the Invention

The present invention relates to medical and dental optical diagnostic instruments, and more particularly to an integrated hand held viewing scope and display for use as an otoscope, ophthalmoscope, larynx illumination, nasopharynx illuminator, dermatologic magnifier and anoscope.

2. Background Information

Various hand held instruments for use by a physician or dentist during examination of a patient have been known in the art for many years. Such hand held instruments include the otoscope for examination of the ear, ophthalmoscope for examination of the eye, larynx illuminator (throat), nasal pharynx illuminator (nasal passages), dermatologic magnifier (skin) and anoscope (lower G.I. tract).

Also, in the prior art, it has been known to employ miniature or micro-video cameras in connection with various surgical procedures which occur in the operating room. Examples of such video cameras are known as remote head color CCD cameras. These cameras typically employ an array of semiconductive chips using a technology known as charge coupled diode sensors. Such micro-cameras are capable of yielding more than 500 lines of resolution per axis, resulting from the use of 400,000 or more pixels. Use of such micro-video cameras and related equipment, such as endocouplers, have been known for some time in connection with certain types of surgery and, particularly, surgery conducted through the use of small incisions in the body wall in videoendoscopy procedures. Such procedures have become increasingly commonplace in connection with procedures upon the gall bladder, appendix, intestine, etc., where the problem is of an internal nature.

In addition to relatively widespread use of such micro-video technology in the operating room, which includes the display of a procedure upon separate monitors, this technology has also been utilized in the dentist's or physician's office in the context of otherwise routine examination and diagnosis. An example of an instrument incorporating this technology is shown, for example, in U.S. Pat. No. 5,762,605, issued to Cane et al. This device discloses a hand held optical diagnostic instrument including a CCD sensor and an external light source. The instrument is coupled to a discreet monitor which may permit both patient and physician to observe an image of the examination. Moreover, devices of this type may be utilized to produce a video record of such an examination and/or provide either a video tape of the examination or selected print frames thereof.

Such devices may also be used to provide a video link to a satellite or other communications means from a video interface of the system. This may enable consultants to be utilized either in real time, or in a batch mode, to provide "second opinions" to the examining medical personnel or paramedic who may be located in a geographically remote region and/or may possess limited skills in the specialty to which the examination relates. Such activity has become known as telemedicine.

A disadvantage of such devices, however, is that they tend to be awkward to use, as such instruments tend to be difficult for the examining physician to hold, to manipulate and to obtain the necessary views for the examination while simultaneously viewing the image on the remote monitor. This is due to the need for the examining care provider to manipulate the instrument relative to the patient, while looking away from the patient to the monitor. Thus, while many prior art instruments may be designed to facilitate manipulation by the user, the ergonomics of such devices tends to divert the user's attention away from the patient during examination, which may result in discomfort to the patient due to errant manipulation of the instrument. This drawback may be particularly problematic with respect to new users, or those with minimal training in the use of such instruments.

Thus, a need exists for an ergonomically improved hand-held dental/medical instrument which enables a user to simultaneously observe both the patient and the instrument while viewing an image captured thereby.

SUMMARY OF THE INVENTION

According to the present invention, a dental/medical instrument includes a body adapted for engagement by a user's hand, a speculum integrally disposed within the body, an image capture device, a light source and a video display. The image capture device, light source and video display are disposed integrally within the body.

In another aspect of the present invention, a dental/medical instrument includes a body adapted for engagement by a user's hand, the body including a speculum disposed integrally therewith, and an image capture device disposed integrally within the body, the image capture device having a central optical axis. A light source is also disposed integrally within the body, the light source being adapted to emit light along at least one light emission axis disposed substantially parallel to the central optical axis. A video display is disposed integrally with the body and is coupled with the video capture device to display an image captured thereby.

A still further aspect of the present invention includes a method of examining a patient, which comprises the steps of:

(a) utilizing an instrument including:
- a body adapted for engagement by a user's hand, the body including a speculum disposed integrally therewith;
- an image capture device;
- a light emitter;
- the image capture device and the light emitter being disposed integrally with the body; and
- a video display disposed integrally with the body; and

(b) manipulating the instrument relative to a patient while the user simultaneously faces both the patient and the video display.

In another aspect, the present invention includes an instrument having a body adapted for engagement by a user's hand. The body includes an integral speculum, a lens and a light outlet, and an integral video display.

In a variation of these aspects, the lens and light outlet are disposed integrally within a nose portion of the speculum. In a further variation, the nose portion comprises a modular unit adapted for alternate engagement and disengagement with said body. Further still, a plurality of modular nose portions may be provided with various sizes and shapes to facilitate discrete examining procedures.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. **1** is a partially perspective elevational view of a dental/medical instrument of the present invention in use relative to a patient;

FIG. **2** is an enlarged, broken-away elevational view of a portion of the instrument of FIG. **1**;

FIG. **3** is a block diagram of the componentry of the present invention;

FIG. **4** is a perspective view of the instrument of FIG. **1** including an additional component of the present invention;

FIG. **5** is a perspective view of a plurality of instruments of FIG. **1** disposed in an optional charging device; and

FIGS. **6***a*–**6***e* are elevational views of alternate embodiments of the dental/medical inspection instrument of the present invention.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

As shown in FIGS. **1**–**3**, the present invention includes a dental/medical instrument **10** for use in diagnostic and related patient inspection/examination. The device includes a body **12** including an integral speculum **14** with a video image capture device or camera **16**, a power supply and a video display **20**. These components, in addition to user actuatable controls including a power switch **22** and image focus control **24**, are preferably disposed integrally with the body **12**. (Portions of the image capture device, such as image sensor **34**, as will be discussed hereinbelow, may be disposed remotely from the body **12**, and coupled thereto through a port **28**.) The body **12** is adapted for convenient engagement and manipulation by a user's hand. The video display is disposed on a display portion of the speculum, while components of the image capture device, such as a lens and light emitter, are disposed on a nose portion of the speculum. As shown in FIGS. **6***a*–**6***e*, the nose portion is modularly replaceable with alternate nose portions sized and shaped to facilitate various discrete medical/dental examination procedures. The present invention thus provides a unitary, hand-held device capable of illuminating and capturing an image of a patient, and displaying the image.

As used herein, the term "light" is defined as electromagnetic energy within the range of frequencies or wavelengths extending from infrared to ultraviolet radiation and including visible light. The term "speculum" as used herein, shall refer to a portion of an instrument adapted for being inserted into a body passage and/or placed externally of a patient, for inspection of the patient.

Turning now to the Figures in greater detail, as shown in FIG. **1**, dental/medical instrument **10** comprises a unitary body **12** including a manually engagable pistol-type grip portion **13** and a speculum portion **14**. As also shown, body **12** includes an integral video display **20** as well as user actuatable controls including a power or on/off switch **22** and a focus control **24**. The instrument **10** also includes integral battery recharging contacts **26** and one or more external ports **28**, which will be discussed hereinbelow.

Turning now to FIG. **2**, lens **30** of the image capture device **16** is disposed within the speculum **14** of the instrument **10**. Moreover, in the embodiment shown, various components of the image capture device **16**, including lens **30** disposed within a lens housing **32**, and an image sensor **34**, are preferably disposed within the speculum **14**. As also shown, lens **30**, housing **32** and sensor **34** are all disposed in image capturing alignment with one another to capture images disposed along an axis of examination **36**. Such image capturing alignment may be provided by disposing both the lens **30** and sensor **34** along a common axis (i.e., axis **36**) as shown. Alternatively, this image capturing alignment may be provided by utilizing an optic coupling such as a light pipe, fiber optic coupling or other wave guide (similar to fiber-optic coupling **46** discussed hereinbelow) to couple the lens **30** with the sensor **34**. One skilled in the art will recognize that use of such an optic coupling advantageously permits the sensor **34** to be disposed at various locations within the instrument **10**, either on or off the axis of examination **36**. Moreover, as mentioned hereinabove, such an arrangement may also facilitate use of a remote sensor **34**, such as a remote digital camera, coupled optically and/or electronically to lens **30** through a port **28**. Instrument **10** also includes an internal light source **38** which includes a light generator **40** such as an array of light emitting diodes (LEDs) **42** disposed on a printed circuit board **44**. Light source **38** further includes an optical coupling such as a light pipe or fiber-optic coupling **46** optically coupled to a light outlet **48**. As shown, light outlet **48** preferably includes distal or terminal portions of the light pipe **46** which are splayed for disposition about the periphery of lens housing **32**. As shown, each of these terminal portions extends substantially parallel to axis of examination **36** to emit light along light emission axes **37** which are substantially parallel to the examination axis **36**. Depending on the application (as discussed hereinbelow with respect to FIGS. **6***a*–**6***e*), such substantially parallel light emission may include light emitted along one or more light emission axes **37** oriented to extend either slightly convergently towards axis **36**, or slightly divergently away from axis **36**. In this regard, the instrument **310** of FIG. **6***d* may utilize one or more slightly convergently disposed light emission axes to illuminate a relatively small area of a patient. Conversely, instrument **210** of FIG. **6***c* may utilize slightly divergent light emission axes, or a combination of convergent and divergent light emission axes, to illuminate a relatively larger area of the patient (i.e., to inspect a region of a patient's skin). In this manner outlet **48** emits light nominally coaxial with axis of examination **36**.

Although light generator **40** preferably includes LEDs **42** as shown, any suitable light generation means, such as miniature incandescent bulbs, compact florescent lighting, or one or more lasers may be utilized. Image sensor **34** may be any suitable miniature video image capture device known to those skilled in the art, such as, for example form factor video cameras, semiconductor chip mounted CCD devices, or other devices commonly utilized in the field of electronic or digital photography. In this regard, the image capture device **16** of the present invention provides nominally the same capabilities commonly associated with conventional digital cameras and the like, namely, the ability to digitally capture, store and retrieve images for display and/or transmission. Such image transmission may be accomplished in a known manner, such as by use of port **28**.

As also shown, a focus control switch **24**, such as a user actuatable thumb wheel as shown, is operatively coupled by cable **50** to the lens housing **32** to focus the image captured by image sensor **34**. In one embodiment, focus control **24** may include a mechanical gear-type control which actuates a cable **50** to effect focusing movement of the lens **30** relative to sensor **34** in a known manner. In such an embodiment, cable **50** may be a conventional mechanical cable. In an alternate embodiment, cable **50** may include an electric wire which serves to couple electrical signals from focus control **24** to an electrical actuator (not shown) coupled to the lens **30** to effect the focusing movement.

Moreover, all or a portion of speculum **14** is advantageously coupled modularly, i.e., in a snap-fit type arrangement, to the body **12** to permit convenient replacement and/or substitution thereof to facilitate various discrete uses. For example, a nose portion **15** (also referred to as "lens sub-system") of the speculum **14** may be modularly engagable with the display portion **17** thereof, as will be discussed in greater detail hereinbelow with respect to FIGS. *6a–6e*.

The instrument power supply includes a DC-DC converter **52** electrically coupled to a DC-AC power inverter **54**. Power inverter **54** is, in turn, electrically coupled to video display **20**. In a preferred embodiment, as shown, instrument **10** includes an internal power source such as a rechargeable or non-rechargeable battery **56** electrically coupled to DC-DC converter **52**. Video display **20** is preferably a color liquid crystal display (LCD) monitor disposed integrally within body **12** in spaced relation to lens housing **32** along axis of examination **36** at a proximal end of speculum **14**. An example of a suitable display **20** is known as a 1.8 inch (4.6 cm) high density LCD display available from Prime View International Co., Ltd., Model number is P18BD1. Moreover, in a preferred embodiment, the substantially planar screen portion **21** of display **20** is disposed substantially orthogonally to the axis of examination **36**. Such placement of monitor **20** advantageously places a displayed image generally within a natural line of sight of speculum **14** defined by axis of examination **36**. This use of the integral video display **20** advantageously provides an integrated one-piece instrument **10** which enables a user to view an image which moves in a natural and intuitive manner in response to movement of the instrument **10** by a user. Advantageously, this action facilitates proper use with little or no training to generally enable a user to operate the instrument with greater tactile sensitivity than prior devices which utilize discreet video displays located remotely from the image sensing device. The use of an integral display **20** disposed within the axis of examination **36** also advantageously tends to improve the efficiency of the examination procedure by enabling the user to look in a single direction for viewing the image captured on the monitor **20**, the instrument **10** and the patient while manipulating the instrument **10**. This aspect thus provides improved ergonomics to enable manipulation of the instrument **10** with greater accuracy than prior art devices which generally require the user to manipulate the device while looking away from the patient to view a remote monitor.

Turning now to FIG. **3**, a rechargeable power source **56** is electrically coupled to contacts **26** which, in turn, are adapted for connection to an AC power source **58**. Internal power source **56** is coupled to DC-DC converter **52** which, as shown, is coupled to a light generator **40** which is coupled to light pipe **46**. DC-DC converter **52** is also coupled to the DC-AC inverter **54** to supply power to a backlight **60** of video display **20**. As further shown, DC-DC converter **52** provides power to a video converter **62** which provides an electronic image signal to the display **20** as well as to external video port **28**. Port **28** may be coupled a remote video display **64**, either directly, or via a computer network (i.e., an intranet or the Internet. As also shown, lens **30** is optically coupled to sensor **34** which is, in turn, electronically coupled to the video converter **62**. Focus control **24** is electrically and/or mechanically coupled to the lens **30**.

Turning now to FIG. **4**, in a preferred embodiment inspection device **10** is adapted for being coupled by its external video port **28** to a remote monitor **64**. The remote monitor **64** may comprise a LCD display, television monitor, and the like, and is preferably wall mounted or movably mounted to enable a patient to view captured images in real time as the dentist or physician views the captured images on the integral display **20**. This aspect of the present invention thus provides the user with a useful tool for explaining and or describing the examination process to the patient. Moreover, the image may be recorded by connecting the video output to a suitable image recorder such as a computer or VCR or other recording device.

As shown in FIG. **5**, an AC powered recharging base **66** may be utilized to receive one or more instruments **10** for recharging power source **56** by coupling external charger contacts **26** (FIG. **1**) to AC power supply **58** (FIG. **3**). Turning now to FIGS. *6a–6e*, in addition to the instrument **10** discussed hereinabove, various alternate embodiments of the present invention are shown as instruments **110**, **210**, **310** and **410**. These embodiments are substantially similar to instrument **10** while utilizing various modular nose portions to facilitate discrete medical/dental examination procedures, as mentioned hereinabove. Nose portion **15** (FIG. *6a*) of the speculum **14** is thus modularly engagable with the display portion **17** thereof for convenient replacement with various alternate nose portions **115**, **215**, **315** and **415** (FIGS. *6b–6e*, respectively). In this regard, an electric focus control arrangement utilizing an electric cable **50**, as discussed hereinabove with respect to FIG. **2**, is preferably provided. Moreover, a light source **38** and image capture device **16** (FIG. **2**) are preferably disposed entirely within each modular (removable) nose portion. These arrangements advantageously simplify modular connection between the nose portions and the display portion **17**, by permitting use of conventional modular electrical connectors. Alternatively, the light source **38** may be disposed within the display portion **17**, with the light pipe **46** (FIG. **2**) fabricated as two discrete portions that are axially aligned with one another when a particular modular nose portion is engaged with the display portion **17**.

As shown, instrument **10** may be conveniently utilized to enable a physician to examine a patient's ear, nose, and throat. As shown in FIG. *6b*, an extended and slightly angled nose portion **115** may be utilized to examine a patient's middle meatus, inferior meatus, superior meatus, and oropharynx. A reversed cone nose portion or lens subsystem **215** as shown in FIG. *6c*, may be utilized to examine a patient's skin. An extended nose portion **315**, as shown in FIG. *6d*, may be utilized to examine animals such as horses, cows, and the like. As shown in FIG. *6e*, an offset lens subsystem **415** may be utilized to facilitate rectal examinations and the like.

In these alternate embodiments of FIGS. *6b–6e*, the substantially planar screen portion **21** of display **20** is disposed substantially orthogonally to either the respective axis of examination **136**, **236**, **336** or **436**, or to a plane which includes the axis of examination. As discussed above with respect to instrument **10**, such placement of monitor **20** advantageously places a displayed image generally within a natural line of sight of speculum **14** defined by the axis of examination. This use of the integral video display **20** advantageously provides an integrated one-piece instrument **10** which enables a user to view an image which moves in a natural and intuitive manner in response to movement of the instrument **10** by a user.

Although various components of the present invention have been shown and described as being disposed within various nose portions **15**, **115**, **215**, **315** and **415**, it should be recognized by those skilled in the art that any arrangement of components may be included or removed from the nose portions without departing from the spirit and scope of the present invention.

Moreover, although several alternate configurations of nose portions or lens subsystems have been provided, those skilled in the art should recognize that nose portions or lens subsystems of substantially any geometry or construction may be utilized without departing from the spirit and scope of the present invention.

The foregoing description is intended primarily for purposes of illustration. Although the invention has been shown and described with respect to an exemplary embodiment thereof, it should be understood by those skilled in the art that the foregoing and various other changes, omissions, and additions in the form and detail thereof may be made therein without departing from the spirit and scope of the invention.

Having thus described the invention, what is claimed is:

1. A portable unitary hand-held dental/medical instrument of the type selected from the group consisting of otoscopes, ophthalmoscopes, larynx scopes, nasopharynx scopes, dermatologic scopes, anoscopes, or veterinary scopes, said instrument comprising:

a body having a pistol-grip adapted for engagement by a user's hand;

said body including a rigid frusto-conical speculum disposed thereon, said speculum having a nose with a distal opening disposed along an axis of examination, said speculum being sized and shaped to allow location of said distal opening a predetermined distance from a target;

an image capture device and a light source, said image capture device and said light source being disposed integrally within said body, to capture a target image viewed by said image capture device through said distal opening; and

a video display housed within said body, said video display being disposed within said axis of examination, to locate a displayed image of the target within said axis of examination.

2. The dental/medical instrument of claim **1**, further comprising a power supply disposed integrally with said body.

3. The dental/medical instrument of claim **2**, further comprising a power source disposed integrally with said body.

4. The dental/medical instrument of claim **2**, wherein said image capture device and said light source are disposed integrally within said speculum.

5. The dental/medical instrument of claim **2**, wherein said image capture device further comprises a lens disposed in optical communication with an image sensor.

6. The dental/medical instrument of claim **5**, wherein said light source emits light substantially coaxially with a central optical axis of said image capture device.

7. The dental/medical instrument of claim **6**, wherein said light source further comprises a light emitting diode.

8. The dental/medical instrument of claim **2**, further comprising a user actuatable power switch disposed integrally on said body.

9. The dental/medical instrument of claim **8**, wherein said power switch is operable by a user's thumb.

10. The dental/medical instrument of claim **2**, further comprising a power supply disposed integrally within said body.

11. The dental/medical instrument of claim **10**, wherein said power supply is adapted for being coupled with an external power source.

12. The dental/medical instrument of claim **11**, wherein said power supply further comprises charging circuitry adapted to recharge rechargeable batteries disposed integrally with said body.

13. The dental/medical instrument of claim **12**, wherein said charging circuitry further comprises contacts disposed externally on said body, said contacts adapted for power coupling contact with an external power source when said body is received within a charger.

14. The dental/medical instrument of claim **1**, further comprising video circuitry adapted to couple said image capture device with said video display.

15. The dental/medical instrument of claim **14**, wherein said video circuitry further comprises an external port disposed on said body, said external port adapted to couple with an external video display.

16. The dental/medical instrument of claim **15**, further comprising an external video display.

17. The dental/medical instrument of claim **1**, wherein said video display further comprises a substantially planar screen portion, said screen portion being disposed substantially orthogonally to said axis of examination.

18. The dental/medical instrument of claim **1**, wherein said video display further comprises a substantially planar screen portion, said screen portion being disposed substantially orthogonally to a plane which includes said axis of examination.

19. The dental/medical instrument of claim **1**, further comprising an image recorder.

20. A dental/medical instrument of the type selected from the group consisting of otoscopes, ophthalmoscopes, larynx scopes, nasopharynx scopes, dermatologic scopes, anoscopes, or veterinary scopes, said instrument comprising:

a body having a pistol-grip adapted for engagement by a user's hand;

said body including a rigid speculum disposed thereon;

an image capture device disposed integrally within said body, said image capture device having a central optical axis;

a light source disposed integrally within said body, said light source being adapted to emit light along at least one light emission axis disposed substantially parallel to said central optical axis; and

a substantially planar video display disposed integrally within said body, said video display being disposed within an axis of examination in substantially orthogonal relation thereto, said display being coupled with said video capture device to display an image captured thereby.

21. A method of examining a patient comprising:

(a) utilizing a portable hand-held instrument of the type selected from the group consisting of otoscopes, ophthalmoscopes, larynx scopes, nasopharynx scopes, dermatologic scopes, anoscopes, or veterinary scopes, said instrument including:

a body having a pistol-grip adapted for engagement by a user's hand, said body including a rigid speculum disposed thereon;

an image capture device;

a light emitter;

said image capture device and said light emitter being disposed integrally with said body; and

a substantially planar video display housed within said body, said video display being disposed within an axis of examination in substantially orthogonal relation thereto; and

(b) manipulating the instrument relative to a patient while the user simultaneously faces both the patient and the video display.

22. The method of claim 21, further comprising the step of:

(c) transmitting the image to a remote display.

23. The method of claim 22, further comprising the step of:

(d) recording the image on an image recorder.

24. A portable hand-held instrument of the type selected from the group consisting of otoscopes, ophthalmoscopes, larynx scopes, nasopharynx scopes, dermatologic scopes, anoscopes, or veterinary scopes, said instrument comprising:

a body having a pistol-grip adapted for engagement by a user's hand;

said body including a frusto-conical speculum disposed thereon; said speculum having a distal opening disposed along an axis of examination, said speculum being sized and shaped to allow location of said distal opening a predetermined distance from a target;

a lens and a light outlet, said lens and said light outlet being disposed integrally within said body; and

a video display disposed within said body, said video display being disposed within said axis of examination.

25. The instrument of claim 24, wherein said lens and light outlet are disposed integrally within a nose portion of said speculum.

26. The instrument of claim 25, wherein said nose portion further comprises a modular unit adapted for alternate engagement and disengagement with said body.

27. The instrument of claim 26, further comprising a plurality of said nose portions being interchangeably engagable with said body.

28. The instrument of claim 27, wherein each of said plurality of nose portions are sized and shaped to facilitate discrete examining procedures.

29. The dental/medical instrument of claim 24, wherein said video display further comprises a substantially planar screen portion, said screen portion being disposed substantially orthogonally to said axis of examination.

30. The dental/medical instrument of claim 24, wherein said video display further comprises a substantially planar screen portion, said screen portion being disposed substantially orthogonally to a plane which includes said axis of examination.

* * * * *

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(19) United States
(12) Patent Application Publication (10) Pub. No.: US 2007/0078340 A1
Wilcox et al. (43) Pub. Date: Apr. 5, 2007

(54) METHOD AND APPARATUS FOR CONTROLLING ULTRASOUND IMAGING SYSTEMS HAVING POSITIONABLE TRANSDUCERS

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(21) Appl. No.: **11/242,161**

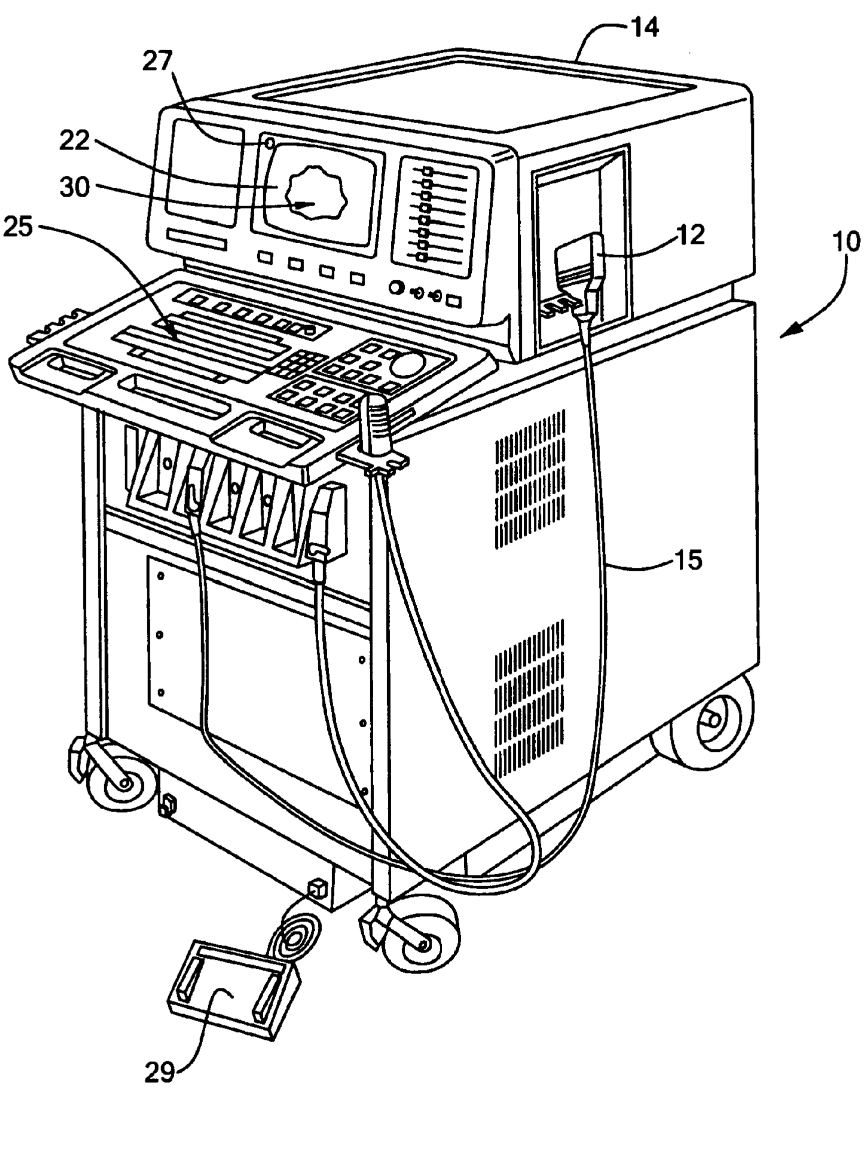
(22) Filed: **Sep. 30, 2005**

Publication Classification

(51) **Int. Cl.**
A61B 8/00 (2006.01)
(52) **U.S. Cl.** **600/437**

(57) **ABSTRACT**

A method and system for providing an operational command signal to a workstation of an imaging system. The workstation is provided imaging data from a positionable transducer. The method and system convert at least one of a predetermined plurality of motion patterns imparted by an operator of the system to the transducer into the operational command signal.



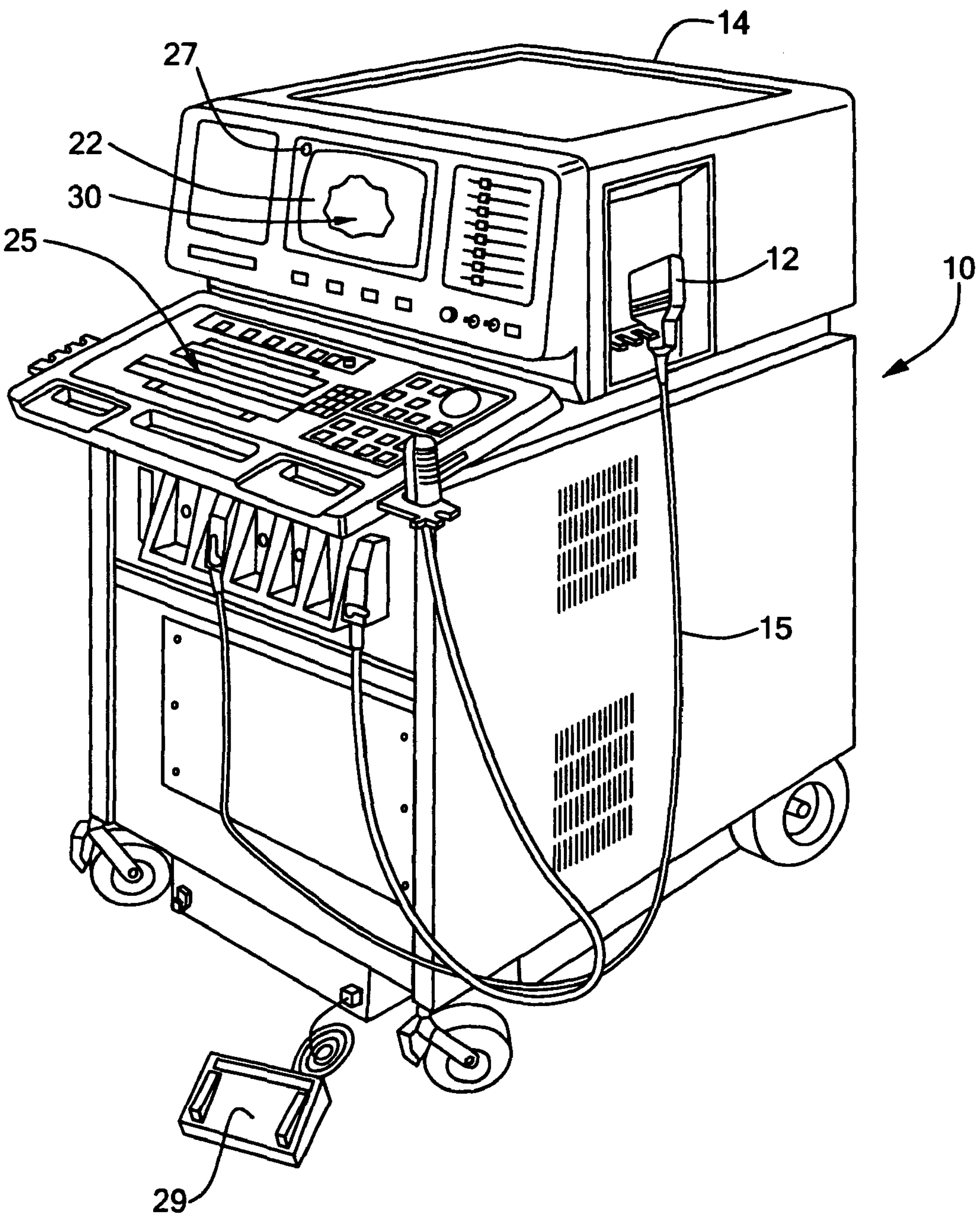


FIG. 1

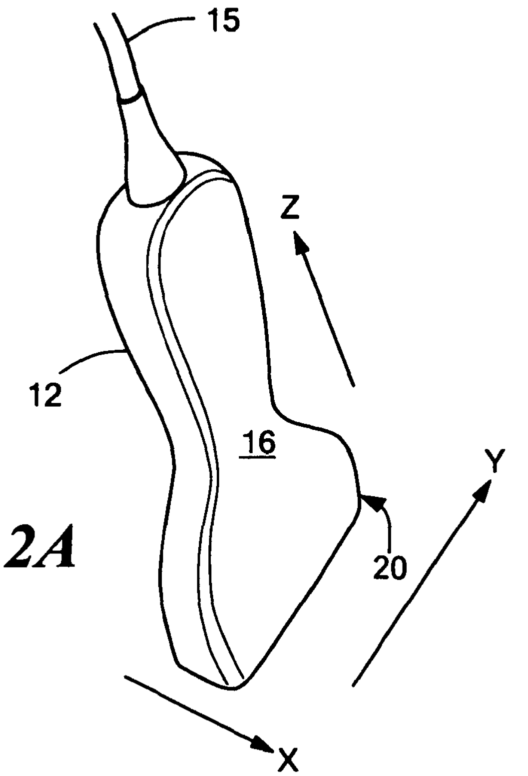


FIG. 2A

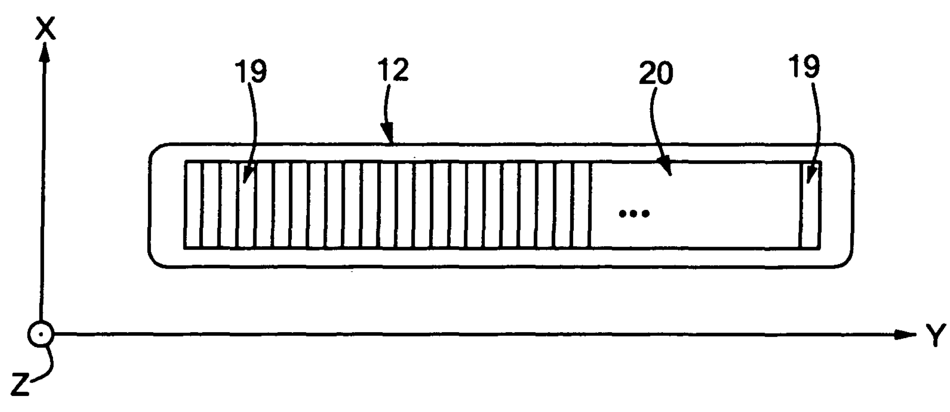


FIG. 2B

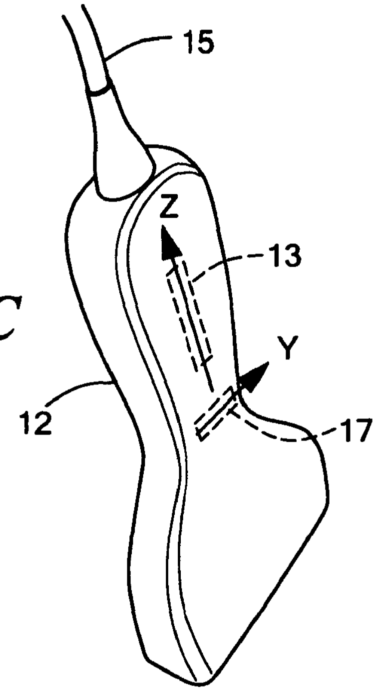


FIG. 2C

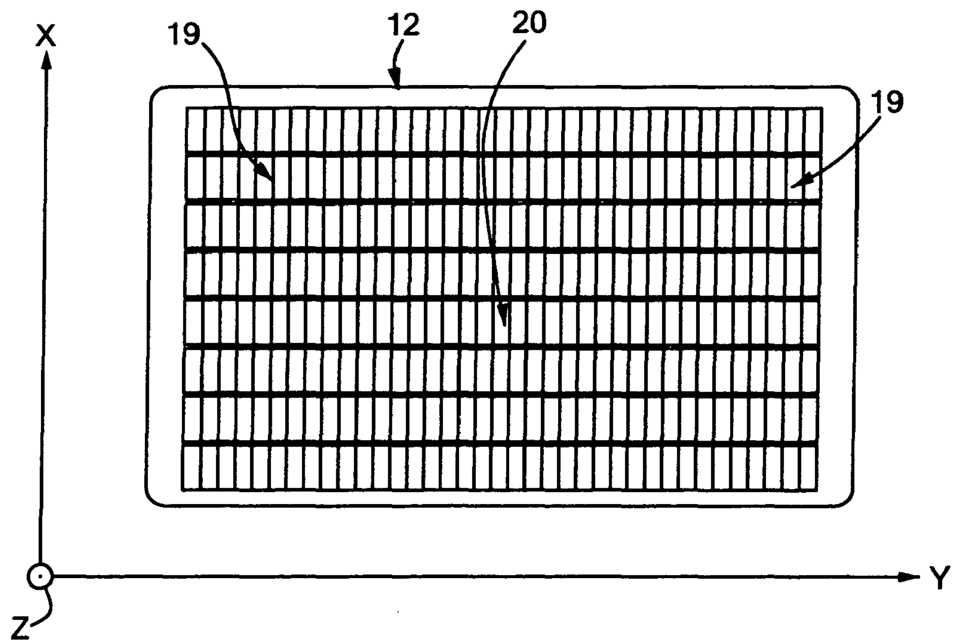


FIG. 2D

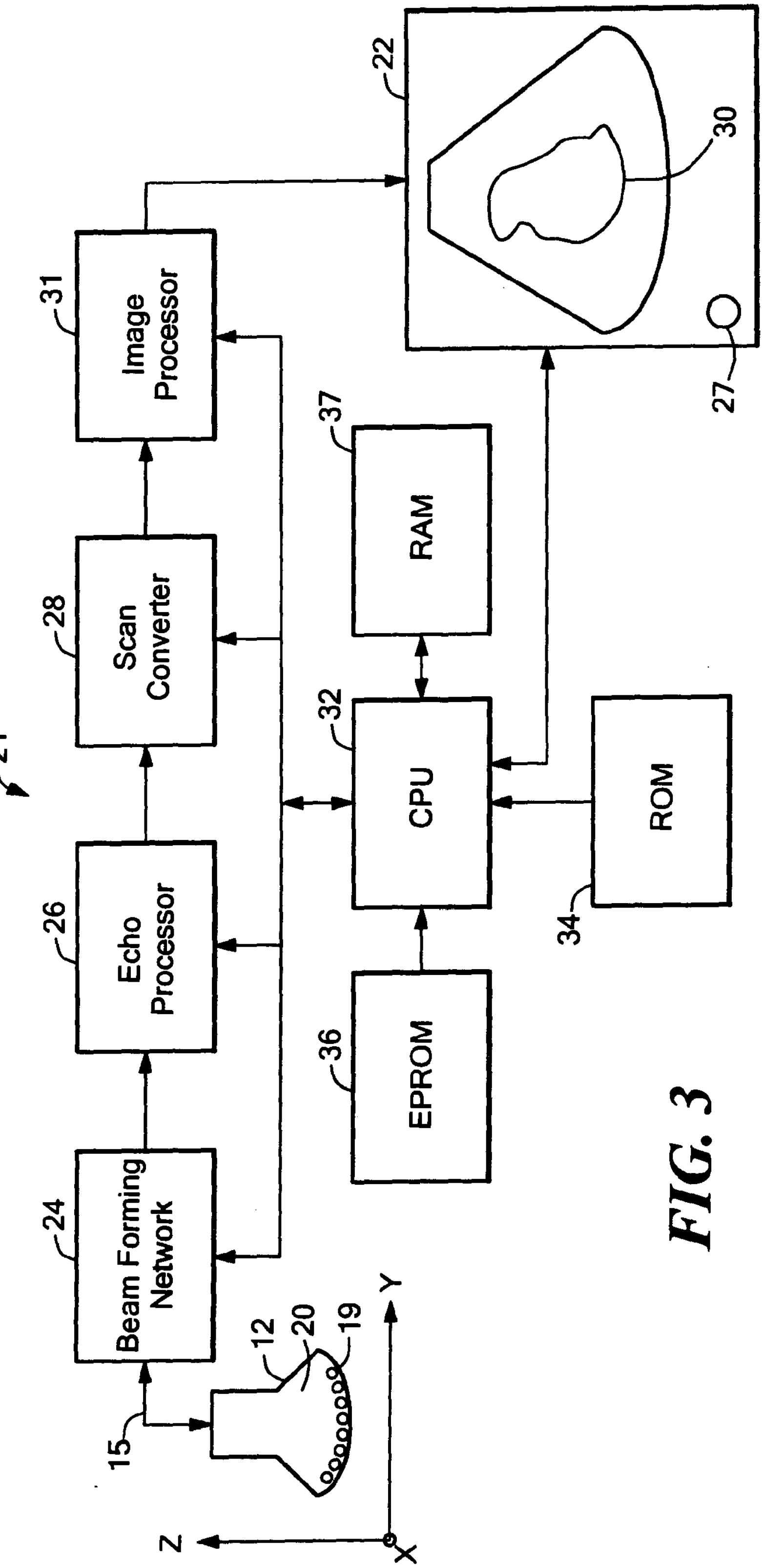

21
Beam Forming Network
24
Echo Processor
26
Scan Converter
28
Image Processor
31
22
30
27
RAM
37
CPU
32
ROM
34
EPROM
36
15
12
20
19
Y
Z
X

FIG. 3

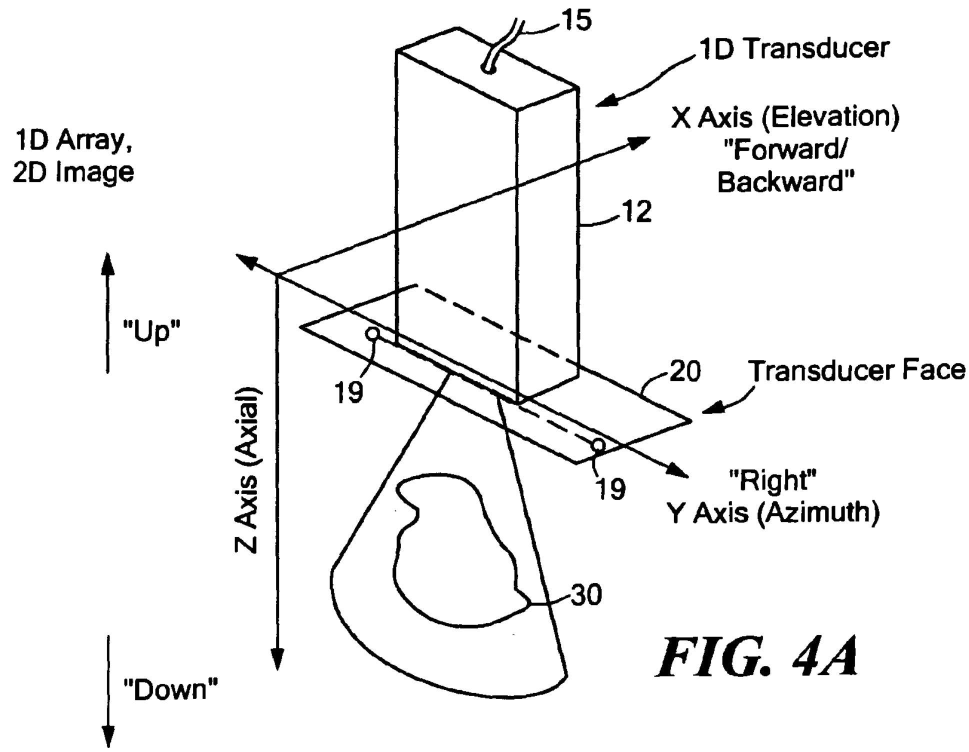

15
1D Transducer
1D Array,
2D Image
X Axis (Elevation)
"Forward/
Backward"
12
"Up"
20
Transducer Face
19
Z Axis (Axial)
"Right"
19
Y Axis (Azimuth)
30
"Down"

FIG. 4A

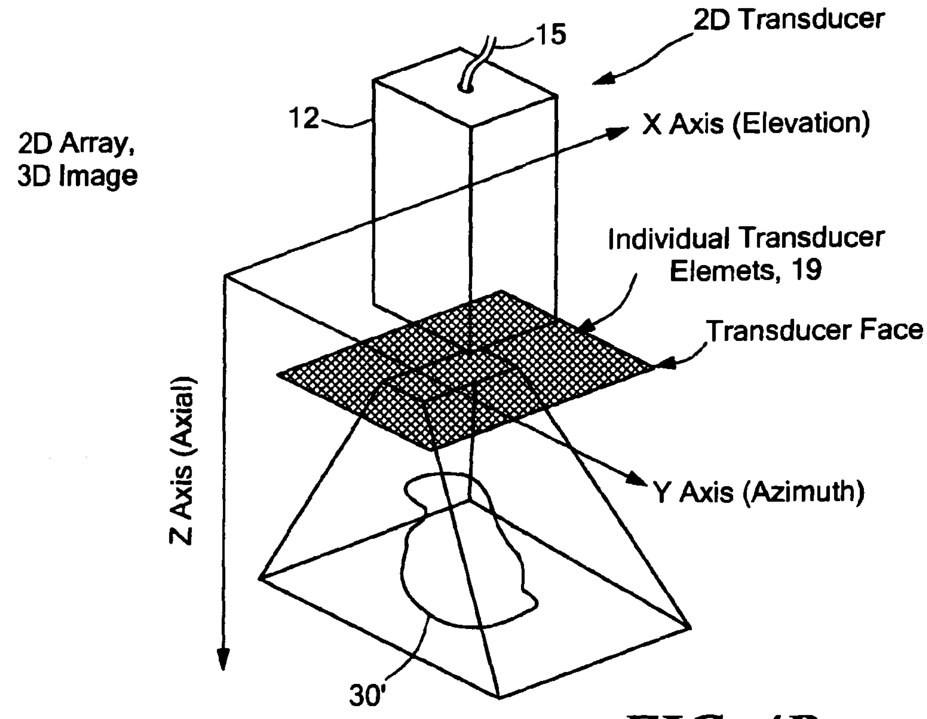

15
2D Transducer
12
2D Array,
3D Image
X Axis (Elevation)
Individual Transducer
Elemets, 19
Transducer Face
Z Axis (Axial)
Y Axis (Azimuth)
30'

FIG. 4B

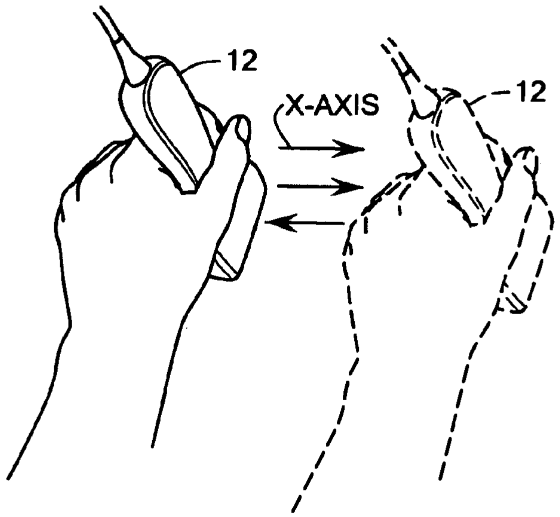


FIG. 5A

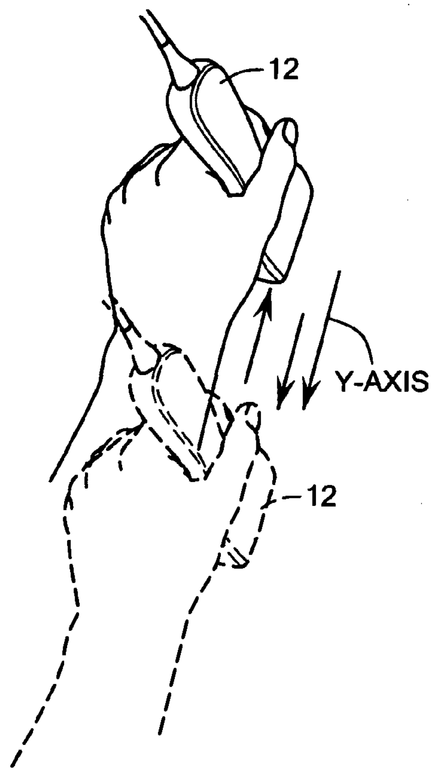


FIG. 5B

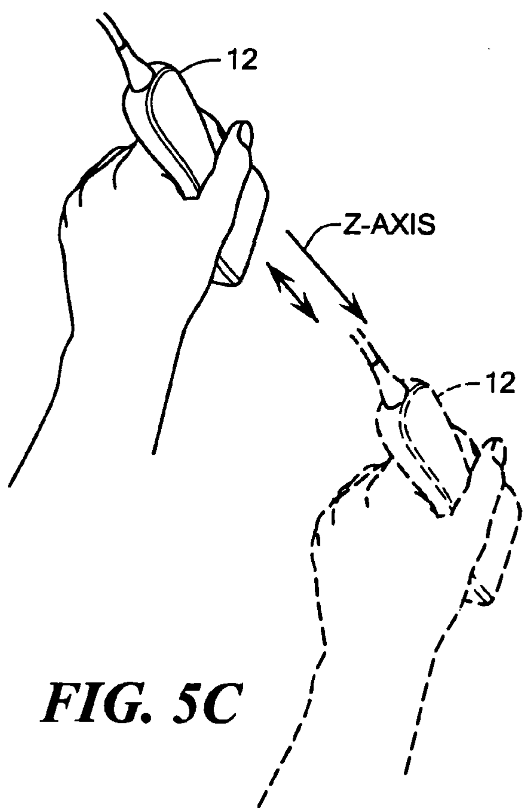
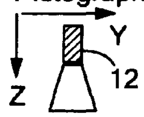
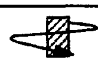
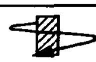
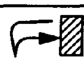


FIG. 5C

13

ID	Name	Pictograph	User interface action
			
1	R-L	 33	Capture the image and store it in a patient database.
2	L-R		Start capturing image data to a movie clip.
3	R-L-R-L		Mouse Right click, bring up a menu.
4	L-R-L-R		Mouse double click, select a user interface object, such as a menu item.
5	R-L-L-R		Invoke an on-screen cursor.
6	L-R-R-L		Select the next measurement in a series of measurements.
7	D-U		Mouse left click.
8	U-D		Start automatic image gain adjustment.
9	D-U-D-U		Start VCR recording.
10	U-D-U-D		Stop VCR recording.
11	R-D-U-L		Start a trace tool.
12	L-D-U-R		Enter a calculation report screen.
13	R-L-D-U	 33	Go to the next stage in a defined exam protocol. This may change a combination of imaging parameters, stopwatch timers, image annotations, measurement tools and calculation package measurements.
14	L-R-D-U	33 	Display the next entry in a series of pre-defined image annotation text strings.

Explanation of pictographs:

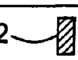
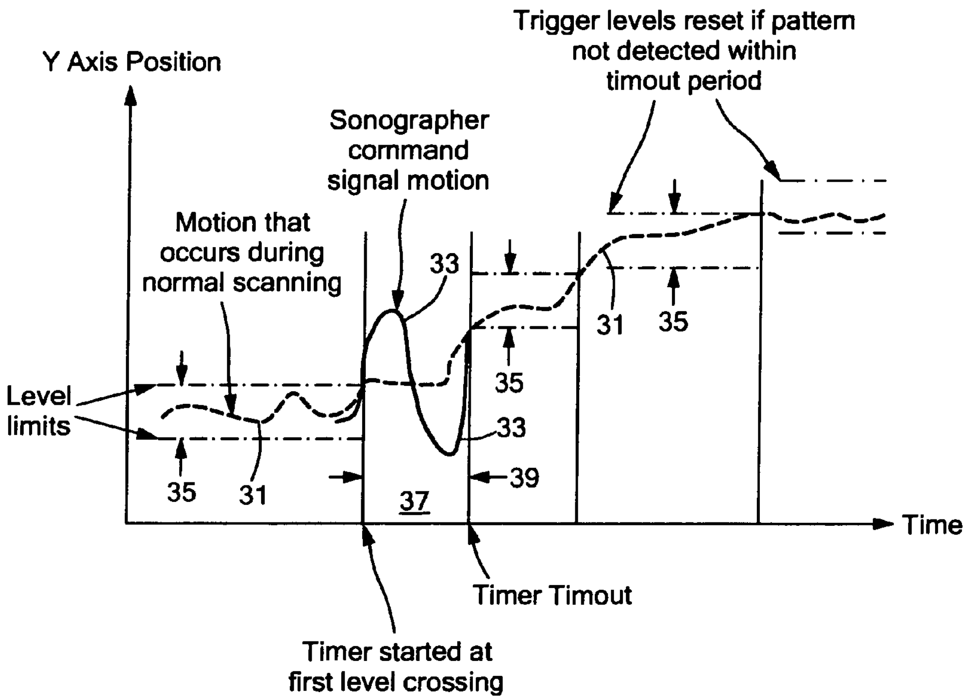
12 	= Transducer
30 	= Vector Image
33 	= Path of transducer motion

FIG. 6A



Y Axis Position
Trigger levels reset if pattern not detected within timout period
Sonographer command signal motion
Motion that occurs during normal scanning
Level limits
33
35
31
37
39
Time
Timer Timout
Timer started at first level crossing

FIG. 6B

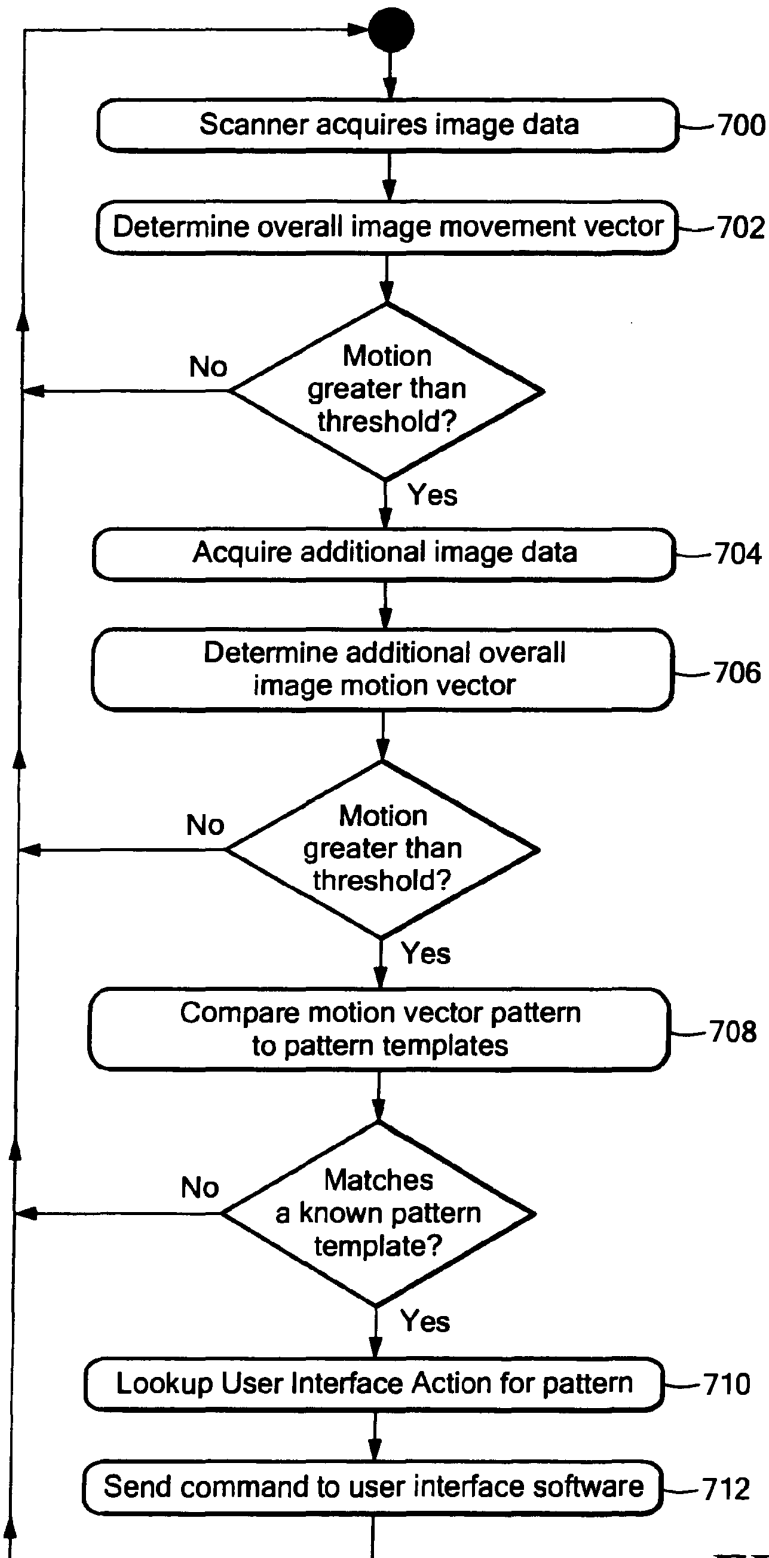

Scanner acquires image data
700
Determine overall image movement vector
702
No
Motion greater than threshold?
Yes
Acquire additional image data
704
Determine additional overall image motion vector
706
No
Motion greater than threshold?
Yes
Compare motion vector pattern to pattern templates
708
No
Matches a known pattern template?
Yes
Lookup User Interface Action for pattern
710
Send command to user interface software
712

FIG. 7

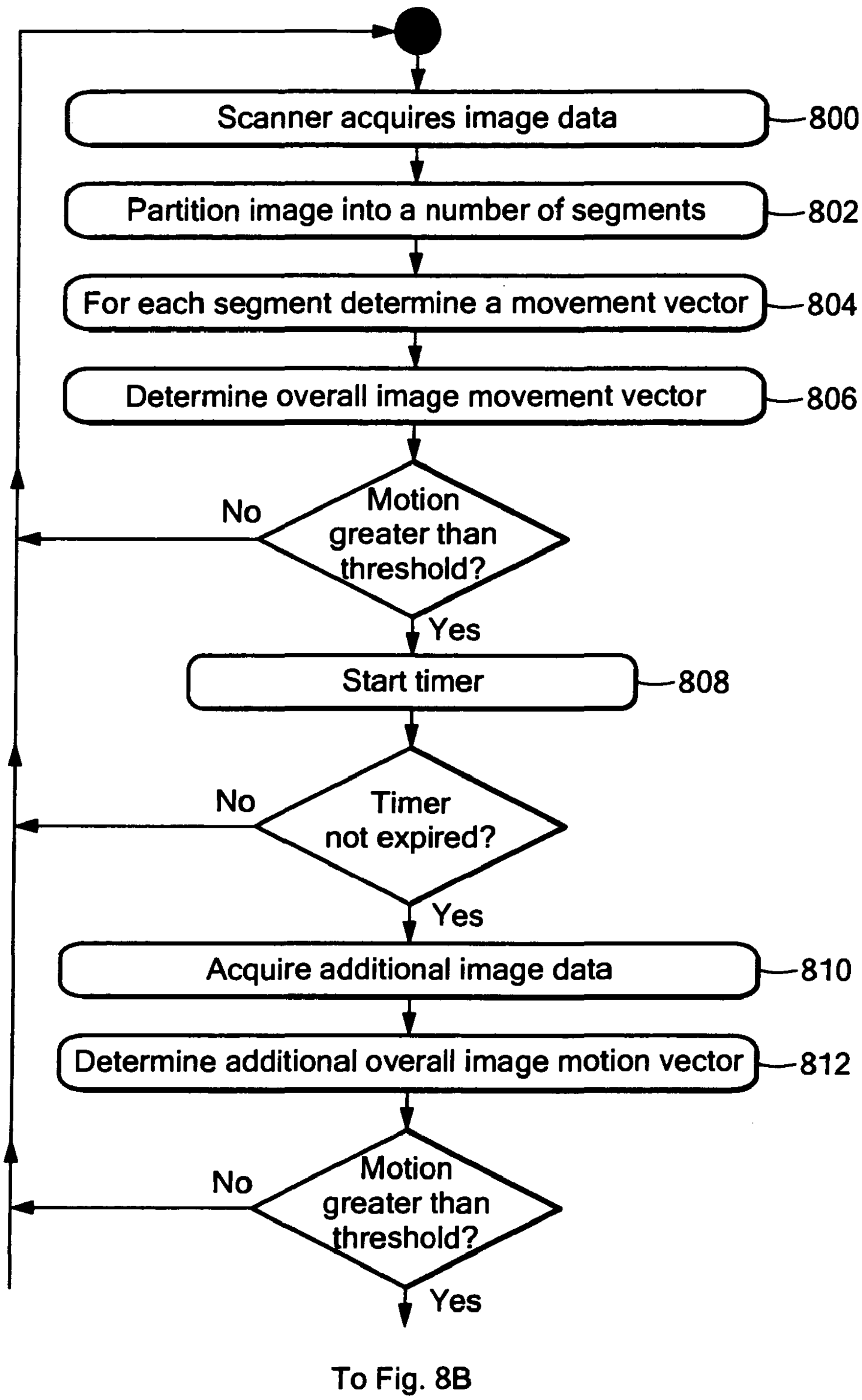

Scanner acquires image data
800
Partition image into a number of segments
802
For each segment determine a movement vector
804
Determine overall image movement vector
806
Motion greater than threshold?
No
Yes
Start timer
808
Timer not expired?
No
Yes
Acquire additional image data
810
Determine additional overall image motion vector
812
Motion greater than threshold?
No
Yes
To Fig. 8B

FIG. 8A

FIG. 8

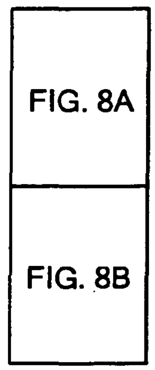


FIG. 8A
FIG. 8B

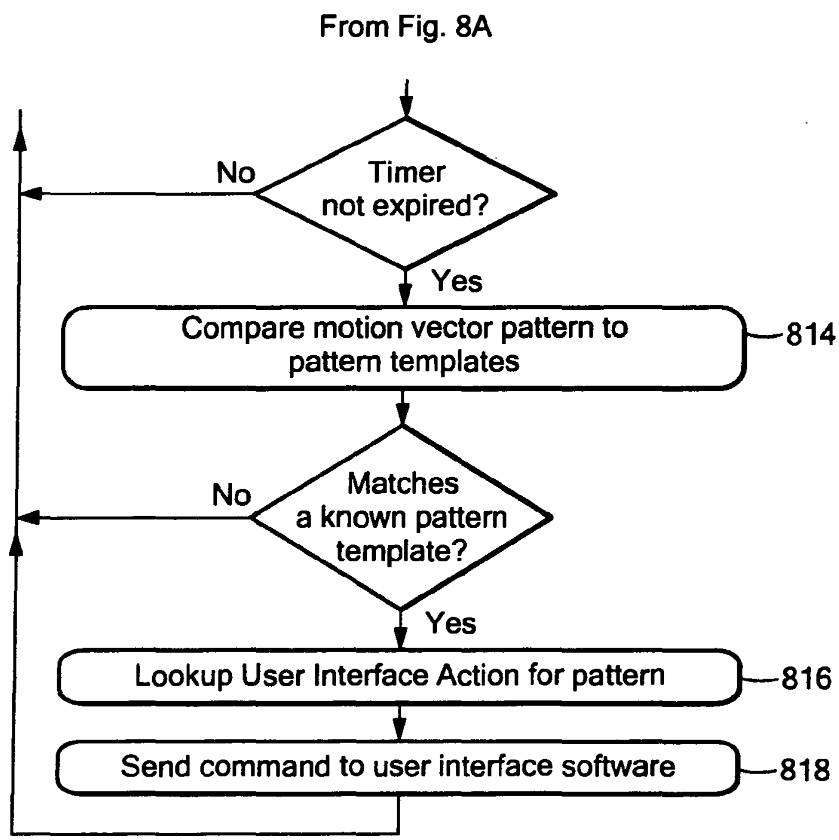

From Fig. 8A
Timer not expired?
No
Yes
Compare motion vector pattern to pattern templates
814
Matches a known pattern template?
No
Yes
Lookup User Interface Action for pattern
816
Send command to user interface software
818

FIG. 8B

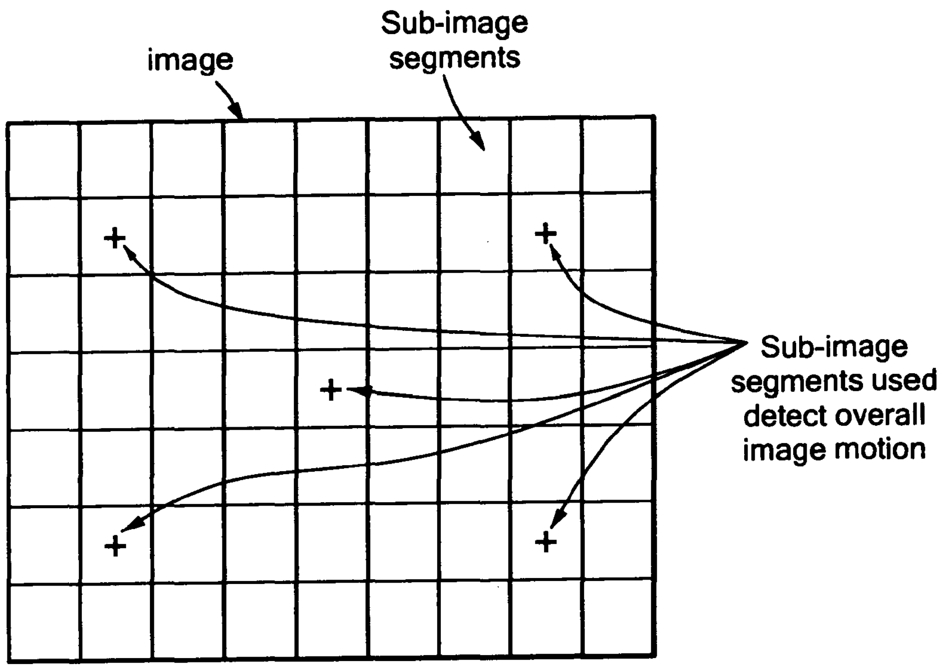


image
Sub-image segments
Sub-image segments used detect overall image motion

FIG. 9

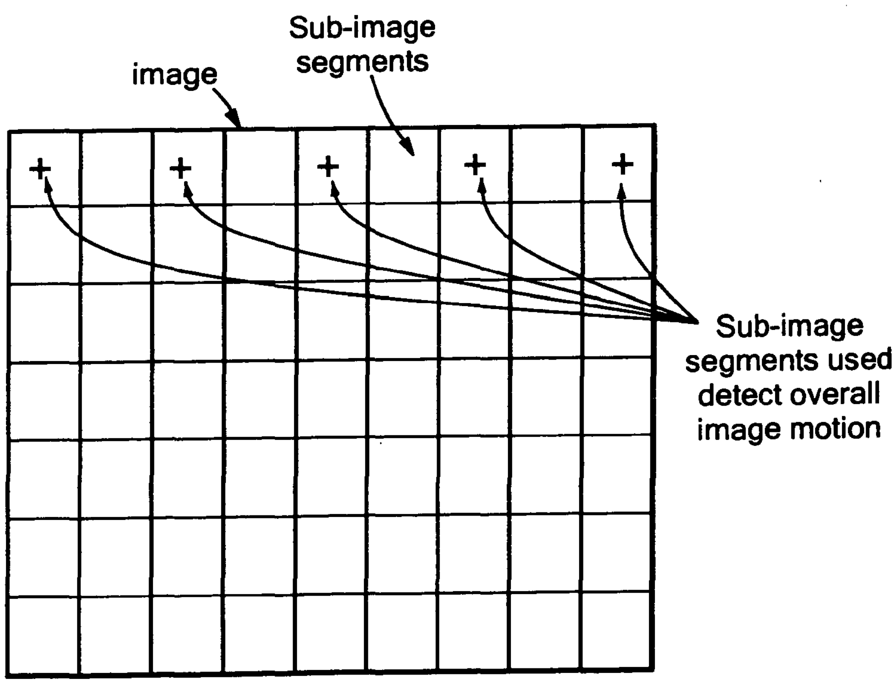


image
Sub-image segments
Sub-image segments used detect overall image motion

FIG. 10

METHOD AND APPARATUS FOR CONTROLLING ULTRASOUND IMAGING SYSTEMS HAVING POSITIONABLE TRANSDUCERS

TECHNICAL FIELD

[0001] This invention relates generally to methods and apparatus for controlling imaging systems and more particularly for controlling imaging systems having positionable transducers.

BACKGROUND

[0002] As is known in the art, one type of imaging system is an ultrasound imaging systems. A conventional ultrasound imaging system includes a positional transducer, typically a sonographer handheld transducer, coupled to a large processing and display workstation or operator interface. The frontal portion of the transducer includes an array of ultrasonic elements which transmit and receive ultrasonic energy for imaging a selected region of a patient. The received ultrasonic energy is converted to electric signals by the transducer and passed to the workstation. The workstation detects, filters and otherwise processes the information to generate a two- or three-dimensional representation of the scanned region.

[0003] The sonographer supplies the control signals for the workstation. Such control signals are typically supplied by the sonographer's free, or non-transducer carrying hand. Scanning situations in both the examination room and other locations often require the sonographer to be in awkward positions for simultaneously reaching the controls with the free hand and placing the frontal portion of the transducer in the proper position on the patient's body. One technique suggested to solve this problem is through voice activation; however, such technique may be prone to error and requires a speech recognition learning phase for each sonographer. Another technique suggested to provide the central signals to the workstation is through a sonographer actuated foot pedal; however such is not practical for all scanning situations.

SUMMARY

[0004] In accordance with the present invention, a method is provided for providing an operational command signals, sometimes herein referred to as control signals, to a workstation of an imaging system. The workstation is provided imaging data from a positionable transducer. One method includes converting at least one of a plurality of predetermined motion patterns imparted by an operator of the system to the transducer into the operational command signals.

[0005] With such method, the operator is provided with a way to control the workstation without taking a hand off of the transducer, or relying on voice control or foot actuated controls. The method reduces the number of times the operator must touch controls on the workstation.

[0006] Another method includes parting the transducer head into multiple regions (in one embodiment, less than four regions) and interpreting the reception of the signals from such regions into operational command signals.

[0007] A third method includes converting detections of predetermined echo signatures into operational command signals.

[0008] In one embodiment, the converting comprises detecting at least one of the predetermined motion patterns and converting such detected motion patterns into a corresponding one of the operational command signals.

[0009] In one embodiment, the detecting comprises comparing a sequence of images formed by the system.

[0010] In one embodiment, the method includes determining from the sequence of images whether the motion imparted to the transducer was either a repositioning of the transducer to produce a different image to be observed by the operator or a motion imparted to produce the corresponding one of the command signals to the workstation.

[0011] In one embodiment, such determining includes comparing types of motions imparted by the operation.

[0012] In one embodiment, such determining includes comparing imparted motion with a level threshold.

[0013] In one embodiment, such determining includes comparing imparted motion with a time duration threshold.

[0014] In one embodiment, a method is provided for providing control signals to a workstation of an imaging system, such workstation being provided imaging data from a positionable transducer. The method includes detecting patterns of motion of the transducer, and converting the patterns to the control signals.

[0015] In one embodiment, the detection is performed by detecting patterns of change in real time images provided by the system.

[0016] In one embodiment, timing of the motion is used to discriminate between motion intended to provide the control signals and motion normally occurring during scanning.

[0017] In one embodiment, patterns of direction of the transducer motion are used to discriminate between motion intended to provide the control signals and motion normally occurring during scanning.

[0018] In one embodiment, a combination of patterns of direction of the transducer motion and timing of the motion are used to discriminate between motion intended to provide the control signals and motion normally occurring during scanning.

[0019] In one embodiment, an imaging system is provided having a workstation and a positionable transducer for providing imaging data to the workstation. The workstation responds to the operational command signals. The workstation includes a memory for storing a table mapping detected motion of the transducer into the command signals.

[0020] In one embodiment, the workstation includes a processor programmed to detect at least one of a predetermined plurality of motion patterns and convert such detected one of the motion patterns into the operational command signals.

[0021] In one embodiment, the transducer has deposed within a housing thereof motion sensors.

[0022] In one embodiment, sensors disposed remote from the transducer sense motion of the transducer.

[0023] In one embodiment, an imaging system is provided having a workstation and a positionable transducer for providing imaging data to the workstation. The workstation

responds to control signals. The workstation includes a processor for detecting patterns of motion of the transducer and converting the patterns to the control signals.

[0024] The details of one or more embodiments of the invention are set forth in the accompanying drawings and the description below. Other features, objects, and advantages of the invention will be apparent from the description and drawings, and from the claims.

DESCRIPTION OF DRAWINGS

[0025] FIG. **1** is a sketch of an imaging system according to the invention;

[0026] FIG. **2**A is an isometric sketch of a transducer used in the system of FIG. **1**;

[0027] FIG. **2**B is a front elevation view of the frontal portion of the transducer of FIG. **2**A;

[0028] FIG. **2**C is an isometric sketch of a transducer adapted for use in the system of FIG. **1** according to one embodiment of the invention;

[0029] FIG. **2**D is a front elevation view of the frontal portion of a 2D array transducer;

[0030] FIG. **3** is a block diagram of a processor used to process imaging data from the transducer of FIGS. **2**A and **2**B to generate an image for an operator of a workstation used in the system of FIG. **1** and to process such data to generate control signal for operation of the workstation;

[0031] FIG. **4**A is a diagram showing a coordinate system for a one-dimensional array transducer used in the system of FIG. **1**, such coordinate system indicating and defining operator motion of the transducer;

[0032] FIG. **4**B is a diagram showing a coordinate system for a two-dimensional array transducer used in the system of FIG. **1**, such coordinate system indicating and defining operator motion of the transducer;

[0033] FIGS. **5**A, **5**B and **5**C show various patterns of motion which may be imparted to the transducer by the operator and then image data which is processed by the processor of FIG. **3** to generate the control signally for the workstation of the system of FIG. **1**;

[0034] FIG. **6**A is a table showing the relationship between a repertoire of motions impartable by the operator to the transducer and the workstation control signals intended by the operator resulting from such motions;

[0035] FIG. **6**B shows a comparison between normal transducer motion occurring during scanning and motion used to initiate a command signal to the workstation of FIG. **1**;

[0036] FIG. **7** is a flow diagram of a process used by the processor of FIG. **3** in generating the workstation control signals from images generated by the transducer;

[0037] FIGS. **8**, **8**A and **8**B are flow diagrams in more detail of the process of FIG. **7** used by the processor of FIG. **3** in generating the workstation control signals from images generated by the transducer;

[0038] FIG. **9** is a diagram showing an image obtained by the processor of FIG. **3** divided into sub-image segments by the processor and used to detect overall image motion; and

[0039] FIG. **10** is a diagram showing an image obtained by the processor of FIG. **3** divided into sub-image segments by the processor with near-field segments used to detect overall image motion.

[0040] Like reference symbols in the various drawings indicate like elements.

DETAILED DESCRIPTION

[0041] FIG. **1** shows an imaging system **10**, here an ultrasound imaging system for medical diagnostics. The system **10** includes a positionable, here handheld, image processing ultrasound device, here a transducer **12** shown in more detail in FIGS. **2**A and **2**B, and a multi-use display device, or operator interface, herein sometime collectively referred to as a workstation **14**. The handheld transducer **12** obtains ultrasound data and formats the ultrasound data for transmission to the workstation **14**, here via a cable **15**. Controls to the workstation **14** are provided by detecting patterns of motion, to be described in more detail below, provided, or imparted, to the transducer **12** by an operator of the system **10**, typically by a sonographer. Suffice it to say here that the pattern of motions may include: an up-down or down-up (i.e., axial) motion of the sonographer's transducer hand holding wrist (i.e., an up flick of the wrist followed by a down flick of the wrist or a sequence of down-up flicks of the wrist); a left-right or right-left (i.e., azimuthal) motion of the sonographer's transducer hand holding wrist (i.e., left-right flicks or right-left flicks of the wrist); for 2D arrays, a forward-and-backward (i.e., elevational) motion of the sonographer's transducer hand holding wrist; a inward-outward motion towards and away from the patient's body, or visa versa, or any combination thereof. The detection of these sonographer's imparted transducer motions may be performed by hardware and/or software to detect patterns of change in real time images. When motion is detected, the timing of the motion is used to discriminate between motion intended to initiate control changes and motion which occurs normally during scanning. In addition, patterns of direction are be used to discriminate between motion intended to initiate control changes and motion which occurs normally during scanning. The combination of timing and direction of transducer **12** motion changes are used to discriminate between transducer motion intended to initiate control changes and motion which occurs normally during scanning.

[0042] The transducer **12** includes a housing **16** (FIG. **2**A) adapted to be easily handheld, such as for example, being less than 8 inches in any dimension and/or having an ergonomic shape for holding in a operator's hand. The housing **16** comprises plastic, rubber, metal, other materials now known or later developed, or combinations thereof. In one embodiment shown in FIG. **2**A, the housing **16** is shaped for ergonomic use or holding by the operator (e.g., sonographer) by having a generally round or curved circumference handle serving as a grip for the sonographer's hand.

[0043] The handheld transducer **12** includes conventional ultrasound circuitry, not shown, within the housing **16**. Thus, the ultrasound circuitry includes, in the frontal portion **20** thereof (FIGS. **2**A and **2**B) an array of ultrasonic elements **19** which transmit and receive ultrasonic energy for imaging a patient, not shown. It is noted that FIG. **2**B is for a one-dimensional array transducer and FIG. **2**D is for a 2D array transducer. Here, the transducer's transmit and receive elements **19** in the frontal portion **20** are arranged in an elongated array along a the longer axis, here the Y axis of the rectangular shaped patient interfacing surface, i.e., the frontal portion **20**, of the housing **16**. The elements **20** in the frontal portion **20** are, as shown in FIG. **3** fed to a display **22** of the workstation **14** (FIG. **1**) serially through: a beamforming network **24**, an echo processor **26**, a scan converter **28**, and an image processor **31** in a conventional manner. The beamforming network **24**, echo processor **26**, scan converter **28**, image processor **31** and display **22** are controlled by a central processing unit (CPU) **32** coupled to a random access memory RAM**37**. The CPU **32** operates in accordance with program instructions stored in a ROM **34**, or in RAM **37**, or in flash memory not shown, or on a hard drive device, not shown. A memory **36**, here an erasable, or other type of programmable semiconductor memory, here a read only memory (ROM) is provided for storing a computer, here microprocessor, executable program, for operating the CPU **32** as described herein. Further, the RAM **37** stores, after being read from the hard drive, not shown, a table (TABLE I) mapping detected motion imparted by the operator of the transducer **12** into command, or control, signals for the workstation **14** (FIG. **1**). Further it should be noted that the user might alter the mapping provided by the table using setup screen touch commands.

[**0044**] Thus, the ultrasound processor **21** (FIG. **3**) scan converts data associated with the radial scan pattern to generate ultrasound image data in a video format (e.g. Cartesian coordinate format). In one embodiment, a single radial scan format with possible changes in depth limits the number of operations for scan converting. Multiple scan formats and associated scan conversions may be used. Video filtering or processing may also be provided. Thus, as noted briefly above, the processor **21** (FIG. **3**) includes the array of transmitting/receiving elements **18**, here an array of piezoelectric crystals that deliver ultrasonic energy into a patient and receive ultrasonic echoes from the patient. Electrical signals representative of the echoes produced by the transducer **12** are delivered to the beamforming network **24** where they are selectively combined to produce an indication of the echo intensity along a particular direction or beam in the patient. The data produced by the beamforming network **24** is fed to the echo processor **26** that calculates echo intensity at each position along a beam and may calculate a Doppler shift of the echoes received along a particular beam. Data from the echo processor **28** is fed to a scan converter **28** that converts the data into a form that can be readily displayed on a video monitor **22**.

[**0045**] The data produced by the scan converter **28** is stored in an the RAM **37** where an additional processing, such as adding color, may be performed prior to displaying the images on a video monitor. Controlling the operation of the above-referenced parts are one or more central processing units, here collectively indicated by the CPU **32**. The central processing units also receive commands from the sonographer. As noted above, controls to the workstation **14** are provided by detecting patterns of motion, to be described in more detail below, provided to the transducer **12** by the sonographer. Thus, the CPU **32** together with the image data stored in RAM **37** and the TABLE I stored in memory **36**, processes the motion detection signals imparted by the sonographer to provide these workstation control signals. Recognition of the motion inputted command by the processor **21** results in the CPU **32** sending a signal to a light and/or buzzer **27** mounted on the workstation **14**, or changing some on-screen indicator. Activation of the light and/or buzzer or on screen indicator **27** provides a visual and/or audible indication to the sonographer that the command has been completed.

[**0046**] It should be understood that the commands or control signals provided to the workstation **14** by detecting patterns of motion provided to the transducer **12** by the sonographer may be supplemented by other tactile commands entered manually by the sonographer to the workstation keyboard **25** (FIG. **1**) or by a foot pedal **29** (FIG. **1**). In either case, these controls allow the sonographer to adjust the operation of the ultrasound machine workstation **14**. In addition, some command or control signals may be sent after some configurable delay after the pattern of motion is detected. This will allow controls which require a stable image, such as image capture, to be included in the command table.

[**0047**] The transducer **12**, as noted above, includes transmit and receive elements **19** (FIGS. **2**A and **2**B). These elements **19** are arranged to provide an array of elements for transducing between acoustical and electrical energies, such as a one-dimensional, 1.5D, two-dimensional or single element transducer. Any of a phased array, linear array, curved array or other arrays may be used. An acoustic window, not shown, is disposed in the frontal portion **20** on the housing **16** adjacent to the transducer **12**.

[**0048**] As noted above, the transducer **12** is electrically coupled to the workstation **14** (FIG. **1**) by a cable **20**. It should be noted that the transducer **12** might be wireless coupled to the workstation **14** as described in U.S. Pat. No. 6,780,154 issued Aug. 24, 2004, inventors Hunt et al., assigned to the same assignee as the present invention, the entire subject matter thereof being incorporated herein by reference.

[**0049**] Referring now again to FIGS. **2**A and **2**B, it is noted that the housing **16** of the transducer **12**, and more particularly the frontal portion **20** thereof having the array, here a one or two-dimensional array, of transmitting and receiving elements, not shown, is rectangular shaped, having its longer dimension along a, here Y, or azimuthal axis, and its shorter dimension along, here, the X, or elevation, axis, as indicated. An axial Z axis is thus along the length of the housing (i.e., an axis perpendicular to both the X and Y axes to provide a conventional Cartesian coordinate system for the transducer **12**.

[**0050**] FIG. **4**A shows the region of a scan of an image **30**, here a sonogram, produced by placing the transducer **12** at one fixed position on the patient's body, not shown. It is first noted that the transducer **12** shown in FIG. **4**A has a one-dimensional array of the transmit/receive elements **19**. It is next noted that the image **30** is the Y-Z plane of the transducer's coordinate system described above in connection with FIGS. **2**A and **2**B. Here, for this one dimensional array transducer we define the following directions of motion impartable by the sonographer to the transducer **12**:

[**0051**] (1) a upward (U) motion is a motion along the −Z axis;

[**0052**] (2) a downward (D) motion is a motion along the +Z axis;

[0053] (3) a leftward (L) motion is a motion along the −Y axis; and

[0054] (4) a rightward (R) motion is a motion along the +Y axis.

[0055] FIG. **4**B shows the region of a scan of an image **30** produced by a transducer **12** having a two dimensional array of elements **19**. It is noted that image **30'** produced by this two dimensional array transducer is a three-dimensional image **30'**. Here, for this two-dimensional array transducer, we define the following directions of motion impartable by the sonographer to the transducer **12**:

[0056] (1) a forward (F) motion is a motion along the +X axis;

[0057] (2) a backward (B) motion is a motion along the −X axis;

[0058] (3) a upward (U) motion is a motion along the −Z axis;

[0059] (4) a downward (D) motion is a motion along the +Z axis;

[0060] (5) a leftward (L) motion is a motion along the −Y axis; and

[0061] (6) a rightward (R) motion is a motion along the +Y axis.

[0062] The ultrasound system **10** (FIG. **1**) is capable of displaying the image **30** in either orientation, (also U/D inverted) it is simply an operator preference. A small symbol, not shown, is displayed on the screen **22** which corresponds to a physical notch, not shown, on the transducer **12** housing so the operator (and anyone viewing the images later) can tell which way the image is oriented. In FIGS. **4**A and **4**B the surface the patient, not shown, is in the X-Y plane, and the Z axis is "into" the patient's body.

[0063] It should be understood that, as is well known, the term "Linear array" refers to a one-dimensional (1D) array used to produce a "Linear" image, while a "Sector array" or "Vector array" refers to a 1D array used to produce a "Sector" image. The physical geometry of the transducers is similar, but vector arrays tend to be smaller. The shape of the image is determined by the way the systems controls the electrical timing of the transmit and receive signals. A third image format is the "Curved Linear" image, produced by a linear transducer with a convex curve along the azimuthal dimension of the transducer surface.

[0064] FIG. **5**A shows of a motion of the transducer **12** by the sonographer along the X-axis (i.e., a forward/backward motion); FIG. **5**B shows of a motion of the transducer **12** by the sonographer along the Y-axis (i.e., a right (R)/left (L) motion; and, FIG. **5**C shows of a motion of the transducer **12** by the sonographer along the Z-axis (i.e., an up (U)/down (D) motion.

[0065] As noted above, the processor **21** (FIG. **3**) detects patterns of these X, Y and/or Z sonographer imparted motions to provide controls to the workstation **14**. The invention consists of software and/or hardware to detect patterns of transducer motion, and hardware and/or software to map those patterns to the activation of system controls. The detection of these sonographer's imparted transducer motions may be performed by hardware and/or software to detect patterns of change in real time images. When motion is detected, the timing of the motion are be used to discriminate between motion intended to initiate control changes and motion which occurs normally during scanning. As noted above, patterns of direction are used to discriminate between motion intended to initiate control changes and motion which occurs normally during scanning. The combination of timing and direction of transducer **12** motion changes are used to discriminate between transducer motion intended to initiate control changes and motion which occurs normally during scanning.

[0066] More particularly, the Table I below and stored in memory **36** (FIG. **3**) provides an exemplary repertoire of motions imparted to the transducer by the sonographer and which are interpreted by data stored in a Table II below of the memory **36**, e.g., an EPROM, of the processor as command, or control signals for the workstation. Thus, the memory stores a table (TABLE I, below) mapping, in this example 14 detectable motions of the transducer 12 each one of the 14 motions (i.e., identified by the designations "ID**1**" through "ID**14**") corresponding to one of 14 command signals for the workstation **14**, as indicated in FIG. **6**A. It is noted that each one of the exemplary patterns **33** (FIG. **6**A) in TABLE I is different from merely changing the position of the transducer **12** to obtain a different scan view. For example, a sequence of a left flick of the wrist followed by a right flick of the wrist is not the type of motion used to merely change the scan view. Further, it is noted that each pattern includes a sequence of at least two flicks of the wrist (each pair of flick typically occurring in a second of time or less). Still further, a single flick of the wrist, as shown by the curve **33** in FIG. **6**B may be used assuming it is fast compared with the motion typically, or normally, used to change transducer image position shown by the curve **31** in FIG. **6**A.

TABLE I

ID	Name	Description
1	R-L	The transducer is moved to the right, then back to the original position
2	L-R	Transducer moved to the left, then back to the original position
3	R-L-R-L	Transducer moved to the right, back to the original position, then back to the right and finally back to the original position.
4	L-R-L-R	Transducer moved to the left, back to the original position, then back to the left, and finally back to the original position.
5	R-L-L-R	Transducer moved to the right, to the left past the original position, then back right to the original position.
6	L-R-R-L	Transducer moved to the left, to ther right past the original position, then back to the original position.
7	D-U	Transducer moved down, then back up.
8	U-D	Transducer moved up, then back down.
9	D-U-D-U	Transducer moved down, then back up, then the motion is repeated.
10	U-D-U-D	Transducer moved up, then back down, then the motion is repeated.
11	R-D-U-L	Transducer moved to the right, then down, then up, then back to the original position
12	L-D-U-R	Transducer moved to the left, then down, then up, then back right to the original position
13	R-L-D-U	Transducer moved to the right, left, down, and back to the original position
14	L-R-D-U	Transducer moved to the left, right, down, and back up to the original position.

[0067]

TABLE II

ID	Name	User interface action
1	R-L	Capture the image and store it in a patient database..
2	L-R	Start capturing image data to a movie clip.
3	R-L-R-L	Mouse Right click, bring up a menu.
4	L-R-L-R	Mouse double click, select a user interface object, such as a menu item.
5	R-L-L-R	Invoke an on-screen cursor.
6	L-R-R-L	Select the next measurement in a series of measurements.
7	D-U	Mouse left click
8	U-D	Start automatic image gain adjustment
9	D-U-D-U	Start VCR recording
10	U-D-U-D	Stop VCR recording
11	R-D-U-L	Start a trace tool
12	L-D-U-R	Enter a calculation report screen
13	R-L-D-U	Go to the next stage in a defined exam protocol. This may change a combination of imaging parameters, stopwatch timers, image annotations, measurement tools and calculation package measurements.
14	L-R-D-U	Display the next entry in a series of pre-defined image annotation text strings.
		Enter cine review playback
		Start voice activation listening
		Start voice annotation recording
		Stop voice annotation recording

[0068] The motion detection (i.e., U, D, L and R) may be performed in any one of a variety of ways. For example, the detection of transducer motion may be done using decimated image data; using Doppler Tissue Imaging, (FIG. **9**) in which dedicated hardware or software will average the computed Doppler velocity and/or Doppler energy signals from a sample set of echo information at a predetermined set of image locations **91**; or in a like manner but with the predetermined set of image locations confined to the near-field of the image, using a pair of micromachined accelerometers **13**, **17** (FIG. **2**C) such as model series ADXL manufactured by Analog Devices, Norwood, Mass., one disposed within the housing **16** of the transducer **12** along the Y axis, and other disposed along for example, either along the X axis or the Z axis, as shown in FIG. **2**C, a rate gyro for sensing twisting or rolling motion of the wrist, such a model series ADXRS manufactured by Analog Devices, Norwood, Mass. or other motion-sensing device disposed within the housing **16** of the transducer **12**; or by a video monitoring camera. Signals from the motion-sensing devices mentioned above disposed within the housing **16** are coupled from the transducer **12** to the workstation **14** through cable **15**, or wireless. Another technique may include mounting light emitting diodes to the transducer body and having light detecting sensors fixed to the workstation or examination room remote from the transducer. One such system is manufactured by Northern Digital (NDI), International Headquarters 103 Randall Drive Waterloo, Ontario Canada N2V 1C5.

[0069] One technique used to detect transducer motion is described in U.S. Pat. No. 6,162,174 entitled "Method for compensating for object motion in ultrasound images", issued Dec. 19, 2000, inventor Friemel, assigned to the same assignee as the present invention, the entire subject matter thereof being incorporated herein by reference. While there transducer motion is detected to remove image flicker, the method included determining transducer motion. As noted above, when motion is detected, the timing of the motion are be used to discriminate between motion intended to initiate control changes and motion which occurs normally during scanning. In addition, patterns of direction are be used to discriminate between motion intended to initiate control changes and motion which occurs normally during scanning. The combination of timing and direction of transducer **12** motion changes are used to discriminate between transducer motion intended to initiate control changes and motion which occurs normally during scanning.

[0070] Referring now to FIG. **7**, a flow diagram of one method used herein to generate workstation commands from sonographer imparted motions to the transducer is shown.

[0071] The scanner (i.e., scanning system) acquires image data (Step **700**). The processor **21** (FIG. **3**) determines the overall image motion vector (Step **702**). If the determined overall image movement vector is greater than a predetermined threshold (i.e., the motion is consistent with the flick of the sonographer's wrist or a rapid up-down motion of the transducer as distinguished from a motion consistent with the sonographer merely changing the position of the transducer to obtain a different view of the region being observed of the patient) the processor **21** acquires additional image data and stores such data in RAM **34** (Step **704**). It is noted that, in general, the magnitude threshold filters out normal, small movements of the sonographer's hand, while the pattern matching filters out normal movement to obtain a different field of view. Further, one type of filter which may be useful would be a high pass filter or differentiator to produce an output signal related to the rate of change of the motion, i.e. the slope of the curve shown in FIG. **6**B. Thus, referring to FIG. **6**B, whenever the magnitude of the motion, i.e., the Y axis in this example, exceed a predetermined threshold, or window **35**, as in time region **37**, a timer, not shown, in the CPU **32** (FIG. **3**) is activated. i.e., indicated as "Timer started at first level crossing". If a second motion exceeding the motion limits is detected before the time duration exceeds, a predetermined time duration window **37**, a command signal is recognized by the CPU **32**. If a single motion exceeds the motion threshold limits, but is not followed by a second motion prior to the timer expiration, the position limits will be reset to the current position.

[0072] Next, in Step **706**, the processor **21** determines additional overall image motion. This may be achieved by the means described in one of the means (e.g., low pass filter) described above. If the determined overall image movement vector is greater than a predetermined threshold (i.e., the motion is consistent with the sonographer's intention to generate a control signal for the workstation **14**), a motion vector pattern is compared to pattern templates at Step **708**.

[0073] Now the process has determined a sequence of two motions. This pattern is now fed to the memory-**36** storing TABLE I and the information is used by TABLE II also stored in memory **36** (Step **710**) to provide the corresponding control signals to the workstation **14** (Step **712**). Also, the light and/or buzzer **27** is activated to provide a visual and/or audible indication to the sonographer that the command has been completed.

[0074] A more detailed flow diagram is shown in FIG. **8**, which further includes FIGS. **8**A and **8**B. Again the scanner acquires image data to generate an image (Step **800**). The processor **21** (FIG. **3**) partitions the generated image **30**, **30**' into a plurality of segments, not shown, Step **802**. For each segment the processor **21** determines a movement vector, not shown, Step **804**. From the plurality of vectors, the processor **21** determines the overall image motion vector, not shown, Step **806**. More details of Steps **802** through **806** are provided in the above-identified in U.S. Pat. No. 6,162,174. Another technique to detect motion is to select a number of strategic image segments, measure the Doppler velocity or energy of each, and add up the velocity vectors. If there is a moving structure in the body in one of the segments, it will be averaged out by the other vectors and produce a small vector, while if the transducer is moving, the sum of the vectors will be relatively large. One possible placement of the image segments used to detect transducer motion is a selection of image segments in the near-field of the image, as shown in FIG. **10**. Such a placement minimizes the effect of normal motion of organs within the body causing false transducer motion detection.

[**0075**] If the determined overall image movement vector is greater than a predetermined threshold (i.e., the motion is consistent with the flick of the sonographer's wrist or a rapid up-down motion of the transducer as distinguished from a motion consistent with the sonographer merely changing the position of the transducer to obtain a different view of the region being observed of the patient), the processor **21** acquires additional image data and the processor starts a timer, not shown, in the CPU **32** (FIG. **3**), Step **808**.

[**0076**] Again the scanner acquires image data to generate an image **30**, **30'**, Step **810**. The processor **21** partitions the generated image into a plurality of segments, not shown, for each segment the processor determines a movement vector, and from the plurality of vectors, the processor determines the overall image motion vector, Step **812**.

[**0077**] If the determined overall image movement vector is greater than a predetermined threshold (i.e., the motion is consistent with the flick of the sonographer's wrist or a rapid up-down motion of the transducer as distinguished from a motion consistent with the sonographer merely changing the position of the transducer to obtain a different view of the region being observed of the patient), and the timer has not expired, i.e., the overall motion has not exceeded a predetermined time, (i.e., the processor **21** has determined a sequence of two motions, the processor **21** compares the motion vector to the vectors stored in TABLE I and the information from TABLE I is used by TABLE II, Step **816** to provide the corresponding control to the workstation Step **818**. Also, the light and/or buzzer **27** is activated to provide a visual and/or audible indication to the sonographer that the command has been completed.

[**0078**] It should be noted that the method described above compares types of motions imparted by the operation. Further, the method described above compares imparted motion with a level threshold. Still further, the method described above compares imparted motion with a time duration threshold. Thus, the method described above comprises detecting patterns of motion of the transducer, and converting the patterns to the control signals. The detection is performed by detecting patterns of change in real time images and/or real time Doppler frequency shift information provided by the system. Further, timing of the motion is used to discriminate between motion intended to provide the control signals and motion normally occurring during scanning. It should be understood that patterns of direction of the transducer motion may used to discriminate between motion intended to provide the control signals and motion normally occurring during scanning. Likewise, timing of the motion is used to discriminate between motion intended to provide the control signals and motion normally occurring during scanning, or a combination of timing and direction may be used for such discrimination.

[**0079**] A number of embodiments of the invention have been described. Nevertheless, it will be understood that various modifications may be made without departing from the spirit and scope of the invention. For example, other commands may be used such as, for example: The operator may press the transducer slightly down and back up to the original position. The detection of this may be mapped to the action of moving to the next step in a protocol driven exam; the operator may move the transducer slightly left and back right to the original position. This may be mapped to pressing the image store key; the operator may move the transducer slightly left and back right to the original position. This may be mapped to increasing the image depth. The operator may remove the transducer from the patient and re-apply it causing the current calculation package to advance to the next measurement. The operator may move the transducer back and forth twice in a "double-wiggle or flick" motion, then stop. This could be mapped to starting or stopping a clip store. Any of the above motions or any detectable intentional motion could be mapped to any desirable operator action or set of actions. Any of the above motions or any detectable intentional motion could be used to start/stop voice control listening. Any of the above motions or any detectable intentional motion could be used to step through a sequence of preset imaging control sets. In combination with some starting action, the motion of the transducer in one axis could be mapped to adjusting the value of a control over a given range. In combination with some starting action, the motion of the transducer in two different axes could be mapped to adjustment of two control values over two given ranges. In combination with some starting action, detection of image change on two axis could be mapped to the movement of an on screen cursor used to interact with on-screen control elements. Moving the transducer in the third axis could be mapped to selections of the control the cursor is over. Further, while the embodiments described above used an ultrasonic handheld imaging transducer, the methods described above may be applied to other types of handheld imaging transducers. Further, other positionable transducers such robotically, or remotely movable transducers may be used. Accordingly, other embodiments are within the scope of the following claims.

[**0080**] In addition to patterns of transducer motion while the transducer is on the patient body, sequences of transducer motion on and off of the body, or motions of the sonographer tapping on the transducer face with a finger or other object may also be used to trigger command signals. When used in this manner, the transducer surface area may be divided into a number of control regions, each region having a different control signal meaning. The length of time of a tap on the transducer face (or head) or the position of the tap on the transducer face (or head) can be used to distinguish different tap types, allowing a binary (or greater) encoding of control signals meanings. For example, two taps on the left end of the transducer followed by one tap on the right can map to selecting a specific exam type. This embodiment allows for the triggering of commands without the sonographer having to remove the transducer from the patient, which would disrupt the exam.

[0081] When a sonographer picks the transducer and introduces a finger or palm as a reflective body, the system will interpret this reception, which exceeds a predefined threshold level, as a signal to activate the color. If one desires, one may further elaborate on this kind of binary encoding to include sequences of free-space and solid-body signals into a Morse logic. Furthermore, the transducer surface area may be divided into N regions to simulate an N part touch sensor to enhance its user-interface capabilities.

[0082] Table III shows an exemplary two region transducer and some command signals that are map-able to particular motions on the transducer.

TABLE III

Action	Region 1	Region 2	Command Signal
Lift the transducer	No touch	No touch	System is prepared for command mode
Lifted transducer	Touch	No touch	Command 1
Lifted transducer	Touch	Touch	Command 2
Lifted transducer	No touch	Touch	Command 3

[0083] Another embodiment of employing a transducer as user-interface is the employment of a calibrated passive substrate comprised of a specific map of echo signatures. This substrate can be a strip of material that is placed near the patient or worn by the sonographer in such a way that the movements of the transducer are minimized. A reception of a distinct signature can signify a desired state and trigger a state change, e.g., the start or stop of an ultrasound exam. A transition between distinct signatures by the movement of the transducer over adjacent parts of the substrate can encode parameter quantity changes. The acceleration of this transition may further signify the magnitude of that quantity change. Table IV illustrates an example of scanning a substrate or material other than a patient with a transducer to trigger a command signal or input data.

TABLE IV

Action	Substrate	Command
Lift the transducer	No contact	System is prepared for command mode
Lifted transducer	Placed on MO substrate	Command 1 (Open Study Utility Page)
Lifted transducer	Placed on Network Cable	Command 2 (Output study data to storage media or network)

[0084] While the invention has been described above by reference to various embodiments, it should be understood that many changes and modifications can be made without departing from the scope of the invention. It is therefore intended that the foregoing detailed description be regarded as illustrative rather than limiting, and that it be understood that it is the following claims, including all equivalents, that are intended to define the spirit and scope of this invention.

What is claimed is:

1. A method for providing an operational command signal to a workstation of an imaging system, said workstation being provided imaging data from a positionable transducer, comprising: converting at least one of a predetermined plurality of motion patterns imparted by an operator of the system to the transducer into said operational command signal.

2. The method of claim 1 wherein said converting comprises:

detecting said at least one motion pattern; and

converting said at least one motion pattern into said operational command signal.

3. The method of claim 2 wherein said detecting comprises comparing a sequence of images formed by the system.

4. The method of claim 3 further comprising determining from the sequence of images whether motion imparted to the transducer was either a repositioning of the transducer to produce a different image to be observed by the operator or a motion imparted to produce the command signal to the workstation.

5. The method of claim 4 wherein said determining includes comparing types of motions imparted by the operation.

6. The method of claim 4 wherein said determining includes comparing imparted motion with a level threshold.

7. The method of claim 4 wherein said determining includes comparing imparted motion with a time duration threshold.

8. The method of claim 4 wherein said determining includes comparing imparted motion with an acceleration threshold.

9. A method for providing control signals to a workstation of an imaging system, said workstation being provided imaging data from a positionable transducer, comprising detecting patterns of motion of the transducer, and converting said patterns to said control signals.

10. The method of claim 9 wherein the detection is performed by detecting patterns of change in real time images provided by the system.

11. The method of claim 10 wherein when motion is detected, timing of the motion is used to discriminate between motion intended to provide the control signals and motion normally occurring during scanning.

12. The method of claim 9 wherein patterns of direction of the transducer motion is used to discriminate between motion intended to provide the control signals and motion normally occurring during scanning.

13. The method of claim 11 wherein patterns of direction of the transducer motion is used to discriminate between motion intended to provide the control signals and motion normally occurring during scanning.

14. The method of claim 4 wherein said motion is imparted by tapping on a transducer face rather than moving said transducer.

15. The method of claim 5 wherein said transducer face is divided into a number of regions, each of said regions corresponding to a distinct map-able control signal.

16. An imaging system comprising:

a workstation;

a positionable transducer for providing imaging data to the workstation;

wherein said workstation responds to operational command signals; and

wherein the workstation includes a memory for storing a table mapping detected motion of the transducer into said command signals.

17. The system of claim 16 wherein said workstation includes a processor programmed to detect at least one of a predetermined plurality of motion patterns and convert said detected at least one motion pattern into said operational command signal.

18. The system of claim 17 wherein said detecting comprises comparing a sequence of images formed by the system.

19. The system of claim 18 wherein the processor is programmed to determine from the sequence of images whether the motion imparted to the transducer was either a repositioning of the transducer to produce a different image to be observed by the operator or a motion imparted to produce the command signal to the workstation.

20. The system of claim 18 wherein said determining includes comparing types of motions imparted by the operation.

21. The system of claim 18 wherein said determining includes comparing imparted motion with a level threshold.

22. The system of claim 18 wherein said determining includes comparing imparted motion with a time duration threshold.

23. The system of claim 16 wherein the transducer has deposed within a housing thereof motion sensors.

24. The system of claim 16 therein wherein motion of the transducer is sensed by sensors remote from the transducer.

25. An imaging system comprising:

a workstation;

a positionable transducer for providing imaging data to the workstation;

wherein said workstation responds to control signals; and

wherein the workstation includes a processor for detecting patterns of motion of the transducer, and converting said patterns to said control signals.

26. The system of claim 25 wherein the detection is performed by detecting patterns of change in real time images provided by the system.

27. The system of claim 26 wherein when motion is detected, timing of the motion is used to discriminate between motion intended to provide the control signals and motion normally occurring during scanning.

28. A method for providing an operational command signal to a workstation of an imaging system comprising:

converting at least one predetermined motion imparted by an operator of said system to at least one of a predetermined region of interest on a surface of a transducer into said operational command signal, wherein said surface of said transducer is partitioned into a plurality of said predetermined regions of interest.

29. A method for providing an operational command signal to a workstation of an imaging system comprising:

converting an echo signature of a substrate into said operational command signal, wherein said echo signature is generated upon contact of said substrate with a transducer.

30. The method of claim 29 wherein said substrate is worn by a sonographer.

* * * * *

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(54) **STERILE NETWORKED INTERFACE FOR MEDICAL SYSTEMS**

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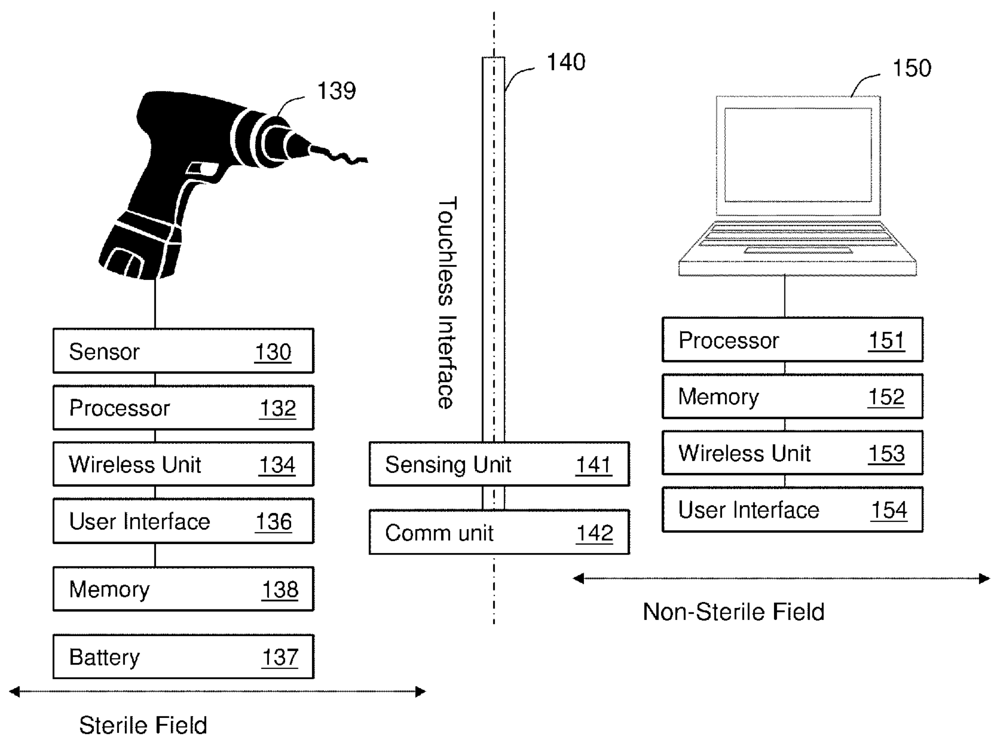
G09G 5/00	(2006.01)

(52) **U.S. Cl.** **345/156**; 606/1; 715/863

(57) **ABSTRACT**

One embodiment of a sterile networked interface system is provided comprising a hand-held surgical tool and a data processing system. The surgical tool includes a sensor for sensing a physical variable related to the surgery, a wireless communication unit to transmit the physical variable to the data processing system, and a battery for powering the hand-held surgical tool. The surgical tool sends the physical variable and orientation information responsive to a touchless gesture control and predetermined orientation of the surgical tool. Other embodiments are disclosed.



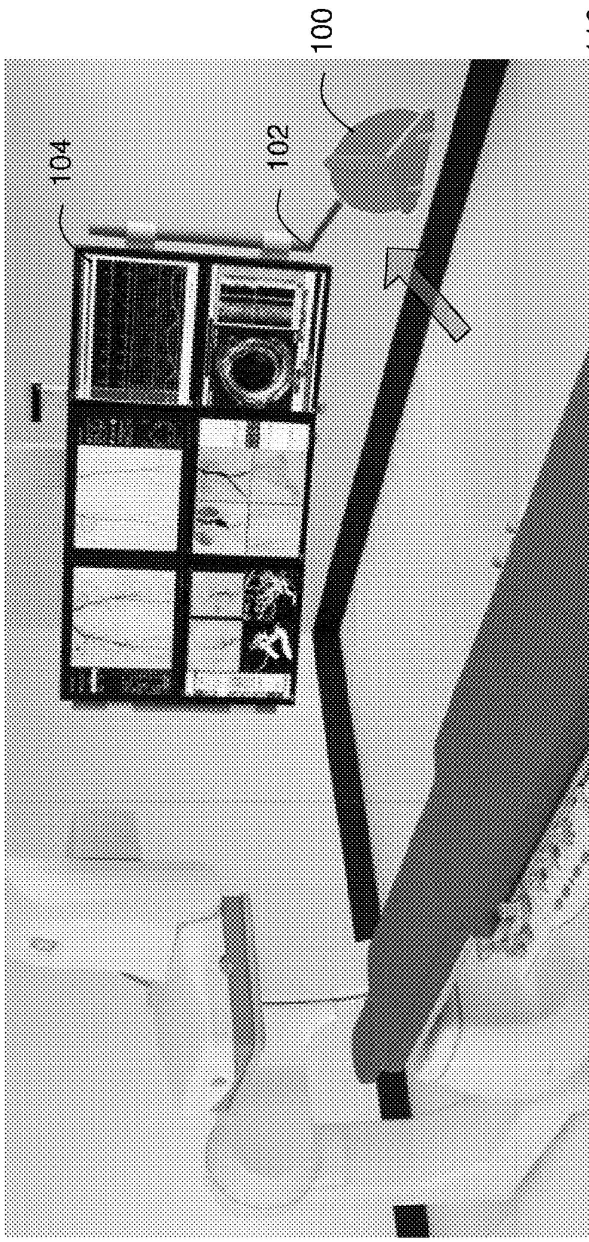


FIG. 1A

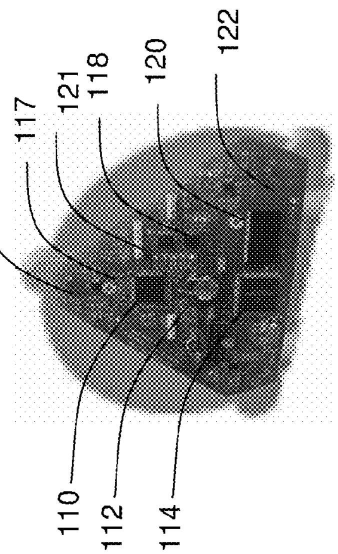


FIG. 1B

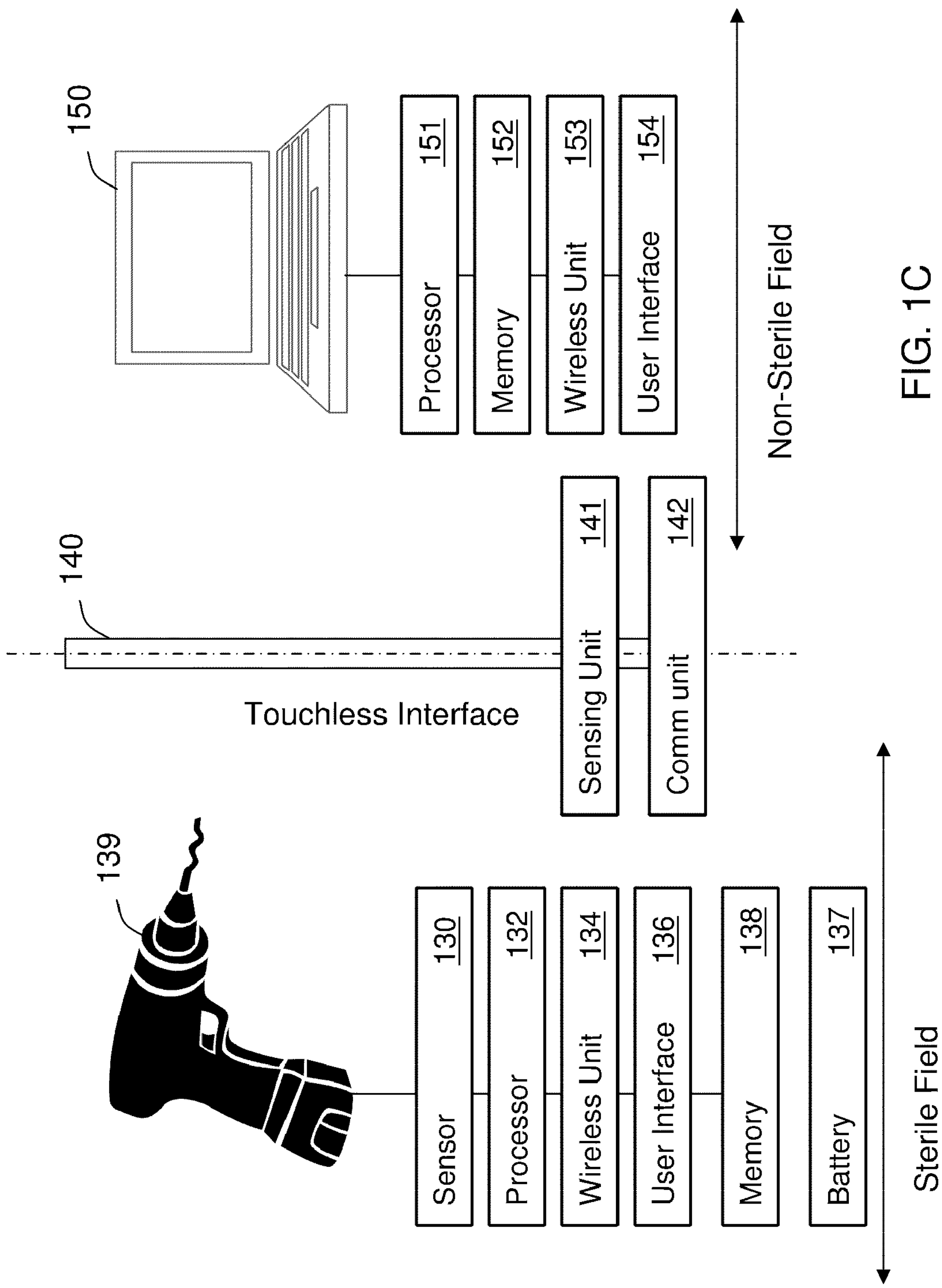

150
Processor 151
Memory 152
Wireless Unit 153
User Interface 154
Non-Sterile Field
140
Touchless Interface
Sensing Unit 141
Comm unit 142
139
Sensor 130
Processor 132
Wireless Unit 134
User Interface 136
Memory 138
Battery 137
Sterile Field

FIG. 1C

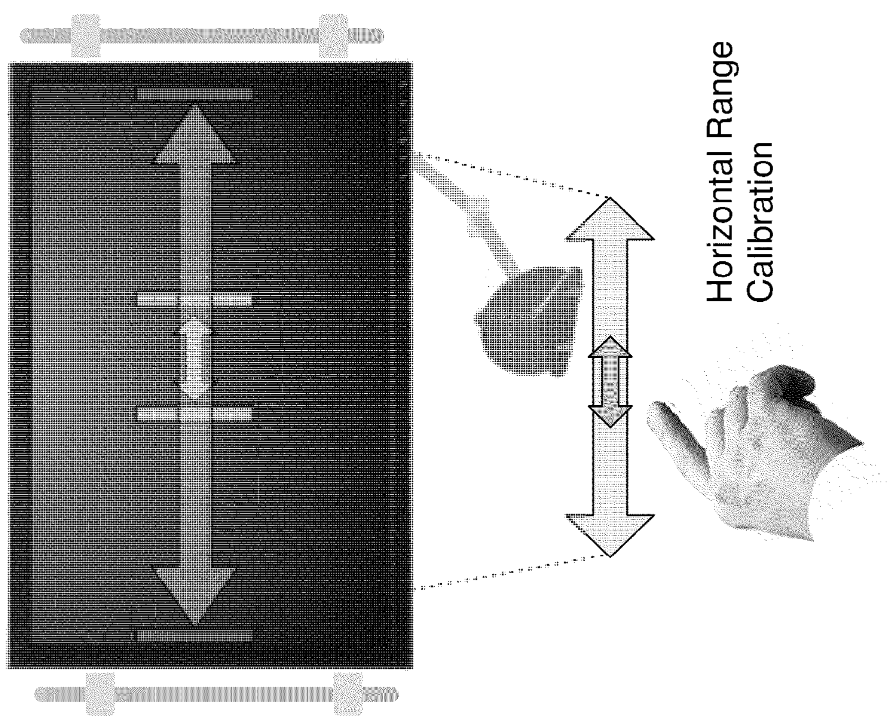

Horizontal Range
Calibration

FIG. 2A

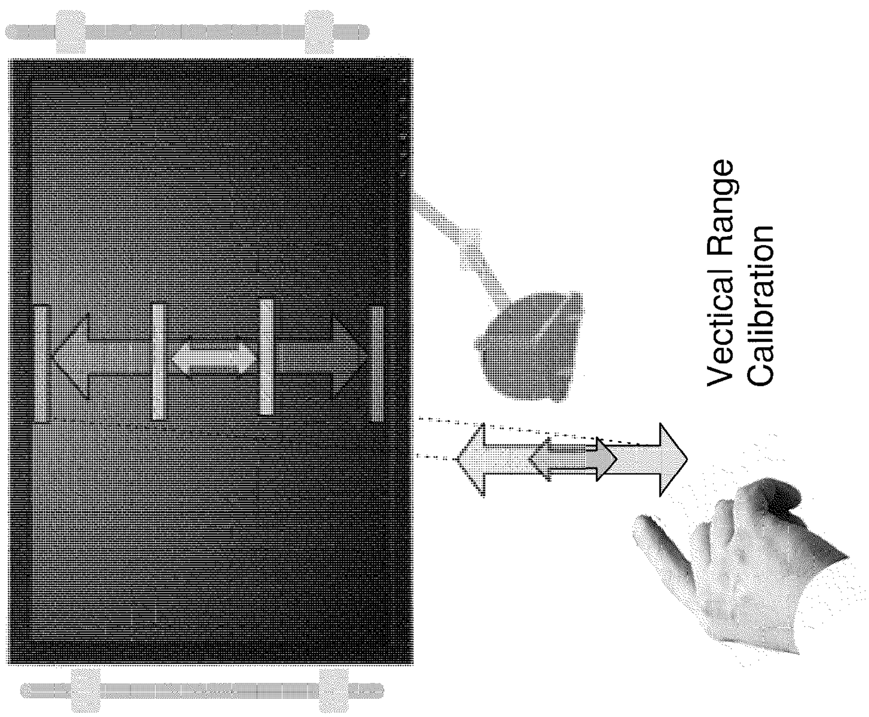

Vectical Range
Calibration

FIG. 2B

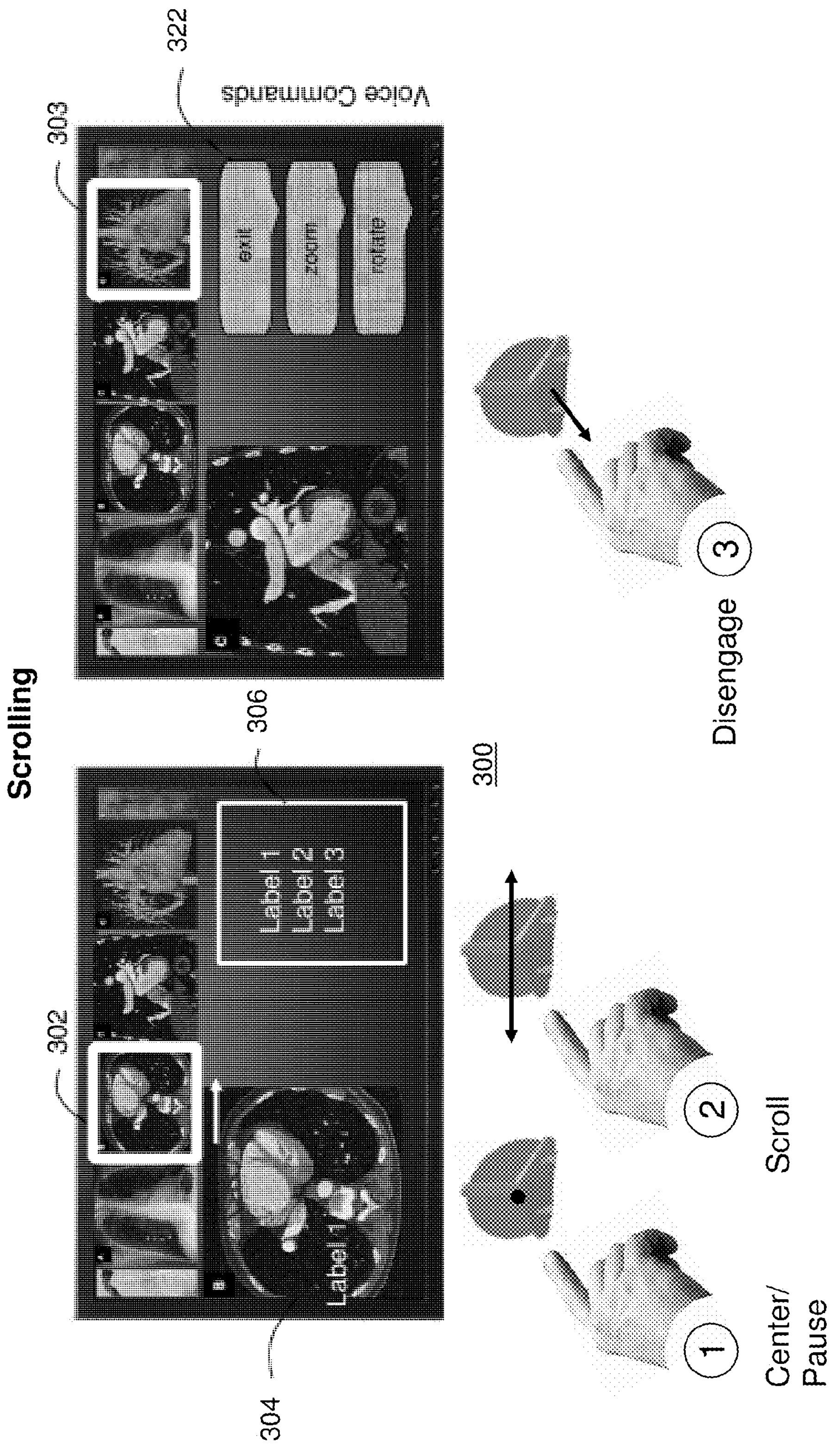
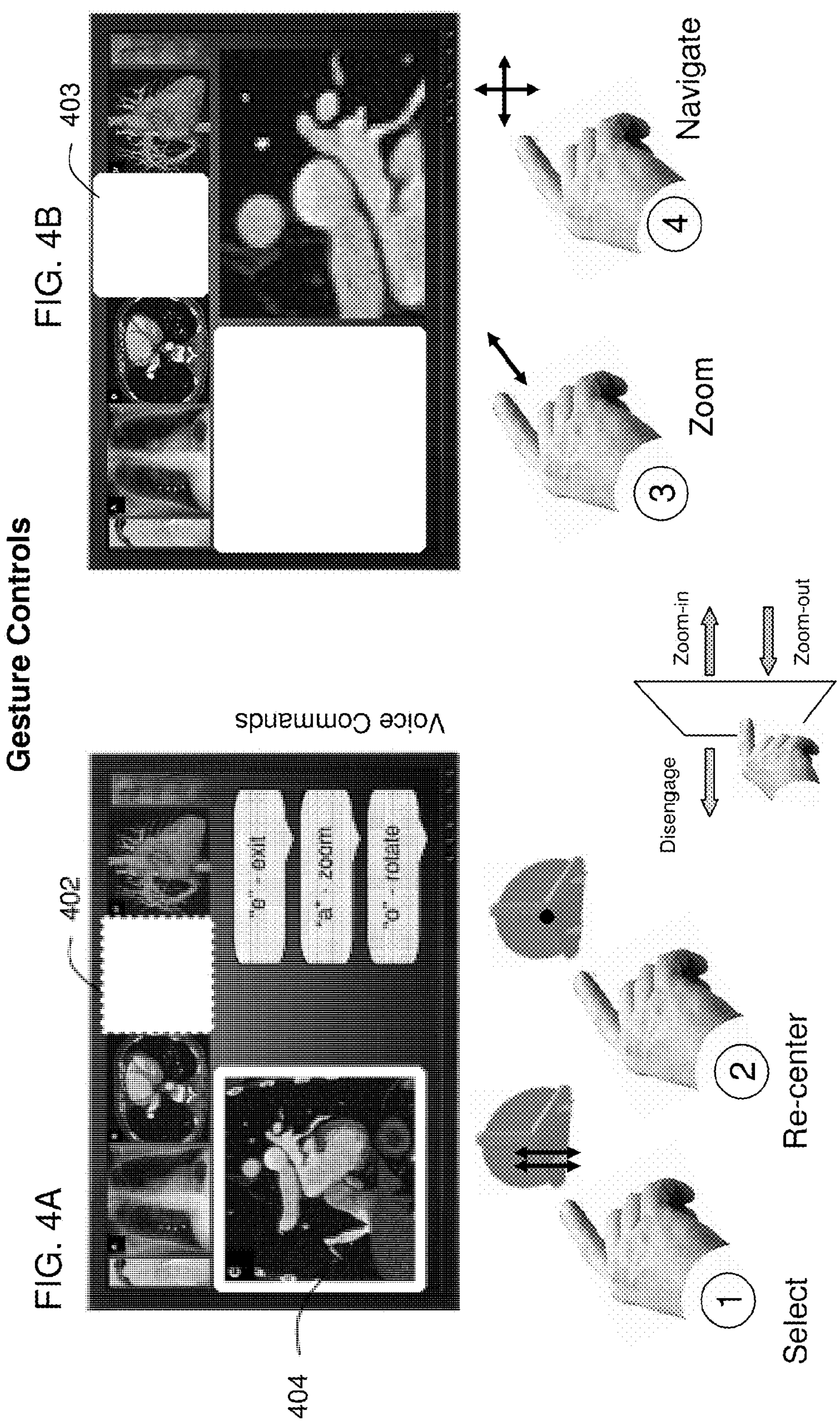

Scrolling
302
303
304
306
322
300
Label 1
Label 1
Label 2
Label 3
exit
zoom
rotate
Voice Commands
1
Center/
Pause
2
Scroll
3
Disengage

FIG. 3A

FIG. 3B


Gesture Controls
FIG. 4A
402
404
Voice Commands
"e" - exit
"a" - zoom
"o" - rotate
Disengage
Zoom-in
Zoom-out
1
Select
2
Re-center
FIG. 4B
403
3
Zoom
4
Navigate

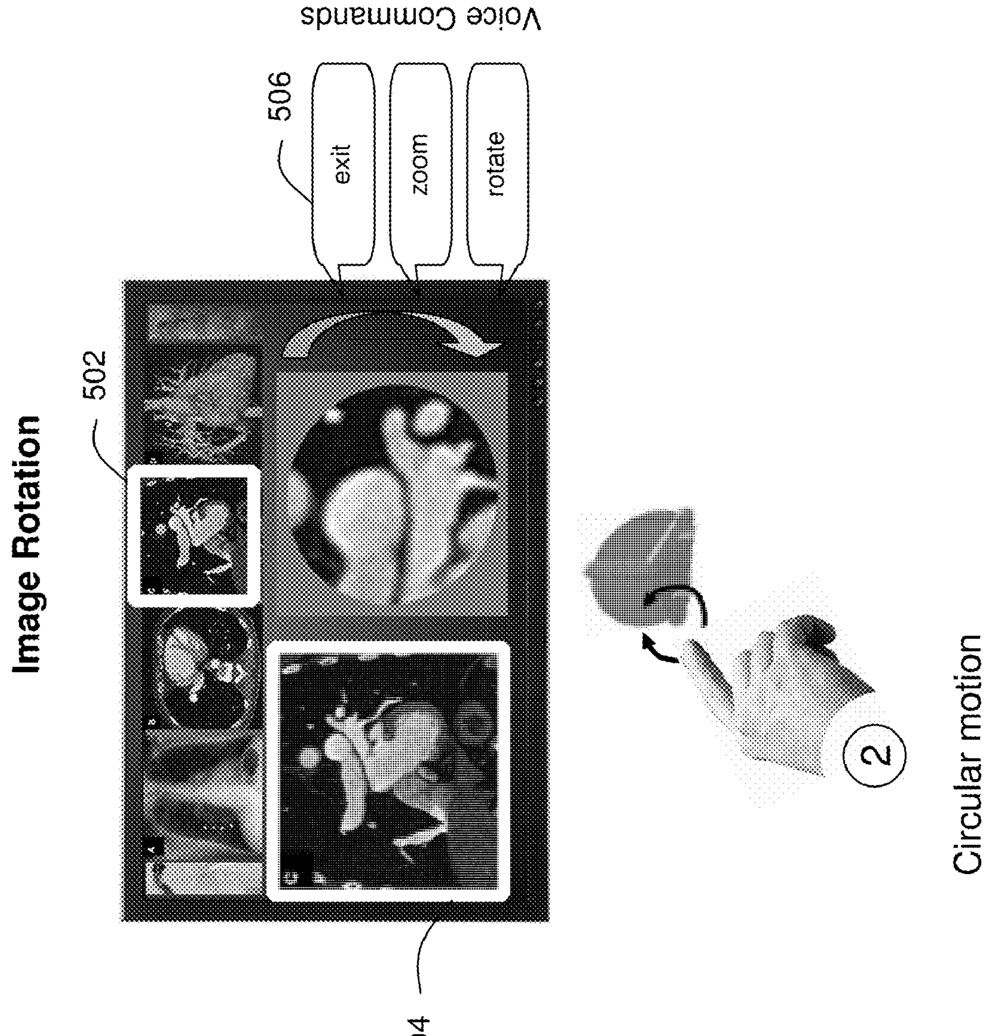


Image Rotation
502
504
506
exit
zoom
rotate
Voice Commands
2
Circular motion

FIG. 5

STERILE NETWORKED INTERFACE FOR MEDICAL SYSTEMS

CROSS-REFERENCE TO RELATED APPLICATION

[0001] This application claims the priority benefit of U.S. Provisional Patent Application No. 61/159,793 filed Mar. 12, 2009, the entire contents of which are hereby incorporated by reference. This application also incorporates by reference the following Utility Applications:

FIELD

[0002] The present embodiments of the invention generally relate to the field of hospital systems, more particularly medical device data processing and control.

BACKGROUND

[0003] As data becomes more readily available in hospitals and clinics, doctors and patients have more information to process. Computer systems and medical devices provide an interface which allows them to retrieve, interpret and display the information. In the operating room environment, computer systems are generally outside the surgical field and operated by a technician. Electronic surgical tools are providing the surgeon with new means for performing surgery. Although the medical devices may communicate with the computer system there still lacks an intuitive user interface which allows the surgeon to retrieve information.

BRIEF DESCRIPTION OF THE DRAWINGS

[0004] The features of the embodiments of the invention, which are believed to be novel, are set forth with particularity in the appended claims. Embodiments of the invention, together with further objects and advantages thereof, may best be understood by reference to the following description, taken in conjunction with the accompanying drawings, in the several figures of which like reference numerals identify like elements, and in which:

[0005] FIG. **1**A is an exemplary illustration of an operating room system configured for touchless user interface control according to one embodiment;

[0006] FIG. **1**B is an exemplary illustration of a sensory device for processing touchless movements and gesture control according to one embodiment;

[0007] FIG. **1**C is an exemplary illustration of a sterile networked interface system according to one embodiment;

[0008] FIGS. **2**A and **2**B are exemplary illustrations for user interface calibration according to one embodiment;

[0009] FIG. **3**A is an exemplary depiction for touchless user interface scrolling according to one embodiment;

[0010] FIGS. **4**A and **4**B are exemplary depictions for touchless user interface gesture controls according to one embodiment; and

[0011] FIG. **5** is an exemplary depiction for touchless user interface image analysis and feedback according to one embodiment.

DETAILED DESCRIPTION

[0012] While the specification concludes with claims defining the features of the invention that are regarded as novel, it is believed that the invention will be better understood from a consideration of the following description in conjunction with the drawing figures, in which like reference numerals are carried forward.

[0013] As required, detailed embodiments of the present invention are disclosed herein; however, it is to be understood that the disclosed embodiments are merely exemplary of the invention, which can be embodied in various forms. Therefore, specific structural and functional details disclosed herein are not to be interpreted as limiting, but merely as a basis for the claims and as a representative basis for teaching one skilled in the art to variously employ the present invention in virtually any appropriately detailed structure. Further, the terms and phrases used herein are not intended to be limiting but rather to provide an understandable description.

[0014] The terms a or an, as used herein, are defined as one or more than one. The term plurality, as used herein, is defined as two or more than two. The term another, as used herein, is defined as at least a second or more. The terms including and/or having, as used herein, are defined as comprising (i.e., open language). The term coupled, as used herein, is defined as connected, although not necessarily directly, and not necessarily mechanically. The terms program, software application, and the like as used herein, are defined as a sequence of instructions designed for execution on a computer system. A program, computer program, or software application may include a subroutine, a function, a procedure, an object method, an object implementation, an executable application, a source code, an object code, a shared library/dynamic load library and/or other sequence of instructions designed for execution on a computer system or embedded electronic device.

[0015] FIG. **1**A shows an exemplary sterile networked interface in an operating room environment comprising a touchless sensing device **100** and a data processing system **104** display. The sensing device **100** permits the surgeon a sterile user interface for interacting and viewing operational data, processing medical information, and viewing surgical tool functionality. It may be positioned 1-2 feet within reach. It can also be placed farther out of the sterile field. As will be described ahead, the touchless sensing device **100** in various embodiments permits the surgeon the ability to scroll, select, rotate and save data via touchless gestures, and in certain embodiments, update operational tool parameters in accordance with a predetermined work flow. Although shown as a separate unit, the touchless sensing device **100** can be configured peripheral to the display or positioned above. One example of an arrangement is disclosed in U.S. patent application Ser. No. 11/683,416, the entire contents of which are hereby incorporated by reference. The touchless sensing device **100** can comprise infrared sensors, ultrasonic sensors, camera elements or a combination thereof as therein specified.

[0016] FIG. **1**B is an exemplary illustration of the components of the touchless sensing device **100** according to one embodiment. The sensing device **100** can include a transmitter **112**, three or more receivers **122** (at the corners), a Digital Signal Processor (DSP) **110** to process sensory information from the receivers **122**, a communications module (e.g., BlueTooth, ZigBee, or other IEEE protocol), a memory **120**, and one or more analog to digital converters and digital to analog converters **118**. Operation of the touchless sensing unit in various configurations for achieving touchless sensing are disclosed in the following U.S. patent applications, all of which are hereby incorporated by reference in their entirety: 11/559,295; 11/559,325; 11/562,404; 12/146,445.

[0017] The touchless sensing device **100** in the configuration shown includes an optical camera element **117** to image an anatomical feature in the sterile field, an ultrasonic transducer **112** to measure a distance to the anatomical feature that is associated with the physical variable, and an accelerometer **121** for identifying an axial tilt and movement. This information can be used by the data processing system in accordance with touchless user input to report proper use and orientation of the surgical tool. As one example, the processor configures one or more of its operational parameters responsive to analyzing the anatomical feature of interest and determining a proper working angle from the orientation.

[0018] FIG. **1**C is a diagrammatic illustration of an exemplary sterile networked interface system. The sterile networked interface system comprises a hand-held surgical tool **139** used within a sterile field during surgery, a touchless interface **140**, and a data processing system **104** outside the sterile field and wirelessly coupled to the surgical tool. The surgical tool comprises a sensor **130** for sensing a physical variable related to the surgery, a wireless communication unit **134** to transmit the physical variable, and a battery **139** for powering the hand-held surgical tool. It is not limited to these features and may include other components of a surgical tool, for example, a processor **132** a user interface **116** and associated memory **138**. It can also include a drill, a saw, a rotor, a stator or other mechanical hardware. The data processing system **150** receives the physical variable and orientation information reported from and related to the hand-held surgical tool during the surgery.

[0019] The surgical tool **139** communicates a physical variable associated with the surgical procedure to the data processing system **104** responsive to the sensing unit **110** detecting a touchless gesture control and predetermined orientation of the surgical tool **109**. The sensing unit **141** (see processor **114** of FIG. **1**B) detects touchless gestures of re-centering, accelerated movements, left-right movements, up-down movements, and zoom in and out movements. Touchless finger pointing and hand gestures control aspects of a user interface presented through the data processing system **104**. Aspects of touchless sensing are disclosed in issued U.S. Pat. No. 7,620,316 which is incorporated by reference in its entirety.

[0020] In another configuration, the hand-held surgical tool **139** includes the touchless sensing device as the user interface component **136** thereon for use within a sterile field during surgery. The hand-held surgical tool **139** comprises the sensor **130** for sensing a physical variable related to the surgery, the wireless communication unit **134** to transmit the physical variable, the battery **137** for powering the hand-held surgical tool. The touchless sensing unit on the hand-held surgical tool identifies a location and movement of a finger or hand gesture, and the processor **132** communicates the physical variable from the hand-held surgical tool **139** to the data processing system **150** responsive to the touchless gesture control and predetermined orientation of the surgical tool. The hand-held surgical tool **139** sends physical variable and orientation information to the data processing system **150** outside the sterile field that is wirelessly coupled to the surgical tool, and that provides operative directives back to the surgical tool for performing a work flow procedure of the surgery based on the physical variable and orientation.

[0021] The touchless user interface **150** comprises a sensing unit **141** for identifying a location and movement of a finger or hand gesture; a processor to operate display information for touchless sensing, touchless image scrolling, selection, and saving, touchless gesture controls, and touchless image rotation; and a communications interface **142** for sending the location and movement to a display of the data processing system for controlling a user interface of the hand-held surgical tool. The data processing system **150** can include a processor **151**, a memory **152**, a wireless unit **153** and user interface **154**. The touchless sensing device **100** provides 1) display calibration for touchless sensing, 2) touchless thumbnail Scrolling, 3) touchless gesture controls, 4) touchless image rotation, 5) small vowel recognition vocabulary for enhanced interface control, and 6) pointing to image features with drag & drop labeling.

[0022] One aspect of range detection and positioning determination as described below are disclosed in issued U.S. Pat. No. 7,414,705 which is incorporated by reference in their entirety. As one particular example, the sensor comprises a pulse shaper for producing a pulse shaped signal, the pulse shaped signal intended for reflecting off an anatomical feature to produce a reflected signal, wherein at least one portion of the pulse shaped signal is at least one among a frequency modulated region, constant frequency region, phase modulated region, and a chirp region, a phase detector for receiving and identifying a relative phase of the reflected signal with respect to a previously received reflected signal, and a processor operatively coupled to the pulse shaper for receiving the reflected signal, tracking a location and a movement of the hand-held surgical tool from an estimated arrival time of the reflected signal and the relative phase, and providing the physical variable to a user interface control in accordance with the location and the movement of the hand-held surgical tool. The processor estimates the location of the first object from a frequency modulated region of the reflected signal, and a velocity of the first object from the relative phase from a continuous frequency region of the reflected signal and responsive to a touchless gesture control and predetermined orientation of the surgical tool communicates the physical variable from the hand-held surgical tool to the data processing system.

[0023] FIGS. **2**A and **2**B shows exemplary calibration steps for setting up the touchless sensing device **100**. The device is calibrated to the display based on the finger range of motion. That is, the dimensions of the touchless sensing space are mapped to the display. For instance, a 6 in left and 6 in right motion (12 inch horizontal span) is mapped to the 30-50 inch wide display range. A 4 in up and 4 in down motion (8 inch vertical span) is mapped to the 20-30 inch display height since screen is rectangular and vertical arm movement may require more lifting (fatiguing) motion. The touchless sensing device **100** can also be used in conjunction with a hand-held device such as a wireless pointer in addition to the previously shown hand-held drill. As illustrated the surgeon pauses finger/hand, then moves finger/hand left and right for desired full range of arm/hand motion. Sensors can also be included in a surgical glove to provide further gesture functionality. The dual bars open during the jitter motion to visually identify the mapped horizontal boundaries. Similarly during height calibration dual bars are shown opening during a left-right jitter motion to visually identify a mapped horizontal boundaries.

[0024] In another embodiment, the touchless sensing unit can be configured for touchless interface control and range detection. In either configuration the sensor identifies a location and movement of a finger or hand gesture, and the communications interface sends the location and movement to a display device of the data processing system for controlling one or more parameters of the surgical tool **139** by way of the touchless user interface **150**. The touchless sensing unit communicates a physical variable captured during a surgical procedure from the surgical tool to the data processing system for presentation in the display responsive to a touchless gesture control and predetermined orientation of the surgical tool. As one example, the user pauses the surgical tool **139** at a certain angle and with the other hand points to the screen. The accelerometer identifies an axial tilt and movement. The processor references the orientation of the hand-held surgical tool with respect to a coordinate system established by the anatomical feature position, tilt and movement. The interface isolates and displays a point of interest, for example, an anatomical feature of the patient according to an orientation of the surgical tool. The surgical tool can capture an image of and a distance to the anatomical feature which is reported on the display. Surgical feedback provided via the touchless user interface can then be used to set one or more parameters of the surgical tool **139** for updating the work flow. The sensor can be operatively coupled to the surgical tool. In another embodiment the sensor is operatively coupled to the data processing system apart from the tool. As another example, the processor **114** references the orientation of a hand-held surgical tool with respect to the anatomical feature, distance, tilt and movement. The data processing system **150** provides operative directives to the surgical tool in accordance with a predetermined work flow that takes into account the physical variable.

[0025] FIGS. **3**A and **3**B shows a thumbnail scrolling user interface on the screen **300**. The screen can include a variable or fixed number of thumbnail images **302** on the top row. To refresh more images, surgeon can re-center (**1**) the finger once its pointed to the far left or right of reach. As another example, the system can have 10 thumbnail images **302** in a buffer, but only show 5 at a time, where the entire 10 images are mapped to the surgeon's full horizontal hand motion to permit scrolling of the 10 images. The active image (the one pointed too) can have a colored box outline for example. That image can be actively displayed in the lower left corner **304** as the surgeon fingers across (scrolls 2) thumbnail images. The surgeon can disengage (3) via retracted finger movement or voice command.

[0026] One example method of thumbnail scrolling five (5) thumbnail images fixed on the display, includes method steps where the surgeon raises and centers finger/hand and pauses for a brief moment (e.g., 1 second) in front of the touchless sensing device **100** to indicate readiness, a border **302** will be displayed indicating touchless control acquired. The surgeon moves their finger/hand left or right to scroll through images. An actively selected image will be outlined by border box and will enlarge in (e.g., left main) display area. The surgeon retracts finger/hand to disengage touchless control, which leaves active image enlarged. Alternatively, surgeon can say a word to disengage (exit) touchless control via voice recognition applications. One example of voice recognition combined with touchless sensing is disclosed in U.S. patent application Ser. No. 12/120,654, the entire contents of which are hereby incorporated by reference.

[0027] FIGS. **4**A and **4**B show exemplary touchless gesture controls for the user interface on the screen **400**. To select an image the surgeon can perform a brief up/down (~1 inch) finger motion. In an alternate configuration, the surgeon can do brief right->re-center movements to scroll to the right, and left->re-center movements to scroll left, so the hand can remain sufficiently centered. A simple voice command can be used to start touchless gesture controls, to override touchless control for image thumbnail scrolling as shown. The 3D location at which the surgeon re-centers the finger-hand can establish the reference zoom plane. The surgeon can slowly move the finger forward (in) to zoom in. Then, the surgeon can slowly move finger back to zoom-out back to the reference zoom plane.

[0028] One example method of gesture control comprises steps where the surgeon jitters the finger/hand up and down to select the image. The thumbnail border turns green and flashes to indicate a waiting state. The surgeon then re-centers and pauses the finger/hand in front of touchless sensing device **100** to acquire gesture control (e.g., thumbnail border then stops flashing and turns solid green indicating ready) Re-centering is also the motion required if the surgeon previously disengaged iPoint control. As one example, the surgeon speaks a voice command to start touchless navigation/zoom, and can then move up/down/left/right to navigate image in conjunction with inward pointing movement to zoom-in on image. (Zoom-out is permitted after zoom-in).

[0029] Means for operation of the touchless sensing unit for gesture control and user interfaces are disclosed in the following U.S. patent applications, all of which are hereby incorporated by reference in their entirety: 11/562,413;11/566,137; 11/566,148; 11/566,156; 11/683,410; 11/683,412; 11/683,413; 11/683,415 and 11/683,416.

[0030] An accelerated retracting finger movement (or voice command) can disable (exit) touchless control thereby temporarily locking the image at the zoom-level and position just prior to the accelerated retracted finger movement. This releases touchless control and permits the surgeon to continue the medical procedure. In order to enable and re-engage touchless control, the surgeon can center and pause the finger/hand in front of the iPoint again. A thumb motion on the same hand an also be performed for control (an action similar to mimicking a thumb trigger). The 3D location at which the surgeon re-centers the finger-hand establishes the reference zoom plane. The surgeon can slowly move the finger forward (in) to zoom in. Then, the surgeon can slowly move finger back to zoom-out back to the reference zoom plane.

[0031] An accelerated retracting finger movement can disable touchless control thereby temporarily locking the image at the zoom-level and position just prior to the accelerated retracted finger movement. This releases touchless control and permits the surgeon to continue the medical procedure. A thumb motion on the same hand can alternatively signal the image lock instead of the accelerated retracting movement). To enable and re-engage touchless control, the surgeon can center and pause the finger/hand in front of the sensing device **100** again. Voice commands can also be used in conjunction with drag and drop labeling. The surgeon can select labels from a user interface **306** which can then be dragged to anatomical features on the image **304**.

[0032] FIG. **5** shows an exemplary touchless user interface application for image rotation. Upon selecting an image **502**, then displayed in a larger window **504**, the surgeon can speak a voice command **506** such as "rotate", to commence touchless rotation controls. The surgeon can then perform touchless clockwise and counter clockwise finger motions to rotate the image. The touchless sensing device **100** translates the finger motions to image translations that rotate the image. The ipoint can identify a finger (or hand) pause to stop rotation and lock to the current rotation to permit surgeon to retract hand. Rotation controls include voice recognition, circular finger motions, and forward and retracting hand motions.

[0033] Means for operation of the touchless sensing unit to detect scrolling, gestures and rotations for controlling user interfaces are disclosed in the following U.S. patent applications, all of which are hereby incorporated by reference in their entirety: 11/839,323; 11/844,329; 11/850,634; 11/850,637; 11/930,014; 11/936,777; 11/936,778; 12/050,790; 12/099,662 and 12/120,654

[0034] The illustrations of embodiments described herein are intended to provide a general understanding of the structure of various embodiments, and they are not intended to serve as a complete description of all the elements and features of apparatus and systems that might make use of the structures described herein. Many other embodiments will be apparent to those of skill in the art upon reviewing the above description. Other embodiments may be utilized and derived therefrom, such that structural and logical substitutions and changes may be made without departing from the scope of this disclosure. Figures are also merely representational and may not be drawn to scale. Certain proportions thereof may be exaggerated, while others may be minimized. Accordingly, the specification and drawings are to be regarded in an illustrative rather than a restrictive sense.

[0035] Such embodiments of the inventive subject matter may be referred to herein, individually and/or collectively, by the term "invention" merely for convenience and without intending to voluntarily limit the scope of this application to any single invention or inventive concept if more than one is in fact disclosed. Thus, although specific embodiments have been illustrated and described herein, it should be appreciated that any arrangement calculated to achieve the same purpose may be substituted for the specific embodiments shown. This disclosure is intended to cover any and all adaptations or variations of various embodiments. Combinations of the above embodiments, and other embodiments not specifically described herein, will be apparent to those of skill in the art upon reviewing the above description.

What is claimed is:

1. A sterile networked interface system comprising

a hand-held surgical tool used within a sterile field during surgery, the surgical tool comprising:

a sensor for sensing a physical variable related to the surgery;

a wireless communication unit to transmit the physical variable; and

a battery for powering the hand-held surgical tool;

a data processing system outside the sterile field wirelessly coupled to the surgical tool for receiving the physical variable and orientation information reported from and related to the hand-held surgical tool during the surgery; and

a touchless interface that responsive to a touchless gesture control and predetermined orientation of the surgical tool communicates the physical variable from the hand-held surgical tool to the data processing system.

2. The sterile networked interface of claim **1** where the touchless user interface comprises:

a sensing unit for identifying a location and movement of a finger or hand gesture; a processor to operate display information for:

touchless sensing,

touchless image scrolling, selection, and saving;

touchless gesture controls, and

touchless image rotation; and

a communications interface for sending the location and movement to a display of the data processing system for controlling a user interface of the hand-held surgical tool.

3. The sterile networked interface of claim **2**, where the processor detects touchless gestures of re-centering, accelerated movements, left-right movements, up-down movements, and zoom in and out movements.

4. The sterile networked interface of claim **1** where the sensor includes

an optical camera element to image an anatomical feature in the sterile field;

an ultrasonic transducer to measure a distance to the anatomical feature that is associated with the physical variable;

and, an accelerometer for identifying an axial tilt and movement; where the processor references the orientation of the hand-held surgical tool with respect to the anatomical feature, distance, tilt and movement.

5. The sterile networked interface of claim **3** where the data processing system provides operative directives to the surgical tool in accordance with a predetermined work flow that takes into account the physical variable.

6. A hand-held surgical tool suitable for use within a sterile field during surgery, the surgical tool comprising:

a sensor for sensing a physical variable related to the surgery;

a wireless communication unit to transmit the physical variable;

a battery for powering the hand-held surgical tool;

a touchless sensing unit on the hand-held surgical tool for identifying a location and movement of a finger or hand gesture; and

a processor to communicates the physical variable from the hand-held surgical tool to a data processing system responsive to the touchless gesture control and predetermined orientation of the surgical tool.

7. The hand-held surgical tool of claim **6** sends the physical variable and orientation information to the data processing system outside the sterile field that is wirelessly coupled to the surgical tool, and that provides operative directives back to the surgical tool for performing a work flow procedure of the surgery based on the physical variable and orientation.

8. The hand-held surgical tool of claim **6**, where the sensor includes

an optical camera element to image an anatomical feature in the sterile field;

an ultrasonic transducer to measure a position of the anatomical feature relative to the hand-held surgical tool that is associated with the physical variable;

and, an accelerometer for identifying an axial tilt and movement; where the processor references the orientation of the hand-held surgical tool with respect to a coordinate system established by the anatomical feature position, tilt and movement.

9. The hand-held surgical tool of claim **6**, where the sensor comprises:

a pulse shaper for producing a pulse shaped signal, the pulse shaped signal intended for reflecting off an anatomical feature to produce a reflected signal, wherein at least one portion of the pulse shaped signal is at least one among a frequency modulated region, constant frequency region, phase modulated region, and a chirp region;

a phase detector for receiving and identifying a relative phase of the reflected signal with respect to a previously received reflected signal, and

a processor operatively coupled to the pulse shaper for receiving the reflected signal, tracking a location and a movement of the hand-held surgical tool from an estimated arrival time of the reflected signal and the relative phase, and providing the physical variable to a user interface control in accordance with the location and the movement of the hand-held surgical tool,

wherein the processor estimates the location of the first object from a frequency modulated region of the reflected signal, and a velocity of the first object from the relative phase from a continuous frequency region of the reflected signal and responsive to a touchless gesture control and predetermined orientation of the surgical tool communicates the physical variable from the hand-held surgical tool to the data processing system.

10. The hand-held surgical tool of claim **6**, where the processor configures one or more of its operational parameters responsive to analyzing the anatomical feature of interest and determining a proper working angle from the orientation.

11. A touchless sensing unit configurable for touchless interface control and range detection, the touchless sensing unit comprising:

a sensor for identifying a touchless location and movement of a finger or hand gesture; and

a communications interface for sending the location and movement to a display device of a data processing system for controlling one or more parameters of a surgical tool by way of a touchless user interface,

where the touchless sensing unit communicates a physical variable captured during a surgical procedure from the surgical tool to the data processing system for presentation in the display responsive to a touchless gesture control of the finger or hand movement and predetermined orientation of the surgical tool.

12. The touchless sensing unit of claim **11**, where the sensor is operatively coupled to the data processing system.

13. The touchless sensing unit of claim **11**, where the sensor is operatively coupled to the surgical tool.

14. The touchless sensing unit of claim **11**, comprising

a wireless communication unit to transmit the physical variable; and

a battery for powering the hand-held surgical tool.

15. The touchless sensing unit of claim **11**, where the sensor includes

an optical camera element to image an anatomical feature in the sterile field;

an ultrasonic transducer to measure a position of the anatomical feature relative to the hand-held surgical tool that is associated with the physical variable;

and, an accelerometer for identifying an axial tilt and movement; where the processor references the orientation of the hand-held surgical tool with respect to a coordinate system established by the anatomical feature position, tilt and movement.

16. The touchless sensing unit of claim **10**, where a display of the data processing system during width calibration shows dual bars open during a left-right jitter motion to visually identify a mapped horizontal boundaries, and during height calibration shows dual bars open during an up-down jitter motion to visually identify a mapped vertical boundaries

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(54) **APPARATUS FOR CARIES DETECTION**

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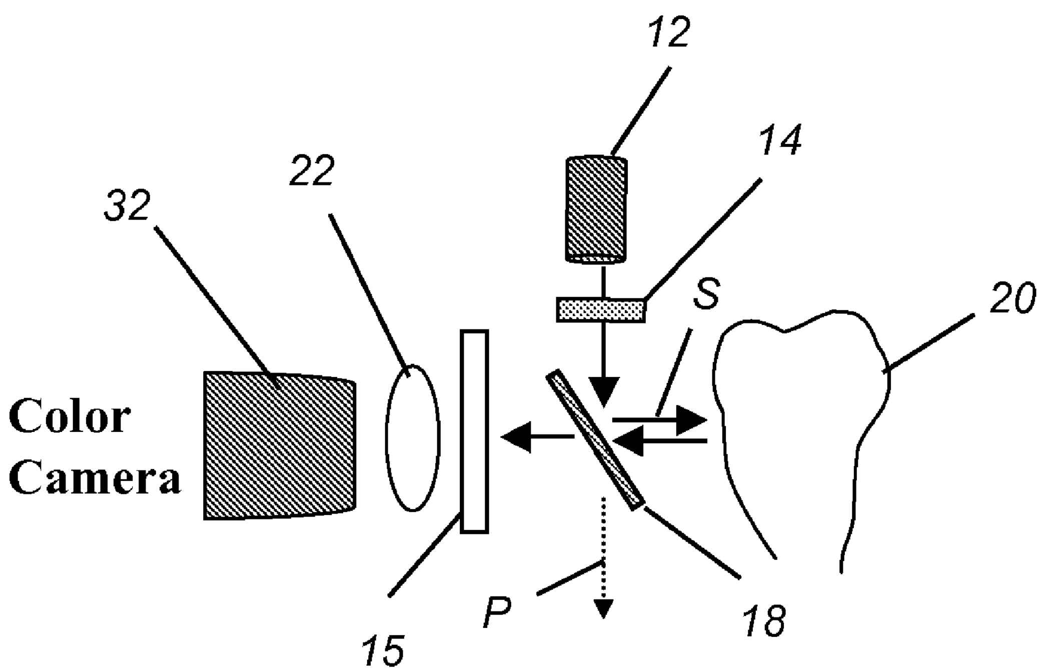
(52) **U.S. Cl.** **433/29**; 433/215

(57) **ABSTRACT**

An apparatus for obtaining an image of a tooth having at least one light source providing incident light having a first spectral range for obtaining a reflectance image (**122**) from the tooth and a second spectral range for exciting a fluorescence image (**120**) from the tooth. A polarizing beamsplitter (**18**) in the path of the incident light from both sources directs light having a first polarization state toward the tooth and directs light from the tooth having a second polarization state along a return path toward a sensor (**68**), wherein the second polarization state is orthogonal to the first polarization state. A first lens (**22**) in the return path directs image-bearing light from the tooth toward the sensor (**68**), and obtains image data from the portion of the light having the second polarization state. A long-pass filter (**15**) in the return path attenuates light in the second spectral range.



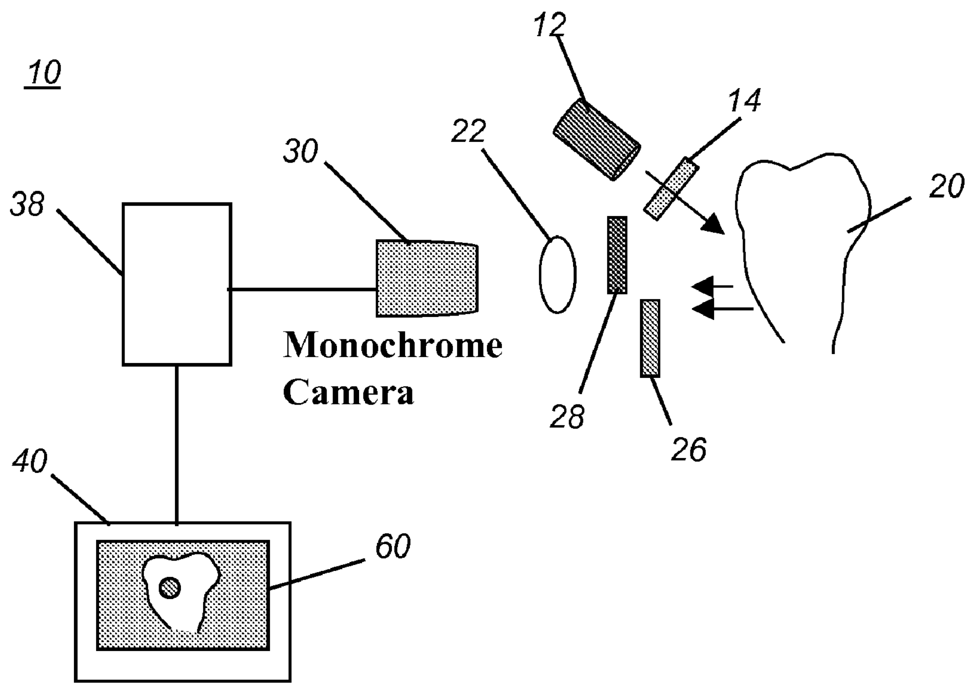


FIG. 1

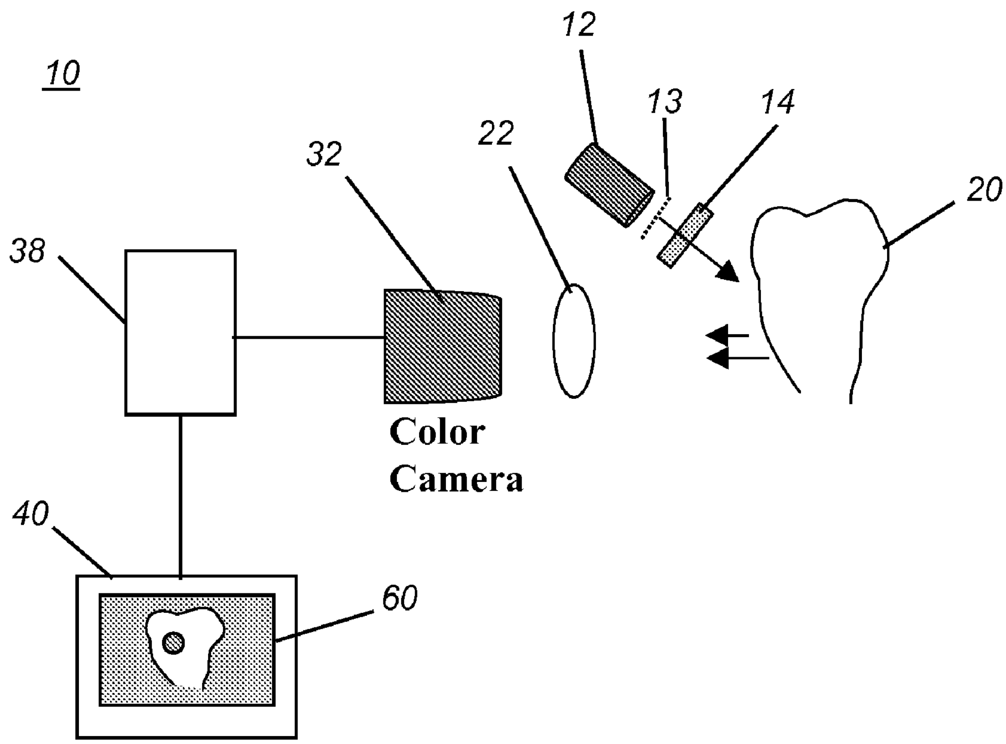


FIG. 2

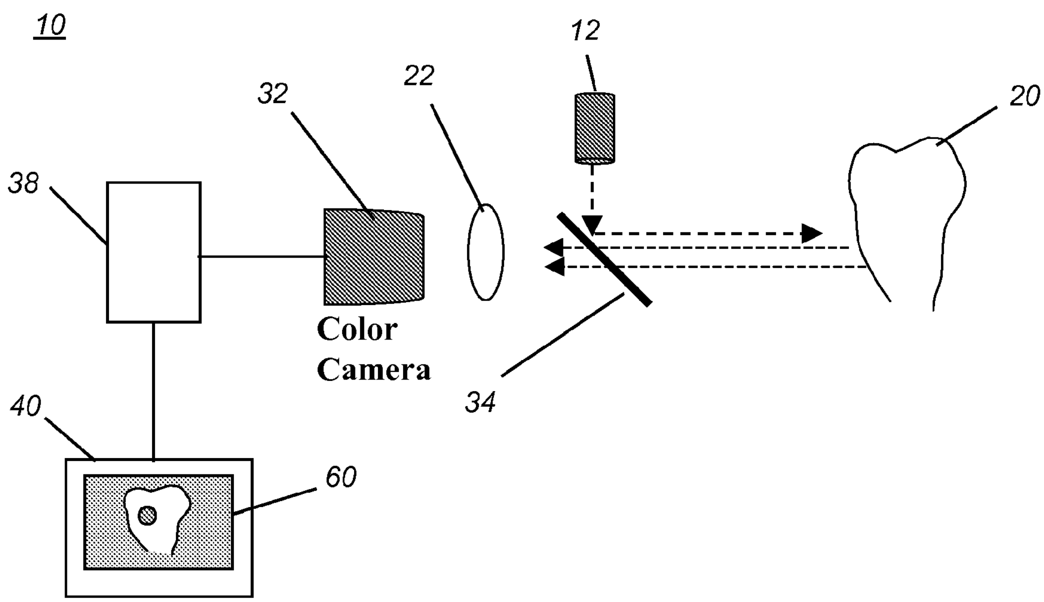


FIG. 3

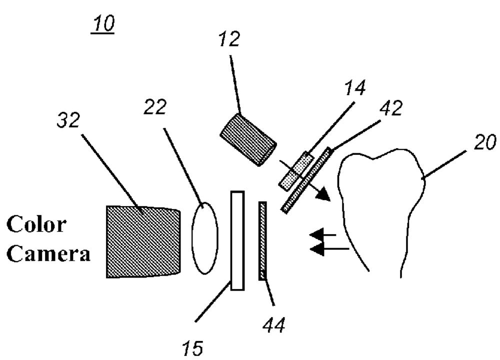
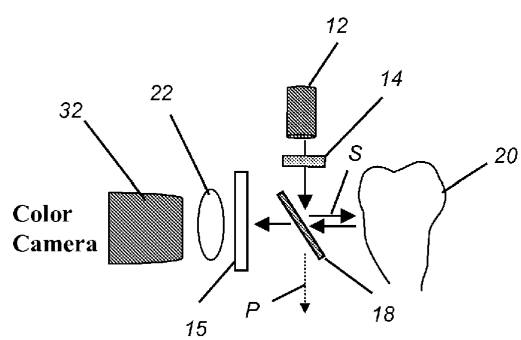

10
12
14
42
32
22
20
Color Camera
15
44

FIG. 4A


12
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32
22
S
20
Color Camera
15
P
18

FIG. 4B

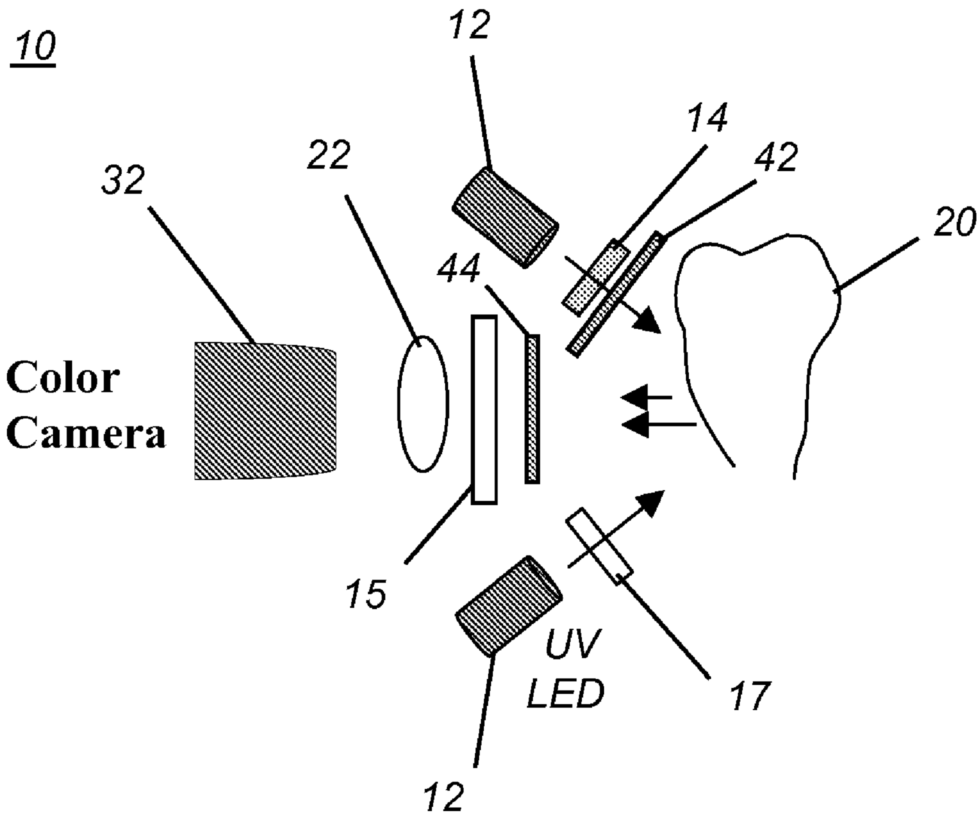

FIG. 4C

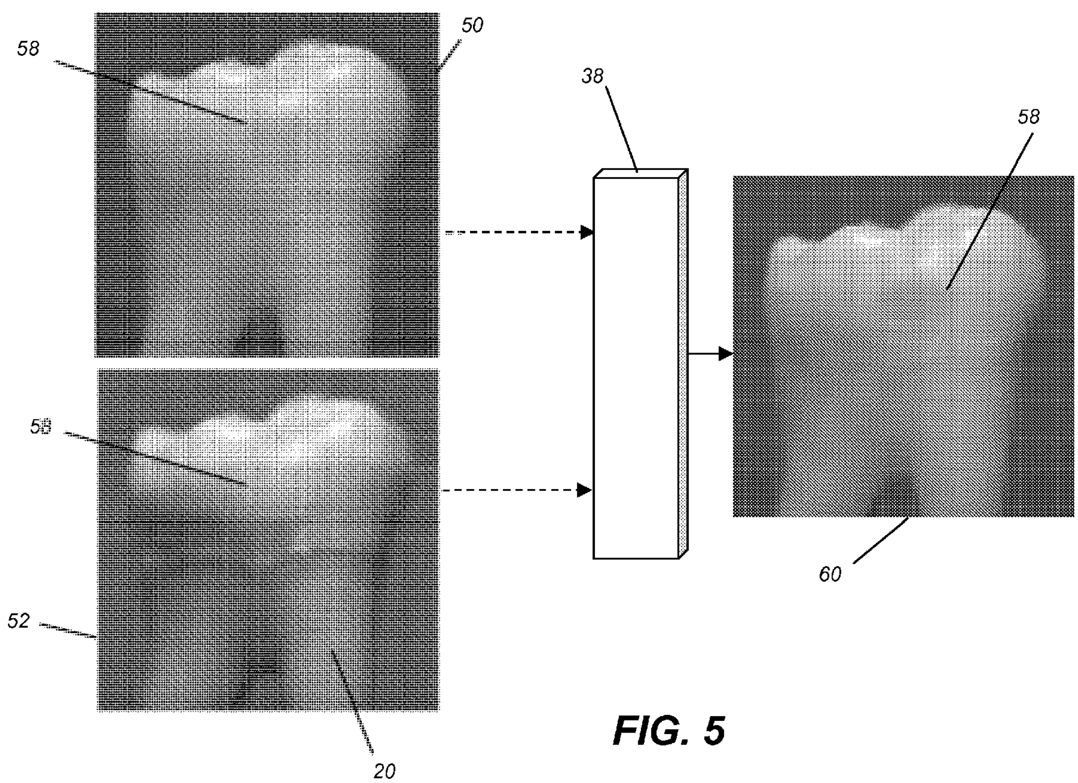

FIG. 5

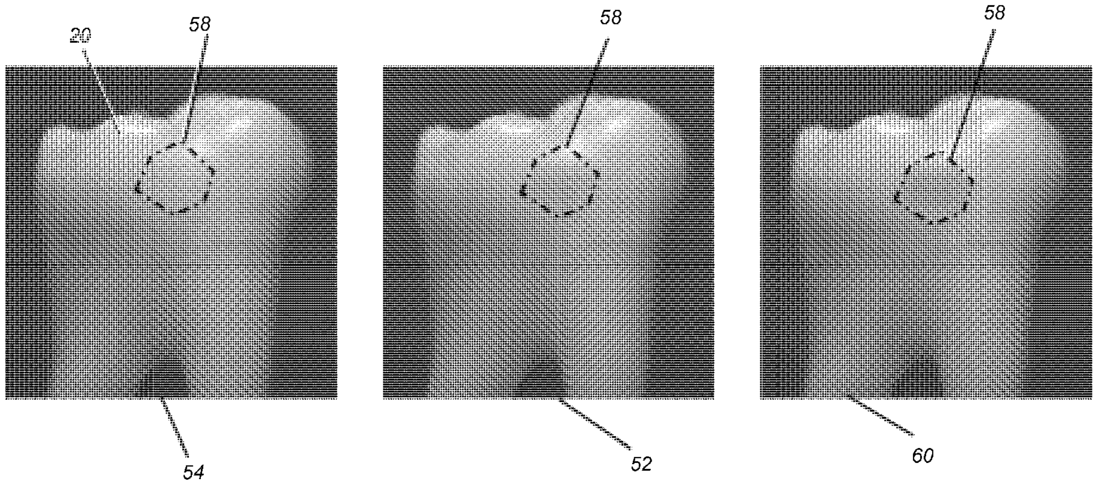

FIG. 6

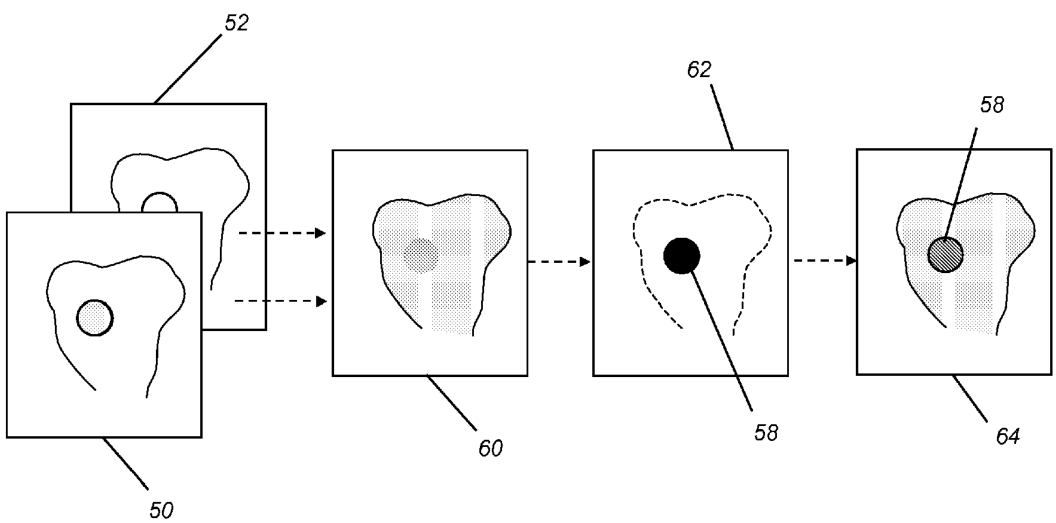

FIG. 7

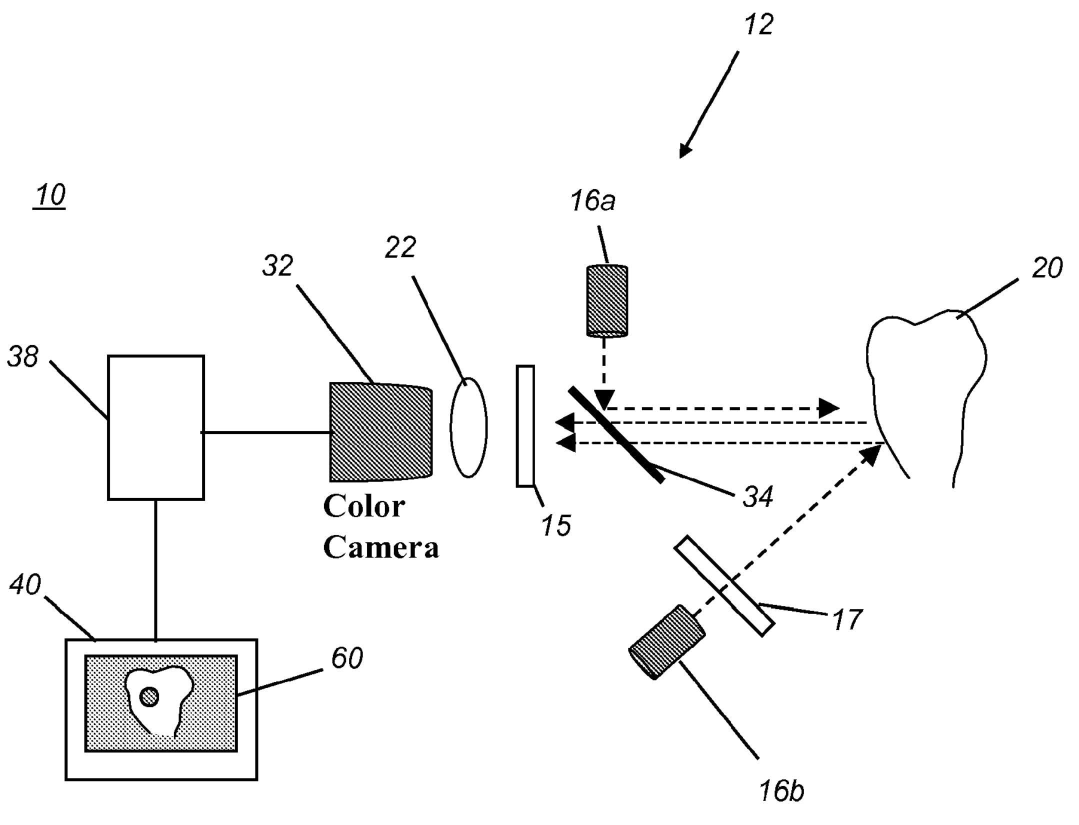

FIG. 8

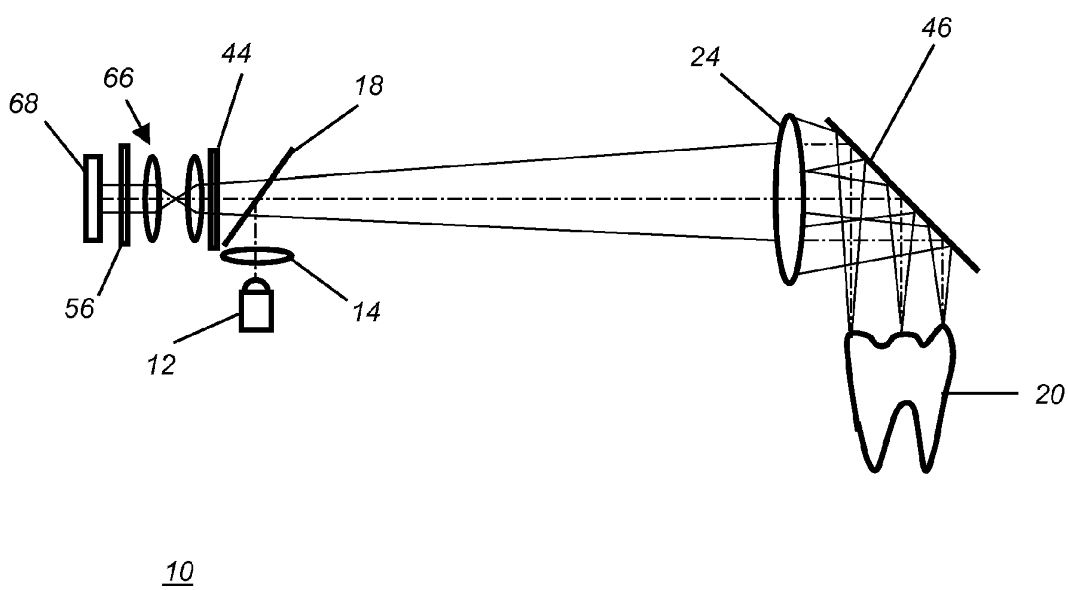

FIG. 9

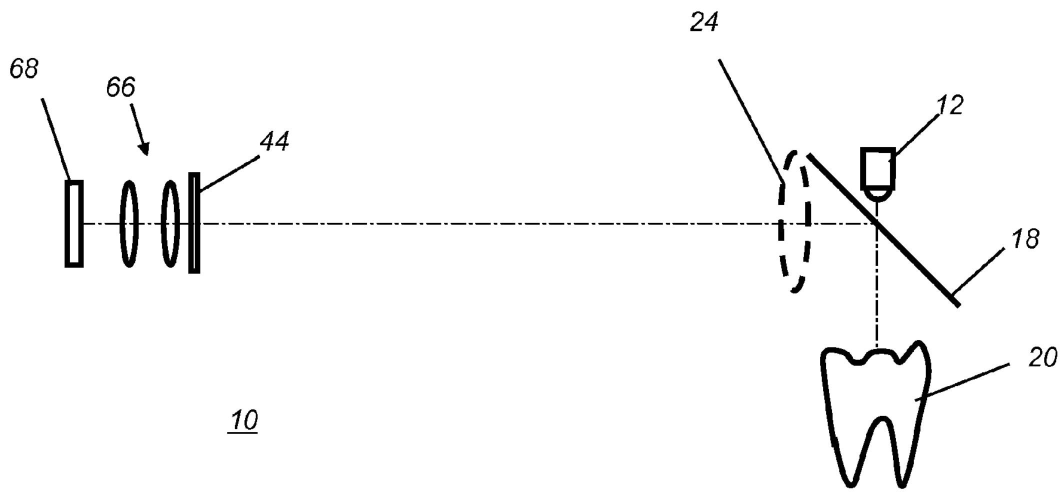

FIG. 10

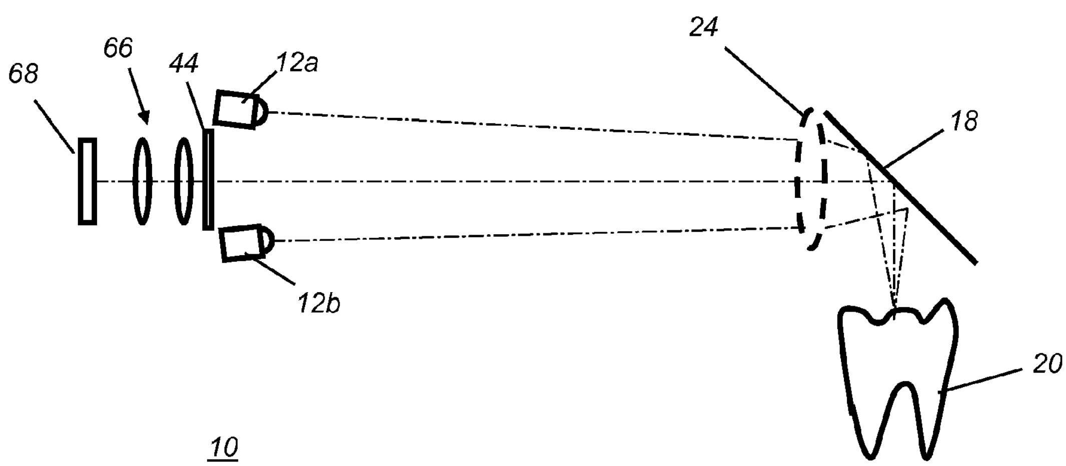

FIG. 11

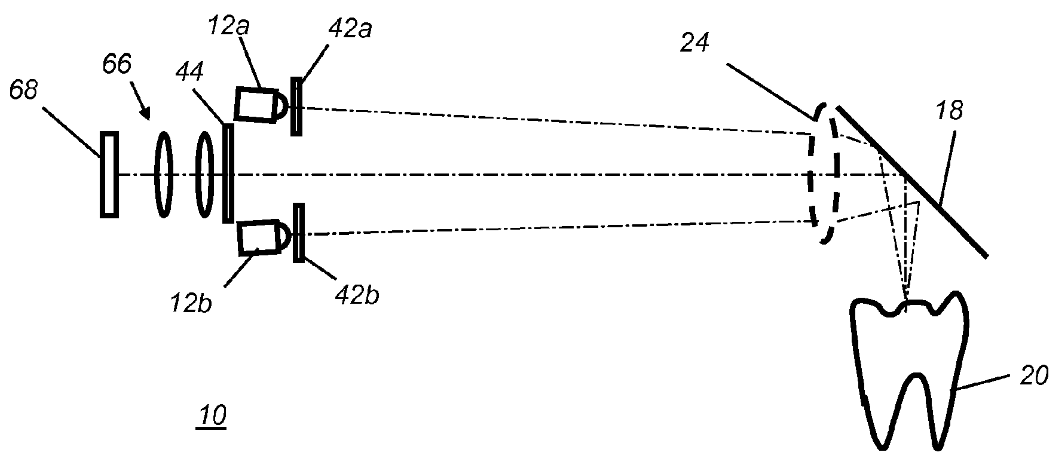

FIG. 12A

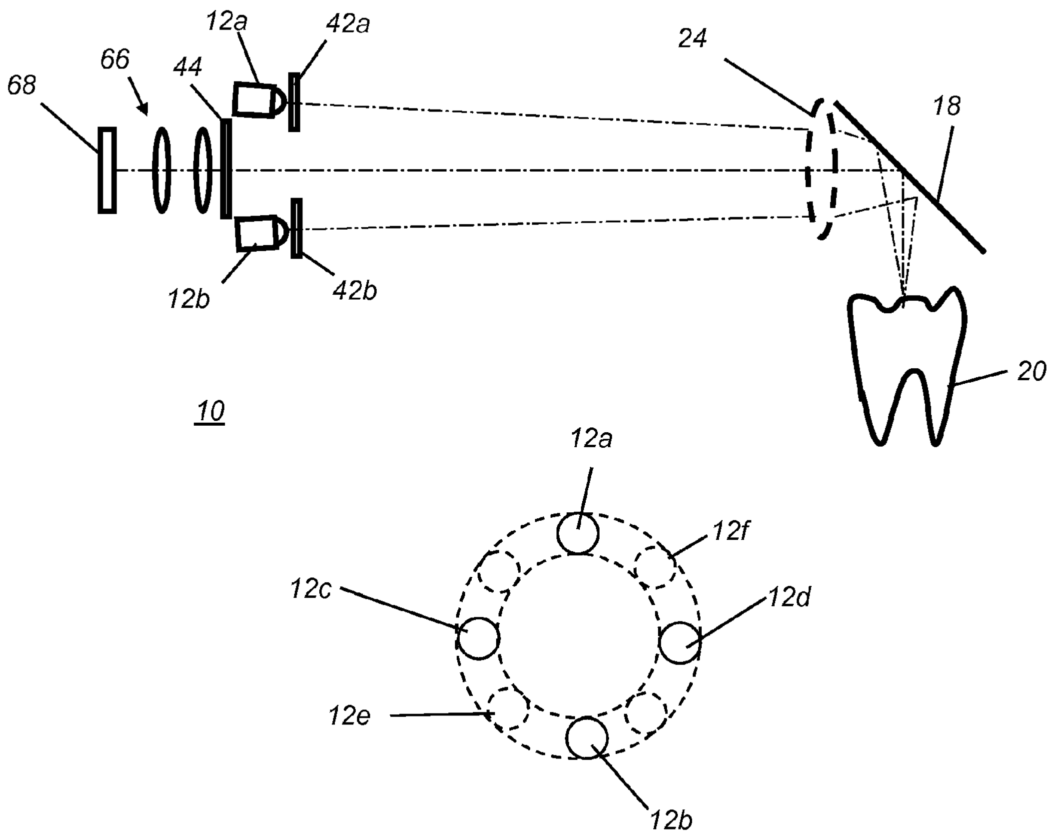

FIG. 12B

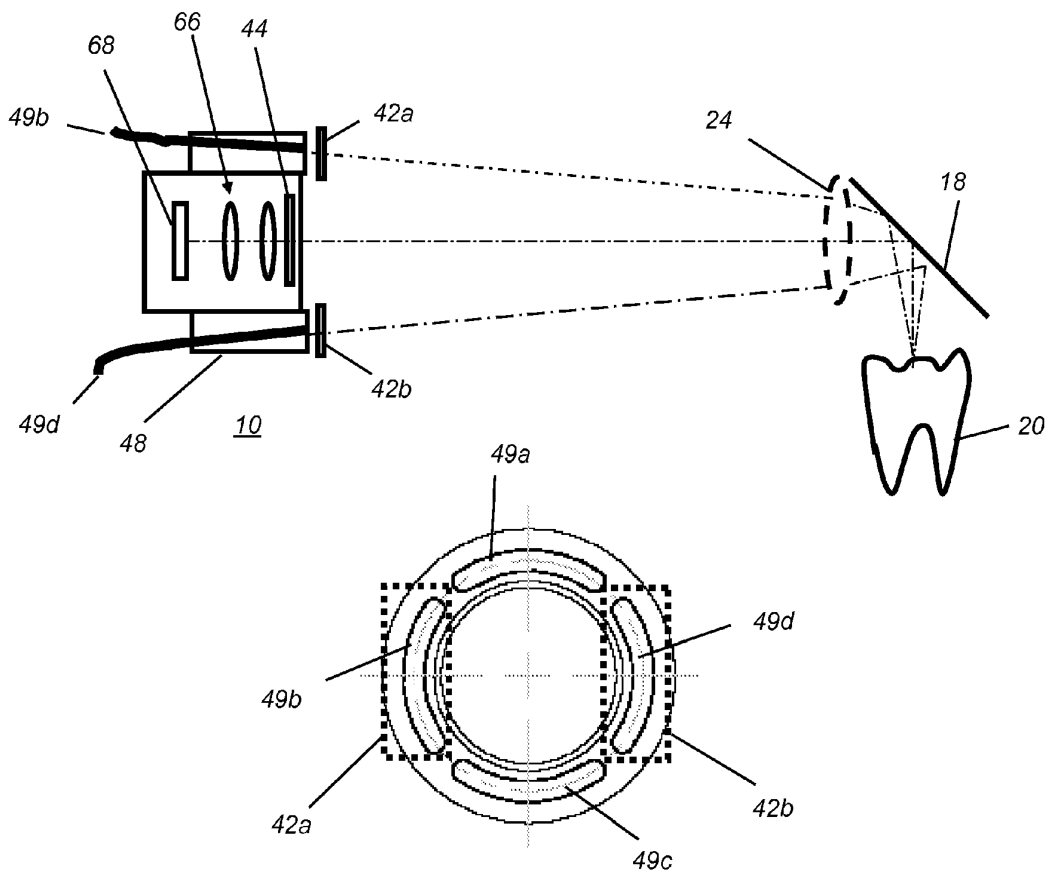

FIG. 12C

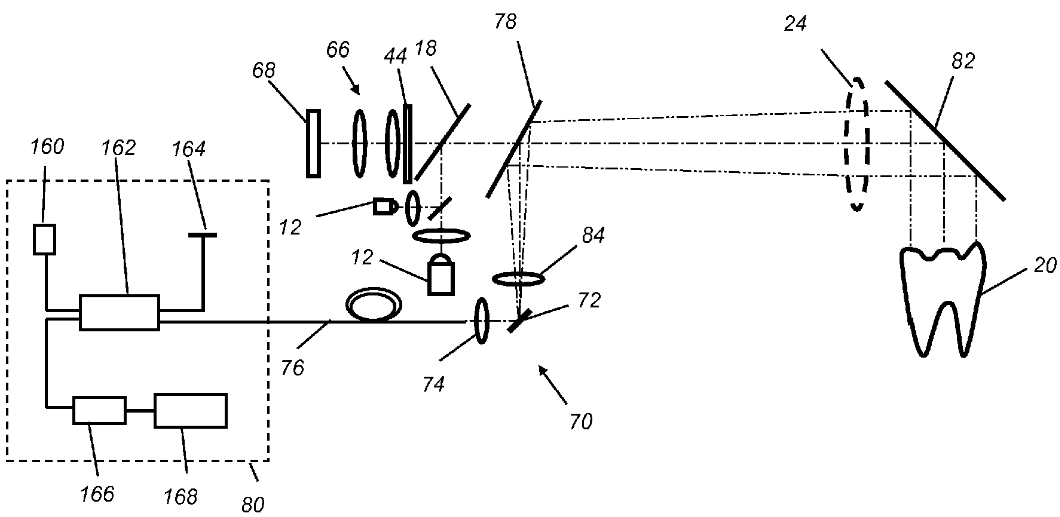

FIG. 13

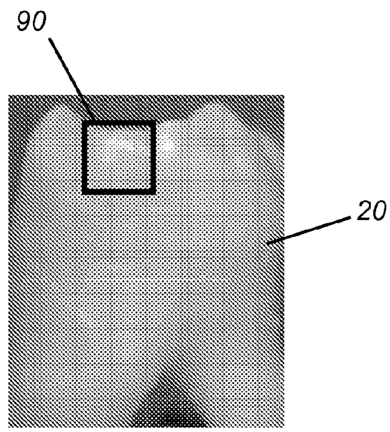

FIG. 14A

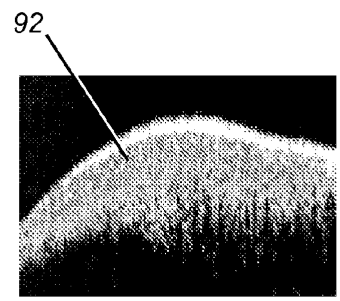

FIG. 14B

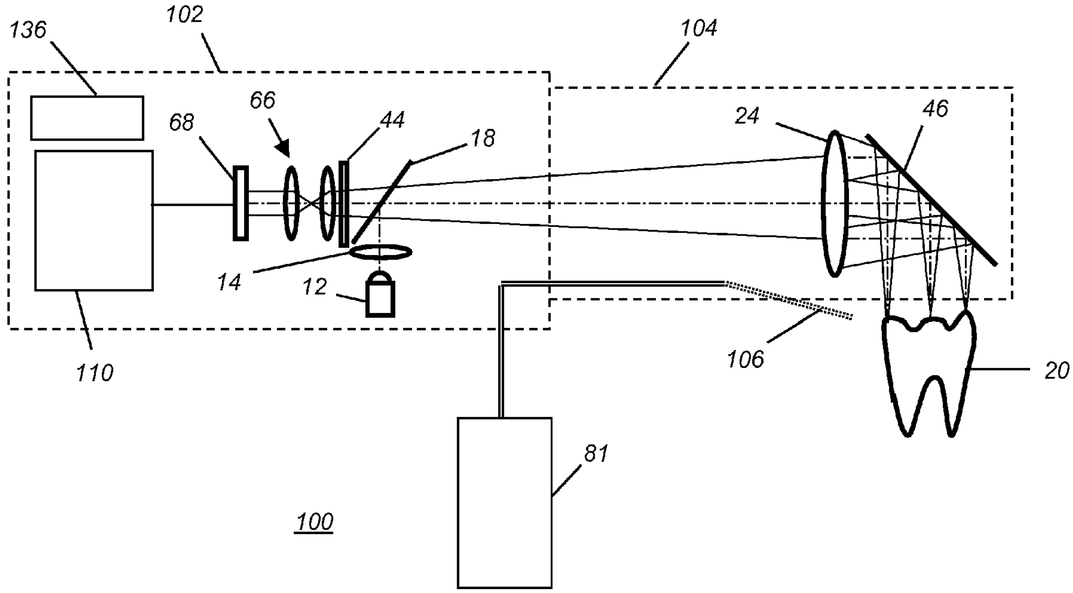

FIG. 15

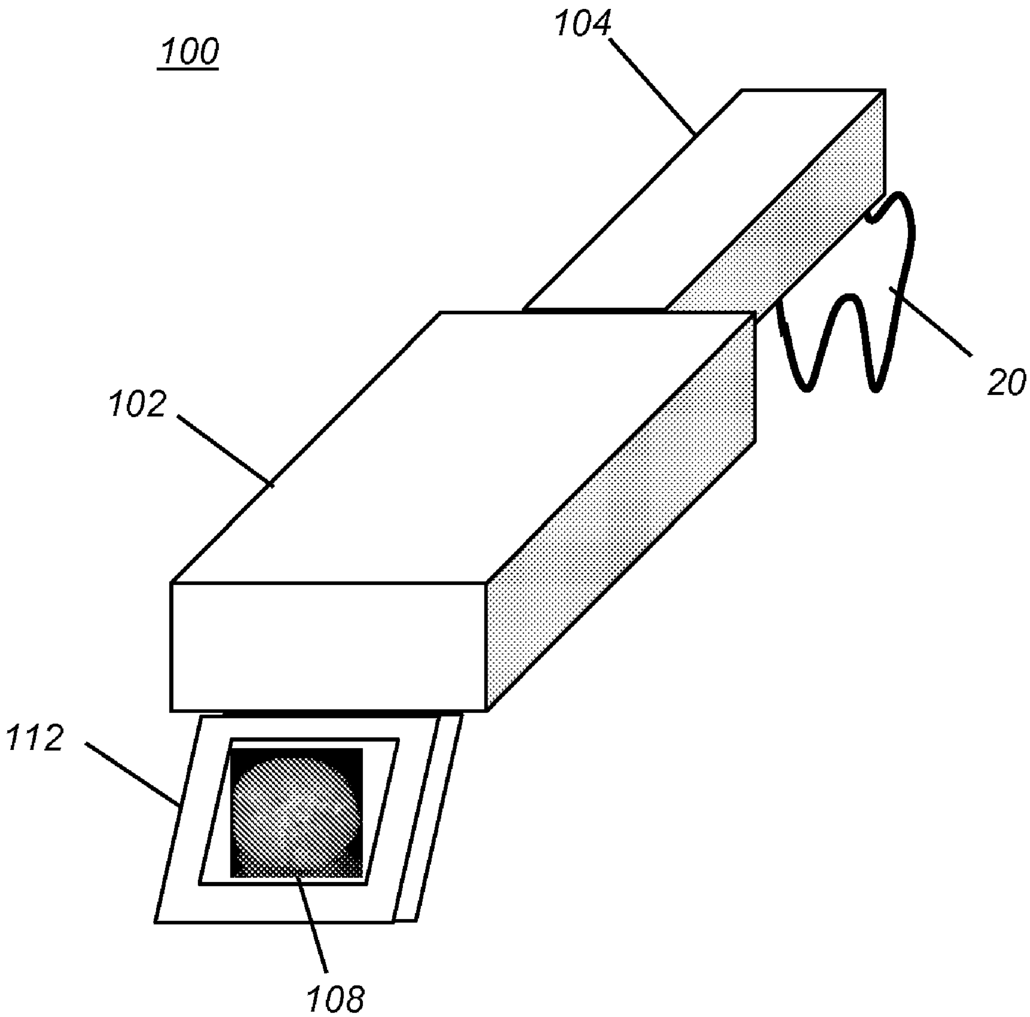

FIG. 16

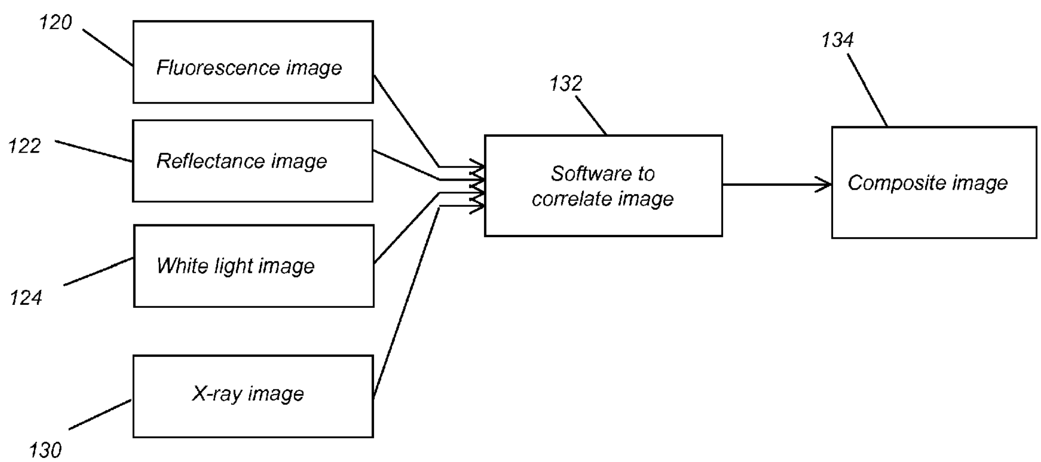
120
Fluorescence image
122
Reflectance image
124
White light image
130
X-ray image
132
Software to correlate image
134
Composite image

FIG. 17

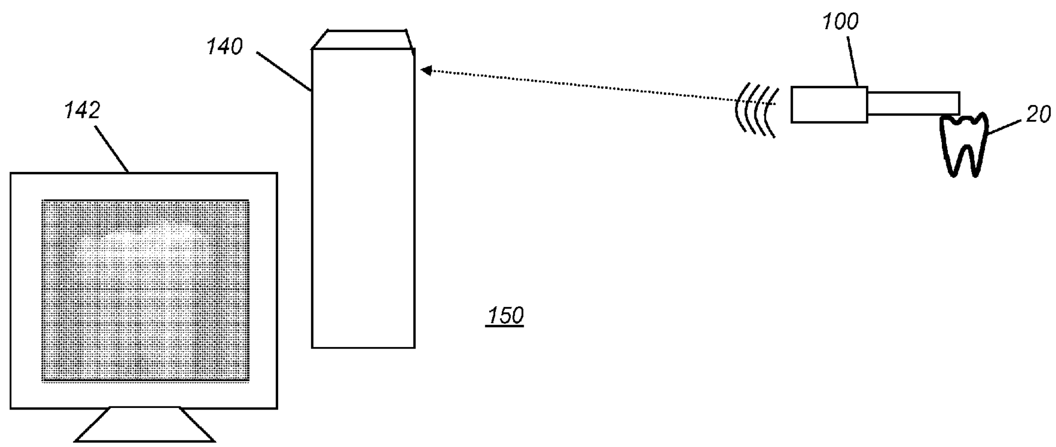

FIG. 18

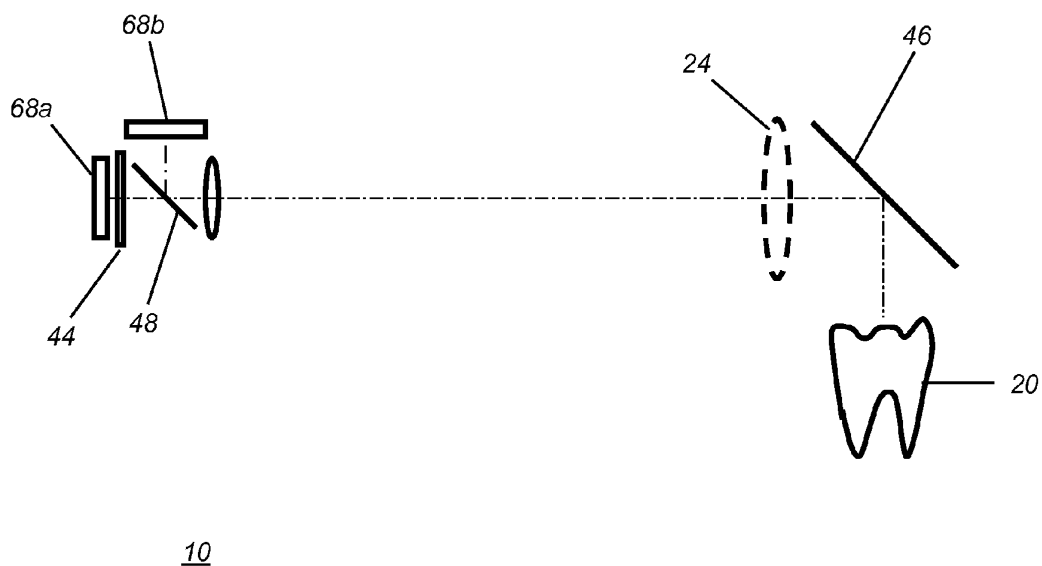

FIG. 19

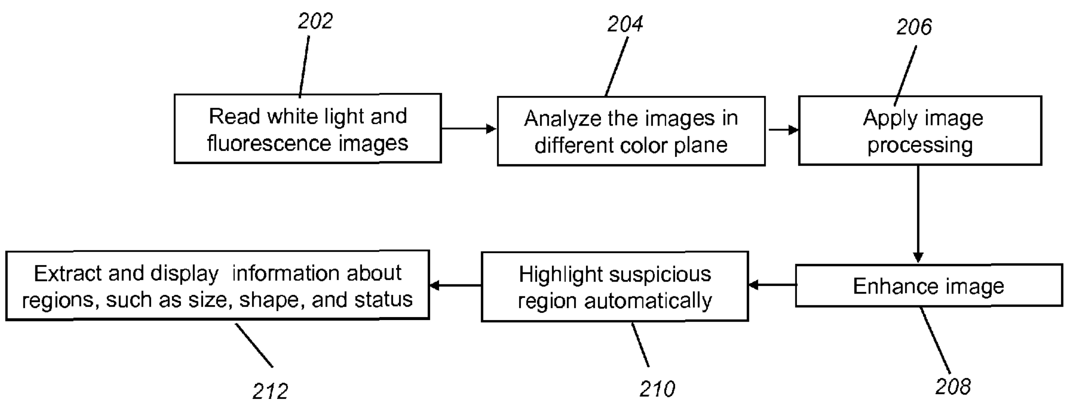
202
204
206
Read white light and fluorescence images
Analyze the images in different color plane
Apply image processing
Extract and display information about regions, such as size, shape, and status
Highlight suspicious region automatically
Enhance image
212
210
208

FIG. 20

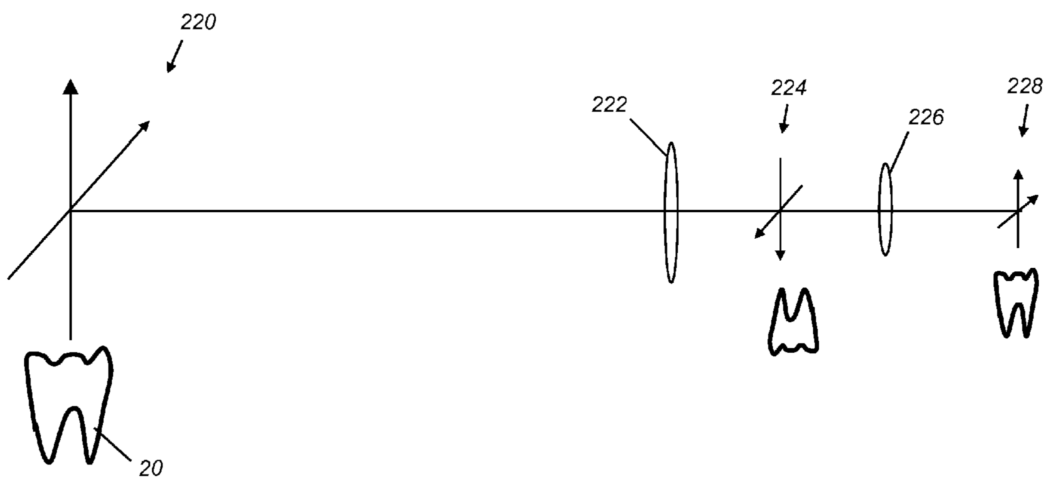

FIG. 21

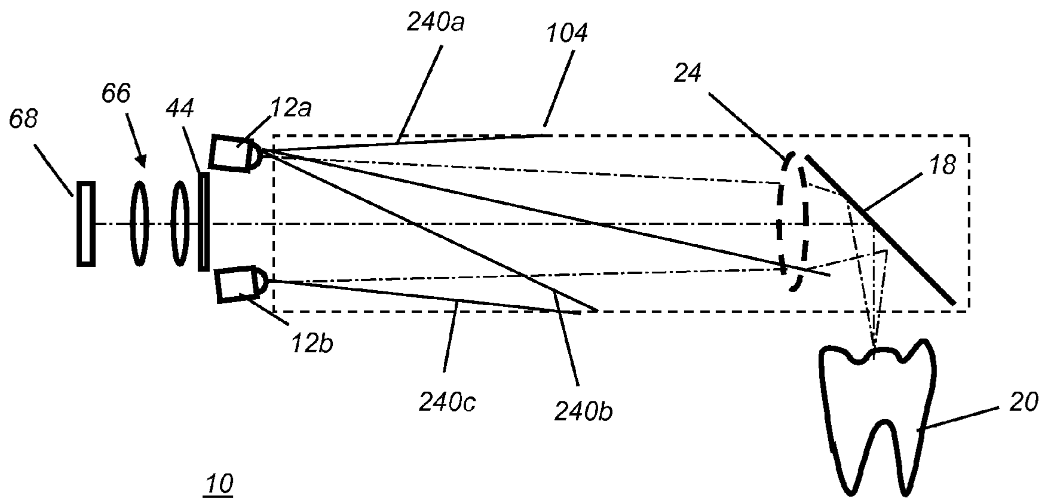

FIG. 22

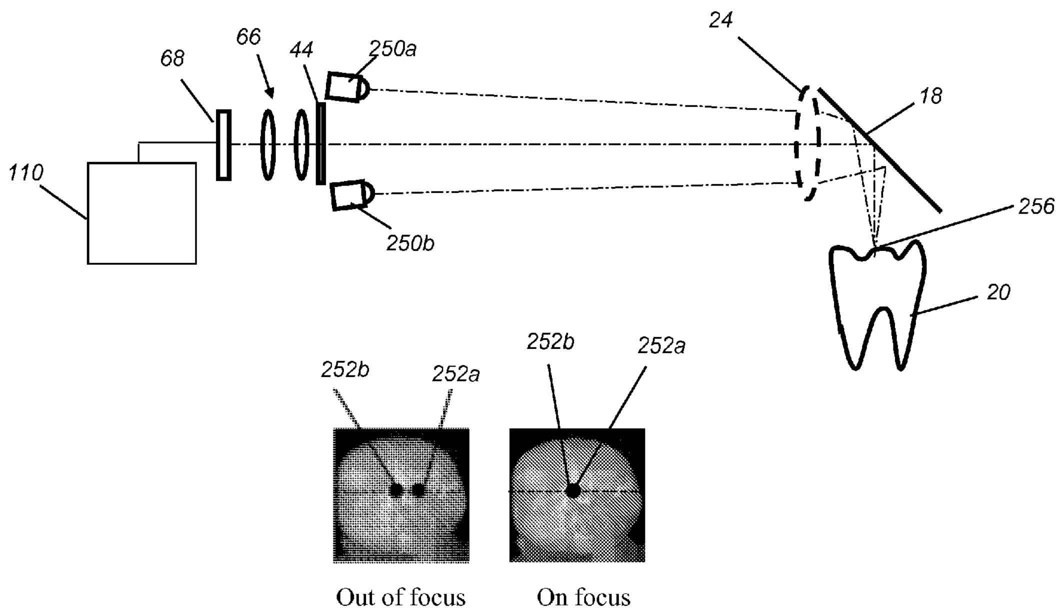
68
66
44
250a
24
18
110
256
250b
20
252b
252a
252b
252a
Out of focus
On focus

FIG. 23A

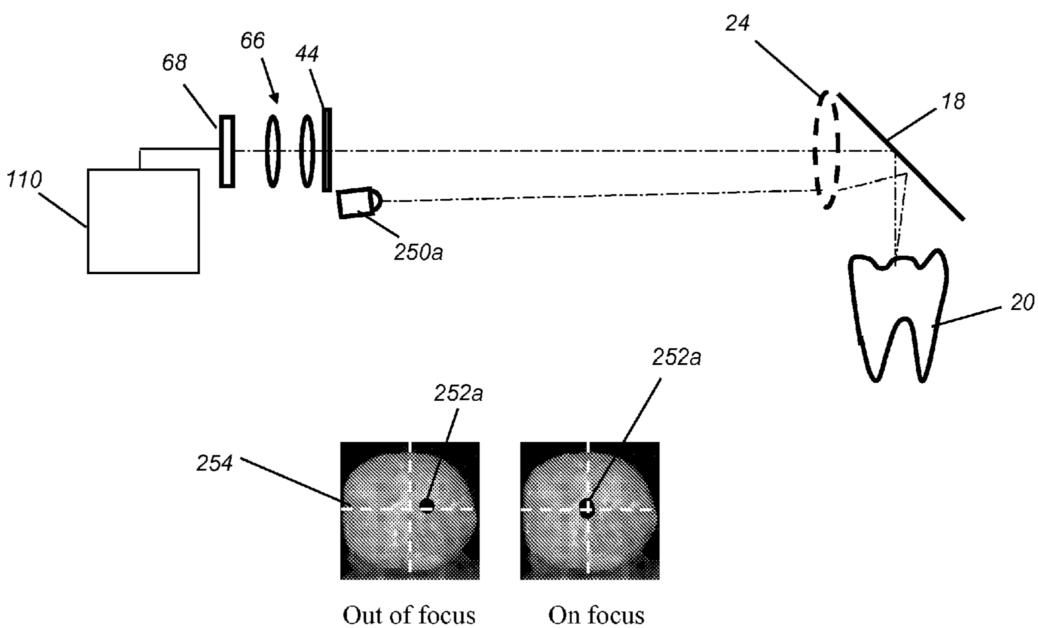

FIG. 23B

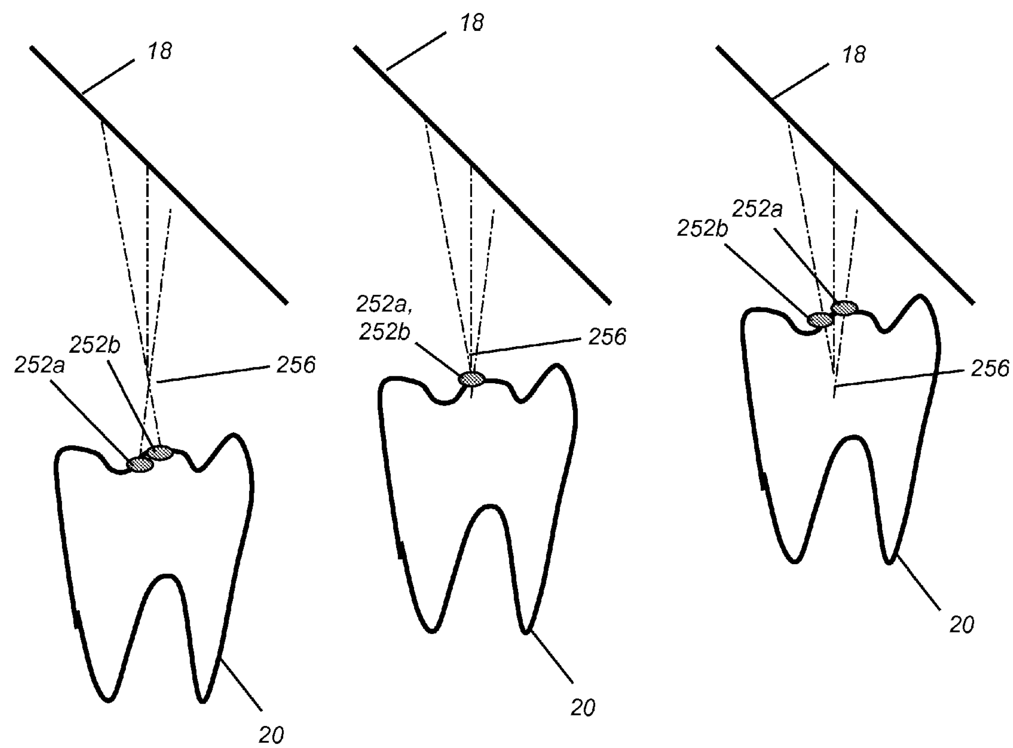

FIG. 23C

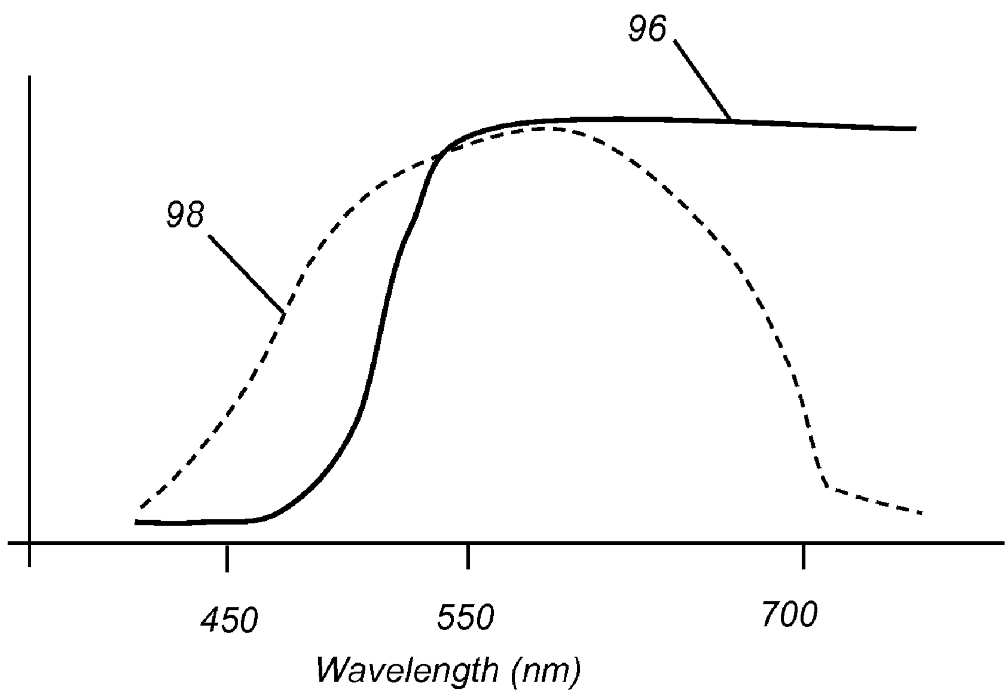

FIG. 24

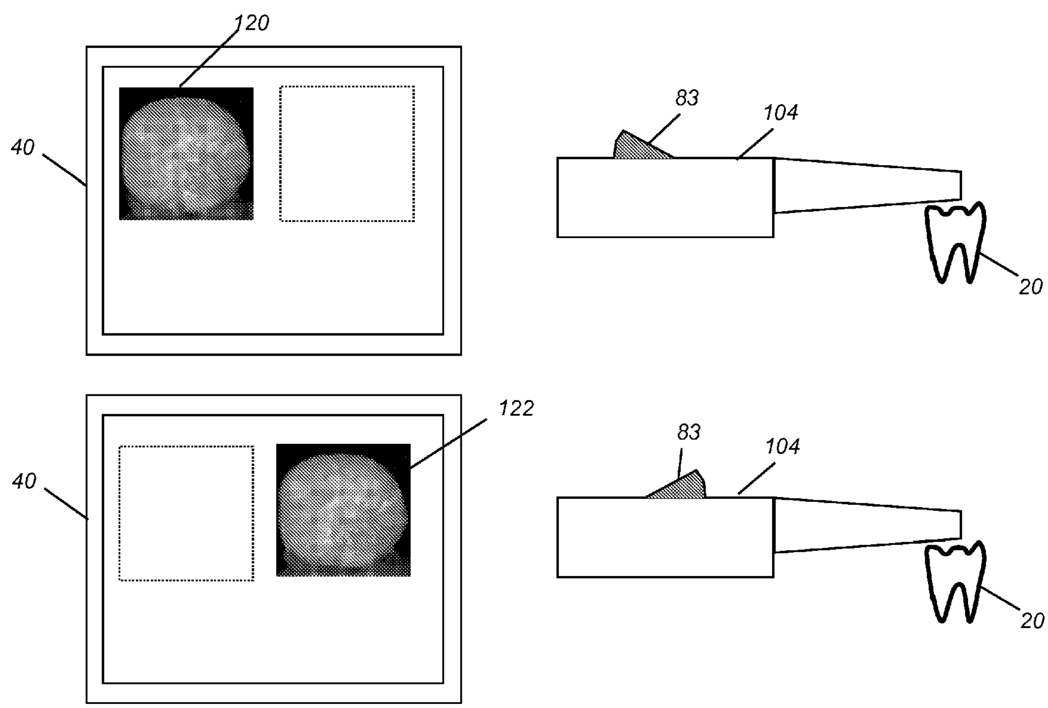

FIG. 25

APPARATUS FOR CARIES DETECTION

CROSS REFERENCE TO RELATED APPLICATIONS

[0001] Reference is made to commonly-assigned copending U.S. application Ser. No. 11/262,869, filed Oct. 31, 2005, entitled METHOD FOR DETECTION OF CARIES, by Wong et al.; U.S. application Ser. No. 11/408,360, filed Apr. 21, 2006, entitled OPTICAL DETECTION OF DENTAL CARIES by Wong et al.; and U.S. patent application Ser. No. ______, filed herewith, entitled LOW COHERENCE DENTAL OCT IMAGING, by Liang et al., the disclosures of which are incorporated herein.

FIELD OF THE INVENTION

[0002] This invention generally relates to methods and apparatus for dental imaging and more particularly relates to an apparatus for caries detection using fluorescence and scattering.

BACKGROUND OF THE INVENTION

[0003] In spite of improvements in detection, treatment, and prevention techniques, dental caries remains a widely prevalent condition affecting people of all age groups. If not properly and promptly treated, caries can lead to permanent tooth damage and even to loss of teeth.

[0004] Traditional methods for caries detection include visual examination and tactile probing with a sharp dental explorer device, often assisted by radiographic (x-ray) imaging. Detection using these methods can be somewhat subjective, varying in accuracy due to many factors, including practitioner expertise, location of the infected site, extent of infection, viewing conditions, accuracy of x-ray equipment and processing, and other factors. There are also hazards associated with conventional detection techniques, including the risk of damaging weakened teeth and spreading infection with tactile methods as well as exposure to x-ray radiation. By the time caries is evident under visual and tactile examination, the disease is generally in an advanced stage, requiring a filling and, if not timely treated, possibly leading to tooth loss.

[0005] In response to the need for improved caries detection methods, there has been considerable interest in improved imaging techniques that do not employ x-rays. One method that has been commercialized employs fluorescence, caused when teeth are illuminated with high intensity blue light. This technique, termed quantitative light-induced fluorescence (QLF), operates on the principle that sound, healthy tooth enamel yields a higher intensity of fluorescence under excitation from some wavelengths than does de-mineralized enamel that has been damaged by caries infection. The strong correlation between mineral loss and loss of fluorescence for blue light excitation is then used to identify and assess carious areas of the tooth. A different relationship has been found for red light excitation, a region of the spectrum for which bacteria and bacterial by-products in carious regions absorb and fluoresce more pronouncedly than do healthy areas.

[0006] Among proposed solutions for optical detection of caries are the following:

[0007] U.S. Pat. No. 4,290,433 (Alfano) discloses a method to detect caries by comparing the excited luminescence in two wavelengths.

[0008] U.S. Pat. No. 4,479,499 (Alfano) describes a method to detect caries by comparing the intensity of the light scattered at two different wavelengths.

[0009] U.S. Pat. No. 4,515,476 (Ingmar) discloses use of a laser for providing excitation energy that generates fluorescence at some other wavelength for locating carious areas.

[0010] U.S. Pat. No. 6,231,338 (de Josselin de Jong et al.) discloses an imaging apparatus for identifying dental caries using fluorescence detection.

[0011] U.S. Patent Application No. 2004/0240716 (de Josselin de Jong et al.) discloses methods for improved image analysis for images obtained from fluorescing tissue.

[0012] Among commercialized products for dental imaging using fluorescence behavior is the QLF Clinical System from Inspektor Research Systems BV, Amsterdam, The Netherlands. Using a different approach, the Diagnodent Laser Caries Detection Aid from KaVo Dental GmbH, Biberach, Germany, detects caries activity monitoring the intensity of fluorescence of bacterial by-products under illumination from red light.

[0013] U.S. Patent Application Publication 2005/0003323 (Katsuda et al.) describes a hand-held imaging apparatus suitable for medical or dental applications, using fluorescence imaging. The '3323 Katsuda et al. disclosure shows an apparatus that receives the reflection light from the diagnostic object and/or the fluorescence of the diagnostic object with different light irradiation. The disclosed apparatus is fairly complicated, requiring switchable filters in the probe, for example. While the apparatus disclosed in the Katsuda et al. '3323 patent application takes advantage of combining reflection light and fluorescence from the diagnostic object in the same optical path, the apparatus does not remove or minimize specular reflection. Any unwanted specular reflection produces false positive results in reflectance imaging. Moreover, with the various illumination embodiments disclosed, the illumination directed toward a tooth or other diagnostic object is not uniform, since the light source is in close proximity to the diagnostic object.

[0014] U.S. Patent Application Publication 2004/0202356 (Stookey et al.) describes mathematical processing of spectral changes in fluorescence in order to detect caries in different stages with improved accuracy. Acknowledging the difficulty of early detection when using spectral fluorescence measurements, the '2356 Stookey et al. disclosure describes approaches for enhancing the spectral values obtained, effecting a transformation of the spectral data that is adapted to the spectral response of the camera that obtains the fluorescent image.

[0015] While the disclosed methods and apparatus show promise in providing non-invasive, non-ionizing imaging methods for caries detection, there is still room for improvement. One recognized drawback with existing techniques that employ fluorescence imaging relates to image contrast. The image provided by fluorescence generation techniques such as QLF can be difficult to assess due to relatively poor contrast between healthy and infected areas. As noted in the '2356 Stookey et al. disclosure, spectral and intensity changes for incipient caries can be very slight, making it difficult to differentiate non-diseased tooth surface irregularities from incipient caries.

[0016] Overall, it is well-recognized that, with fluorescence techniques, the image contrast that is obtained corresponds to the severity of the condition. Accurate identification of caries using these techniques often requires that the condition be at a more advanced stage, beyond incipient or early caries, because the difference in fluorescence between carious and sound tooth structure is very small for caries at an early stage. In such cases, detection accuracy using fluorescence techniques may not show marked improvement over conventional methods. Because of this shortcoming, the use of fluorescence effects appears to have some practical limits that prevent accurate diagnosis of incipient caries. As a result, a caries condition may continue undetected until it is more serious, requiring a filling, for example.

[0017] Detection of caries at very early stages is of particular interest for preventive dentistry. As noted earlier, conventional techniques generally fail to detect caries at a stage at which the condition can be reversed. As a general rule of thumb, incipient caries is a lesion that has not penetrated substantially into the tooth enamel. Where such a caries lesion is identified before it threatens the dentin portion of the tooth, remineralization can often be accomplished, reversing the early damage and preventing the need for a filling. More advanced caries, however, grows increasingly more difficult to treat, most often requiring some type of filling or other type of intervention.

[0018] In order to take advantage of opportunities for non-invasive dental techniques to forestall caries, it is necessary that caries be detected at the onset. In many cases, as is acknowledged in the '2356 Stookey et al. disclosure, this level of detection has been found to be difficult to achieve using existing fluorescence imaging techniques, such as QLF. As a result, early caries can continue undetected, so that by the time positive detection is obtained, the opportunity for reversal using low-cost preventive measures can be lost.

[0019] U.S. Pat. No. 6,522,407 (Everett et al.) discloses the application of polarimetry principles to dental imaging. One system described in the Everett et al. '407 teaching provides a first polarizer in the illumination path for directing a polarized light to the tooth. A second polarizer is provided in the path of reflected light. In one position, the polarizer transmits light of a horizontal polarization. Then, the polarizer is oriented to transmit light having an orthogonal polarization. Intensity of these two polarization states of the reflected light can then be compared to calculate the degree of depolarization of light scattered from the tooth. The result of this comparison then provides information on a detected caries infection.

[0020] While the approach disclosed in the Everett et al. '407 patent takes advantage of polarization differences that can result from backscattering of light, the apparatus and methods described therein require the use of multiple polarizers, one in the illumination path, the other in the imaging path. Moreover, the imaging path polarizer must somehow be readily switchable between a reference polarization state and its orthogonal polarization state. Thus, this solution has inherent disadvantages for allowing a reduced package size for caries detection optics. It would be advantageous to provide a simpler solution for caries imaging, a solution not concerned with measuring a degree of depolarization, thus using a smaller number of components and not requiring switchable orientation of a polarizer between one of two positions.

[0021] As is described in one embodiment of the Everett et al. '407 patent disclosure, optical coherence tomography (OCT) has been proposed as a tool for dental and periodontal imaging, as well as for other medical imaging applications. For example:

- **[0022]** U.S. Pat. No. 5,321,501 (Swanson et al.) describes principles of OCT scanning and measurement as used in medical imaging applications;
- **[0023]** U.S. Pat. No. 5,570,182 (Nathel et al.) describes the use of OCT for imaging of tooth and gum structures;
- **[0024]** U.S. Pat. No. 6,179,611 (Everett et al.) describes a dental explorer tool that is configured to provide a scanned OCT image;
- **[0025]** U.S. Patent Application Publication No. 2005/0024646 (Quadling et al.) describes the use of time-domain and Fourier-domain OCT systems for dental imaging;
- **[0026]** Japanese Patent Application Publication No. JP 2004-344260 (Kunitoshi et al.) discloses an optical diagnostic apparatus equipped with a camera for visual observation of a tooth part, with visible light for illuminating a surface image, and an OCT device for scanning the indicated region of a surface image using an alternate light source.

[0027] While OCT solutions, such as those described above, can provide very detailed imaging of structure beneath the surface of a tooth, OCT imaging itself can be time-consuming and computation-intensive. OCT images would be most valuable if obtained within one or more local regions of interest, rather than obtained over widespread areas. That is, once a dental professional identifies a specific area of interest, then OCT imaging could be provided for that particular area only. Conventional solutions, however, have not combined visible light imaging with OCT imaging in the same imaging apparatus.

[0028] Thus, it can be seen that there is a need for a non-invasive, non-ionizing imaging method for caries detection that offers improved accuracy for detection of caries, particularly in its earlier stages, with a reduced number of components and reduced complexity over conventional solutions.

SUMMARY OF THE INVENTION

[0029] The present invention provides an apparatus for imaging a tooth comprising:

- **[0030]** (a) at least one light source providing incident light having a first spectral range for obtaining a reflectance image on the tooth and a second spectral range for exciting a fluorescence image of the tooth;
- **[0031]** (b) a polarizing beamsplitter in a path of the incident light, the polarizing beamsplitter directing light having a first polarization state toward the tooth and directing light from the tooth having a second polarization state along a return path toward a sensor, wherein the second polarization state is orthogonal to the first polarization state;
- **[0032]** (c) a lens positioned in the return path to direct image-bearing light from the tooth toward the sensor for obtaining image data from the portion of the light having the second polarization state; and
- **[0033]** (d) a long-pass filter in the return path, to attenuate light in the second spectral range and to transmit light in the first spectral range.

[0034] It is a feature of the present invention that it utilizes both fluorescence and reflectance image data for dental imaging.

[0035] It is an advantage of the present invention that it offers enhancement over existing fluorescence imaging techniques, useful for detection of caries in its incipient stages.

[0036] These and other objects, features, and advantages of the present invention will become apparent to those skilled in the art upon a reading of the following detailed description when taken in conjunction with the drawings wherein there is shown and described an illustrative embodiment of the invention.

BRIEF DESCRIPTION OF THE DRAWINGS

[0037] While the specification concludes with claims particularly pointing out and distinctly claiming the subject matter of the present invention, it is believed that the invention will be better understood from the following description when taken in conjunction with the accompanying drawings, wherein:

[0038] FIG. **1** is a schematic block diagram of an imaging apparatus for caries detection according to one embodiment;

[0039] FIG. **2** is a schematic block diagram of an imaging apparatus for caries detection according to an alternate embodiment;

[0040] FIG. **3** is a schematic block diagram of an imaging apparatus for caries detection according to an alternate embodiment;

[0041] FIG. **4**A is a schematic block diagram of an imaging apparatus for caries detection according to an alternate embodiment using polarized light;

[0042] FIG. **4**B is a schematic block diagram of an imaging apparatus for caries detection according to an alternate embodiment using a polarizing beamsplitter to provide polarized light;

[0043] FIG. **4**C is a schematic block diagram of an alternate embodiment using a band pass filter with a narrow band light source;

[0044] FIG. **5** is a view showing the process for combining dental image data to generate a fluorescence image with reflectance enhancement according to the present invention;

[0045] FIG. **6** is a composite view showing the contrast improvement of the present invention in a side-by-side comparison with conventional visual and fluorescence methods;

[0046] FIG. **7** is a block diagram showing a sequence of image processing for generating an enhanced threshold image according to one embodiment;

[0047] FIG. **8** is a schematic block diagram of an imaging apparatus for caries detection according to an alternate embodiment using multiple light sources;

[0048] FIG. **9** is a schematic block diagram of an imaging apparatus for caries detection using polarized light in one embodiment of the present invention;

[0049] FIG. **10** is a schematic block diagram of an imaging apparatus for caries detection using polarized light in an alternate embodiment of the present invention;

[0050] FIG. **11** is a schematic block diagram of an imaging apparatus for caries detection using polarized light in an alternate embodiment of the present invention;

[0051] FIG. **12**A is a schematic block diagram of an imaging apparatus for caries detection using polarized light from two sources in an alternate embodiment of the present invention;

[0052] FIG. **12**B is a schematic block diagram of an imaging apparatus for caries detection using a ring illuminator with LEDs in an alternate embodiment of the present invention;

[0053] FIG. **12**C is a schematic block diagram of an imaging apparatus for caries detection using a fiber ring illuminator in an alternate embodiment of the present invention;

[0054] FIG. **13** is a schematic block diagram of an imaging apparatus for caries detection using polarized light and OCT scanning in one embodiment;

[0055] FIG. **14**A is a plan view of an operator interface screen in one embodiment;

[0056] FIG. **14** B is an example display of OCT scanning results;

[0057] FIG. **15** is a block diagram showing an arrangement of a hand-held imaging apparatus in one embodiment;

[0058] FIG. **16** is a perspective view showing an imaging apparatus having an integral display;

[0059] FIG. **17** is a block diagram showing combination of multiple types of images in order to form a composite image;

[0060] FIG. **18** is a block diagram showing a wireless dental imaging system in one embodiment;

[0061] FIG. **19** is a block diagram of an alternate embodiment for the imaging probe with two sensors;

[0062] FIG. **20** is a logic flow diagram for image processing workflow;

[0063] FIG. **21** is a block diagram showing an image relay arrangement used in one embodiment;

[0064] FIG. **22** is a block diagram showing the path of emitted light within the apparatus of the present invention;

[0065] FIGS. **23**A and **23**B are block diagrams of embodiments for image capture with auto-focusing capability;

[0066] FIG. **23**C is a diagram showing how focusing indicators operate;

[0067] FIG. **24** is a graph showing characteristic curves for white light and for a long pass filter used in the apparatus of the present invention; and

[0068] FIG. **25** is a diagram showing operation of a toggle switch for obtaining separate images.

DETAILED DESCRIPTION OF THE INVENTION

[0069] The present description is directed in particular to elements forming part of, or cooperating more directly with, apparatus in accordance with the invention. It is to be understood that elements not specifically shown or described may take various forms well known to those skilled in the art.

[0070] As noted in the preceding background section, it is known that fluorescence can be used to detect dental caries using either of two characteristic responses: First, excitation by a blue light source causes healthy tooth tissue to fluoresce in the green spectrum. Secondly, excitation by a red light source can cause bacterial by-products, such as those indicating caries, to fluoresce in the red spectrum.

[0071] In order for an understanding of how light is used in the present invention, it is important to give more precise definition to the terms "reflectance" and "back-scattering" as they are used in biomedical applications in general and, more particularly, in the method and apparatus of the present invention. In broadest optical parlance, reflectance generally denotes the sum total of both specular reflectance and scattered reflectance. (Specular reflection is that component of the excitation light that is reflected by the tooth surface at the same angle as the incident angle.) In biomedical applications, however, as in the dental application of the present invention, the specular component of reflectance is of no interest and is, instead, generally detrimental to obtaining an image or measurement from a sample. The component of reflectance that is of interest for the present application is from back-scattered light only. Specular reflectance must be blocked or otherwise removed from the imaging path. With this distinction in mind, the term "back-scattered reflectance" is used in the present application to denote the component of reflectance that is of interest. "Back-scattered reflectance" is defined as that component of the excitation light that is elastically back-scattered over a wide range of angles by the illuminated tooth structure. "Reflectance image" data, as this term is used in the present invention, refers to image data obtained from back-scattered reflectance only, since specular reflectance is blocked or kept to a minimum. In the scientific literature, back-scattered reflectance may also be referred to as back-reflectance or simply as backscattering. Back-scattered reflectance is at the same wavelength as the excitation light.

[0072] It has been shown that light scattering properties differ between sound and carious dental regions. In particular, reflectance of light from the illuminated area can be at measurably different levels for normal versus carious areas. This change in reflectance, taken alone, may not be sufficiently pronounced to be of diagnostic value when considered by itself, since this effect is very slight, although detectable. For more advanced stages of caries, for example, back-scattered reflectance may be less effective an indicator than at earlier stages.

[0073] In conventional fluorescence measurements such as those obtained using QLF techniques, reflectance itself is an effect that is avoided rather than utilized. A filter is usually employed to block off all excitation light from reaching the detection device. For this reason, the slight but perceptible change in back-scattered reflectance from excitation light has received little attention for diagnosing caries.

[0074] The inventors have found, however, that this back-scattered reflectance change can be used in conjunction with fluorescence effects to more clearly and more accurately pinpoint a carious location. Moreover, the inventors have observed that the change in light scattering activity, while it can generally be detected wherever a caries condition exists, is more pronounced in areas of incipient caries. This back-scattered reflectance change is evident at early stages of caries, even when fluorescent effects are least pronounced.

[0075] The present invention takes advantage of the observed back-scattering behavior for incipient caries and uses this effect, in combination with fluorescence effects described previously in the background section, to provide an improved capability for dental imaging to detect caries. The inventive technique, hereafter referred to as fluorescence imaging with reflectance enhancement (FIRE), not only helps to increase the contrast of images over that of earlier approaches, but also makes it possible to detect incipient caries at stages where preventive measures are likely to effect remineralization, repairing damage done by the caries infection at a stage well before more complex restorative measures are necessary. Advantageously, FIRE detection can be accurate at an earlier stage of caries infection than has been exhibited using existing fluorescence approaches that measure fluorescence alone.

Imaging Apparatus

[0076] Referring to FIG. **1**, there is shown one basic optical arrangement for an imaging apparatus **10** for caries detection using the FIRE method in one embodiment. A light source **12** directs an incident light, at a blue wavelength range or other suitable wavelength range, toward tooth **20** through an optional lens **14** or other light beam conditioning component. The tooth **20** may be illuminated at a smooth surface (as shown) or at an occlusal surface (not shown). Two components of light are then detected by a monochrome camera **30** through a lens **22**: a back-scattered light component having the same wavelength as the incident light and having measurable reflectance; and a fluorescent light that has been excited due to the incident light. For FIRE imaging, specular reflection causes false positives and is undesirable. To minimize specular reflection pick up, the camera **30** is positioned at a suitable angle with respect to the light source **12**. This allows imaging of back-scattered light without the confounding influence of a specularly reflected component.

[0077] In the embodiment of FIG. **1**, monochrome camera **30** has color filters **26** and **28**. One of color filters **26** or **28** is used during reflectance imaging; the other is used during fluorescence imaging. A processing apparatus **38** obtains and processes the reflectance and fluorescence image data and forms a FIRE image **60**. FIRE image **60** is an enhanced diagnostic image that can be printed or can appear on a display **40**. FIRE image **60** data can also be transmitted to storage or transmitted to another site for display.

[0078] Referring to FIG. **2**, there is shown the basic optics arrangement in an alternate embodiment using a color camera **32**. With this arrangement, auxiliary filters would not generally be needed, since color camera **32** would be able to obtain the reflectance and fluorescence images from the color separations of the full color image of tooth **20**.

[0079] Light source **12** is typically centered around a blue wavelength, such as about 405 nm in one embodiment. In practice, light source **12** could emit light ranging in wavelength from an upper ultraviolet range to blue, between about 300 and 500 nm. Light source **12** can be a laser or could be fabricated using one or more light emitting diodes (LEDs). Alternately, a broadband source, such as a xenon lamp, having a supporting color filter for passing the desired wavelengths could be used. Lens **14** or other optical elements may serve to condition the incident light, such as by controlling the uniformity and size of the illumination area. For example, a diffuser **13**, shown as a dotted line in FIG. **2**, might be used before or after lens **14** to smooth out the hot spots of an LED beam. The path of illumination light might include light guiding or light distributing structures such as an optical fiber or a liquid light guide, for example (not shown). Light level is typically a few milliwatts in intensity, but can be more or less, depending on the light conditioning and sensing components used.

[0080] Referring to the basic optical arrangement shown in FIG. **3**, illumination components could alternately direct light at normal incidence, turned through a beamsplitter **34**. Camera **32** would then be disposed to obtain the image light that is transmitted through beamsplitter **34**. Other options for illumination include multiple light sources directed at the tooth with angular incidence from one or more sides. Alternately, the illumination might use an annular ring or an arrangement of LED sources distributed about a center such as in a circular array to provide light uniformly from multiple angles as shown in FIGS. **12**A and **12**B. Illumination could also be provided through an optical fiber or fiber array as shown in FIG. **12**C.

[0081] The imaging optics, represented as lens **22** in FIGS. **1-3**, could include any suitable arrangement of optical components, with possible configurations ranging from a single lens component to a multi-element lens. Clear imaging of the tooth surface, which is not flat but can have areas that are both smoothly contoured and highly ridged, requires that imaging optics have sufficient depth of field. Preferably, for optimal resolution, the imaging optics provides an image size that substantially fills the sensor element of the camera.

[0082] Image capture can be performed by either monochrome camera **30** (FIG. **1**) or color camera **32** (FIG. **2**). Typically, camera **30** or **32** employs a CMOS or CCD sensor. The monochrome version would typically employ a retractable spectral filter **26**, **28** suitable for the wavelength of interest. For light source **12** having a blue wavelength, spectral filter **26** for capturing reflectance image data would transmit predominately blue light. Spectral filter **28** for capturing fluorescence image data would transmit light at a different wavelength, such as predominately green light. Preferably, spectral filters **26** and **28** are automatically switched into place to allow capture of both reflectance and fluorescence images in very close succession. Both images are obtained from the same position to allow accurate registration of the image data.

[0083] Spectral filter **28** would be optimized with a passband that captures fluorescence data over a range of suitable wavelengths. The fluorescent effect that has been obtained from tooth **20** can have a relative broad spectral distribution in the visible range, with light emitted that is outside the wavelength range of the light used for excitation. The fluorescent emission is typically between about 450 nm and 600 nm, while generally peaking in the green region, roughly from around 510 nm to about 550 nm. Thus a green light filter is generally preferred for spectral filter **28** in order to obtain this fluorescence image at its highest energy levels. With color camera **32**, the green image data is generally used for this same reason. This green image data is also obtained through a green light filter, such as a green filter in a color filter array (CFA), as is well known to those skilled in the color image capture art. However, other ranges of the visible spectrum could also be used in other embodiments.

[0084] Camera controls are suitably adjusted for obtaining each type of image. For example, when capturing the fluorescence image, it is necessary to make appropriate exposure adjustments for gain, shutter speed, and aperture, since this image may not be intense. When using color camera **32** (FIG. **2**), color filtering is performed by the color filter arrays on the camera image sensor. The reflectance image is captured in the blue color plane; simultaneously, the fluorescence image is captured in the green color plane. That is, a single exposure captures both back-scattered reflectance and fluorescence images.

[0085] Processing apparatus **38** is typically a computer workstation but may, in its broadest application, be any type of control logic processing component or system that is capable of obtaining image data from camera **30** or **32** and executing image processing algorithms upon that data to generate the FIRE image **60** data. Processing apparatus **38** may be local or may connect to image sensing components over a networked interface.

[0086] Referring to FIG. **5**, there is shown, in schematic form, how the FIRE image **60** is formed according to the present invention. Two images of tooth **20** are obtained, a green fluorescence image **50** and a blue reflectance image **52**. As noted earlier, it must be emphasized that the reflectance light used for reflectance image **52** and its data is from back-scattered reflectance, with specular reflectance blocked or kept as low as possible. In the example of FIG. **5**, there is a carious region **58**, represented in phantom outline in each of images **50**, **52**, and **60**, which causes a slight decrease in fluorescence and a slight increase in reflectance. The carious region **58** may be imperceptible or barely perceptible in either fluorescence image **50** or reflectance image **52**, taken individually. Processing apparatus **38** operates upon the image data using an image processing algorithm as discussed below for both images **50** and **52** and provides FIRE image **60** as a result. The contrast between carious region **58** and sound tooth structure is heightened, so that a caries condition is made more visible in FIRE image **60**.

[0087] FIG. **6** shows the contrast improvement of the present invention in a side-by-side comparison with a visual white-light image **54** and conventional fluorescence methods. For caries at a very early stage, the carious region **58** may look indistinct from the surrounding healthy tooth structure in white-light image **54**, either as perceived directly by eye or as captured by an intraoral camera. In the green fluorescence image **52** captured by existing fluorescence method, the carious region **58** may show up as a very faint, hardly noticeable shadow. In contrast, in the FIRE image **60** generated by the present invention, the same carious region **58** shows up as a darker, more detectable spot. Clearly, the FIRE image **60**, with its contrast enhancement, offers greater diagnostic value.

Image Processing

[0088] As described earlier with reference to FIGS. **5** and **6**, processing of the image data uses both the reflectance and fluorescence image data to generate a final image that can be used to identify carious areas of the tooth. There are a number of alternative processing methods for combining the reflectance and fluorescence image data to form FIRE image **60** for diagnosis. Commonly-assigned U.S. patent application Ser. No. 11/262,869, cited above, describes one method for combining reflectance and fluorescence image data, using scalar multipliers and finding a difference between scaled reflectance and fluorescence values.

[0089] Following an initial combination of fluorescence and reflectance values, additional image processing may also be of benefit. A thresholding operation, executed using image processing techniques familiar to those skilled in the imaging arts, or some other suitable conditioning of the combined image data used for FIRE image **60**, may be used to further enhance the contrast between a carious region and sound tooth structure. Referring to FIG. **7**, there is shown, in block diagram form, a sequence of image processing for generating an enhanced threshold FIRE image **64** according to one embodiment. Fluorescence image **50** and reflectance image **52** are first combined to form FIRE image **60**, as described previously. A thresholding operation is next performed, providing threshold image **62** that defines more clearly the area of interest, carious region **58**. Then, threshold image **62** is combined with original FIRE image **60** to generate enhanced threshold FIRE image **64**. Similarly, the results of threshold detection can also be superimposed onto a white light image **54** (FIG. **6**) in order to definitively outline the location of a carious infection.

[0090] It can be readily appreciated that any number of complex image processing algorithms could alternately be used for combining the reflectance and fluorescence image data in order to obtain an enhanced image that identifies carious regions more clearly. It may be advantageous to apply a number of different imaging algorithms to the image data in order to obtain the most useful result. In one embodiment, an operator can elect to use any of a set of different image processing algorithms for conditioning the fluorescence and reflectance image data obtained. This would allow the operator to check the image data when processed in a number of different ways and may be helpful for optimizing the detection of carious lesions having different shape-related characteristics or that occur over different areas of the tooth surface.

[0091] It is emphasized that the image contrast enhancement achieved in the present invention, because it employs both reflectance and fluorescence data, is advantaged over conventional methods that use fluorescent image data only. Conventionally, where only fluorescence data is obtained, image processing has been employed to optimize the data, such as to transform fluorescence data based on spectral response of the camera or of camera filters or other suitable characteristics. For example, the method of the '2356 Stookey et al. disclosure, cited above, performs this type of optimization, transforming fluorescence image data based on camera response. However, these conventional approaches overlook the added advantage of additional image information that the back-scattered reflectance data obtains.

ALTERNATE EMBODIMENTS

[0092] The method of the present invention admits a number of alternate embodiments. For example, the contrast of either or both of the reflectance and fluorescence images may be improved by the use of a polarizing element. It has been observed that enamel, having a highly structured composition, is sensitive to the polarization of incident light. Polarized light has been used to improve the sensitivity of dental imaging techniques, for example, in "Imaging Caries Lesions and Lesion Progression with Polarization Sensitive Optical Coherence Tomography" in *J. Biomed Opt.,* 2002 October; 7(4): pp. 618-627, by Fried et al.

[0093] Specular reflection tends to preserve the polarization state of the incident light. For example, where the incident light is s-polarized, the specular reflected light is also s-polarized. Backscattering, on the other hand, tends to de-polarize or randomize the polarization of the incident light. Where incident light is s-polarized, back-scattered light has both s- and p-polarization components. Using a polarizer and analyzer, this difference in polarization handling can be employed to help eliminate unwanted specular reflectance from the reflectance image, so that only back-scattered reflectance is obtained.

[0094] Referring to FIG. **4**A, there is shown an embodiment of imaging apparatus **10** that expands upon the basic model shown in FIGS. **1-3**, employing a polarizer **42** in the path of the incident illumination light and other supporting optics. Polarizer **42** transmits linearly polarized incident light. An optional analyzer **44** may also be provided in the return path of image-bearing light from tooth **20** as a means to minimize the specular reflectance component. With this polarizer **42**/analyzer **44** combination as polarizing elements, reflectance light in the return path and sensed by camera **30** or **32** is predominantly back-scattered light, that portion of the reflectance that is desirable for combination with the fluorescence image data according to the present invention. A long-pass filter **15** in the path of returned light from the tooth is used to attenuate ultraviolet and shorter wavelength visible light (for example, light over the blue portion of the spectrum, centered near about 405+/−40 nm) and to pass longer wavelength light. This arrangement minimizes the effect of blue light that may be used to excite fluorescence (normally centered in the green portion of the spectrum, nominally about 550 nm) and, by attenuating this shorter-wavelength light, allows the use of a white light source as light source **12** for obtaining a reflectance image. The curves of FIG. **24** show the overall relationship between a white light curve **98** (shown with a dashed line) and a long-pass filter curve **96**.

[0095] FIG. **4**C shows an alternate embodiment using multiple light sources **12**, each light source **12** having a different spectral range. Here, one light source **12** is a white light source for obtaining the reflectance image. The typical spectral range for a white light source can include wavelengths from about 400 to about 700 nm. The other light source **12** is a UV LED or other source that emits light having shorter wavelengths for exciting fluorescent emission. For example, its spectral range may be well within 300-500 nm. A band pass filter **17** can be used to narrow the band and reduce optical crosstalk from this second light source into the fluorescence image.

[0096] Where there are multiple light sources **12**, individual light sources **12** can be toggled on and off in order to obtain the corresponding reflectance or fluorescence image at any one time. For the embodiment described with reference to FIG. **4**C, for example, white light source **12** is on to obtain the reflectance image (or white light image) at camera **32** or other sensor. The other UV LED source is off. Then, when white light source **12** is turned off and the UV LED source is energized, a fluorescence image can be obtained.

[0097] FIG. **25** shows an embodiment with an imaging probe **104** having a toggle switch **83** and the corresponding display **40** for each position of toggle switch **83**. In one position, as shown in the upper portion of FIG. **25**, toggle switch **83** enables capture of fluorescence image **120**. In another position, shown in the lower portion of FIG. **25**, toggle switch **83** enables capture of reflectance image **122**.

[0098] In an alternate embodiment, toggling in this fashion can be accomplished automatically, such as by control logic circuitry in communication with camera **32** or sensor in imaging apparatus **10**. This arrangement allows a single camera **32** or other sensor to obtain images of different types.

[0099] An alternate embodiment, shown in FIG. **4**B, employs a polarizing beamsplitter **18** (sometimes termed a polarization beamsplitter) as a polarizing element. In this arrangement, polarizing beamsplitter **18** advantageously performs the functions of both the polarizer and the analyzer for image-bearing light, thus offering a more compact solution. Tracing the path of illumination and image-bearing light shows how polarizing beamsplitter **18** performs this function. Illumination from light source **12** is essentially unpolarized. Polarizing beamsplitter **18** transmits p-polarization, as shown by the dotted arrow in FIG. 4B, and reflects s-polarization, directing this light to tooth **20**. At the tooth **20**, back-scattering depolarizes this light. Polarizing beamsplitter **18** treats the back-scattered light in the same manner, transmitting the p-polarization and reflecting the s-polarization. The resulting p-polarized light can then be filtered at long-pass filter **15**, and detected at camera **30** (with suitable color filter as was described with reference to FIG. **1**) or color camera **32**. Because specular reflected light is s-polarized, polarizing beamsplitter **18** effectively removes this specular reflective component from the light that reaches camera **30**, **32**.

[0100] Polarized illumination results in further improvement in image contrast, but at the expense of light level, as can be seen from the description of FIGS. **4**A and **4**B. Hence, when using polarized light in this way, it may be necessary to employ a higher intensity light source **12**. This employment of polarized illumination is particularly advantaged for obtaining the reflectance image data and is also advantaged when obtaining the fluorescence image data, increasing image contrast and minimizing the effects of specular reflection.

[0101] One type of polarizer **42** that has particular advantages for use in imaging apparatus **10** is the wire grid polarizer, such as those available from Moxtek Inc. of Orem, Utah and described in U.S. Pat. No. 6,122,103 (Perkins et al.) The wire grid polarizer exhibits good angular and color response, with relatively good transmission over the blue spectral range. Either or both polarizer **42** and analyzer **44** in the configuration of FIG. **4**A could be wire grid polarizers. Wire grid polarizing beamsplitters are also available, and can be used in the configuration of FIG. **4**B.

[0102] The method of the present invention takes advantage of the way the tooth tissue responds to incident light of sufficient intensity, using the combination of fluorescence and light reflectance to indicate carious areas of the tooth with improved accuracy and clarity. In this way, the present invention offers an improvement upon existing non-invasive fluorescence detection techniques for caries. As was described in the background section given above, images that have been obtained using fluorescence only may not clearly show caries due to low contrast. The method of the present invention provides images having improved contrast and is, therefore, of more potential benefit to the diagnostician for identifying caries.

[0103] In addition, unlike earlier approaches using fluorescence alone, the method of the present invention also provides images that can be used to detect caries in its very early incipient stages. This added capability, made possible because of the perceptible back-scattering effects for very early carious lesions, extends the usefulness of the fluorescence technique and helps in detecting caries during its reversible stages, so that fillings or other restorative strategies might not be needed.

[0104] Referring to FIG. **9**, there is shown an embodiment of imaging apparatus **10** using polarized light from a polarizing beamsplitter **18** and using a telecentric field lens **24**. Light source **12**, typically a light source in the blue wavelength range for exciting maximum fluorescence from tooth **20** provides illumination through lens **14** and onto polarizing beamsplitter **18**. Here, one polarization state transmits, the other is reflected. In a typical embodiment, p-polarized light is transmitted through polarizing beamsplitter **18** and is, therefore, discarded. The s-polarized light is reflected toward tooth **20**, guided by field lens **24** and an optional turning mirror **46** or other reflective surface. Light returning from tooth **20** can include a specular reflection component and a back-scattered reflection component. Specular reflectance does not change the polarization state. Thus, for the s-polarized illumination, that is, for the unwanted specularly reflected component, the reflected light is directed back toward light source **12**. As has been observed, back-scattered reflectance undergoes some amount of depolarization. Thus, some of the back-scattered reflected light has p-polarization and is transmitted through polarizing beamsplitter **18**. This returning light may be further conditioned by optional analyzer **44** and then directed by an imaging lens **66** to sensor **68**, such as a camera, through color filter **56**. Long pass filtering (not shown in FIG. **9**) could also be employed in the path of light returned from tooth **20**. Color filter **56** is used in this arrangement to block light from the light source that was used to excite fluorescence, since the response of the color filter array (CFA) built inside the sensor is typically not sharp enough to block the light from the light source in this region. In this way, the returning light directed to sensor **68** is fluorescence only.

[0105] The use of telecentric field lens **24** is advantaged in the embodiment of FIG. **9**. Telecentric optics provides constant magnification within the depth of field, which is particularly useful for highly contoured structures such as teeth that are imaged at a short distance. Perspective distortion is minimized. Telecentric field lens **24** could be a multi-element lens, represented by a single lens symbol in FIG. **9**. Light source **12** may be any suitable color, including white, blue, green, red, or near infrared, for example. Light source **12** may also be a more complex assembly capable of providing light at different spectral bands, such as through the use of movable color filters. FIG. **10** shows an alternate embodiment of imaging apparatus **10** in which no turning mirror is used. Instead, polarizing beamsplitter **18** is disposed in the imaging path between field lens **24** and tooth **20**. Alternately, if no field lens is used, polarizing beamsplitter **18** is disposed in the imaging path just before tooth **20**. Light source **12** is positioned to direct illumination through polarizing beamsplitter **18**, so that the illumination effectively bypasses field lens **24** if any. Specularly reflected light is again discarded by means of polarizing beamsplitter **18** and analyzer **44**.

[0106] The block diagram of FIG. **11** shows an alternate embodiment of imaging apparatus **10** in which two separate light sources **12***a* and **12***b* are used. Light sources **12***a* and **12***b* may both emit the same wavelengths or may emit different wavelengths. They may illuminate tooth **20** simultaneously or one at a time. Polarizing beamsplitter **18** is disposed in the imaging path between field lens **24** and tooth **20**, thus providing both turning and polarization functions.

[0107] FIG. **12**A shows another alternate embodiment, similar to that shown in FIG. **11**, in which each of light sources **12***a* and **12***b* has a corresponding polarizer **42***a* and **42***b*. A turning mirror could be substituted for polarizing beamsplitter **18** in this embodiment; however, the use of both polarized illumination, as provided from the combination of light sources **12***a* and **12***b* and their corresponding polarizers **42***a* and **42***b*, and polarizing beamsplitter **18** can be advantageous for improving image quality. FIG. **12**B is another embodiment with additional LEDs to increase the light level on the tooth or other object. As described above, the LEDs can be white light LEDs and/or blue LEDs. In order to achieve uniform illumination, the arrangement of LEDs, with respect to the tooth or other object, should be symmetric.

[0108] FIG. **12**C is another embodiment with an alternate illumination implementation. In this embodiment, fiber bundles are used to direct light from LEDs or other light source to the tooth or other object. In FIG. **12**C, four optical fiber bundles **49***a*-**49***d* are used. Fiber bundles **49***a* and **49***b* are used to deliver white light to the object. Two polarizers **42***a* and **42***b* are placed in front of the output surface of optical fiber bundles **49***b*, **49***d* to create linear polarized illumination. Fiber bundles **49***c* and **49***d* couple the light from Blue or UV LEDs or other light sources to excite the fluorescence from the object.

[0109] FIG. **19** is an alternate embodiment for the imaging probe with two sensors **68***a* and **68***b*. One dichroic mirror **48** is used as a spectral separator in this embodiment to direct the reflected light with different spectral bands to two different sensors. For example, in one embodiment, dichroic mirror **48** transmits light within the visible spectrum (440 nm to 650 nm) and reflects UV (<400 nm) and NIR (>700 nm). With this embodiment, the imaging probe can also be employed in other applications, such as for tooth color shade matching and for soft tissue imaging, for example.

[0110] In one embodiment, the apparatus displays a fluorescence image, instead of a white light image, as the live video image. This enables the operator to screen the tooth for caries detection using fluorescence imaging and to assess tooth condition using the white light image for other applications. One switch is necessary, either in the probe or in the software, so that the user can select the live video image mode based on the application. The switch in the probe can be a two-step button switch. Without pressing the button switch, the live video image is a white light image. When the button is pressed to its half way travel position, the fluorescence image becomes the live video image. Both fluorescence and white light images can be captured and saved when the button is pressed to its full travel position.

[0111] With high-speed electronics and software, two live video images can be displayed in the monitor to the user. Both single-sensor and dual-sensor configurations can be used to display two live video images. In order to obtain two live images and avoid crosstalk, the LEDs with different wavelengths need to be switched alternately on and off. An advantage in displaying two live video images is that the user can compare the fluorescence and white light image and diagnose suspicious regions of these images. Using image processing utilities described subsequently, a suspicious region can be highlighted automatically when the fluorescence and white image are alternately obtained.

[0112] One common difficulty with conventional intraoral cameras and caries detection image devices is that the live video image moves in the direction opposite to probe movement. This is due to imaging lens properties: the image is reversed when using only one imaging lens. Several optical methods can be applied to form the image. One of the methods is to use an image relay technique, as shown in FIG. **21**. Image lens **222** forms an intermediate image **224** of the object, tooth **20**. The orientation of intermediate image **224** is opposite to the object **220**. An image lens **226** then forms a final image **228** of intermediate image **224**. The orientation of image **228** is the same as the object, tooth **20**. Using this embodiment, the moving direction of the final image **228** will be the same as the probe movement. In addition, folding mirrors can be used to change image orientation as necessary. Even without such extra optical components to change image orientation, software can manipulate the image to correct the image orientation that is displayed to the user.

[0113] FIGS. **23**A and **23**B are two embodiments for image capture with auto-focusing capability. For simplicity, white light LEDs and LEDs for fluorescence imaging are not shown in FIGS. **23**A and **23**B. Light sources **250***a* and **250***b* are LEDs with integral lenses. Collimating lenses in light sources **250***a* and **250***b* form images **252***a* and **252***b*, respectively, onto a cross point **256** of the object plane and optical axis. As shown in FIG. **23**A, when the probe is not in the right position (indicating focus), images **252***a* and **252***b* do not overlap. FIG. **23**C shows how this is implemented in one embodiment, with tooth **20** at different positions relative to cross point **256**. At left in this figure, tooth **20** is beyond cross point **256**, thus out of focus. At right, tooth **20** is within cross point **256**, also out of focus. In the central portion of this figure, tooth **20** is positioned within focus. To achieve focus with this arrangement, the operator simply moves the probe so that images **252***a* and **252***b* overlap. When images **252***a* and **252***b* overlap, the user can instruct the system to take the images. As an alternative embodiment, auto focus can be provided. Software working with or within control circuitry **110** can detect and track the positions of images **252***a* and **252***b*, using light detection techniques familiar to those skilled in the imaging arts. The software can then trigger sensor **68** or the camera to take the images once images **252***a* and **252***b* overlap.

[0114] FIG. **23**B is a simplified version of FIG. **23**A. In this configuration, only one LED and lens **250***a* is used. A crosshair **254** displays on the monitor to indicate the center of the image and the optical axis. When images **252***a* align with crosshair **254**, the probe is on focus. If software is applied to track the position of image **252***a*, the use of crosshair **254** or similar feature is not required.

Embodiments Using Optical Coherence Tomography (OCT)

[0115] Optical coherence tomography (OCT) is a non-invasive imaging technique that employs interferometric principles to obtain high resolution, cross-sectional tomographic images of internal microstructures of the tooth and other tissue that cannot be obtained using conventional imaging techniques. Due to differences in the backscattering from carious and healthy dental enamel OCT can determine the depth of penetration of the caries into the tooth and determine if it has reached the dentin enamel junction. From area OCT data it is possible to quantify the size, shape, depth, and determine the volume of carious regions in a tooth.

[0116] In an OCT imaging system for living tissue, light from a low-coherence source, such as an LED or other light source, can be used. This light is directed down two different optical paths: a reference arm of known length and sample arm, which goes to the tooth. Reflected light from both reference and sample arms is then recombined, and interference effects are used to determine characteristics of the underlying features of the sample. Interference effects occur when the optical path lengths of the reference and sample arms are equal within the coherence length of the light source. As the path length difference between the reference arm and the sample arm is changed the depth of penetration in the sample is modified in a similar manner. Typically in biological tissues NIR light of around 1300 nm can penetrate about 3-4 mm as is the case with dental tissue. In a time domain OCT system the reference arm delay path relative to the sample arm delay path is alternately increased monotonically and decreased monotonically to create depth scans at a high rate. To create a 2-dimensional scan the sample measurement location is changed in a linear manner during repetitive depth scans such as with a galvanometer.

[0117] In an OCT system **80** shown in FIG. **13**, light from a low-coherence light source **160**, such as an LED or other light source, can be used. This light is split and made to travel down two different optical paths being a reference arm **164** with a built in reference delay scanner to alternately change its path length and a sample arm **76** that goes to the tooth by a beamsplitting and combining element **162**. Reflected light from both reference and sample arms is then recombined by beamsplitting and combining element **162**, and interference effects are used to determine characteristics of the underlying features of the sample. The reference arm and sample arm pathlengths are made to be the same at some part of the reference delay scanning operation to enable observation of interference effects. The recombined and interfering light from beamsplitting and combining element **162** is then sent to a detector and processing electronics **166** where the optical interference signal is converted to an electrical signal which is then acquired by data acquisition hardware and computer system **168** for further processing and display. The optical elements of OCT system **80** are configured as an interferometer.

[0118] Still referring to FIG. **13**, there is shown an embodiment of imaging apparatus **10** using both FIRE imaging methods and OCT imaging. Light source **12**, polarizing beamsplitter **18**, field lens **24**, a turning mirror **82**, imaging lens **66**, and sensor **68** provide the FIRE imaging function along an optical path as described previously. An OCT imager **70** directs light for OCT scanning into the optical path that is shared with the FIRE imaging components. Light from OCT system **80** is directed through a sample arm **76** and through a collimating lens **74** to a scanning element **72**, such as a galvanometer, for example. A dichroic mirror **78** is transmissive to visible light and reflective for near-IR and longer wavelengths. This sample arm light is then directed from dichroic mirror **78** to tooth **20** through the optical system that includes a scanning lens **84** and field lens **24**. Field lens **24** is not required for non-telecentric OCT scanning. Returned light from tooth **20** travels the same optical path and is recombined with light from the reference arm of interferometer **162**.

[0119] OCT scans are 2-dimensional in the plane of the impinging beam. Image-forming logic combines adjacent lines of successive 2-dimensional scans (length along the galvanometer scan line and depth) to form a multi-dimensional volume image of the sample (tooth) structure, including portions of the tooth that lie beneath the surface.

[0120] For OCT imager **70**, the light provided is continuous wave low coherence or broadband light, and may be from a source such as a super luminescent diode, diode-pumped solid-state crystal source, or diode-pumped rare earth-doped fiber source, for example. In one embodiment, near-IR light is used, such as light having wavelengths near 1310 nm, for example.

[0121] While the OCT scan is a particularly powerful tool for helping to show the condition of the tooth beneath the surface, it can be appreciated that this type of detailed information is not needed for every tooth or for every point along a tooth surface. Instead, it would be advantageous to be able to identify specific areas of interest and apply OCT imaging to just those areas. Referring to FIG. **14**A, there is shown a display of tooth **20**. An area of interest **90** can be identified by a diagnostician for OCT scanning. For example, using operator interface tools at processing apparatus **38** and display **40** (FIGS. **1-3**), an operator can outline area of interest **90** on display **40**. This could be done using a computer mouse or some type of electronic stylus as a pointer, for example. The OCT scan can then be performed when a probe or other portion of imaging apparatus **10** of FIG. **13** is brought into the proximity of area of interest **90**. Referring to FIG. **14**B, there is shown a typical image from OCT data **92** in one embodiment.

Probe Embodiment

[0122] The components of imaging apparatus **10** of the present invention can be packaged in a number of ways, including compact arrangements that are designed for ease of handling by the examining dentist or technician. Referring to FIG. **15**, there is shown an embodiment of a hand-held dental imaging apparatus **100** according to the present invention. Here, a handle **102**, shown in phantom outline, houses light source **12**, sensor **68**, and their supporting illumination and imaging path components. A probe **104** attaches to a handle **102** and may act merely as a cover or, in other embodiments, support lens **22** and turning mirror **46** in proper positioning for tooth imaging. Control circuitry **110** can include switches, memory, and control logic for controlling device operation. In one embodiment, control circuitry **110** can simply include one or more switches for controlling components, such as an on/off switch for light source **12**. Control circuitry **110** can be a microprocessor in the probe or externally connected, configured with programmed logic for controlling probe functions and obtaining image data. Optionally, the function of control circuitry **110** can be performed at processing apparatus **38** (FIGS. **1-3**). In other embodiments, control circuitry **110** can include sensing, storage, and more complex control logic components for managing the operation of hand-held imaging apparatus **100**. Control circuitry **110** can connect to a wireless interface **136** for connection with a communicating device, such as computer workstation or server, for example. FIG. **18** shows an imaging system **150** using wireless transmission. Hand-held imaging apparatus **100** obtains an image upon operator instruction, such as with the press of a control button, for example. The image can then be sent to a control logic processor **140**, such as a computer workstation, server, or dedicated microprocessor based system, for example. A display **142** can then be used to display the image obtained. Wireless connection of hand-held imaging apparatus **100** can be advantageous, allowing imaging data to be obtained at processing apparatus **38** without the need for hardwired connection. Any of a number of wireless interface protocols could be used, such as Bluetooth data transmission, as one example.

[0123] Dental imaging apparatus **100** may be configured differently for different patients, such as having an adult size and a children's size, for example. In one embodiment, removable probe **104** is provided in different sizes for this purpose. Alternately, probe **104** could be differently configured for the type of tooth or angle used, for example. Probe **104** could be disposable or could be provided with sterilizable contact components. Probe **104** could also be adapted for different types of imaging. In one embodiment, changing probe **104** allows use of different optical components, so that a wider angle imaging probe can be used for some types of imaging and a smaller area imaging probe used for single tooth caries detection. One or more external lenses could be added or attached to probe **104** for specific imaging types.

[0124] Probe **104** could also serve as a device for drying tooth **20** to improve imaging. In particular, fluorescence imaging benefits from having a dry tooth surface. In one embodiment, as shown in FIG. **15**, a tube **106** providing an outlet for directing pressurized air or other drying gas from a pressurized gas source **81** onto tooth **20** is provided as part of probe **104**. Probe **104** could serve as an air tunnel or conduit for pressurized air; optionally, separate tubing could be required for this purpose.

[0125] FIG. **16** shows an embodiment of hand-held imaging apparatus **100** having a display **112**. Display **112** could be, for example, a liquid crystal (LC) or organic light emitting diode (OLED) display that is coupled to handle **102** as shown. A displayed image **108** could be provided for assisting the dentist or technician in positioning probe **104** appropriately against tooth **20**. Using this arrangement, a white light source is used to provide the image on display **112** and remains on unless FIRE imaging is taking place. At an operator command entry, such as pressing a switch on hand-held imaging apparatus **100** or pressing a keyboard key, the white light image is taken. Then the white light goes off and the fluorescence imaging light source, for example, a blue LED, is activated. Once the fluorescence and white light images are obtained, the white light goes back on. When using display **112** or a conventional video monitor, the white light image helps as a navigation aid. Using a display monitor, the use of white light imaging allows the display of an individual area to the patient.

[0126] In order to obtain an image, probe **104** can be held in position against the tooth, using the tooth surface as a positional reference for imaging. This provides a stable imaging arrangement and fixed optical working distance. This configuration yields improved image quality and consistency. Placing probe **104** directly against the tooth has particular advantages for OCT imaging, as described earlier, since this technique operates over a small distance along the axis.

[0127] In order to image different surfaces of the tooth, a folding mirror inside the probe, such as folding mirror **18** as shown in FIG. **22**, is typically required. One problem related to this folding mirror is the undesired fogging of the mirror surface that often can occur. A number of methods are used in intraoral cameras to address this fogging problem. For example, in one embodiment, the mirror is heated so that its temperature approximates the temperature of the mouth. One drawback with this approach is that it requires an added heating element and current source for the heating element. In another embodiment of the present invention, an anti-fog coating is applied as a treatment to the mirror surface. With this arrangement, no additional components are required. Another embodiment is to bond an anti-fog film to the mirror surface.

[0128] The embodiments shown in FIGS. **11** and **12A-12C** use LEDs as light sources **12***a*, **12***b* to illuminate tooth **20** directly, without any light-shaping optical element. Since the divergent angle of the light from LED is usually large, a sizable portion of the emitted light strikes the inner surface of the probe, as shown in FIG. **22**. The large angle rays **240***a*, **240***b* and **240***c* in FIG. **22** hit the inner surface of the probe. If the probe inner surface is designed to be absorptive, the light hitting the surface is absorbed and does not reach tooth **20**. In one embodiment, the inner surface of the probe is reflective, so that the light incident on this surface is reflected and eventually reaches the tooth. There are two advantages with this design. One advantage is increased efficiency, since all of the light reaches tooth **20** except for some absorption loss. Another advantage relates to the uniformity of the illumination on tooth **20**. With a reflective inner surface, the probe operates as a light pipe. This integrates the light spatially and angularly, and provides uniform illumination to the tooth.

Imaging Software

[0129] One method for reducing false-positive readings or, similarly, false-negative readings, is to correlate images obtained from multiple sources. For example, images separately obtained using x-ray equipment can be combined with images that have been obtained using imaging apparatus **10** of the present invention. Imaging software, provided in processing apparatus **38** (FIGS. **1-3**) allows correlation of images of tooth **20** from different sources, whether obtained solely using imaging apparatus **10** or obtained from some combination of devices including imaging apparatus **10**.

[0130] Referring to FIG. **17**, there is shown, in block diagram form, a processing scheme using images from multiple sources. A fluorescence image **120**, a reflectance image **122**, and a white light image **124** are obtained from imaging apparatus **10**, as described earlier. An x-ray image **130** is obtained from a separate x-ray apparatus. Image correlation software **132** takes two or more of these images and correlates the data accordingly to form a composite image **134** from these multiple image types. Composite image **134** can then be displayed or used by automated diagnosis software in order to identify regions of interest for a specific tooth. In one embodiment, the images are provided upon operator request. The operator specifies a tooth by number and, optionally, indicates the types of image needed or the sources of images to combine. Software in processing apparatus **38** then generates and displays the resultant image.

[0131] As one example of the value of using combined images, white light image **124** is particularly useful for identifying stained areas, amalgams, and other tooth conditions and treatments that might otherwise appear to indicate a caries condition. However, as was described earlier, the use of white light illumination is often not sufficient for accurate diagnosis of caries, particularly in its earlier stages. Combining the white light image with some combination that includes one or more of fluorescence and x-ray images helps to provide useful information on tooth condition. Similarly, any two or more of the four types of images shown in FIG. **17** could be combined by image correlation software **132** for providing a more accurate diagnostic image.

[0132] Imaging software can also be used to help minimize or eliminate the effects of specular reflection. Even where polarized light components can provide some measure of isolation from specular reflection, it can be advantageous to eliminate any remaining specular effects using image processing. Data filtering can be used to correct for unwanted specular reflection in the data. Information from other types of imaging can also be used, as is shown in FIG. **17**. Another method for compensating for specular reflection is to obtain successive images of the same tooth at different light intensity levels, since the relative amount of specular light detected would increase at a rate different from light due to other effects.

[0133] Another key feature of the image processing software is to enhance the image obtained and automatically highlight suspicious areas such as white spots. FIG. **20** shows the flowchart for image processing workflow. As the first step **202**, the software reads white light and fluorescence images. The software then analyzes the contents in different color planes in white light and fluorescence images in a step **204**. With the information obtained from the white light and fluorescence images, different image processing algorithms such as color rendering, contrast enhancement, and segmentation, can be applied to enhance the image in steps **206** and **208**. Some of the algorithms are discussed earlier with relation to image processing. Also, image processing algorithms can be used to identify the nature of each region, based on the color information in each color plane, and to highlight each region automatically in an enhancement step **210**. As a final step **212**, the tooth information, such as the size, shape and status of the suspicious area, can be extracted and displayed to the dental professionals.

[0134] The invention has been described in detail with particular reference to certain preferred embodiments thereof, but it will be understood that variations and modifications can be effected within the scope of the invention as described above, and as noted in the appended claims, by a person of ordinary skill in the art without departing from the scope of the invention.

[0135] For example, various types of light sources **12** could be used, with various different embodiments employing a camera or other type of image sensor. While a single light source **12** could be used for fluorescence excitation, it may be beneficial to apply light from multiple incident light sources **12** for obtaining multiple images. Referring to the alternate embodiment of FIG. **8**, light source **12** might be a more complex assembly that includes one light source **16***a* for providing light of appropriate energy level and wavelength for exciting fluorescent emission and another light source **16***b* for providing illumination at different times. The additional light source **16***b* could provide light at wavelength and energy levels best suited for back-scattered reflectance imaging. Or, it could provide white light illumination, or other multicolor illumination, for capturing a white light image or multicolor image which, when displayed side-by-side with a FIRE image, can help to identify features that might otherwise confound caries detection, such as stains or hypo calcification. The white light image itself might also provide the back-scattered reflectance data that is used with the fluorescence data for generating the FIRE image. Supporting optics for both illumination and image-bearing light paths could have any number of forms. A variety of support components could be fitted about the tooth and used by the dentist or dental technician who obtains the images. Such components might be used, for example, to appropriately position the light source or sensing elements or to ease patient discomfort during imaging.

[0136] Thus, what is provided is an apparatus and method for caries detection at early and at later stages using combined effects of back-scattered reflectance and fluorescence.

PARTS LIST

[0137] **10** imaging apparatus
[0138] **12** light source
[0139] **12***a* light source
[0140] **12***b* light source
[0141] **13** diffuser
[0142] **14** lens
[0143] **15** filter
[0144] **16***a* light source
[0145] **16***b* light source
[0146] **17** filter
[0147] **18** polarizing beamsplitter
[0148] **20** tooth
[0149] **22** lens
[0150] **24** field lens
[0151] **26** filter
[0152] **28** filter
[0153] **30** camera
[0154] **32** camera
[0155] **34** beamsplitter
[0156] **38** processing apparatus
[0157] **40** display
[0158] **42** polarizer
[0159] **42***a* polarizer
[0160] **42***b* polarizer
[0161] **44** analyzer
[0162] **46** turning mirror
[0163] **48** dichroic mirror
[0164] **49***a* fiber bundle
[0165] **49***b* fiber bundle
[0166] **49***c* fiber bundle
[0167] **49***d* fiber bundle
[0168] **50** fluorescence image
[0169] **52** reflectance image
[0170] **54** white-light image
[0171] **56** filter
[0172] **58** carious region
[0173] **60** FIRE image
[0174] **62** threshold image
[0175] **64** enhanced threshold FIRE image
[0176] **66** lens
[0177] **68** sensor
[0178] **68***a* sensor
[0179] **68***b* sensor
[0180] **70** OCT imager
[0181] **72** scanning element
[0182] **74** lens
[0183] **76** sample arm
[0184] **78** dichroic mirror
[0185] **80** OCT system
[0186] **81** gas source
[0187] **82** mirror
[0188] **83** switch
[0189] **84** scanning lens
[0190] **90** area of interest
[0191] **92** OCT data
[0192] **96** filter curve
[0193] **98** white light curve
[0194] **100** imaging apparatus
[0195] **102** handle

[0196] **104** probe
[0197] **106** tube
[0198] **108** image
[0199] **110** control circuitry
[0200] **112** display
[0201] **120** fluorescence image
[0202] **122** reflectance image
[0203] **124** white light image
[0204] **130** x-ray image
[0205] **132** image correlation software
[0206] **134** composite image
[0207] **136** wireless interface
[0208] **140** control logic processor
[0209] **142** display
[0210] **150** imaging system
[0211] **160** light source
[0212] **162** beamsplitting and combining element
[0213] **164** reference arm
[0214] **166** detector and processing electronics
[0215] **168** data acquisition hardware and computer system
[0216] **202** step
[0217] **204** step
[0218] **206** step
[0219] **208** step
[0220] **210** step
[0221] **212** step
[0222] **220** object (tooth)
[0223] **222** lens **1**
[0224] **224** intermediate image
[0225] **226** lens **2**
[0226] **228** final image
[0227] **240***a* ray
[0228] **240***b* ray
[0229] **240***c* ray
[0230] **250***a* light source
[0231] **250***b* light source
[0232] **252***a* image
[0233] **252***b* image
[0234] **254** crosshair
[0235] **256** cross point

1. An apparatus for imaging a tooth comprising:
(a) at least one light source providing incident light having a first spectral range for obtaining a reflectance image on the tooth and a second spectral range for exciting a fluorescence image of the tooth;
(b) a polarizing beamsplitter in a path of the incident light, the polarizing beamsplitter directing light having a first polarization state toward the tooth and directing light from the tooth having a second polarization state along a return path toward a sensor, wherein the second polarization state is orthogonal to the first polarization state;
(c) a lens positioned in the return path to direct image-bearing light from the tooth toward the sensor for obtaining image data from the portion of the light having the second polarization state; and
(d) a long-pass filter in the return path, to attenuate light in the second spectral range and to transmit light in the first spectral range.

2. The apparatus of claim **1** wherein the polarizing beamsplitter is a wire grid polarizing beamsplitter.

3. The apparatus of claim **1** wherein said light source is comprised of a first light source having a first spectral range and a second light source having a second spectral range.

4. The apparatus of claim **1** wherein the lens is telecentric in object space.

5. The apparatus of claim **1** wherein the sensor is a complementary metal oxide semiconductor (CMOS) sensor.

6. The apparatus of claim **1** wherein the sensor is a charged couple device (CCD) sensor.

7. The apparatus of claim **1** wherein the light source is taken from the group consisting of an LED, an incandescent bulb, a super luminescent diode, a diode-pumped solid-state crystal source, and a diode-pumped rare earth-doped fiber source.

8. The apparatus of claim **1** further comprising an analyzer in the return path.

9. The apparatus of claim **1** wherein the first spectral range is between about 400 nm and 700 nm.

10. The apparatus of claim **1** further comprising:
(e) a display coupled to the sensor for presenting the image data obtained therefrom.

11. The apparatus of claim **3** wherein the light source further comprises a third light and a fourth light, wherein both the third and fourth lights direct a beam toward a point that corresponds with the focus of the lens.

12. The apparatus of claim **3** further comprising a band pass filter in the path of the second light source.

13. The apparatus of claim **1** further comprising:
(e) an interferometer coupled along the optical path for obtaining an image of a portion of the tooth using optical coherence tomography.

14. The apparatus of claim **1** wherein the second spectral range is between about 300 nm and 500 nm.

15. The apparatus according to claim **1** further comprising an outlet for directing a pressurized gas toward the tooth.

16. The apparatus according to claim **11** further comprising control logic that automatically detects overlap of light from the third and fourth lights as focus and initiates capture of image data at the sensor.

17. The apparatus according to claim **1** further comprising a switch enabling an operator to enable either the light in the second spectral range or the light in the first spectral range.

18. The apparatus according to claim **1** further comprising a second lens for imaging an intermediate image formed by the first lens onto the sensor.

19. An apparatus for imaging a tooth comprising:
(a) at least one light source for providing an incident light having a first spectral range for obtaining a reflectance image on the tooth and a second spectral range for exciting a fluorescence image of the tooth;
(b) a polarizer in the path of the incident light and disposed to direct light having a first polarization state toward the tooth;
(c) an analyzer disposed to direct light obtained from the tooth and having a second polarization state along a return path toward a sensor, wherein the second polarization state is substantially orthogonal to the first polarization state;
(d) a lens positioned in the return path to direct image-bearing light from the tooth toward the sensor for obtaining image data from the portion of the light having the second polarization state; and

(e) a long-pass filter in the return path, to attenuate light in the second spectral range and to transmit light in the first spectral range.

20. The apparatus according to claim **19** further comprising:

(f) a display mounted on the body of the apparatus and in communication with the sensor for displaying the image of the tooth.

21. The apparatus as in claim **19** further comprising:

(f) an interferometer coupled along the optical path for obtaining an image of a portion of the tooth using optical coherence tomography.

22. An apparatus for imaging a tooth comprising:

(a) a handle portion for handling and positioning by an operator;

(b) a probe portion, separable from the handle portion, for placement in the proximity of the tooth;

(c) an optical subsystem housed within the handle and probe portions comprising:

(i) at least one light source providing incident light having a first spectral range for obtaining a reflectance image on the tooth and a second spectral range for exciting a fluorescence image of the tooth;

(ii) a polarizing beamsplitter in a path of the incident light, the polarizing beamsplitter directing light having a first polarization state toward the tooth and directing light from the tooth having a second polarization state along a return path toward a sensor, wherein the second polarization state is orthogonal to the first polarization state;

(iii) a lens positioned in the return path to direct image-bearing light from the tooth toward the sensor for obtaining image data from the portion of the light having the second polarization state; and

(iv) a long-pass filter in the return path, to attenuate light in the second spectral range and to transmit light in the first spectral range.

23. The apparatus according to claim **22** wherein the handle portion further comprises an operator control for initiating operation to obtain an image.

24. The apparatus according to claim **22** further comprising a wireless interface for sending image data to a communicating device.

25. The apparatus according to claim **22** further comprising a display for operator viewing of the image data obtained.

26. The apparatus according to claim **25** wherein the display is taken from the group consisting of a liquid crystal (LC) display and an organic light emitting diode (OLED) display.

27. The apparatus according to claim **22** further comprising an outlet for directing a pressurized gas toward the tooth.

28. The apparatus according to claim **22** wherein the probe portion is disposable.

29. The apparatus according to claim **22** further comprising at least one folding mirror in the optical path.

30. The apparatus according to claim **29** wherein the at least one folding mirror is treated to reduce fogging effects.

31. The apparatus according to claim **22** wherein the probe portion comprises a reflective inner surface.

32. The apparatus according to claim **29** wherein the probe is in communication with a display and wherein the at least one folding mirror cooperates with other components along the optical path to track the tooth surface during movement of the probe.

33. An apparatus for imaging a tooth comprising:

(a) a handle portion for handling and positioning by an operator;

(b) a probe portion, separable from the handle portion, for placement in the proximity of the tooth;

(c) an optical subsystem housed within the handle and probe portions comprising:

(i) at least one light source providing incident light having a first spectral range for obtaining a reflectance image on the tooth and a second spectral range for exciting a fluorescence image of the tooth;

(ii) a polarizer in the path of the incident light and disposed to direct light having a first polarization state toward the tooth;

(iii) an analyzer disposed to direct light obtained from the tooth and having a second polarization state along a return path toward a sensor, wherein the second polarization state is substantially orthogonal to the first polarization state;

(iv) a lens positioned in the return path to direct image-bearing light from the tooth toward the sensor for obtaining image data from the portion of the light having the second polarization state; and

(v) a long-pass filter in the return path, to attenuate light in the second spectral range and to transmit light in the first spectral range.

34. An apparatus for imaging a tooth comprising:

(a) at least one light source for providing, along an optical path, an incident light to illuminate the tooth;

(b) a spectral separator in the optical path to direct light of a first spectral band that is reflected from the tooth toward a first sensor and other light from the tooth toward a second sensor; and

(c) a lens positioned in the optical path to form an image of the tooth, through the spectral separator, onto the first and second sensors for obtaining image data from the tooth.

35. The apparatus of claim **34** wherein the spectral separator is a dichroic beamsplitter.

36. The apparatus of claim **34** wherein the first sensor obtains a reflected light image and the second sensor obtains a fluorescence light image.

37. A method for imaging a tooth comprising:

(a) providing incident light having a first spectral range for obtaining a reflectance image from the tooth;

(b) providing incident light having a second spectral range for exciting a fluorescence image from the tooth;

(c) directing light having a first polarization state toward the tooth and directing light from the tooth having a second polarization state along a return path toward a sensor, wherein the second polarization state is orthogonal to the first polarization state;

(d) directing image-bearing light from the tooth toward the sensor for obtaining image data from the portion of the light having the second polarization state; and

(e) attenuating light in the second spectral range and transmitting light in the first spectral range.

38. The method according to claim **37** wherein directing image-bearing light toward the sensor comprises forming an intermediate image in the return path and further comprising re-imaging the intermediate image onto the sensor.

39. The method according to claim **37** further comprising displaying an image obtained by the sensor.

40. The method according to claim **39** wherein the incident light and sensor are provided using a hand-held probe and wherein movement of the probe from one position to another is displayed as movement in the same direction.

41. The method according to claim **37** further comprising obtaining an image of a portion of the tooth using optical coherence tomography.

* * * * *

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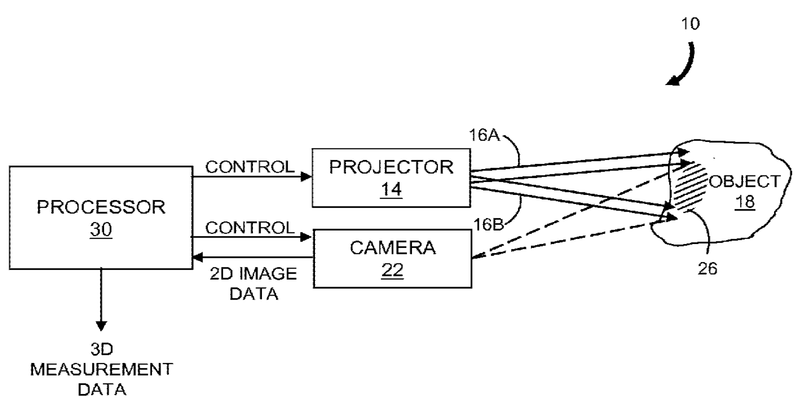

FIG. 1

(57) Abstract: Described is a user-manipulated imaging device for measuring a three-dimensional surface of an object. The device includes an imager configured for acquiring two-dimensional images of the surface and a device housing coupled to the imager and configured for manual positioning of the imager. The device also includes a processor in communication with the imager and configured to generate three-dimensional surface data based on the two-dimensional images. The device further includes a display coupled to the device housing and in communication with at least one of the imager and the processor. The display shows images of the surface and is observable within a field of view of the user while the device housing is manually positioned within the field of view and relative to the surface. In various embodiments, the display shows the two-dimensional images and representations of the three-dimensional surface data.

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INTEGRATED DISPLAY IN A HAND-HELD THREE-DIMENSIONAL METROLOGY SYSTEM

RELATED APPLICATION

This application claims the benefit of the earlier filing date of U.S. Provisional Patent Application Serial No. 61/227,255, filed July 21, 2009, titled "Integrated Display in a Hand-Held Three-Dimensional Metrology System," the entirety of which is incorporated herein by reference.

FIELD OF THE INVENTION

The invention relates to the field of three-dimensional imaging and more specifically to the field of displaying non-contact surface measurement data for dental and medical applications.

BACKGROUND OF THE INVENTION

A variety of precision non-contact three-dimensional (3D) metrology systems have been developed for dental and medical applications. Conventional systems typically include a handheld camera or scanner connected to a processing unit that communicates with a display monitor. The display monitor presents a variety of information to the user. The information can include control options, acquired images, and operator assistance information such as an indication of an optimal focus condition. This configuration requires the user to look in two directions, that is, to look at the position of the handheld device with respect to the patient and to look at the display monitor to determine that proper images are being acquired. Thus the time and effort to obtain the desired measurement data is adversely affected by the requirement for the user to alternately view the position of the device and view the acquired images.

SUMMARY

In one aspect, the invention features a method of displaying information for a user-manipulated 3D imaging device. The method includes acquiring a plurality of two-dimensional (2D) images of a surface of an object with an imaging device manipulated by a user in position relative to the surface of the object and within a field of view of the user. The 2D images are processed to generate three-dimensional surface data for the surface of the object. Measurement data are displayed to the user within the field of view of the user during continued manipulation of the imaging device. In one embodiment, the displayed measurement information includes the two-dimensional images acquired by the imaging device and, in another embodiment, the displayed information includes a representation of the 3D surface data.

In another aspect, the invention features a user-manipulated imaging device for measuring a 3D surface of an object. The imaging device includes an imager, a device housing, a processor and a display. The imager is configured for acquiring 2D images of a surface of the object. The device housing is coupled to the imager and configured for manipulation by a user to position the imager relative to the surface of the object. The processor communicates with the imager and is configured to generate 3D surface data for the surface based on the 2D images. The display is coupled to the device housing and communicates with at least one of the imager and the processor. The display shows images of the surface observable within a field of view of the user while the device housing is manually positioned within the field of view of the user relative to the surface. In one embodiment, the display shows the 2D images of the surface acquired by the imager and, in another embodiment, the display shows a representation of the 3D surface data generated by the processor.

BRIEF DESCRIPTION OF THE DRAWINGS

The above and further advantages of this invention may be better understood by referring to the following description in conjunction with the accompanying drawings, in which like numerals indicate like structural elements and features in the various figures. The drawings are not necessarily to scale, emphasis instead being placed upon illustrating the principles of the invention.

FIG. 1 illustrates a 3D imaging device that projects a structured light pattern onto an object.

FIG. 2 is a flowchart representation of an embodiment of a measurement procedure using a hand-held 3D imaging device according to the invention.

FIG. 3 illustrates an embodiment of a user-manipulated imaging device according to the invention.

FIG. 4A illustrates an embodiment of a user-manipulated imaging device according to the invention and showing a display panel in an open position.

FIG. 4B illustrates the user-manipulated imaging device of FIG. 4A showing the display panel in a closed position.

DETAILED DESCRIPTION

In brief overview, the invention relates to a user-manipulated 3D metrology device such as a hand-held camera or scanning device. The device includes an integrated display monitor that provides the user with convenient access to control options, acquired images, and operator assistance indications within a field of view of the user. Advantageously, the location of the operating tip of the device relative to the object being measured can be viewed without the need to redirect the view of the user to a display monitor. For medical and dental 3D metrology devices, the user positions and aligns the device to a patient while simultaneously viewing a display of the acquired images or data. As a result, measurement data are obtained with less time and operator effort than is required for conventional user-manipulated 3D metrology devices.

The present teaching will now be described in more detail with reference to exemplary embodiments thereof as shown in the accompanying drawings. While the present teaching is described in conjunction with various embodiments and examples, it is not intended that the present teaching be limited to such embodiments. On the contrary, the present teaching encompasses various alternatives, modifications and equivalents, as will be appreciated by those of skill in the art. Those of ordinary skill in the art having access to the teaching herein will recognize additional implementations, modifications and embodiments, as well as other fields of use, which are within the scope of the present disclosure as described herein.

In a typical dental or medical 3D camera or scanner imaging system, a series of 2D intensity images of an object surface is acquired where the illumination for each image can vary. In some systems, structured light patterns are projected onto the surface and detected in each 2D intensity image. FIG. 1 shows an example of a 3D imaging system 10 in which the structured light pattern is generated by a projector 14 as a pair of overlapping coherent optical beams 16A and 16B that illuminate the object 18. The 3D imaging system 10 may be constructed to operate in accordance with the principles described in U.S. Patent No. 5,870,191, titled “Apparatus and Methods for Surface Contour Measurement,” incorporated herein by reference in its entirety. A CCD camera 22 is used to acquire images of the illuminated object 18. The fringe pattern 26 resulting from the interference of the two beams 16 is varied between successive 2D images acquired by the camera 22. For example, the fringes in the fringe pattern 26 can be shifted by changing the phase difference between the two beams 16.

A processor 30 calculates the distance from the camera 22 to the object surface for each image pixel based on the intensity values for the pixel in the 2D images. Thus the process creates a set of 3D coordinates, that is, a "point cloud," for the object surface.

In a dynamic 3D imaging system, a series of point clouds is acquired while the camera or scanner is in motion relative to the object surface. For example, the imaging system can be a handheld device that a user manually positions relative to the object surface. In some applications, multiple objects surfaces are measured by moving the device relative to the objects so that surfaces obscured from view of the device in one position are observable by the device in another position. A processor registers the overlapped region of adjacent point clouds, using a 3D correlation technique or other registration technique, to transform each successive point cloud into an initial coordinate space. The successive point clouds are thus "stitched" into a common reference space.

Referring to FIG. 2, at the start of an embodiment of a measurement procedure 100 according to the invention, the user aligns and positions (step 110) the hand-held imaging device relative to the patient while acquiring 2D images of a patient area of interest. The 2D images are processed (step 120) to generate 3D surface data of the area of interest. The user simultaneously observes measurement images in a display while controlling (step 130) the positioning and motion of the handheld imaging device with respect to the patient. The images in the display can be the acquired 2D images. Alternatively, the displayed images can be 3D surface representations generated by processing the acquired 2D images. By way of examples, the 3D surface representations can be 3D wire-mesh representations of point clouds or artificial surface displays that comprise simple geometrical shapes (e.g., triangles) between neighboring points in point clouds.

Providing a display that is in communication with the processor and mounted to or otherwise integrated with the 3D imaging device according to the principles of the invention permits the user to see the acquired 2D images, 3D surface representation, other display information or combinations of such images and information simultaneous with the observation and continued manipulation of the 3D imaging device relative to the patient. Thus the user can more easily and rapidly complete the measurement procedure than would be possible using a conventional handheld dental or medical imaging device. Other displayed information can include operator assistance information such as a slide bar shown along the edge of the display to indicate measured position within a usable imaging range, the distance to a surface of the object being measured, and a color box to indicate the current mode of the device, such as idle, preview and scan modes.

In one embodiment, the display includes a touchscreen that permits the user to input selection data while maintaining the handheld device in proper position relative to the patient. Control options shown on the touchscreen display can include, by way of example, preview, scan and stop function activation "buttons;" save and redo buttons presented at the completion of a scan, and input data buttons. For example, in dental applications, the input data buttons can be used to indicate the jaw to be imaged (upper or lower) or particular teeth to be imaged for a partial jaw scan.

In another embodiment illustrated in FIG. 3, the imaging device 34 includes a miniature display 38 similar to the displays typically used in mass-produced cell phones for consumers. The miniature display 38 can be embedded in a side of the device housing 42 and optionally has a viewing surface that is flush with the housing 42. By way of a specific example, the miniature display 38 may have a 1.8 inch diagonal viewing area. In one embodiment, the display is a compact liquid crystal display (LCD).

In an alternative embodiment, a display 46 is integral to a panel 50 that is pivotally attached to a side of a device housing 54 for the 3D imaging device 58 shown in FIG. 4A and FIG. 4B. The panel 50 is small enough to be compatible with the overall dimensions of the device 58 and yet include a display 46 that is large enough to present detailed images to the user. By way of a specific example, the display 46 can have a four inch diagonal viewing area. FIG. 4A shows the panel 50 in an open position in which the user views the displayed images, 3D representations and information. FIG. 4B shows the panel 50 in a closed position such that the panel 50 is substantially parallel and adjacent to the side of the device housing 54. The closed position is intended for when the device 58 is stored or otherwise not in use for extended periods of time.

In the embodiments described above, the device according to the invention is generally described as a handheld device; however, the invention also contemplates that the device can be manually adjusted or manipulated by a user without being directly held by hand.

While the invention has been shown and described with reference to specific embodiments, it should be understood by those skilled in the art that various changes in form and detail may be made therein without departing from the spirit and scope of the invention.

What is claimed is:

CLAIMS

1. A method of displaying information for a user-manipulated three-dimensional imaging device, the method comprising:

acquiring a plurality of two-dimensional images of a surface of an object with an imaging device manipulated by a user in position relative to the surface of the object and within a field of view of the user;

processing the two-dimensional images to generate three-dimensional surface data for the surface of the object; and

displaying measurement information to the user within the field of view of the user during continued manual manipulation of the imaging device.

2. The method of claim 1 wherein the displayed measurement information comprises the two-dimensional images acquired by the imaging device.

3. The method of claim 1 wherein the displayed measurement information comprises a representation of the three-dimensional surface data.

4. The method of claim 1 wherein the displayed measurement information comprises operator assistance information.

5. The method of claim 4 wherein the operator assistance information comprises a distance to the surface of the object.

6. A user-manipulated imaging device for measuring a three-dimensional surface of an object, comprising:

an imager configured for acquiring two-dimensional images of a surface of an object;

a device housing coupled to the imager and configured for manipulation by a user to position the imager relative to the surface of the object;

a processor in communication with the imager and configured to generate three-dimensional surface data for the surface based on the two-dimensional images; and

a display coupled to the device housing and in communication with at least one of the imager and the processor, the display showing images of the surface observable within a field of view of the user while the device housing is manually positioned within the field of view of the user relative to the surface.

7. The user-manipulated device of claim 6 wherein the images shown in the display are the two-dimensional images of the surface acquired by the imager.

8. The user-manipulated device of claim 6 wherein the images shown in the display are representations of the three-dimensional surface data generated by the processor.

9. The user-manipulated device of claim 6 wherein the display shows operator assistance information.

10. The user-manipulated device of claim 9 wherein the operator assistance information includes a distance to the surface of the object.

11. The user-manipulated device of claim 6 wherein the display is a touchscreen display configured to receive data input from the user.

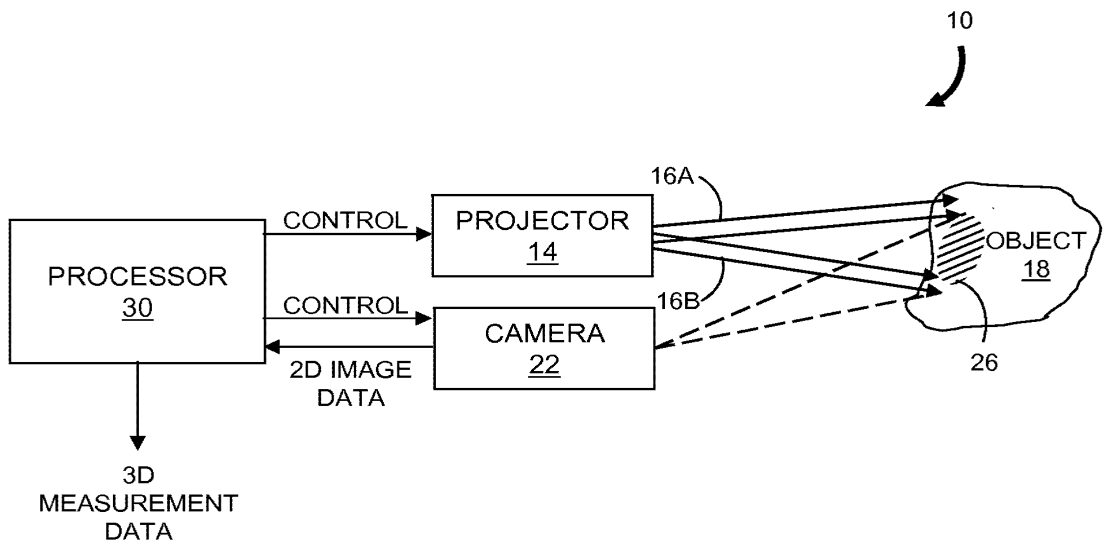
12. The user-manipulated device of claim 6 wherein the display comprises a liquid crystal display (LCD).

13. The user-manipulated device of claim 6 wherein the display comprises a display panel pivotably secured to a side of the device housing, the display panel extending away from a surface of the device housing while in an open position and extending substantially parallel to the surface of the device housing while in a closed position, and wherein images of the surface are observable to the user while the display panel is in the open position.

14. The user-manipulated device of claim 6 wherein the display comprises a viewing surface that is substantially flush with a side of the device housing.

15. The user-manipulated device of claim 6 further comprising a projector in communication with the processor and configured for projecting a structured light pattern onto the surface of the object.

16. The user-manipulated device of claim 15 wherein the projector comprises a source of coherent optical beams for illuminating the surface of the object with a fringe pattern.


10
PROCESSOR
30
CONTROL
CONTROL
2D IMAGE
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PROJECTOR
14
CAMERA
22
16A
16B
OBJECT
18
26
3D
MEASUREMENT
DATA

FIG. 1

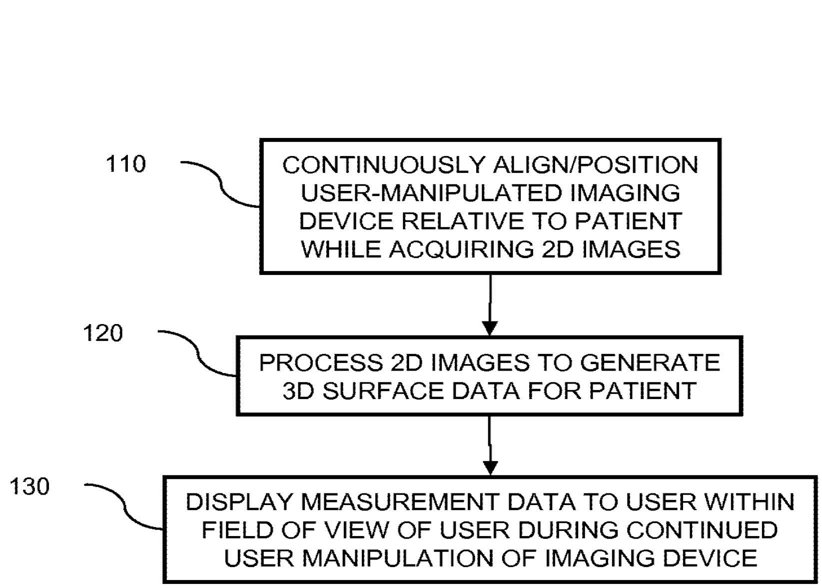
100
110
CONTINUOUSLY ALIGN/POSITION USER-MANIPULATED IMAGING DEVICE RELATIVE TO PATIENT WHILE ACQUIRING 2D IMAGES
120
PROCESS 2D IMAGES TO GENERATE 3D SURFACE DATA FOR PATIENT
130
DISPLAY MEASUREMENT DATA TO USER WITHIN FIELD OF VIEW OF USER DURING CONTINUED USER MANIPULATION OF IMAGING DEVICE

FIG. 2

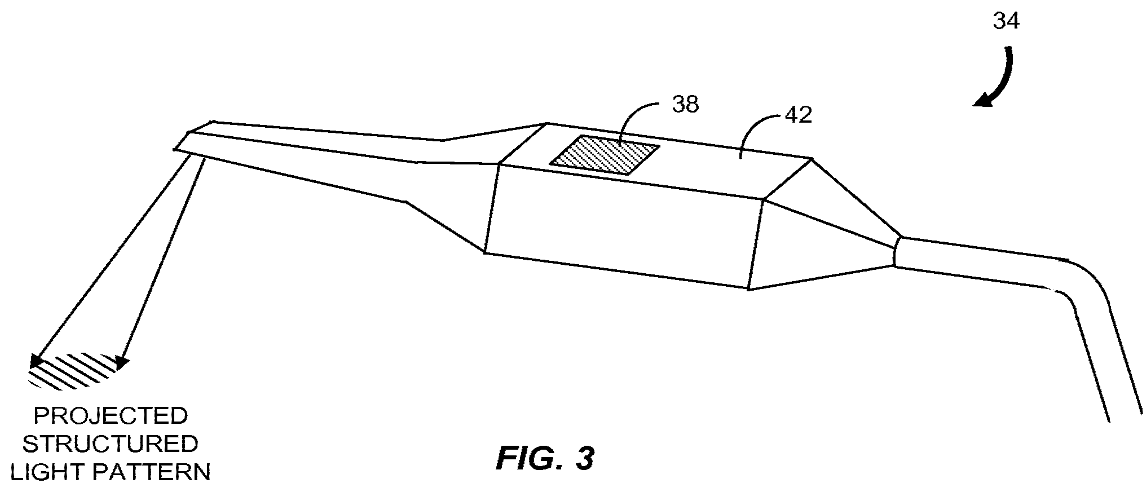

FIG. 3

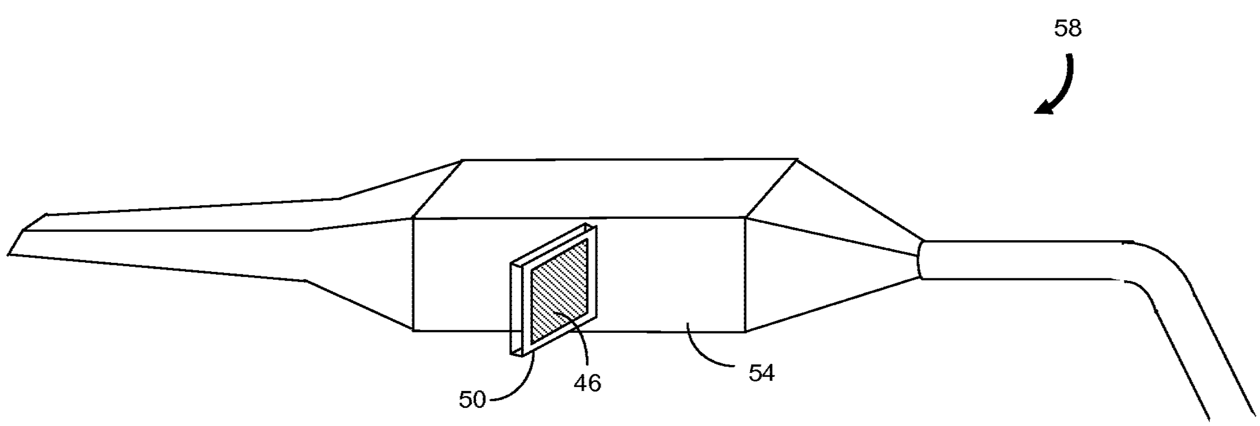

FIG. 4A

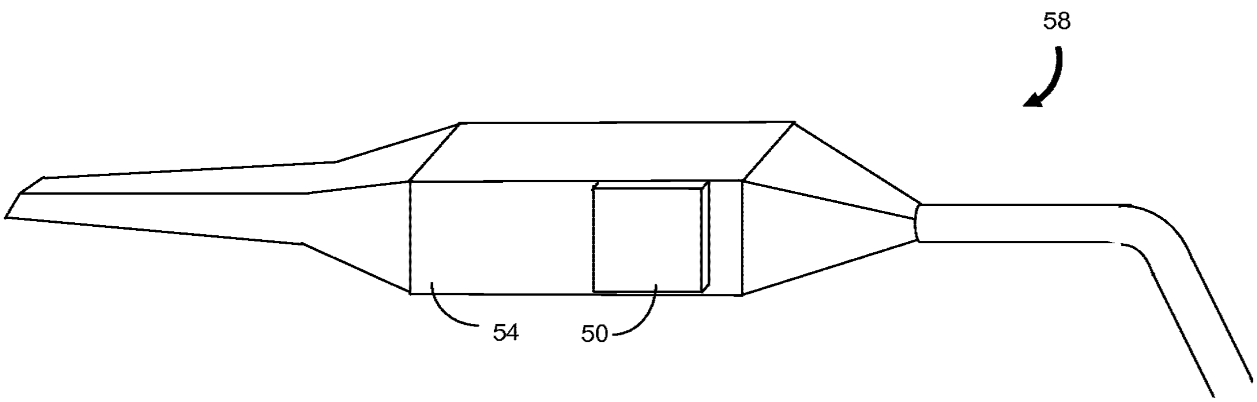

FIG. 4B

INTERNATIONAL SEARCH REPORT

International application No.
PCT/US 10/41045

A. CLASSIFICATION OF SUBJECT MATTER
IPC(8) - A61C 3/00 (2010.01)
USPC - 433/29
According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
IPC - A61C 3/00 (2010.01)
USPC - 433/29

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched
USPC - 345/419,420,421,422,423,424,426,427

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)
PubWEST (PGPB,USPT,USOC,EPAB,JPAB); Google Scholar
Search terms - display, screen, touch screen, fringe patter, two dimension$, three dimension$, pivot$, hinge$, control$, distance, surface, contour

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X --- Y	US 2005/0237581 A1 (KNIGHTON et al.) 27 October 2005 (27.10.2005) entire document, especially para [0025]-[0035,] [0047]-[0048], [0052]-[0054]; Fig 1, 6	1-12, 14 --- 13, 15-16
Y	US 7,046,286 B1 (KOBAYASHI et al.) 16 May 2006 (16.05.2006) Fig 4-6	13
Y	US 6,438,272 B1 (HUANG et al.) 20 August 2002 (20.08.2002) col 5, ln 4-34	15-16

☐ Further documents are listed in the continuation of Box C. ☐

* Special categories of cited documents:
"A" document defining the general state of the art which is not considered to be of particular relevance
"E" earlier application or patent but published on or after the international filing date
"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)
"O" document referring to an oral disclosure, use, exhibition or other means
"P" document published prior to the international filing date but later than the priority date claimed
"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention
"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone
"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art
"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
16 September 2010 (16.09.2010)	27 SEP 2010

Name and mailing address of the ISA/US	Authorized officer:
Mail Stop PCT, Attn: ISA/US, Commissioner for Patents P.O. Box 1450, Alexandria, Virginia 22313-1450 Facsimile No. 571-273-3201	Lee W. Young PCT Helpdesk: 571-272-4300 PCT OSP: 571-272-7774

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Declarations under Rule 4.17:

— *as to applicant's entitlement to apply for and be granted a patent (Rule 4.17(ii))*

— *of inventorship (Rule 4.17(iv))*

[Continued on next page]

(54) **Title**: SYSTEM WITH 3D USER INTERFACE INTEGRATION

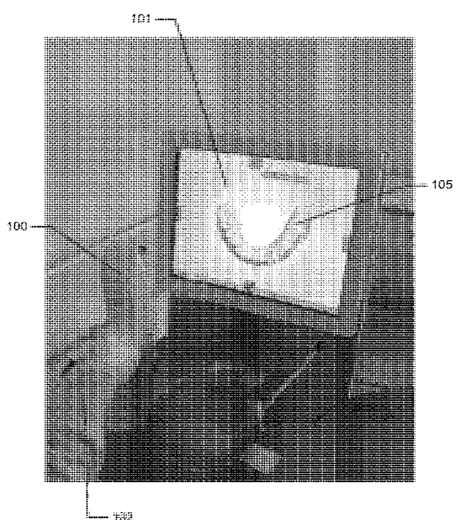

Fig. 2a)

(57) **Abstract**: Disclosed is a system comprising a handheld device (100) and at least one display (101), where the handheld device (100) is adapted for performing at least one action in a physical 3D environment. The actions include measuring, modifying, manipulating, recording, touching, sensing, scanning, moving, transforming, cutting, welding, chemically treating, cleaning. The display (101) is adapted for visually representing the physical 3D environment, and where the handheld device (100) is adapted for remotely controlling the view with which the 3D environment is represented on the display (101).

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Published:

— *with international search report (Art. 21(3))*

System with 3D user interface integration

Field of the invention

This invention generally relates to a method and a system comprising a handheld device and at least one display.

Background of the invention

3D visualization is important in many fields of industry and medicine, where 3D information is becoming more and more predominant.

Displaying and inspecting 3D information is inherently difficult. To fully understand a 3D object or entire environment on a screen, the user should generally be able to rotate the object or scene, such that many or preferentially all surfaces are displayed. This is true even for 3D displays, e.g. stereoscopic or holographic, where from a given viewing position and with a given viewing angle, the user will only see some surfaces of an arbitrary 3D environment. Often, the user will also want to zoom into details or zoom out for an overview.

Various user interaction devices are in use for software that displays 3D data; these devices are: 3D mice, space balls, and touch screens. The operation of these current interaction devices requires physically touching them.

Physically touching a user-interaction device can be a disadvantage in medical applications due to risks of cross-contamination between patients or between patient and operator, or in industrial applications in dirty environments.

Several non-touch user interfaces for 3D data viewing in medical applications have been described in the literature. Vogt et al (2004) describe a touchless interactive system for in-situ visualization of 3D medical imaging data. The user interface is based on tracking of reflective markers, where a camera is mounted on the physician's head. Graetzel et al (2004) describe a touchless system that interprets hand gestures as mouse actions. It is based on stereo vision and intended for use in minimally invasive surgery.

It remains a problem to improve systems that require user interfaces for view control, which for example can be used for clinical purposes.

Summary

Disclosed is a system comprising a handheld device and at least one display, where the handheld device is adapted for performing at least one action in a physical 3D environment, where the at least one display is adapted for visually representing the physical 3D environment, and where the handheld device is adapted for remotely controlling the view with which said 3D environment is represented on the display.

The system may be adapted for switching between performing the at least one action in the physical 3D environment, and remotely controlling the view with which the 3D environment is represented on the display.

The system disclosed here performs the integration of 3D user interface functionality with any other handheld device with other operating functionality, such that the operator ideally only touches this latter device that is intended to be touched. A particular example of such a handheld device is one that records some 3D geometry, for example a handheld 3D scanner.

The handheld device is a multi-purpose device, such as a dual-purpose or two-purpose device, i.e. a device both for performing actions in the physical 3D environment, such as measuring and manipulating, and for remotely controlling the view of the 3D environment on the display.

Geometrically, a view is determined by the virtual observer's/camera's position and orientation relative to the 3D environment or its visual representation. If the display is two-dimensional, the view is also determined by the type of projection. A view may also be determined by a magnification factor.

The virtual observer's and the 3D environment's position and orientation are always relative to each other. In terms of user experience in software systems with 3D input devices, the user may feel that for example, he/she is moving the 3D environment while remaining stationary himself/herself, but there is always an equivalent movement of the virtual observer/camera that gives the same results on the display. Often, descriptions of 3D software systems use the expression “pan” to indicate an apparent translational movement of the 3D environment, “rotate” to indicate a rotational movement of the 3D environment, and “zoom” to indicate a change in magnification factor.

Graphically, a view can represent a 3D environment by means of photographs or as some kind of virtual representation such as a computer graphic, or similar. A computer graphic can be rendered for example with texture and/or shading and/or virtual light sources and/or light models for surface properties. A computer graphic can also be a simplified representation of the 3D environment, for example a mesh, an outline, or an otherwise simplified representation. All or parts of the 3D environment can also be rendered with some degree of transparency. A view may represent the 3D environment in total or only parts thereof.

All of the touch-less prior art systems are 3D user interface devices only. In many prior art applications, the operator using such user interface device will also hold and work with another device that really is the central device in the overall application, e.g. a medical instrument.

It is thus an advantage of the present system that the 3D user-interface functionality is integrated in the central device, which is used for performing some kind of action.

In some embodiments the handheld device is adapted for remotely controlling the magnification with which the 3D environment is represented on the display.

In some embodiments the handheld device is adapted for changing the rendering of the 3D environment on the display.

In some embodiments the view is defined as viewing angle and/or viewing position.

In some embodiments the at least one action comprises one or more of the actions of:

- measuring,
- recording,
- scanning,
- manipulating,
- modifying.

In some embodiments the 3D environment comprises one or more 3D objects.

In some embodiments the handheld device is adapted to be held in one hand by an operator.

In some embodiments the display is adapted to represent the 3D environment from multiple views.

In some embodiments the display is adapted to represent the 3D environment from different viewing angles and/or viewing positions.

In some embodiments the view of the 3D environment in the at least one display is at least partly determined by the motion of the operator's hand holding said device.

In some embodiments the magnification represented in the at least one display is at least partly determined by the motion of the operator's hand holding said device.

In some embodiments the handheld device is adapted to record the 3D geometry of the 3D environment.

Thus the handheld device may be an intraoral dental scanner, which records the 3D geometry of a patient's teeth. The operator may move the scanner along the teeth of the patient for capturing the 3D geometry of the relevant teeth, e.g. all teeth. The scanner may comprise motion sensors for taking the movement of the scanner into account while creating the 3D model of the scanned teeth.

The 3D model of the teeth may be shown on a display, and the display may for example be a PC screen and/or the like.

The user interface functionality may comprise incorporating motion sensors in the scanner to provide that the user can determine the view on the screen by moving the scanner. Pointing the scanner down can provide that the scanned teeth are shown given a downward viewing angle. Holding the scanner in a horizontal position can provide that the viewing angle is likewise horizontal.

In some embodiments the handheld device comprises at least one user-interface element. A user-interface element is an element which the user may manipulate in order to activate a function on the user interface of the software. Typically the use interface is graphically presented on the display of the system.

The handheld device may furthermore be provided with an actuator, which switches the handheld device between performing the at least one action and remotely controlling the view. By providing such a manual switching function that enables the operator to switch between performing the at least one action and remotely controlling the view, the operator may easily control what is performed.

Such an actuator can for example be in the form of a button, switch or contact. In other embodiments it could be a touch sensitive surface or element.

In another embodiment the actuator could be a motion sensor provided in the handheld device that function as the actuator when it registers a specific type of movement, for example if the operator shakes the handheld device. Examples of such motion sensors will be described herein with respect to the user-interface element, however, the person skilled in the art will based on the disclosure herein understand that such motion sensors may also be used as actuators as discussed.

For example, the handheld device can in one embodiment be an intra-oral 3D scanner used by a dentist. The scanner is set to be performing the action of scanning a dental area when the actuator is in one position. When the actuator is switched into a second position the handheld is set to control the view with which the 3D environment is represented on the display. This could for example be that when the dentist have scanned a part of or the complete desired area of an dental arch he can activate the actuator which then allows the dentist to remotely control the view of the 3D representation of the scanned area on the display by using the handheld device.

For example, the actuator could be a button. When the button is pressed quickly the handheld device is prepared for scanning, i.e. it is set for performing at least one action, the scanning procedure, in the physical 3D environment. The scanning is stopped when the button is pressed quickly a second time.

While the scanning is performed a virtual 3D representation is visually built on the display.

The user can now press and hold the button. This will put the handheld in a controller mode, where the handheld device is adapted for remotely controlling the view with which the 3D environment, such as scanned teeth, is represented on the display. While holding the button pressed the system will use signals from a motion sensor in the handheld device to determine how to present the view of the virtual 3D environment. Thus, if the user turns or otherwise moves the hand that holds the handheld device the view of the virtual 3D environment on the display will change accordingly.

Thus, the dentist may use the same handheld device for both scanning an area and subsequently verifying that the scan has been executed correctly without having to move away from the patient or touching any other equipment than already present in his hands.

In one embodiment the user-interface element is the same as the actuator, or where several user-interface elements are present at least one also functions as an actuator.
The system may be equipped with a button as an additional element providing the user-interface functionality.

In an example the handheld device is a handheld intraoral scanner, and the display is a computer screen. The operator or user may be a dentist, an assistant and/or the like. The operation functionality of the device may be to record some intraoral 3D geometry, and the user interface functionality may be to rotate, pan, and zoom the scanned data on the computer screen.

In some embodiments the at least one user-interface element is at least one motion sensor.

Thus the integration of the user interface functionality in the device may be provided by motion sensors, which can be accelerometers inside the scanner, whose readings determine the orientation of the display on the screen of the 3D model of the teeth acquired by the scanner. Additional functionality, e.g. to start/stop scanning, may be provided by a button. The button may be located where the operator's or user's index finger can reach it conveniently.

Prior art intraoral scanners use a touch screen, a trackball, or a mouse to determine the view in the display. These prior art user interface devices can be inconvenient, awkward and difficult to use, and they can be labor-intensive, and thus costly to sterilize or disinfect. An intraoral scanner should always be disinfected between scanning different patients, because the scanner is in and may come in contact with the mouth or other parts of the patient being scanned.

The operator or user, e.g. dentist, may use one hand or both hands to hold the intraoral scanner while scanning, and the scanner may be light enough and comfortable to be held with just one hand for a longer time while scanning.

The device can also be held with one or two hands, while using the device as remote control for e.g. changing the view in the display. It is an advantage of the touchless user interface functionality that in clinical situations, the operator can maintain both hands clean, disinfected, or even sterile.

An advantage of the system is that it allows an iterative process of working in a 3D environment without releasing the handheld device during said process. For the above intraoral scanning system example, the operator, e.g. dentist, can record some teeth surface geometry with a handheld device that is an intraoral scanner, inspect coverage of the surface recording by using that same handheld device to move, e.g. rotate, the recorded surface on the display, e.g. a computer screen, detect possible gaps or holes in the coverage of the scanned teeth, and then for example arrange the scanner in the region where the gaps were located and continue recording teeth surface geometry there. Over this entire iterative cycle, which can be repeated more than once, such as as many times as required for obtaining a desired scan coverage of the teeth, the dentist does not have to lay the handheld intraoral scanner out of his or her hands.

In some embodiments, the 3D user interface functionality is exploited in a separate location than the operation functionality. For the above intraoral scanning system example, the scanning operation is performed in the oral cavity of the patient, while the user interface functionality is more flexibly exploited when the scanner is outside the patient’s mouth. The key characteristic and advantage of the system, again, is that the dentist can exploit the dual and integrated functionality, that is operation and user interface, of the scanner without laying it out of his or her hands.

The above intraoral scanning system is an example of an embodiment. Other examples for operation functionality or performing actions could be drilling, welding, grinding, cutting, soldering, photographing, filming, measuring, executing some surgical procedure etc..

The display of the system can be a 2D computer screen, a 3D display that projects stereoscopic image pairs, a volumetric display creating a 3D effect, such as a swept-volume display, a static volume display, a parallax barrier display, a holographic display etc.. Even with a 3D display, the operator has only one viewing position and viewing angle relative to the 3D environment at a time. The operator can move his/her head to assume another viewing position and/or viewing angle physically, but generally, it may be more convenient to use the handheld device with its built-in user interface functionality, e.g. the remote controlling, to change the viewing position and/or viewing angle represented in the display.

In some embodiments the system comprises multiple displays, or one or more displays that are divided into regions. For example, several sub-windows on a PC screen can represent different views of the 3D environment. The handheld device can be used to change the view in all of them, or only some of them.

In some embodiments the user interface functionality comprises the use of gestures.

Gestures made by e.g. the operator can be used to change, shift or toggle between sub-windows, and the user-interface functionality can be limited to an active sub-window or one of several displays.

In some embodiments the gestures are adapted to be detected by the at least one motion sensor. Gestures can alternatively and/or additionally be detected by range sensors or other sensors that record body motion.

The operator does not have to constantly watch the at least one display of the system. In many applications, the operator will shift between viewing and possible manipulating the display and performing another operation with the handheld device. Thus it is an advantage that the operator does not have to touch other user interface devices. However, in some cases it may not be possible for the operator to fully avoid touching other devices, and in these cases it is an advantage that fewer touches are required compared to a system where a handheld device does not provide any user interface functionality at all.

In some embodiments the at least one display is arranged separate from the handheld device.

In some embodiments the at least one display is defined as a first display, and where the system further comprises a second display.

In some embodiments the second display is arranged on the handheld device.

In some embodiments the second display is arranged on the handheld device in a position such that the display is adapted to be viewed by the operator, while the operator is operating the handheld device.

In some embodiments the second display indicates where the handheld device is positioned relative to the 3D environment.

In some embodiments the first display and/or the second display provides instructions for the operator.

The display(s) can be arranged in multiple ways. For example, they can be mounted on a wall, placed on some sort of stand or a cart, placed on a rack or desk, or other.

In some embodiments at least one display is mounted on the device itself. It can be advantageous to have a display on the device itself because with such an arrangement, the operator's eyes need not focus alternatingly between different distances. In some cases, the operating functionality may require a close look at the device and the vicinity of the 3D environment it operates in, and this may be at a distance at most as far away as the operator's hand. Especially in crowded environments such as dentist's clinics, surgical operation theatres, or industrial workplaces, it may be difficult to place an external display closely to the device.

In some embodiments visual information is provided to the operator on one or more means other than the first display.

In some embodiments audible information to the operator is provided to the operator.

Thus in some embodiments, the system provides additional information to the operator. In some embodiments, the system includes other visual clues shown on means other than the display(s), such as LEDs on the device. In some embodiments, the system provides audible information to the operator, for example by different sounds and/or by speech.

Said information provided to the operator can comprise instructions for use, warnings, and the like.
The information can aid with improving the action performance or operation functionality of the device, for example by indicating how well an action or operation is being performed, and/or instructions to the operator aimed at improving the ease of the action or operation and/or the quality of the action or operation's results. For example, a LED can change in color and/or flashing frequency. In a scanner, the information can relate to how well the scanned 3D environment is in focus and/or to scan quality and/or to scan coverage. The information can comprise instructions on how best to position the scanner such as to attain good scan quality and/or scan coverage. The instructions can be used for planning and/or performing bracket placement. The instructions can be in the form of a messenger system to the operator.

In some embodiments, some 3D user interface functionality is provided by at least one motion sensor built into the device. Examples of motion sensors are accelerometers, gyros, and magnetometers and/or the like. These sensors can sense rotations, lateral motion, and/or combinations thereof. Other motion sensors use infrared sensing. For example, at least one infrared sensor can be mounted on the device and at least one infrared emitter can be mounted in the surroundings of the device. Conversely, the at least one emitter can be mounted on the device, and the at least one sensors in the surroundings. Yet another possibility is to use infrared reflector(s) on the device and both sensor(s) and emitter(s) on the surroundings, or again conversely. Thus motion can be sensed by a variety of principles.

Through proper signal processing, some sensors can recognize additional operator actions; for example gestures such as taps, waving, or shaking of the handheld device. Thus, these gestures can also be exploited in the 3D user interface functionality.

In some embodiments the handheld device comprises at least two motion sensors providing sensor fusion. Sensor fusion can be used to achieve a better motion signal from for example raw gyro, accelerometer, and/or magnetometer data. Sensor fusion can be implemented in ICs such as the InvenSense MPU 3000.

In some embodiments the handheld device comprises at least one user-interface element other than the at least one motion sensor.

In some embodiments the at least one other user-interface element is a touch-sensitive element.

In some embodiments the at least one other user-interface element is a button.

In some embodiments the at least one other user-interface element is a scroll-wheel.

In some embodiments, user interface functionality is provided through additional elements on the device. Thus these additional elements can for example be buttons, scroll wheels, touch-sensitive fields, proximity sensors and/or the like.

The additional user interface elements can be exploited or utilized in a workflow suitable for the field of application of the device. The workflow may be implemented in some user software application that may also control the display and thus the view represented thereon. A given interface element can supply multiple user inputs to the software. For example, a button can provide both a single click and a double click. For example, a double click can mean to advance to a subsequent step in a workflow. For the example of intraoral scanning, three steps within the workflow can be to scan the lower mouth, the upper mouth, and the bite. A touch-sensitive field can provide strokes in multiple directions each with a different effect, etc. Providing multiple user inputs from a user interface elements is advantageous because the number of user interface elements on the device can be reduced relative to a situation where each user interface element only provides one user input.

The motion sensors can also be exploited in a workflow. For example, lifting the device, which can be sensed by an accelerometer, can represent some type of user input, for example to start some action. In a device that is a scanner, it may start scanning. Conversely, placing the device back in some sort of holder, which can be sensed by an accelerometer as no acceleration occur over some period of time, can stop said action.

If the action performed by the device is some kind of recording, for example scanning, for example 3D scanning, the results of the recording can also be exploited as user inputs, possibly along with user inputs from other user interface elements. For example, with a 3D scanner with a limited depth of field, it may be possible to detect whether any objects within the 3D environments are present in the volume corresponding to this depth of field by detecting whether any 3D points are recorded. User inputs can depend on such detected presence. For example, a button click on an intraoral scanner can provide a different user input depending on whether the scanner is in the mouth, where teeth are detectable, or significantly away from and outside the mouth. Also the effect of motion sensor signals can be interpreted differently for either situation. For example, the scanner may only change the view represented on the display when it is outside the mouth.

In some embodiments the handheld device is adapted to change a viewing angle with which the 3D environment is represented on the at least one display.

In some embodiments the handheld device is adapted to change a magnification factor with which the 3D environment is represented on the at least one display.

In some embodiments the handheld device is adapted to change a viewing position with which the 3D environment is represented on the at least one display.

In some embodiments the view of the 3D environment comprises a viewing angle, a magnification factor, and/or a viewing position.

In some embodiments the view of the 3D environment comprises rendering of texture and/or shading.

In some embodiments the at least one display is divided into multiple regions, each showing the 3D environment with a different view.

Thus in some embodiments the user interface functionality comprises changing the view with which the 3D environment is displayed. Changes in view can comprise changes in viewing angle, viewing position, magnification and/or the like. A change in viewing angle can naturally be effected by rotating the device. Rotation is naturally sensed by the aid of gyros and/or relative to gravity sensed by an accelerometer. Zooming, i.e. a change in magnification, can for example be achieved by pushing the handheld device forward and backward, respectively. A translational change of the viewing position, i.e., panning, can for example be achieved by pushing the handheld device up/down and/or sideways.

In some embodiments the user interface functionality comprises selecting or choosing items on a display or any other functionality provided by graphical user interfaces in computers known in the art. The operator may perform the selection. The Lava C.O.S scanner marketed by 3M ESPE has additional buttons on the handheld device, but it is not possible to manipulate the view by these. Their only purpose is to allow navigation through a menu system, and to start/stop scanning.

In some embodiments the user interface functionality comprises manipulating the 3D environment displayed on the screen. For example, the operator may effect deformations or change the position or orientation of objects in the 3D environment. Thus, in some embodiments the user interface functionality comprises virtual user interface functionality, which can be that the 3D data are manipulated, but the physical 3D environment in which the device operates may not be manipulated.

In some embodiments the handheld device is an intraoral scanner and/or an in-the-ear scanner. If the scanner comprises a tip, this tip may be exchanged whereby the scanner can become suitable for scanning in the mouth or in the ear. Since the ear is a smaller cavity than the mouth, the tip for fitting into an ear may be smaller than a tip for fitting in the mouth.

In some embodiments the handheld device is a surgical instrument. In some embodiments, the surgical instrument comprises at least one motion sensor, which is built-in in the instrument.

In some embodiments the handheld device is a mechanical tool. In some embodiments, the tool has at least one motion sensor built in. In other embodiments, other user-interface elements are built in as well, for example buttons, scroll wheels, touch-sensitive fields, or proximity sensors.

In some embodiment the 3D geometry of the 3D environment is known a-priori or a 3D representation of the environment is known a priori, i.e. before the actions (s) are performed. For example in surgery, a CT scan may have been taken before the surgical procedure. The handheld device in this example could be a surgical instrument that a physician needs to apply in the proper 3D position. To make sure this proper position is reached, it could be beneficial to view the 3D environment from multiple perspectives interactively, i.e. without having to release the surgical instrument.

An advantage of the system, also in the above surgery example, is the ability of the handheld device to record the 3D environment at least partially, typically in a 3D field-of-view that is smaller than the volume represented in the a-priori data. The 3D data recorded by the handheld device can be registered in real time with the a-priori data, such that the position and orientation of the device can be detected.

In some embodiments the 3D geometry comprises a 3D surface of the environment.

In some embodiments the 3D geometry comprises a 3D volumetric representation of the environment.

Thus the 3D environment can be displayed as volumetric data, or as surface, or a combination thereof. Volumetric data are typically represented by voxels. Voxels can comprise multiple scalar values. Surface data are typically represented as meshed, such as triangulated meshes, or point clouds.

The scanning may be performed by means of LED scanning, laser light scanning, white light scanning, X-ray scanning, and/or CT scanning.

The present invention relates to different aspects including the system described above and in the following, and corresponding systems, methods, devices, uses, and/or product means, each yielding one or more of the benefits and advantages described in connection with the first mentioned aspect, and each having one or more embodiments corresponding to the embodiments described in connection with the first mentioned aspect and/or disclosed in the appended claims.

In particular, disclosed herein is a method of interaction between a handheld device and at least one display, where the method comprises the steps of:
- performing at least one action in a physical 3D environment by means of the handheld device;
- visually representing the physical 3D environment by the at least one display; and
- remotely controlling the view of the represented 3D environment on the display by means of the handheld device.

Furthermore, the invention relates to a computer program product comprising program code means for causing a data processing system to perform the method according to any of the embodiments, when said program code means are executed on the data processing system, and a computer program product, comprising a computer-readable medium having stored there on the program code means.

According to another aspect, disclosed is a system comprising a handheld device for operating in a 3D environment and at least one display for visualizing said environment, where the display is adapted to represent said environment from multiple perspectives,
where said device is adapted to be held in one hand by an operator, and where the perspective represented in the at least one display is at least partly determined by the motion of the operator's hand holding said device.

According to another aspect, disclosed is a system comprising a handheld device for operating in a 3D environment and at least one display for visualizing said environment, where the display is adapted to represent said environment in multiple views,
where said device is adapted to be held in one hand by an operator, where the view represented in the at least one display is at least partly determined by the motion of the operator's hand holding said device, and where the device has at least one touch-sensitive user interface element.

The motion of the operator's hand is typically determined by a motion sensor arranged in the handheld device.

Definitions

3D geometry: A constellation of matter or its virtual representation in a three-dimensional space.

3D environment: A constellation of physical objects each having a 3D geometry in a three-dimensional space.

View: The way a 3D environment is represented on a display. Geometrically, a view is determined by the virtual observer's/camera's position and orientation. If the display is two-dimensional, the view is also determined by the type of projection. A view may also be determined by a magnification factor. Graphically, a view can show the 3D environment by means of photographs or as some kind of virtual representation such as a computer graphic, or similar. A computer graphic can be rendered for example with texture and/or shading and/or virtual light sources and/or light models for surface properties. A computer graphic can also be a simplified representation of the 3D environment, for example a mesh, an outline, or an otherwise simplified representation. All or parts of the 3D environment can also be rendered with some degree of transparency. A view may represent the 3D environment in total or only parts thereof.

Functionality: A purpose or intended use.

Performing action(s) or operating functionality: Actions or functionality that includes some type of interaction with a 3D environment, such as measuring, modifying, manipulating, recording, touching, sensing, scanning, moving, transforming, cutting, welding, chemically treating, cleaning, etc. The term “operating” is thus not directed to surgical procedures, but operating may comprise surgical procedures.

User Interface Functionality: Functionality for interaction between a human user and a machine with a display.

Handheld device: An object that has at least one functionality and that is held by a human operator’s hand or both hands while performing this at least one functionality.

3D scanner: A device that analyzes a real-world object or 3D environment to collect data on its shape and possibly its appearance.

Coverage of scan: The degree to which a physical surface is represented by recorded data after a scanning operation.

Motion sensor: A sensor detecting motion. Motion can be detected by: sound (acoustic sensors), opacity (optical and infrared sensors and video image processors), geomagnetism (magnetic sensors, magnetometers), reflection of transmitted energy (infrared laser radar, ultrasonic sensors, and microwave radar sensors), electromagnetic induction (inductive-loop detectors), and vibration (triboelectric, seismic, and inertia-switch sensors). MEMS accelerometers, gyros, and magnetometers are examples of motions sensors.

Workflow: a sequence of tasks implemented in software.

Brief description of the drawings

The above and/or additional objects, features and advantages of the present invention, will be further elucidated by the following illustrative and non-limiting detailed description of embodiments of the present invention, with reference to the appended drawings, wherein:

Fig. 1 shows an example of the system comprising a handheld device and a display.

Fig. 2 shows an example of user interface functionality in the form of remote controlling using the handheld device.

Fig. 3 shows an example of the handheld device.

Fig. 4 shows an example of a flow-chart of a method of interaction between a handheld device and a display.

Detailed description

In the following description, reference is made to the accompanying figures, which show by way of illustration how the invention may be practiced.

Fig. 1 shows an example of the system comprising a handheld device and a display. The handheld device 100 is in this example an intraoral dental scanner, which records the 3D geometry of the patient's teeth. The operator 102 moves the scanner along the teeth of the patient 104 for capturing the 3D geometry of the relevant teeth, e.g. all teeth. The scanner comprises motion sensors (not visible) for taken the movement of the scanner into account while creating the 3D model 105 of the scanned teeth. The display 101 is in this example a PC screen displaying the data recorded by the scanner.

Fig. 2 shows an example of user interface functionality in the form of remote controlling using the handheld device. The motion sensors (not shown) in the handheld device 100, e.g. scanner, provide that the user 102 can determine the view shown on the display 101, e.g. screen, by moving the handheld device 100.
Fig. 2a) shows that pointing the device 100 down can provide that the 3D model 105 of the scanned teeth is shown from a downward viewing angle.
Fig. 2b) shows that holding the scanner in a horizontal position can provide that the viewing angle is likewise horizontally from the front, such that the 3D model 105 of the scanned teeth is shown from the front.

Fig. 3 shows an example of the handheld device.
The handheld device 100 is in this example an intraoral scanner with a pistol-grip. The scanner comprises a housing 106 comprising the pistol-grip part 107, and a tip 108 adapted for insertion in the mouth of the patient. In this example the scanner also is equipped with a button 103 which is an additional element providing user-interface functionality.

The example system as shown in fig. 1, fig. 2 and fig. 3 comprises a device 100 which is a handheld intraoral scanner and a display 101 which is a computer screen. The operator 102 may be a dentist, an assistant and/or the like. In an example, the action performance or operation functionality of the device 100 is to record some intraoral 3D geometry, and the user interface functionality is to rotate, pan, and zoom the 3D model 105 of the scanned data on the computer screen 101. The integration of the user interface functionality in the device 100 is provided by motion sensors (not visible), which can be accelerometers inside the scanner 100, whose readings determine the orientation, as seen in Figs 2a and 2b, of the display on the screen of the 3D model 105 of the teeth acquired by the scanner 100. Additional functionality, e.g. to start/stop scanning, may be provided by the button 103 as seen in fig. 3. In the example system, the button 103 is located where the user's index finger can reach it conveniently.

In fig. 1 the dentist 102 uses two hands to hold the intraoral scanner 100 while scanning, but it is understood that the scanner 100 can also be held with one hand while scanning. The device 100 can also be held with one or two hands, while changing the perspective of the 3D model 105 in the display 101. The example shown in Figure 1 thus illustrates the advantage of the touchless user interface functionality, because in many clinical situations, the operator 102 should maintain both hands clean, disinfected, or even sterile.

The 3D user interface functionality may be exploited in a separate location than the operation functionality. For the above intraoral scanning system example, the scanning operation is performed in the oral cavity of the patient, see fig. 1, while the user interface functionality is more flexibly exploited when the scanner is outside the patient's mouth, see figs 2 and 3.

Fig. 4 shows an example of a flow-chart of a method of interaction between a handheld device and a display.

In step 101 at least one action in a physical 3D environment is performed by means of the handheld device. This action may the scanning of teeth as shown in fig. 1.

In step 102 the physical 3D environment is visually represented by the at least one display. This may be the display of the 3D model of the scanned teeth as seen in fig 1.

In step 103 the view of the represented 3D environment shown on the display is remotely controlled on the display by means of the handheld device. This may be the control of the viewing angle of the 3D model as seen in fig. 2.

All the steps of the method may be repeated one or more times. The order in which the steps are performed may be different than the order described above, which is indicated by the dotted lines in the figure. If one or more of the steps are performed more times, the order of the steps may also be different.

Although some embodiments have been described and shown in detail, the invention is not restricted to them, but may also be embodied in other ways within the scope of the subject matter defined in the following claims. In particular, it is to be understood that other embodiments may be utilised and structural and functional modifications may be made without departing from the scope of the present invention.

In device claims enumerating several means, several of these means can be embodied by one and the same item of hardware. The mere fact that certain measures are recited in mutually different dependent claims or described in different embodiments does not indicate that a combination of these measures cannot be used to advantage.

It should be emphasized that the term "comprises/comprising" when used in this specification is taken to specify the presence of stated features, integers, steps or components but does not preclude the presence or addition of one or more other features, integers, steps, components or groups thereof.

The features of the method described above and in the following may be implemented in software and carried out on a data processing system or other processing means caused by the execution of computer-executable instructions. The instructions may be program code means loaded in a memory, such as a RAM, from a storage medium or from another computer via a computer network. Alternatively, the described features may be implemented by hardwired circuitry instead of software or in combination with software.

Literature:

C. Graetzel, T. Fong, S. Grange, and C. Baur. A Non-Contact Mouse for Surgeon-Computer Interaction. Technology and Health Care, 12(3), 2004.

Vogt S., Khamene A., Niemann H., Sauer F., An AR system with intuitive user interface for manipulation and visualization of 3D medical data, Stud. Health Technol. Inform. 2004;98, pp. 397-403.

Embodiments

The following embodiments relates to one aspect of the system as disclosed by the description herein.

1. A system comprising a handheld device and at least one display, where the handheld device is adapted for performing at least one action in a physical 3D environment, where the at least one display is adapted for visually representing the physical 3D environment, and where the handheld device is adapted for remotely controlling the view with which the 3D environment is represented on the display.

2. The system according to any one or more of the preceding embodiments, wherein the view is defined as viewing angle and/or viewing position.

3. The system according to any one or more of the preceding embodiments, wherein the handheld device is adapted for remotely controlling the magnification with which the 3D environment is represented on the display.

4. The system according to any one or more of the preceding embodiments, wherein the handheld device is adapted for changing the rendering of the 3D environment on the display.

5. The system according to any one or more of the preceding embodiments, wherein the at least one action comprises one or more of:
- measuring,
- recording,
- scanning,
- manipulating, and/or
- modifying.

6. The system according to any one or more of the preceding embodiments, wherein the 3D environment comprises one or more 3D objects.

7. The system according to any one or more of the preceding embodiments, wherein the handheld device is adapted to be held in one hand by an operator.

8. The system according to any one or more of the preceding embodiments, wherein the display is adapted to represent the 3D environment from multiple views..

9. The system according to any one or more of the preceding embodiments, wherein the view of the 3D environment represented in the at least one display is at least partly determined by the motion of the operator's hand holding said device.

10. The system according to any one or more of the preceding embodiments, wherein the magnification represented in the at least one display is at least partly determined by the motion of the operator's hand holding said device.

11. The system according to any one or more of the preceding embodiments, wherein the handheld device is adapted to record the 3D geometry of the 3D environment.

12. The system according to any one or more of the preceding embodiments, wherein the 3D geometry of the 3D environment is known a-priori.

13. The system according to any one or more of the preceding embodiments, wherein the handheld device comprises at least one user-interface element.

14. The system according to any one or more of the preceding embodiments, wherein the at least one user-interface element is at least one motion sensor.

15. The system according to any one or more of the preceding embodiments, wherein the handheld device comprises at least two motion sensors providing sensor fusion.

16. The system according to any one or more of the preceding embodiments, wherein the user interface functionality comprises the use of gestures.

17. The system according to any one or more of the preceding embodiments, wherein the gestures are detected by the at least one motion sensor.

18. The system according to any one or more of the preceding embodiments, wherein the handheld device comprises at least one user-interface element other than the at least one motion sensor.

19. The system according to any one or more of the preceding embodiments, wherein the at least one other user-interface element is a touch-sensitive element.

20. The system according to any one or more of the preceding embodiments, wherein the at least one other user-interface element is a button.

21. The system according to any one or more of the preceding embodiments, wherein the at least one other user-interface element is a scroll wheel.

22. The system according to any one or more of the preceding embodiments, wherein the handheld device is adapted to change a viewing angle with which the 3D environment is represented on the at least one display.

23. The system according to any of the preceding embodiments, wherein the handheld device is adapted to change a magnification factor with which the 3D environment is represented on the at least one display.

24. The system according to any one or more of the preceding embodiments, wherein the handheld device is adapted to change a viewing position with which the 3D environment is represented on the at least one display.

25. The system according to any one or more of the preceding embodiments, wherein the view of the 3D environment comprises a viewing angle, a magnification factor, and/or a viewing position.

26. The system according to any one or more of the preceding embodiments, wherein the view of the 3D environment comprises rendering of texture and/or shading.

27. The system according to any one or more of the preceding embodiments, wherein the at least one display is divided into multiple regions, each showing the 3D environment with a different view.

28. The system according to any one or more of the preceding embodiments, wherein the 3D geometry comprises a 3D surface of the environment.

29. The system according to any one or more of the preceding embodiments, wherein the 3D geometry comprises a 3D volumetric representation of the environment.

30. The system according to any one or more of the preceding embodiments, wherein the handheld device is an intra-oral 3D scanner.

31. The system according to any one or more of the preceding embodiments, wherein the handheld device is a surgical instrument.

32. The system according to any one or more of the preceding embodiments, wherein the handheld device is a mechanical tool.

33. The system according to any one or more of the preceding embodiments, wherein the handheld device is an in-ear 3D scanner.

34. The system according to any one or more of the preceding embodiments, wherein the at least one display is arranged separate from the handheld device.

35. The system according to any one or more of the preceding embodiments, wherein the at least one display is arranged on a cart.

36. The system according to any one or more of the preceding embodiments, wherein the at least one display is defined as a first display, and where the system further comprises a second display.

37. The system according to any one or more of the preceding embodiments, wherein the second display is arranged on the handheld device.

38. The system according to any one or more of the preceding embodiments, wherein the second display is arranged on the handheld device in a position such that the display is adapted to be viewed by the operator, while the operator is operating the handheld device.

39. The system according to any one or more of the preceding embodiments, wherein the second display indicates where the handheld device is positioned relative to the 3D environment.

40. The system according to any one or more of the preceding embodiments, wherein the first display and/or the second display provides instructions for the operator.

41. The system according to any one or more of the preceding embodiments, wherein visual information is provided to the operator on one or more means other than the first display.

42. The system according to any one or more of the preceding embodiments, wherein audible information to the operator is provided to the operator.

43. The system according to any one or more of the preceding embodiments, wherein the scanning is performed by means of LED scanning, laser light scanning, white light scanning, X-ray scanning, and/or CT scanning.

44. A method of interaction between a handheld device and at least one display, where the method comprises the steps of:
- performing at least one action in a physical 3D environment by means of the handheld device;
- visually representing the physical 3D environment by the at least one display; and
- remotely controlling the view of the represented 3D environment on the display by means of the handheld device.

45. A computer program product comprising program code means for causing a data processing system to perform the method of any one or more of the preceding embodiments, when said program code means are executed on the data processing system.

46. A computer program product according to the previous embodiment, comprising a computer-readable medium having stored there on the program code means.

Claims

1. A system comprising a handheld device and at least one display, where the handheld device is adapted for switching between
- performing at least one action in a physical 3D environment, where the at least one display is adapted for visually representing the physical 3D environment, and
- remotely controlling the view with which the 3D environment is represented on the display.

2. A system according to any one or more of the preceding claims, wherein the handheld device is adapted to record the 3D geometry of the 3D environment.

3. A system according to any one or more of the preceding claims, wherein means for manually switching between performing the at least one action and remotely controlling the view is provided on the handheld device.

4. A system according to claim 3, wherein the means for manually switching is an actuator, such as a button, a switch or a contact.

5. The system according to any one or more of the preceding claims, wherein the view is defined as viewing angle and/or viewing position.

6. The system according to any one or more of the preceding claims, wherein the handheld device is adapted for remotely controlling the magnification with which the 3D environment is represented on the display.

7. The system according to any one or more of the preceding claims, wherein the handheld device is adapted for changing the rendering of the 3D environment on the display.

8. The system according to any one or more of the preceding claims, wherein the at least one action comprises one or more of:
- measuring,
- recording,
- scanning,
- manipulating, and/or
- modifying.

9. The system according to any one or more of the preceding claims, wherein the 3D environment comprises one or more 3D objects.

10. The system according to any one or more of the preceding claims, wherein the handheld device is adapted to be held in one hand by an operator.

11. The system according to any one or more of the preceding claims, wherein the display is adapted to represent the 3D environment from multiple views.

12. The system according to any one or more of the preceding claims, wherein the handheld device comprises at least one motion sensor.

13. The system according to any one or more of the preceding claims, wherein the view of the 3D environment represented in the at least one display is at least partly determined by the at least one motion sensor.

14. The system according to any one or more of the preceding claims, wherein the magnification represented in the at least one display is at least partly determined by the at least one motion sensor.

15. The system according to any one or more of the preceding claims, wherein the handheld device is adapted to record the 3D geometry of the 3D environment.

16. The system according to any one or more of the preceding claims, wherein the 3D geometry of the 3D environment is known a-priori.

17. The system according to any one or more of the preceding claims, wherein the handheld device comprises at least one user-interface element.

18. The system according to any one or more of the preceding claims, wherein the at least one user-interface element is at least one motion sensor.

19. The system according to any one or more of the preceding claims, wherein the handheld device comprises at least two motion sensors providing sensor fusion.

20. The system according to any one or more of the preceding claims, wherein the user interface functionality comprises the use of gestures.

21. The system according to any one or more of the preceding claims, wherein the gestures are detected by the at least one motion sensor.

22. The system according to any one or more of the preceding claims, wherein the handheld device comprises at least one user-interface element other than the at least one motion sensor.

23. The system according to any one or more of the preceding claims, wherein the at least one other user-interface element is a touch-sensitive element.

24. The system according to any one or more of the preceding claims, wherein the at least one other user-interface element is a button.

25. The system according to any one or more of the preceding claims, wherein the at least one other user-interface element is a scroll wheel.

26. The system according to any one or more of the preceding claims, wherein the handheld device is adapted to change a viewing angle with which the 3D environment is represented on the at least one display.

27. The system according to any of the preceding claims, wherein the handheld device is adapted to change a magnification factor with which the 3D environment is represented on the at least one display.

28. The system according to any one or more of the preceding claims, wherein the handheld device is adapted to change a viewing position with which the 3D environment is represented on the at least one display.

29. The system according to any one or more of the preceding claims, wherein the view of the 3D environment comprises a viewing angle, a magnification factor, and/or a viewing position.

30. The system according to any one or more of the preceding claims, wherein the view of the 3D environment comprises rendering of texture and/or shading.

31. The system according to any one or more of the preceding claims, wherein the at least one display is divided into multiple regions, each showing the 3D environment with a different view.

32. The system according to any one or more of the preceding claims, wherein the 3D geometry comprises a 3D surface of the environment.

33. The system according to any one or more of the preceding claims, wherein the 3D geometry comprises a 3D volumetric representation of the environment.

34. The system according to any one or more of the preceding claims, wherein the handheld device is an intra-oral 3D scanner.

35. The system according to any one or more of the preceding claims, wherein the handheld device is a surgical instrument.

36. The system according to any one or more of the preceding claims, wherein the handheld device is a mechanical tool.

37. The system according to any one or more of the preceding claims, wherein the handheld device is an in-ear 3D scanner.

38. The system according to any one or more of the preceding claims, wherein the at least one display is arranged separate from the handheld device.

39. The system according to any one or more of the preceding claims, wherein the at least one display is arranged on a cart.

40. The system according to any one or more of the preceding claims, wherein the at least one display is defined as a first display, and where the system further comprises a second display.

41. The system according to any one or more of the preceding claims, wherein the second display is arranged on the handheld device.

42. The system according to any one or more of the preceding claims, wherein the second display is arranged on the handheld device in a position such that the display is adapted to be viewed by the operator, while the operator is operating the handheld device.

43. The system according to any one or more of the preceding claims, wherein the second display indicates where the handheld device is positioned relative to the 3D environment.

44. The system according to any one or more of the preceding claims, wherein the first display and/or the second display provides instructions for the operator.

45. The system according to any one or more of the preceding claims, wherein visual information is provided to the operator on one or more means other than the first display.

46. The system according to any one or more of the preceding claims, wherein audible information to the operator is provided to the operator.

47. The system according to any one or more of the preceding claims, wherein the scanning is performed by means of LED scanning, laser light scanning, white light scanning, X-ray scanning, and/or CT scanning.

48. The system according to any one or more of the preceding claims, wherein a graphical pointer is provided on the display for representing the movement of the handheld device when the handheld device is used to

remotely controlling the view with which the 3D environment is represented on the display.

49. The system according to any one or more of the preceding claims, wherein the handheld device is an intra-oral 3D scanner and the at least one action performed in the physical 3D environment is scanning and that the view is remotely controlled by at least one motion sensor arranged in the handheld device, and wherein an actuator provided on the handheld device switches between performing the at least one action and remotely controlling the view.

50. A method of interaction between a handheld device and at least one display, where the method comprises the steps of:

- performing at least one action in a physical 3D environment by means of the handheld device;
- visually representing the physical 3D environment by the at least one display; and
- remotely controlling the view of the represented 3D environment on the display by means of the handheld device.

51. A computer program product comprising program code means for causing a data processing system to perform the method of claim 44, when said program code means are executed on the data processing system.

52. A computer program product according to the previous claim, comprising a computer-readable medium having stored there on the program code means.

1/5

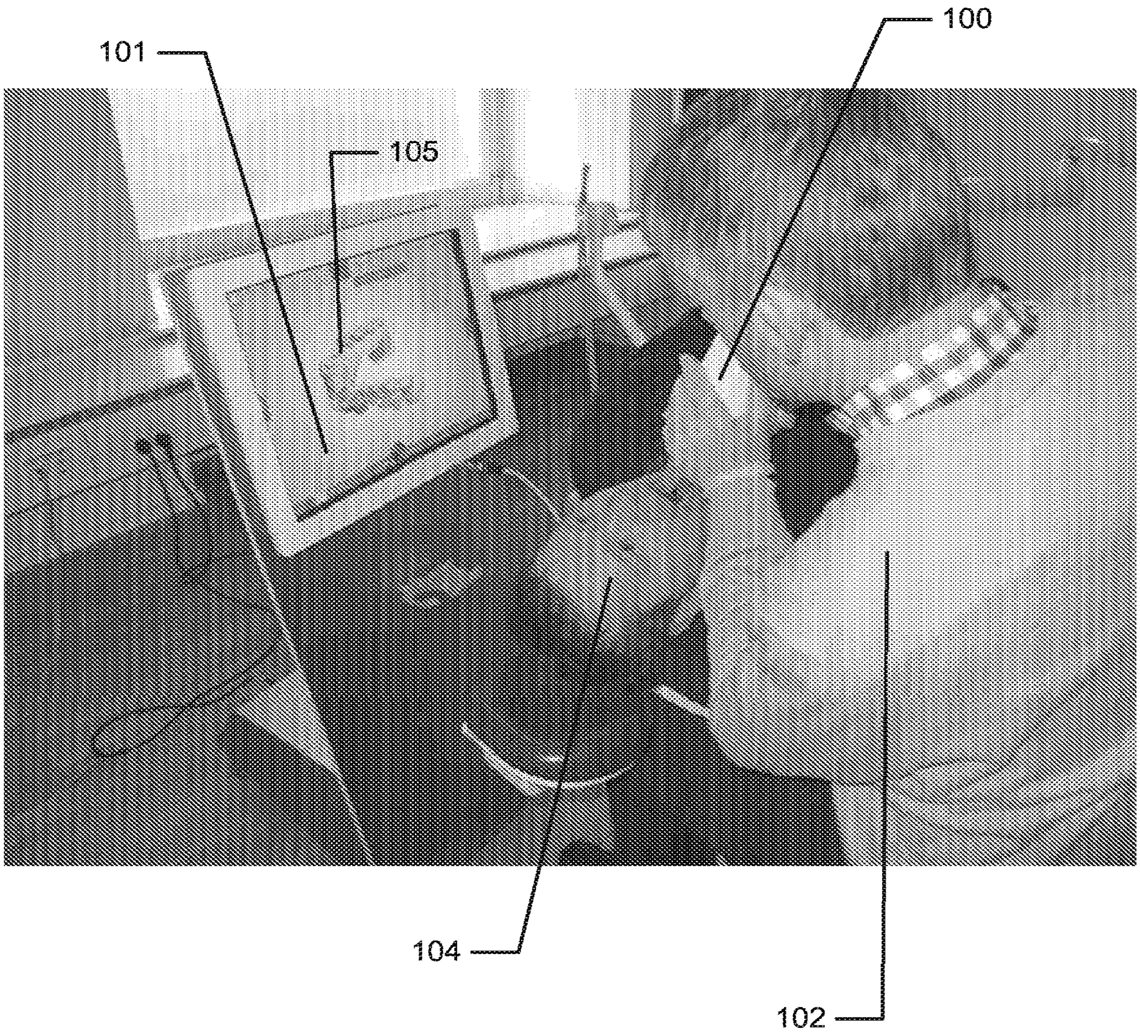

Fig. 1

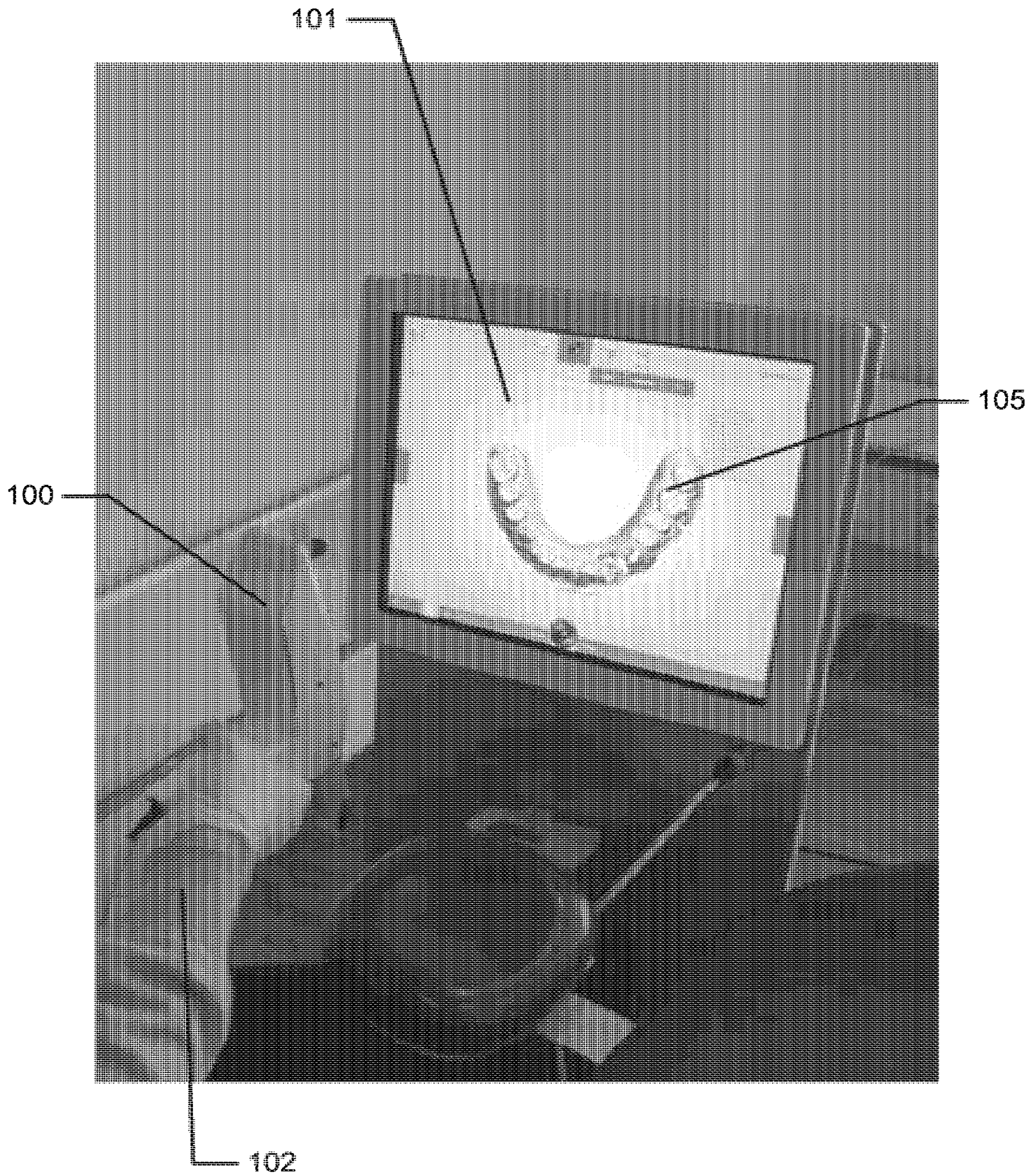

Fig. 2a)

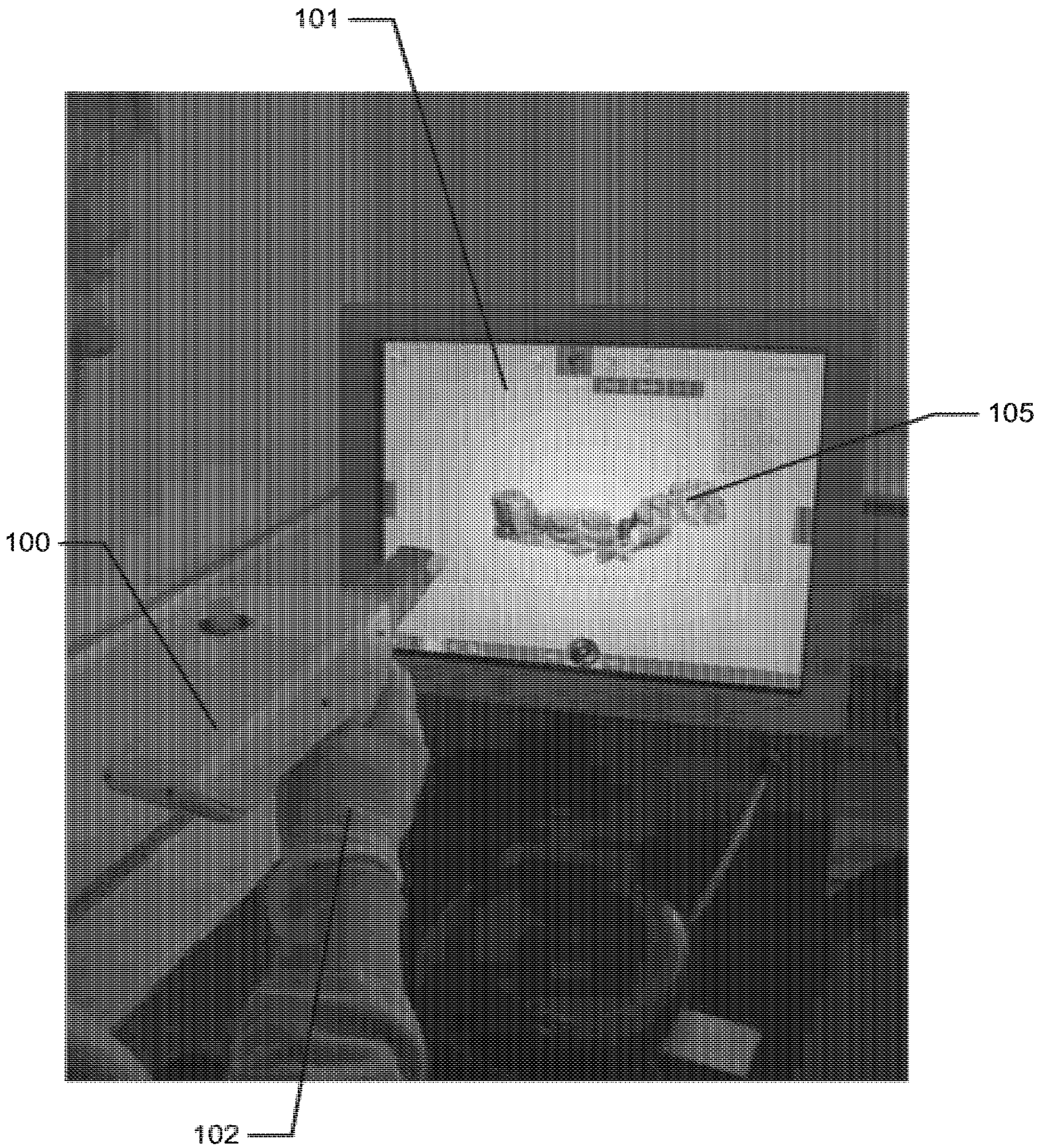

Fig. 2b)

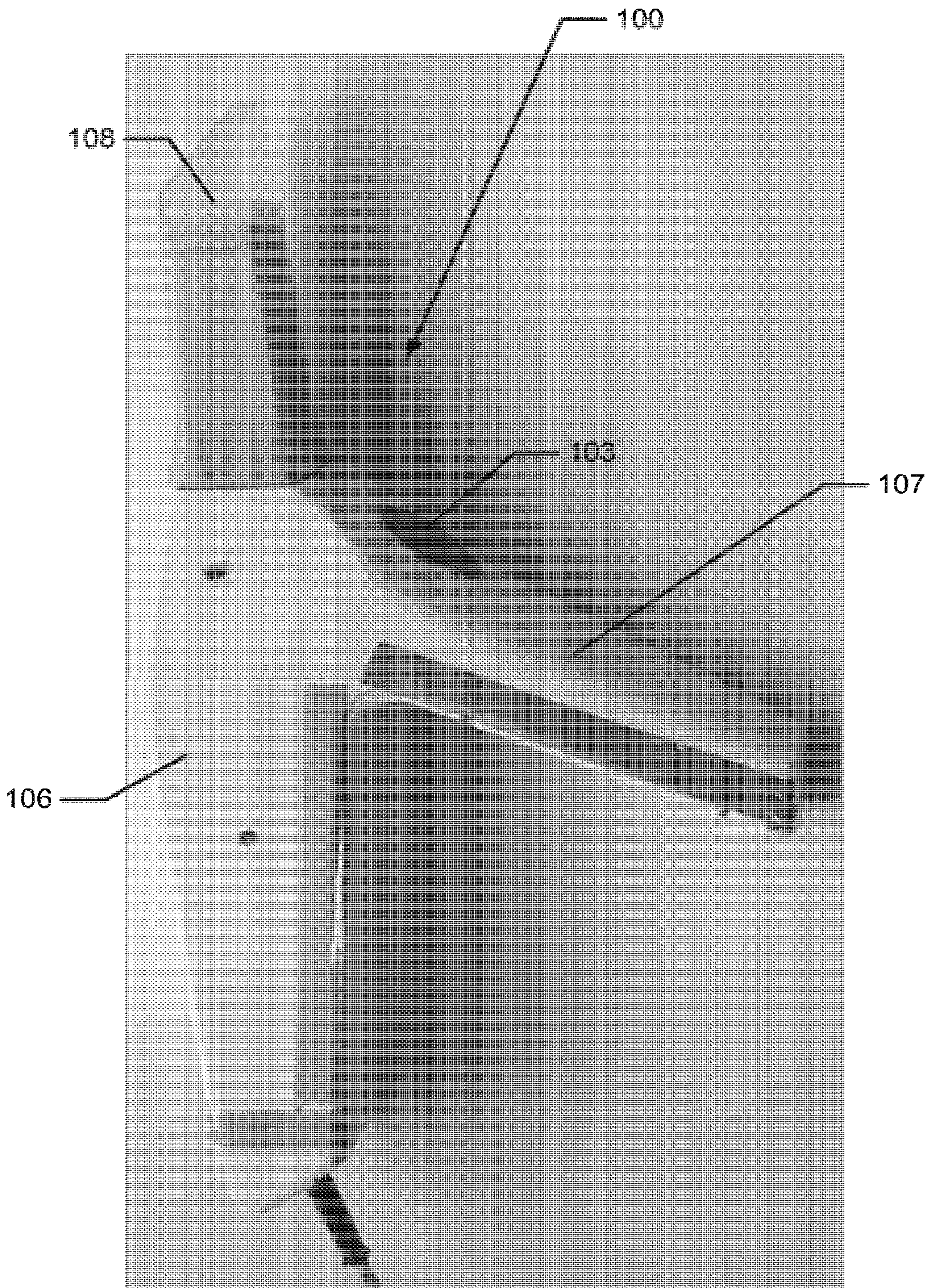

Fig. 3

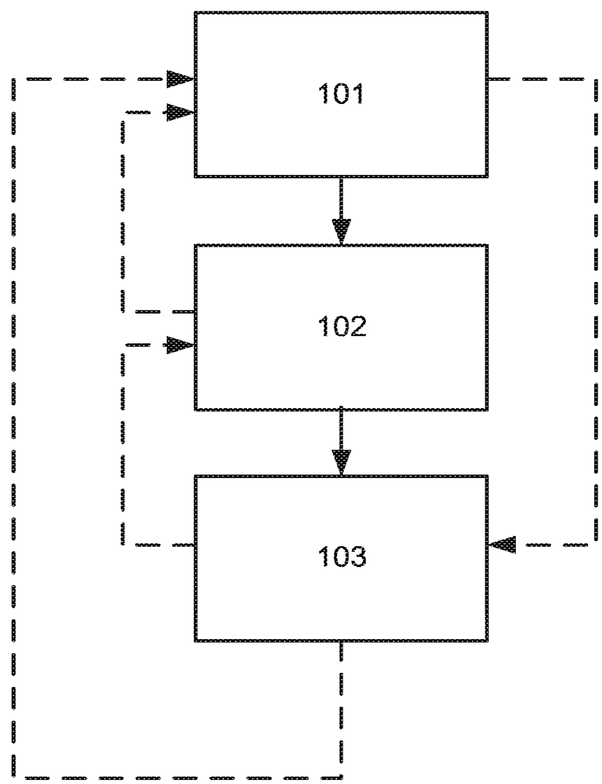

Fig. 4

INTERNATIONAL SEARCH REPORT

International application No.
PCT/DK2011/050461

A. CLASSIFICATION OF SUBJECT MATTER
G01B 11/24 (2006.01), A61C 13/00 (2006.01)

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
IPC/EC: G06F, G01B, A61C; ICO: K63F; FT:4C061/CC

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched
DK, SE, FI, NO (IPC classes as above)

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)
EPODOC, WPI, TXTE

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X; A	US 2009/0217207 A1 (KAGERMEIER et al) 2009.08.27, entire application, in particular sections [0007], [0009], [0012]-[0013], [0019]-[0020], [0023], [0035]-[0039], fig. 1-4	1-33, 38-48, 50-52; 34, 49
X; A	WO 2004/066615 A1 (NOKIA CORPORATION) 2004.08.05, page 3, line 16 to page 4, line 2, page 25, line 12, to page 26, line 5.	1, 3-14, 16-33, 38-48, 50-52; 2, 15, 34, 49
X; A	US 2003/0158482 A1 (POLAND et al) 2003.08.21, sections [0032], [0034], figs 6, 8.	1-11, 15-17, 26-33, 38-39, 46, 48, 50-52; 12-14, 18-25, 34, 40, 41-45, 47
A	US 2009/0061381 A1 (DURBIN et al) 2009.03.05, sections [0018]-[0019], [0024]	1-33, 38-52

☐ Further documents are listed in the continuation of Box C. ☒ See patent family annex.

* Special categories of cited documents:
"A" document defining the general state of the art which is not considered to be of particular relevance
"E" earlier application or patent but published on or after the international filing date
"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)
"O" document referring to an oral disclosure, use, exhibition or other means
"P" document published prior to the international filing date but later than the priority date claimed
"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention
"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone
"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art
"&" document member of the same patent family

Date of the actual completion of the international search
17/02/2012

Date of mailing of the international search report
22/02/2012

Name and mailing address of the ISA/
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Form PCT/ISA/210 (second sheet) (July 2009)

INTERNATIONAL SEARCH REPORT

International application No.
PCT/DK2011/050461

Box No. II Observations where certain claims were found unsearchable (Continuation of item 2 of first sheet)

This international search report has not been established in respect of certain claims under Article 17(2)(a) for the following reasons:

1. ☐ Claims Nos.:
because they relate to subject matter not required to be searched by this Authority, namely:

2. ☐ Claims Nos.:
because they relate to parts of the international application that do not comply with the prescribed requirements to such an extent that no meaningful international search can be carried out, specifically:

3. ☐ Claims Nos.:
because they are dependent claims and are not drafted in accordance with the second and third sentences of Rule 6.4(a).

Box No. III Observations where unity of invention is lacking (Continuation of item 3 of first sheet)

This International Searching Authority found multiple inventions in this international application, as follows:
See extra sheet

1. ☐ As all required additional search fees were timely paid by the applicant, this international search report covers all searchable claims.

2. ☐ As all searchable claims could be searched without effort justifying additional fees, this Authority did not invite payment of additional fees.

3. ☐ As only some of the required additional search fees were timely paid by the applicant, this international search report covers only those claims for which fees were paid, specifically claims Nos.:

4. ☒ No required additional search fees were timely paid by the applicant. Consequently, this international search report is restricted to the invention first mentioned in the claims; it is covered by claims Nos.:
1-34, 38-52

Remark on Protest

☐ The additional search fees were accompanied by the applicant's protest and, where applicable, the payment of a protest fee.

☐ The additional search fees were accompanied by the applicant's protest but the applicable protest fee was not paid within the time limit specified in the invitation.

☐ No protest accompanied the payment of additional search fees.

Form PCT/ISA/210 (continuation of first sheet (2)) (July 2009)

INTERNATIONAL SEARCH REPORT
Information on patent family members

International application No.
PCT/DK2011/050461

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
US2009217207 A1 20090827		CN101513350 A 20090826 DE102008010717 A1 20090827	
WO2004066615 A1 20040805		US2006146009 A1 20060706 EP1588552 A1 20051026 AU2003303787 A1 20040813	
US2003158482 A1 20030821		JP2005517515 A 20050616 WO03071306 A1 20030828 EP1488253 A1 20041222 EP1488253 B1 20060920 DE60308495T T2 20070606 CN1636151 A 20050706 CN100340867C C 20071003 AU2003247479 A1 20030909 AT340365T T 20061015 US7141020 B2 20061128	
US2009061381 A1 20090305		WO2009033108 A1 20090312 KR20100066538 A 20100617 JP2010538302 A 20101209 EP2185891 A1 20100519 CA2698525 A1 20090312	

Form PCT/ISA/210 (patent family annex) (July 2009)

Continuation of Box no. III

This International Searching Authority found multible inventions.

US 2009/0217207 A1 (KAGERMEIER et al) 2009.08.27 describes a system comprising a handheld device (10) and at least one display (3, 22), where the handheld device is adapted for switching between
-performing at least one action in a physical 3D environment, where the at least one display is adapted for visually representing the physical 3D environment ([0013], [0037]), and
-remotely controlling the view with which the 3D environment is represented on the display ([0007], [0036], [0039])

The general concept described in the independent claim 1 is known from US 2009/0217207, and the application does therefore describe 4 inventions

A: Claims 2-34, 38-52 describe modifications of a system, a method, and a computer program product comprising a handheld device for performing at least one action, and for remotely controlling the view, and wherein the handheld device is an intra-oral 3D scanner
B: Claim 35 describes a system wherein the handheld device of claim 1 is a surgical instrument
C: Claim 36 describes a system wherein the handheld device of claim 1 is a mechanical tool
D: Claim 37 describes a system wherein the handheld device of claim 1 is an in-ear 3D scanner

There is no Single General Inventive Concept among the inventions A, B, C and D, and there is, therefore, not a technical relationship to link the invention as defined in Rules 13.1 and 13.2 PCT.

Electronic Acknowledgement Receipt

EFS ID:	38575687
Application Number:	16526281
International Application Number:	
Confirmation Number:	9657
Title of Invention:	SYSTEM WITH 3D USER INTERFACE INTEGRATION
First Named Inventor/Applicant Name:	Henrik ÖJELUND
Customer Number:	21839
Filer:	Stephany Gale Small/Kendra Eckbold
Filer Authorized By:	Stephany Gale Small
Attorney Docket Number:	0079124-000266
Receipt Date:	13-FEB-2020
Filing Date:	30-JUL-2019
Time Stamp:	10:47:31
Application Type:	Utility under 35 USC 111(a)

Payment information:

Submitted with Payment	no

File Listing:

Document Number	Document Description	File Name	File Size(Bytes)/ Message Digest	Multi Part /.zip	Pages (if appl.)
1	Information Disclosure Statement (IDS) Form (SB08)	Second_IDS.pdf	612326 d71e292d34767860ce0cef90ce9918e1468f6e64	no	4

Warnings:

Information:					
2	Non Patent Literature	US6361489B1.pdf	901480 5f98e540425ce44b71ad95405785827f487e5557	no	11
Warnings:					
Information:					
3	Non Patent Literature	US20070078340A1.pdf	1469384 18cdd16d65ed73825575c17d20a08e44073a1d14	no	21
Warnings:					
Information:					
4	Non Patent Literature	US20100231509A1.pdf	2063054 92659026cf22b60ee0353b24adce2c9e33434bf2	no	12
Warnings:					
Information:					
5	Non Patent Literature	US20080063998A1.pdf	2207420 457b5d7d2ef5cfe5057aa21ba6270285f1a5e05e	no	45
Warnings:					
Information:					
6	Foreign Reference	WO2011011193.pdf	548650 b7c66c7328550ae0107bfafdee422a06d52a327c	no	16
Warnings:					
Information:					
7	Foreign Reference	WO2012076013.pdf	2779981 b14fa61eb4f73101226d1b24d10ef6a9268dbe8e	no	51
Warnings:					
Information:					
			Total Files Size (in bytes):	10582295	

This Acknowledgement Receipt evidences receipt on the noted date by the USPTO of the indicated documents, characterized by the applicant, and including page counts, where applicable. It serves as evidence of receipt similar to a Post Card, as described in MPEP 503.

New Applications Under 35 U.S.C. 111
If a new application is being filed and the application includes the necessary components for a filing date (see 37 CFR 1.53(b)-(d) and MPEP 506), a Filing Receipt (37 CFR 1.54) will be issued in due course and the date shown on this Acknowledgement Receipt will establish the filing date of the application.
National Stage of an International Application under 35 U.S.C. 371
If a timely submission to enter the national stage of an international application is compliant with the conditions of 35 U.S.C. 371 and other applicable requirements a Form PCT/DO/EO/903 indicating acceptance of the application as a national stage submission under 35 U.S.C. 371 will be issued in addition to the Filing Receipt, in due course.
New International Application Filed with the USPTO as a Receiving Office
If a new international application is being filed and the international application includes the necessary components for an international filing date (see PCT Article 11 and MPEP 1810), a Notification of the International Application Number and of the International Filing Date (Form PCT/RO/105) will be issued in due course, subject to prescriptions concerning national security, and the date shown on this Acknowledgement Receipt will establish the international filing date of the application.

Attorney Docket No. 0079124-000266

IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

In re Patent Application of	)	
Henrik ÖJELUND et al.	)	Group Art Unit: 3992
Reissue Application Serial No.: 16/526,281	)	Examiner: Peng KE
Filed: July 30, 2019	)	Confirmation No.: 9657
For: SYSTEM WITH 3D USER INTERFACE INTEGRATION	)	

SECOND PRELIMINARY AMENDMENT

Commissioner for Patents
P.O. Box 1450
Alexandria, VA 22313-1450

Commissioner:

Prior to examination of the above-captioned patent application, kindly amend the application as follows:

AMENDMENTS TO THE CLAIMS:

The following listing of claims will replace all prior versions and listings of claims in this application.

LISTING OF CLAIMS:

1. (amended) A scanning system for scanning a 3D environment, the scanning system comprising:

a handheld device including an optical scanner, wherein the 3D environment to be scanned is selected by pointing the optical scanner at the 3D environment; and

at least one display remotely connected to the handheld device,

wherein the handheld device is adapted for performing at least one scanning action in a physical 3D environment, and the at least one display is adapted for visually representing the physical 3D environment; and

the handheld device includes a 3D user interface for remotely controlling the display to adjust the view with which the 3D environment is represented on the display,

wherein the handheld device comprises at least one motion sensor, and wherein the at least one motion sensor is a sensor that directly detects motion.

2. (amended) [A] The scanning system according to claim 1, wherein the handheld device is adapted to record the 3D geometry of the 3D environment.

3. (amended) [A] The scanning system according to claim 1, wherein the handheld device includes an actuator [means] for manually switching between performing the at least one scanning action and remotely controlling the view.

Please cancel Claim 4.

5. (amended) The scanning system according to claim [4] 1, wherein the view of the 3D environment represented in the at least one display is at least partly determined by the at least one motion sensor.

6. (amended) The scanning system according to claim [4] 1, wherein functionality of the 3D user interface comprises a use of gestures.

7. (amended) The scanning system according to claim 6, wherein the gestures are detected by the at least one motion sensor.

8. (amended) The scanning system according to claim [4] 1, wherein the [user-interface is other than the at least one motion sensor] handheld device further comprises at least one of an infrared sensor, a range sensor, or a proximity sensor.

9. (amended) The scanning system according to claim 1, wherein the handheld device is adapted to change a viewing angle with which the 3D environment is represented on the at least one display.

10. (amended) The scanning system according to claim 1, wherein the handheld device is adapted to change a magnification factor with which the 3D environment is represented on the at least one display.

11. (amended) The scanning system according to claim 1, wherein the handheld device is an intra-oral 3D scanner.

12. (amended) The scanning system according to claim 1, wherein the handheld device includes a surgical instrument.

13. (amended) The scanning system according to claim 1, wherein the handheld device includes a mechanical tool.

14. (amended) The scanning system according to claim 1, wherein the handheld device is an in-ear 3D scanner.

15. (amended) The scanning system according to claim 1, wherein the at least one display is defined as a first display, and where the system further comprises a second display.

16. (amended) The scanning system according to claim 15, wherein the second display indicates where the handheld device is positioned relative to the 3D environment.

17. (amended) The scanning system according to claim 15, wherein the first display and/or the second display provides instructions for the operator.

18. (amended) The scanning system according to claim 1, wherein audible information is provided to the operator.

19. (amended) A system comprising:

a handheld device and at least one display;

wherein the handheld device is adapted for switching between performing at least one action in a physical 3D environment, wherein the at least one display is adapted for visually representing the physical 3D environment; and remotely controlling the display to adjust the view with which the 3D environment is represented on the display;

wherein the handheld device is an intra-oral 3D scanner and the at least one action performed in the physical 3D environment is scanning and that the view is remotely controlled by at least one motion sensor arranged in the handheld device, and wherein an actuator provided on the handheld device switches between performing the at least one action and remotely controlling the view, and wherein the at least one motion sensor is a sensor that directly detects motion.

20. (new) The scanning system according to claim 1, wherein the at least one motion sensor is an accelerometer, gyro, or magnetometer.

21. (new) The scanning system according to claim 1, wherein the at least one motion sensor is adapted for taking the movement of the scanner into account while performing the scanning.

22. (new) The scanning system according to claim 1, wherein the system comprises at least two motion sensors and wherein the at least two motion sensors provide sensor fusion.

23. (new) The scanning system according to claim 1, wherein the at least one motion sensor is the 3D user interface for remotely controlling the display, wherein the view on the display is determined by moving the handheld scanner.

24. (new) The scanning system according to claim 23, wherein moving the handheld scanner to point down causes the view on the display to be a downward viewing angle.

25. (new) The scanning system according to claim 1, wherein the handheld device further comprises a user-interface element

26. (new) The scanning system according to claim 25, wherein the user-interface element comprises a touch-sensitive element, a button, a scroll-wheel, or a proximity sensor.

27. (new) The scanning system according to claim 25, wherein the user-interface element provides more than one user input.

28. (new) The scanning system according to claim 25, wherein the at least one motion sensor and/or the user-interface element are utilized in a workflow.

29. (new) The system according to claim 19, wherein the handheld device is adapted to change a magnification factor of the view represented on the at least one display which is determined by the motion of the operator's hand holding the handheld device, through the use of the at least one motion sensor.

30. (new) The scanning system according to claim 1, wherein the at least one display is arranged on a cart.

31. (new) The scanning system according to claim 1, wherein the at least one display is divided into multiple regions.

32. (new) The system according to claim 19, wherein the handheld device further comprises a user interface element,

wherein switching to remotely controlling the view puts the handheld device into a controller mode,

wherein holding the user interface element and/or the actuator on the handheld device in conjunction with moving the handheld device determines the view of the 3D environment on the display in accordance with signals from the motion sensor.

33. (new) A scanning system for scanning a 3D environment, the scanning system comprising:

a handheld device including an optical scanner, wherein the 3D environment to be scanned is selected by pointing the optical scanner at the 3D environment; and

at least one display remotely connected to the handheld device, wherein the handheld device is adapted for performing at least one scanning action in a physical 3D environment, and the at least one display is adapted for visually representing the physical 3D environment; and

wherein the handheld device includes at least one motion sensor for remotely controlling the display to adjust the view with which the 3D environment is represented on the display; and

wherein the at least one motion sensor is an accelerometer, gyro, or magnetometer.

34. (new) The scanning system according to claim 33, wherein the handheld device further comprises at least two user interface elements.

35. (new) The scanning system according to claim 34, wherein the at least two user interface elements comprises at least one button and a touch-sensitive element, and wherein the display is on a cart.

36. (new) The scanning system according to claim 35, wherein the at least one button and the touch-sensitive element provides more than one user input.

37. (new) The scanning system according to claim 36, wherein at least one of the user input provides for manually switching between performing the at least one scanning action and remotely controlling the view.

38. (new) The scanning system according to claim 37, wherein switching to remotely controlling the view puts the handheld device into a controller mode, wherein holding at least one user interface element on the handheld device in conjunction with moving the handheld device determines the view of the 3D environment on the display in accordance with signals from the motion sensor.

39. (new) The scanning system according to claim 37, wherein switching to remotely controlling the view puts the handheld device into a controller mode and wherein when in controller mode, moving the handheld device down results in showing the view of the 3D environment from a downward viewing angle on the display.

40. (new) The scanning system according to claim 1, wherein the at least one display is a 3D display, whereby a 3D representation of the 3D environment is displayed on the 3D display; and wherein the handheld device is an intra-oral 3D scanner or an in-ear 3D scanner.

41. (new) The scanning system according to claim 40, wherein the 3D display is configured to project stereoscopic image pairs of the 3D representation.

42. (new) The scanning system according to claim 40, wherein the 3D display is volumetric display configured to create a 3D effect of the 3D representation.

43. (new) The system according to claim 19, wherein the at least one display is a 3D display, whereby a 3D representation of the 3D environment is displayed on the 3D display; and wherein the 3D display is configured to project stereoscopic image pairs of the 3D representation.

44. (new) The scanning system according to claim 33, wherein the at least one display is a 3D display, whereby a 3D representation of the 3D environment is displayed on the 3D display; wherein the handheld device is an intra-oral 3D scanner or an in-ear 3D scanner; and wherein the 3D display is configured to project stereoscopic image pairs of the 3D representation.

REMARKS

This communication is submitted in accordance with 37 C.F.R. § 1.173.

Status of Claims and Support for Claim Changes

This application for a narrowing reissue is being filed with original patent Claims 1-19, of which Claims 1-3, 5-19 are amended and Claim 4 is canceled, and new Claims 20-44 are added.

As of the filing of this second preliminary amendment, Claims 1-3, 5-44 are pending.

The following table lists the status of the claims as well as non-limiting, exemplary support for the claim amendments and the new claims.

Claim	Status/Support
1	Pending and Amended. Non-limiting, exemplary support found at original Claims 1 and 4; col. 1, lines 58-60; col. 6, lines 46-50; col. 9, lines 59-60; and col. 10, line 35.
2	Pending and Amended. Non-limiting, exemplary support found at original Claim 1.
3	Pending and Amended. Non-limiting, exemplary support found at original Claim 1; and col. 3, lines 28-31.
4	Canceled.
5	Pending and Amended. Non-limiting, exemplary support found at original Claim 1.
6	Pending and Amended. Non-limiting, exemplary support found at original Claims 1 and 4; col. 1, lines 58-60; and col. 5, lines 37-38 and 43-46.
7	Pending and Amended. Non-limiting, exemplary support found at original Claim 1.
8	Pending and Amended. Non-limiting, exemplary support found at original Claims 1 and 4; col. 5, lines 43-46; col. 6, lines 51-58; and col. 7, lines 14-17.
9	Pending and Amended. Non-limiting, exemplary support found at original Claim 1.
10	Pending and Amended. Non-limiting, exemplary support found at original Claim 1.

11	Pending and Amended. Non-limiting, exemplary support found at original Claim 1.
12	Pending and Amended. Non-limiting, exemplary support found at original Claim 1.
13	Pending and Amended. Non-limiting, exemplary support found at original Claim 1.
14	Pending and Amended. Non-limiting, exemplary support found at original Claim 1.
15	Pending and Amended. Non-limiting, exemplary support found at original Claim 1.
16	Pending and Amended. Non-limiting, exemplary support found at original Claim 1.
17	Pending and Amended. Non-limiting, exemplary support found at original Claim 1.
18	Pending and Amended. Non-limiting, exemplary support found at original Claim 1.
19	Pending and Amended. Non-limiting, exemplary support found at col. 6, lines 46-50; col. 9, lines 59-60; and col. 10, line 35.
20	Pending and New. Non-limiting, exemplary support found at col. 6, lines 46-50.
21	Pending and New. Non-limiting, exemplary support found at col. 3, lines 10-12.
22	Pending and New. Non-limiting, exemplary support found at col. 6, line 65-col. 7, line 3.
23	Pending and New. Non-limiting, exemplary support found at original Claim 19; col. 3, lines 15-17; and col. 4, lines 6-8.
24	Pending and New. Non-limiting, exemplary support found at Fig. 2a; col. 3, lines 18-19; and col. 11, lines 9-17.
25	Pending and New. Non-limiting, exemplary support found at col. 7, lines 4-17.
26	Pending and New. Non-limiting, exemplary support found at col. 7, lines 4-17.
27	Pending and New. Non-limiting, exemplary support found at col. 7, lines 22-34.
28	Pending and New. Non-limiting, exemplary support found at col. 7, lines 18-34.
29	Pending and New. Non-limiting, exemplary support found at original Claim 10; col. 9, lines 45-60; and col. 13, lines 28-31.
30	Pending and New. Non-limiting, exemplary support found at col. 14, lines 45-47.
31	Pending and New. Non-limiting, exemplary support found at col. 14, lines 19-21.
32	Pending and New. Non-limiting, exemplary support found at original Claim

	19; col. 3, line 66-col. 4, line 8; and col. 7, lines 4-17.
33	Pending and New. Non-limiting, exemplary support found at original Claims 1, 4, 19; col. 6, lines 46-50.
34	Pending and New. Non-limiting, exemplary support found at col. 7, lines 4-34.
35	Pending and New. Non-limiting, exemplary support found at col. 7, lines 4-34; and col. 14, lines 45-47.
36	Pending and New. Non-limiting, exemplary support found at col. 7, lines 22-34.
37	Pending and New. Non-limiting, exemplary support found at original Claims 3 and 19; and col. 3, lines 28-37.
38	Pending and New. Non-limiting, exemplary support found at col. 3, lines 15-17; and col. 3, line 66-col. 4, line 8.
39	Pending and New. Non-limiting, exemplary support found at Fig. 2a; col. 3, lines 15-19; col. 3, line 66-col. 4, line 8; and col. 11, lines 9-17.
40	Pending and New. Non-limiting, exemplary support found at Fig. 1; col. 5, lines 19-30; col. 3, lines 6-12 and 47-48; col. 4, lines 47-48; col. 5, lines 14-15; and col. 8, lines 39-40.
41	Pending and New. Non-limiting, exemplary support found at col. 5, lines 19-30.
42	Pending and New. Non-limiting, exemplary support found at col. 5, lines 19-30.
43	Pending and New. Non-limiting, exemplary support found at col. 5, lines 19-30.
44	Pending and New. Non-limiting, exemplary support found at Fig. 1; col. 5, lines 19-30; col. 3, lines 6-12 and 47-48; col. 4, lines 47-48; col. 5, lines 14-15; and col. 8, lines 39-40.

Early and favorable action concerning this application is respectfully requested.

If there are any questions concerning this Second Preliminary Amendment Pursuant To 37 C.F.R. § 1.173, or the reissue application in general, the Examiner is respectfully requested to telephone the undersigned representative so that prosecution of the application may be expedited.

The Director is hereby authorized to charge any appropriate fees under 37 C.F.R. §§ 1.16, 1.17 and 1.20(d) and 1.21 that may be required by this paper, and to credit any overpayment, to Deposit Account No. 02-4800.

Favorable consideration of the application in view of the foregoing amendments is respectfully requested. Should any questions arise in connection with this application, it is respectfully requested that the undersigned be contacted at the number indicated below.

Respectfully submitted,

BUCHANAN INGERSOLL & ROONEY PC

Date October 28, 2019

By: /Stephany G. Small/
Stephany G. Small, Ph.D.
Registration No. 69,532

Customer No. 21839
703 836 6620

Attorney Docket No.: 0079124-000266

IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

In re Application of	)	
	)	Group Art Unit: 3992
Henrik ÖJELUND *et al.*	)	
	)	Examiner: Peng KE
Reissue Application Serial No.: 16/526,281	)	
	)	Confirmation No.: 9657
Filed: July 30, 2019	)	
	)	
For: SYSTEM WITH 3D USER INTERFACE INTEGRATION	)	

FIRST INFORMATION DISCLOSURE STATEMENT

Commissioner for Patents
P.O. Box 1450
Alexandria, VA 22313-1450

Commissioner:

In accordance with the duty of disclosure as set forth in 37 C.F.R. § 1.56, the accompanying information is being submitted in accordance with 37 C.F.R. §§ 1.97 and 1.98.

To assist the Examiner, the documents are listed on the attached substitute for forms PTO/SB/08a and PTO/SB/08b. It is respectfully requested that an Examiner-initialed copy of this form be returned to the undersigned.

The documents are being submitted within three (3) months of the filing or entry of the national stage of this application or before the first Office Action on the merits, whichever is later. Because these documents are being filed within the time period set forth in 37 C.F.R. § 1.97(b), no fee or statement is required.

The Director is hereby authorized to charge any appropriate fees under 37 C.F.R. §§ 1.16, 1.17, and 1.21 that may be required by this paper, and to credit any overpayment, to Deposit Account No. 02-4800.

Respectfully submitted,
BUCHANAN INGERSOLL & ROONEY PC

Dated: October 28, 2019

By: /Stephany G. Small/
Stephany G. Small, Ph.D.
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Substitute for form PTO/SB/08a and PTO/SB/08b				Complete if Known	
FIRST INFORMATION DISCLOSURE STATEMENT BY APPLICANT				**Application Number**	16/526,281
				Filing Date	July 30, 2019
				First Named Inventor	Henrik ÖJELUND
(use as many sheets as necessary)				**Examiner Name**	Peng KE
Sheet	1	of	4	**Attorney Docket Number**	0079124-000266

U.S. PATENTS

Examiner Initials	Item No.	Patent Number	Kind Code (if known)	Name of Patentee or Applicant of Cited Document	Issue Date (MM-DD-YYYY)
	1.	9,329,675	B2	Öjelund *et al.* (IPR2018-00197, Ex. 1001) (IPR2018-00198, Ex. 1001)	05-03-2016
	2.	8,903,746	B2	Brennan *et al.* (IPR2018-00197, Ex. 1007) (IPR2018-00198, Ex. 1007)	12-02-2014
	3.	7,221,332	B2	Miller *et al.* (IPR2018-00197, Ex. 1013) (IPR2018-00198, Ex. 1013)	05-22-2007
	4.	5,377,011	A	Koch (IPR2018-00197, Ex. 1014) (IPR2018-00198, Ex. 1014)	12-27-1994
	5.	6,485,413	B1	Boppart *et al.* (IPR2018-00197, Ex. 1015) (IPR2018-00198, Ex. 1015)	11-26-2002
	6.	5,131,844	A	Marinaccio *et al.* (IPR2018-00197, Ex. 1020) (IPR2018-00198, Ex. 1020)	07-21-1992
	7.	6,592,371	B2	Durbin *et al.* (IPR2018-00197, Ex. 1021) (IPR2018-00198, Ex. 1021)	07-15-2003
	8.	5,722,412	A	Pflugrath *et al.* (IPR2018-00197, Ex. 1024) (IPR2018-00198, Ex. 1024)	03-03-1998
	9.	6,645,148	B2	Nguyen-Dinh *et al.* (IPR2018-00197, Ex. 1025) (IPR2018-00198, Ex. 1025)	11-11-2003
	10.	5,181,181	A	Glynn (IPR2018-00197, Ex. 1027) (IPR2018-00198, Ex. 1027)	01-19-1993
	11.	6,227,850	B1	Chishti *et al.* (IPR2018-00197, Ex. 1030) (IPR2018-00198, Ex. 1030)	05-08-2001
	12.	7,213,214	B2	Baar *et al.* (IPR2018-00197, Ex. 1032) (IPR2018-00198, Ex. 1032)	05-01-2007
	13.	7,551,353	B2	Kim *et al.* (IPR2018-00197, Ex. 1034) (IPR2018-00198, Ex. 1034)	06-23-2009
	14.	7,813,591	B2	Paley *et al.* (IPR2018-00198, Ex. 2001)	10-12-2010
	15.	7,141,020	B2	Poland *et al.*	11-28-2006
	16.	6,967,644	B1	Kobayashi	11-22-2005
	17.	7,831,292	B2	Quaid *et al.*	11-09-2010
	18.	8,035,637	B2	Kriveshko	10-11-2011
	19.	8,384,665	B1	Powers *et al.*	02-26-2013
	20.	6,135,961	A	Pflugrath *et al.*	10-24-2000

U.S. PATENT APPLICATION PUBLICATIONS

Examiner Initials	Item No.	Document Number	Kind Code (if known)	Name of Patentee or Applicant of Cited Document	Publication Date (MM-DD-YYYY)
	21.	2007/0171220	A1	Kriveshko (IPR2018-00197, Ex. 1005) (IPR2018-00198, Ex. 1005)	07-26-2007
	22.	2006/0020204	A1	Serra *et al.* (IPR2018-00197, Ex. 1006) (IPR2018-00198, Ex. 1006)	01-26-2006
	23.	2006/0212260	A1	Kopelman *et al.* (IPR2018-00197, Ex. 1008) (IPR2018-00198, Ex. 1008)	09-21-2006

Examiner Signature		Date Considered	

*EXAMINER: Initial if reference considered, whether or not citation is in conformance with M.P.E.P. § 609. Draw line through citation if not in conformance and not considered. Include copy of this form with next communication to Applicant.

Form Letters1

Substitute for form PTO/SB/08a and PTO/SB/08b	Complete if Known	
FIRST INFORMATION DISCLOSURE STATEMENT BY APPLICANT	**Application Number**	16/526,281
	Filing Date	July 30, 2019
	First Named Inventor	Henrik ÖJELUND
(use as many sheets as necessary)	**Examiner Name**	Peng KE
Sheet 2 of 4	**Attorney Docket Number**	0079124-000266

	24.	2007/0172112	A1	Paley *et al.* (IPR2018-00197, Ex. 1009) (IPR2018-00198, Ex. 1009)	07-26-2007
	25.	2012/0179035	A1	Boudier (IPR2018-00197, Ex. 1010) (IPR2018-00198, Ex. 1010)	07-12-2012
	26.	2009/0322676	A1	Kerr *et al.* (IPR2018-00197, Ex. 1011) (IPR2018-00198, Ex. 1011)	12-31-2009
	27.	2005/0237581	A1	Knighton *et al.* (IPR2018-00197, Ex. 1026) (IPR2018-00198, Ex. 1026)	10-27-2005
	28.	2006/0092133	A1	Touma *et al.* (IPR2018-00197, Ex. 1028) (IPR2018-00198, Ex. 1028)	05-04-2006
	29.	2010/0009308	A1	Wen *et al.* (IPR2018-00197, Ex. 1031) (IPR2018-00198, Ex. 1031)	01-14-2010
	30.	2003/0164952	A1	Deichmann *et al.* (IPR2018-00197, Ex. 1033) (IPR2018-00198, Ex. 1033)	09-04-2003
	31.	2009/0040175	A1	Xu *et al.* (IPR2018-00197, Ex. 2001) (IPR2018-00198, Ex. 2003)	02-12-2009
	32.	2009/0217207	A1	Kagermeier *et al.*	08-27-2009
	33.	2003/0158482	A1	Poland *et al.*	08-21-2003
	34.	2009/0061381	A1	Durbin *et al.*	03-05-2009
	35.	2006/0146009	A1	Syrbe *et al.*	07-06-2006
	36.	2004/0204787	A1	Kopelman *et al.*	10-14-2004
	37.	2005/0057745	A1	Bontje	03-17-2005
	38.	2006/0025684	A1	Quistgaard *et al.*	02-02-2006
	39.	2014/0022352	A1	Fisker *et al* (IPR2018-00197, Ex. 1039)	01-23-2014

FOREIGN PATENT DOCUMENTS

Examiner Initials	Item No.	Country Code[1], Number, Kind Code	Publication Date (MM-DD-YYYY)	Name of Patentee or Applicant of Cited Document
	40.	WO 2010/064156 A1 (IPR2018-00197, Ex. 1012) (IPR2018-00198, Ex. 1012)	06-10-2010	Poland *et al.*
	41.	EP 2200332 A1 (IPR2018-00197 Ex. 1019) (IPR2018-00198, Ex. 1019)	06-23-2010	Thominet
	42.	WO 00/08415 A1 (IPR2018-00198, Ex. 1037)	02-17-2000	Babayoff *et al.*
	43.	WO 2010/145669 A1	12-23-2010	3Shape A/S *et al.*
	44.	WO 2011/120526 A1	10-06-2011	3Shape A/S *et al.*
	45.	WO 2004/066615 A1	08-05-2004	Nokia Corporation
	46.	CN 101513350 A with English Abstract	08-26-2009	Siemans AG
	47.	WO 2009/089126 A1	07-16-2009	3M Innovative Properties Company
	48.	WO 2001/011193 A1	01-27-2011	Dimensional Photonics International, Inc.
	49.	WO 2007/084727 A1	07-26-2007	3M Innovative Properties Company
	50.	WO 2013/010910 A1 (IPR2018-00197, Ex. 1040)	01-24-2013	3Shape A/S *et al.*

NON-PATENT LITERATURE DOCUMENTS

Examiner Initials	Item No.	Include name of the author (in CAPITAL LETTERS), title of the article (when appropriate), title of the item (book, magazine, journal, serial, symposium, catalog, etc.), date, page(s), volume-issue number(s), publisher, city and/or country where published.

Examiner Signature		Date Considered	

*EXAMINER: Initial if reference considered, whether or not citation is in conformance with M.P.E.P. § 609. Draw line through citation if not in conformance and not considered. Include copy of this form with next communication to Applicant.

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				Filing Date	July 30, 2019
				First Named Inventor	Henrik ÖJELUND
				Examiner Name	Peng KE
Sheet	3	of	4	**Attorney Docket Number**	0079124-000266

	51.	Petition for Inter Partes Review of U.S. Patent 9,329,675, filed November 22, 2017 in IPR2018-00197.
	52.	Patent Owner's Preliminary Response to the Petition for Inter Partes Review of U.S. Patent No. 9,329,675, filed March 3, 2018 in IPR2018-00197.
	53.	Institution Decision entered May 30, 2018 in IPR20198-00197.
	54.	Patent Owner's Response to the Petition for Inter Partes Review of U.S. Patent No. 9,329,675, filed August 20, 2018 in IPR2018-00197.
	55.	Petitioner's Reply to Patent Owner's Response, filed November 14, 2018, in IPR2018-00197.
	56.	Petitioner's Demonstratives filed January 31, 2019, in IPR2018-00197.
	57.	Patent Owner's Submission of Demonstratives for Oral Argument filed January 31, 2019, in IPR2018-00197.
	58.	Petition for Inter Partes Review of U.S. Patent No. 9,329,675, filed November 22, 2017 in IPR2018-00198.
	59.	Patent Owner's Preliminary Response to the Petition for Inter Partes Review of U.S. Patent No. 9,329,675, filed March 3, 2018 in IPR2018-00198.
	60.	Decision Denying Institution entered May 30, 2018 in IPR20198-00198.
	61.	Petitioner's Request for Rehearing of Institution Decision, filed June 29, 2018 in IPR20198-00198.
	62.	Decision Denying Petitioner's Request for Rehearing, entered December 4, 2018 in IPR20198-00198.
	63.	U.S. Patent No. 9,329,675 File History (IPR2018-00197, Ex. 1002) (IPR2018-00198, Ex. 1002)
	64.	Declaration of Dr. Chandrajit L. Bajaj (IPR2018-00197, Ex. 1003)
	65.	Declaration of Dr. Chandrajit L. Bajaj (IPR2018-00198, Ex. 1003)
	66.	Dr. Chandrajit L. Bajaj Curriculum Vitae (IPR2018-00197, Ex. 1004) (IPR2018-00198, Ex. 1004)
	67.	Karatas *et al.*, "Three-dimensional imaging techniques: A literature review," European Journal of Dentistry , Vol. 8, Issue 1, 2014; pp. 132-140. (IPR2018-00197, Ex. 1016) (IPR2018-00198, Ex. 1016)
	68.	Broadbent H.B., "A New X-Ray Technique and Its Application to Orthodontia," The Angle Orthodontist, Vol. I, No. 2, February 4, 1931; pp. 45-66. (IPR2018-00197, Ex. 1017) (IPR2018-00198, Ex. 1017)
	69.	Birnbaum *et al.*, "Dental Impressions Using 3D Digital Scanners: Virtual Becomes Reality," (IPR2018-00197, Ex. 1018) (IPR2018-00198, Ex. 1018)
	70.	Ireland *et al.*, "3D surface imaging in dentistry what we are looking at," British Dental Journal, Vol. 205, No. 7, October 11, 2008; pp. 387-392. (IPR2018-00197, Ex. 1022) (IPR2018-00198, Ex. 1022)
	71.	Hajeer *et al.*, "Current Products and Practices Applications of 3D imaging in orthodontics: Part II," Journal of Orthodontics, Vol. 31, 2004; pp. 154-162. (IPR2018-00197, Ex. 1023) (IPR2018-00198, Ex. 1023)
	72.	Bornik *et al.*, "A Hybrid User Interface for Manipulation of Volumetric Medical Data," 3D User Interfaces, 2006; 8 pages. (IPR2018-00197, Ex. 1029) (IPR2018-00198, Ex. 1029)
	73.	Giammanco, et. al., "Using 3D Laser Scanning Technology to Create Digital Models of Hailstones," American Meteorological Society, July 2017; pp. 1341-1347. (IPR2018-00197, Ex. 1036) (IPR2018-00198, Ex. 1036)
	74.	D. A. Bowman et al., "Theory and Practice" 3D User Interfaces, 4:96-101, July 2004. (IPR2018-00197, Ex. 1038)
	75.	EPO Prosecution History of European Patent Application No. 11847582.1, filed June 19, 2013. (IPR2018-00198, Ex. 1038)
	76.	Yoshida, Hiroshi *et al.*, "Intraoral Ultrasonic Scanning as a Diagnostic Aid," J. CRANIO-MAX.-FAC. SURG. 15 (1987), pp. 306-311. (IPR2018-00197, Ex. 2002) (IPR2018-00198, Ex. 2004)
	77.	Moran, Carmel M *et al.*, "A Comparison of the Imaging Performance of High Resolution Ultrasound Scanners for Preclinical Imaging," ULTRASOUND IN MED. & BIOL., Vol. 37, No. 3 (2011), pp. 493-501. (IPR2018-00197, Ex. 2003) (IPR2018-00198, Ex. 2005)

Examiner Signature		Date Considered	

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				Filing Date	July 30, 2019
				First Named Inventor	Henrik ÖJELUND
(use as many sheets as necessary)				Examiner Name	Peng KE
Sheet	4	of	4	Attorney Docket Number	0079124-000266

	78.	Ahn, Jae Sung, *et al.*, "Development of Three-Dimensional Dental Scanning Apparatus Using Structured Illumination," Sensors, 17, 1634 (2017), 9 pages. (IPR2018-00197, Ex. 2004) (IPR2018-00198, Ex. 2002)
	79.	U.S. Patent Application Serial No. 10/744,869. (IPR2018-00197, Ex. 2005)
	80.	B.C. Chua *et al.*, "SonoDEX: 3D space management and visualization of ultrasound data," INTERNATIONAL CONGRESS SERIES 1281:143-148 (2005). (IPR2018-00197, Ex. 2006)
	81.	Deposition Transcript of Chandrajit Bajaj, Ph.D. on July 25, 2018 with Errata Sheet. (IPR2018-00197, Ex. 2008)
	82.	J. Mackinlay *et al.*, "A Semantic Analysis of the Design Space of Input Devices," HUMAN-COMPUTER INTERACTION 5:145-190 (1990). (IPR2018-00197, Ex. 2009)
	83.	"Taxonomies of Input" in DEVELOPING A TAXONOMY OF INPUT 4.1-4.16 (Jan. 4, 2009) available at https://www.billbuxton.com/input04.Taxonomies.pdf. (IPR2018-00197, Ex. 2010)
	84.	Declaration of Ravin Balakrishnan, Ph.D. (IPR2018-00197, Ex. 2011)
	85.	*Curriculum Vitae* of Ravin Balakrishnan, Ph.D. (IPR2018-00197, Ex. 2012)
	86.	D. Bowman, *et al., 3D User Interfaces Theory and Practice* § 4.1.1 "Input Device Characteristics" pp 88-89; § 4.2.2 "2D Mice and Trackballs" pp 91-92; § 4.8.2 "Input Device Taxonomies" pp 128-132 (2005). (IPR2018-00197, Ex. 2013)
	87.	J. Jerald, *The VR Book: Human-Centered Design for Virtual Reality* § 27.1.3 (2016). (IPR2018-00197, Ex. 2014)
	88.	International Search Report (PCT/ISA/210) issued on February 22, 2012 in International Application No. PCT/DK2011/050461.
	89.	C. Graetzel, *et al.*, A Non-Contact Mouse for Surgeon-Computer Interaction, Technology and Helath Care, 12(3):1-19, 2004.
	90.	S. Vogt *et al.*, An AR System With Intuitive User Interface For Manipulation And Visualization of 3D Medical Data, Stud. Health Technol. Inform., Medicine Meets Virtual Reality, 12(98):397-403, 2004.
	91.	Xia *et al.*, Three-Dimensional Virtual Reality, IEEE Transactions on Information Technology in Biomedicine, 5(2):97-107, June 2001.
	92.	First Office Action issued April 3, 2015 in corresponding Chinese Patent Application No. 201180066956.6 (13 pages).
	93.	Second Office Acton issued in corresponding Chinese Patent Application No. 201180066956.6 dated November 18, 2015, with English translation (27 pages).
	94.	Deposition Transcript of Dr. Ravin Balakrishnan.
	95.	Record of Oral Hearing held February 4, 2019 from IPR2018-00197
	96.	Final Written Decision, entered May 29, 2019- Termination Decision Document from IPR2018-00197 [Paper 22]

Examiner Signature		Date Considered	

*EXAMINER: Initial if reference considered, whether or not citation is in conformance with M.P.E.P. § 609. Draw line through citation if not in conformance and not considered. Include copy of this form with next communication to Applicant.

Form Letters1

(12) INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

(19) **World Intellectual Property Organization**
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PCT

(10) **International Publication Number**
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(51) **International Patent Classification:**
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(21) **International Application Number:** PCT/IB2009/054999

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61/1 19,5 12 3 December 2008 (03.12.2008) US

(71) **Applicant** *(for all designated States except US):* **KONINKLIJKE PHILIPS ELECTRONICS,** N.V. [NIVNL]; Groenewoudseweg 1, NL-5621 BA Eindhoven (NL).

(72) **Inventors; and**

(75) **Inventors/Applicants** *(for US only):* **POLAND, Mckee** [US/US]; P.O. Box 3001 345 Scarborough Road, Briarcliff Manor, New York 105 10-8001 (US). WILSON, **Martha Gail Grewe** [US/US]; P.O. Box 3001 345 Scarbarough Road, Briarcliff Manor, New York 105 10-8001 (US).

(74) **Agent:** DAMEN, Daniel, M.; Philips Intellectual Property & Standards, High Tech Campus 44, P.O. Box 220, NL-5600 AE Eindhoven (NL).

(81) **Designated States** *(unless otherwise indicated, for every kind of national protection available):* AE, AG, AL, AM, AO, AT, AU, AZ, BA, BB, BG, BH, BR, BW, BY, BZ, CA, CH, CL, CN, CO, CR, CU, CZ, DE, DK, DM, DO, DZ, EC, EE, EG, ES, FI, GB, GD, GE, GH, GM, GT, HN, HR, HU, ID, IL, IN, IS, JP, KE, KG, KM, KN, KP, KR, KZ, LA, LC, LK, LR, LS, LT, LU, LY, MA, MD, ME, MG, MK, MN, MW, MX, MY, MZ, NA, NG, NI, NO, NZ, OM, PE, PG, PH, PL, PT, RO, RS, RU, SC, SD, SE, SG, SK, SL, SM, ST, SV, SY, TJ, TM, TN, TR, TT, TZ, UA, UG, US, UZ, VC, VN, ZA, ZM, ZW.

(84) **Designated States** *(unless otherwise indicated, for every kind of regional protection available):* ARIPO (BW, GH, GM, KE, LS, MW, MZ, NA, SD, SL, SZ, TZ, UG, ZM, ZW), Eurasian (AM, AZ, BY, KG, KZ, MD, RU, TJ,

[Continued on next page]

(54) **Title:** ULTRASOUND ASSEMBLY AND SYSTEM COMPRISING INTERCHANGABLE TRANSDUCERS AND DISPLAYS

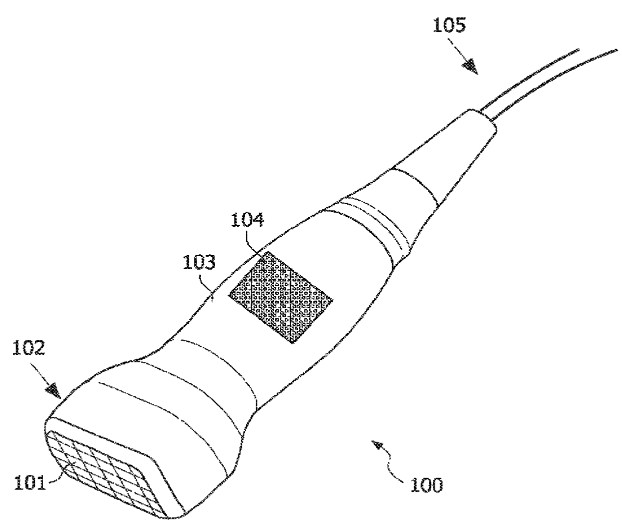

FIG. 1

(57) **Abstract:** An ultrasound assembly comprises a module having an input side and an output side; an ultrasound transducer comprising a micro-beamformer configured for attachment to and detachment from the input side of the module; and a display attached to the output side of the module. An ultrasound system is also described.

WO 2010/064156 A1

TM), European (AT, BE, BG, CH, CY, CZ, DE, DK, EE, ES, FI, FR, GB, GR, HR, HU, IE, IS, IT, LT, LU, LV, MC, MK, kr, NL, NO, PL, PT, RO, SE, SI, SK, SM, TR), OAPI (BF, BJ, CF, CG, CI, CM, GA, GN, GQ, GW, **ML, MR, NE, SN, TD, TG).**

Declarations under Rule 4.17:

— *as to applicant's entitlement to apply for and be granted a patent (Rule 4.17(U))*

— *as to the applicant's entitlement to claim the priority of the earlier application (Rule 4.17(iii))*

Published:

— *with international search report (Art. 21(3))*

ULTRASOUND ASSEMBLY AND SYSTEM COMPRISING INTERCHANGABLE TRANSDUCERS AND DISPLAYS

BACKGROUND AND SUMMARY

Acoustic waves (including, specifically, ultrasound waves) are useful in many scientific or technical fields, such as in medical diagnosis and medical procedures, non-destructive control of mechanical parts and underwater imaging, etc. Acoustic waves allow diagnoses and visualizations which are complementary to optical observations, because acoustic waves can travel in media that are not transparent to electromagnetic waves.

In one application, acoustic waves are employed by a medical practitioner in the course of performing a medical procedure or to provide images of a particular anatomical region of a body. Often, an acoustic imaging apparatus is employed to provide images of an area of interest to the medical practitioner to facilitate successful performance of the medical procedure.

As should be appreciated by one having ordinary skill in the art, the acoustic imaging apparatus comprises an ultrasound transducer and signal processing electronics that capture the electrical signal from the acoustic transducer and process the signal for display on one type of monitor or another. The monitor may then be viewed by the medical practitioner real-time, or may be stored/reproduced for later review, or both.

As is known, there are various types of transducers that can be used to capture ultrasonic images. For example, there are linear, curved linear and phased array transducers, which may be used in ultrasound. These transducers may have elements arranged in a one-dimensional or a two-dimensional fashion, which can enable the capturing of either a narrow slice of echo data, multiple narrow slices of echo data in different orientations with respect to each other, or a full volume set of echo data. Each type of array has advantages, and depending on the medical anatomy being imaged (due to different target depths or imaging window accessibility) , a medical practitioner may select one type of transducer over another. As should be appreciated, in known systems this results in duplicative transducer electronics, transducer housings, and cables, and thus increases the overall capital expenditure for the medical facility.

Furthermore, the arrangement of the medical equipment in the imaging room can be challenging due to the placement of the ultrasound system and its display, which the user needs to look at during the scanning session. Storing and using multiple transducer probes in the imaging room exacerbates the problem of crowding the patient area with cables and equipment.

In addition, in such known systems, the main ultrasound system and its display are similarly problematic for placement, since they are typically bulky and relatively immobile. Traditional ultrasound scanners are large, weighing up to several hundred pounds, and are integrated with wheeled carts. Even newer "compact" ultrasound display systems, typically mounted semi-permanently on smaller, lighter carts, must be transported to a practical location such that the display is visible to the sonographer but the cart is sufficiently out of the way of the medical procedure. This is a difficult compromise to achieve, and often leads to awkward viewing angles or motions such as leaning across the patient by the medical practitioner to view the display.

What is needed, therefore, is an ultrasound assembly and system that overcomes at least the shortcomings of the known assemblies and systems described above.

In accordance with a representative embodiment, an ultrasound assembly comprises a module having an input side and an output side; an ultrasound transducer comprising a micro-beamf ormer configured for attachment and detachment from the input side of the module; and a display attached to the output side of the module.

In accordance with another representative embodiment, a system for ultrasound imaging comprises an ultrasound assembly. The ultrasound assembly comprises: a module having an input side and an output side; a ultrasound transducer comprising a micro-beamf ormer configured for attachment and detachment from the input side of the module; and a display attached to the output side of the module .

BRIEF DESCRIPTION OF THE DRAWINGS

The present teachings are best understood from the following detailed description when read with the accompanying drawing figures. The features are not necessarily drawn to scale. Wherever practical, like reference numerals refer to like features.

Fig. 1 is a perspective view of an ultrasound assembly in accordance with a representative embodiment.

Fig. 2 is a simplified schematic diagram of an ultrasound assembly in accordance with a representative embodiment .

Fig. 3 is a simplified block diagram of a system for ultrasound imaging in accordance with a representative embodiment .

DEFINED TERMINOLOGY

As used herein, the terms ^a' or ^an' , as used herein are defined as one or more than one.

In addition to their ordinary meanings, the terms ^substantial' or ^substantially' mean to with acceptable limits or degree to one having ordinary skill in the art.

In addition to their ordinary meanings, the term ^approximately' mean to within an acceptable limit or amount to one having ordinary skill in the art. For example, ^approximately the same' means that one of ordinary skill in the art would consider the items being compared to be the same.

DETAILED DESCRIPTION

In the following detailed description, for purposes of explanation and not limitation, representative embodiments disclosing specific details are set forth in order to provide a thorough understanding of the present teachings.

Descriptions of known devices, materials and manufacturing methods may be omitted so as to avoid obscuring the description of the example embodiments. Nonetheless, such devices, materials and methods that are within the purview of one of ordinary skill in the art may be used in accordance with the representative embodiments.

Fig. 1 is a perspective view of an ultrasound assembly 100 in accordance with a representative embodiment. The assembly comprises a phased array transducer 102 having transducer elements 101 in a forward portion thereof. The transducer elements 101 are shown in a two-dimensional array in the representative embodiment. As will become clearer as the present description continues, the transducer elements may be arranged in a linear array, or in a curved linear array, or other transducer arrangement within the purview of one having ordinary skill in the art. It is noted that a lens covering the elements 101 is normally included; but is not shown in the various Figs.

The transducer 102 is connected to an ultrasound (US) module 103 in a detachable manner. The module 103 illustratively comprises a display 104 configured to provide an ultrasound image (not shown) garnered from the transducer 102. The display 104 is illustratively a small form-factor liquid crystal display (LCD) device but may be a display based on other technologies. For example, the display 104 may be a small form-factor organic light emitting diode (OLED) device to name only one alternative to the LCD. Other types of displays based on known technologies are contemplated.

Notably, because the assembly 100 is designed and intended for hand-held use by a medical practitioner, the display 104 is beneficially of a comparatively small form-factor as mentioned above. It is contemplated that the display 104 may be the only display of an ultrasound system; or an auxiliary display used by the medical practitioner during a medical procedure or test. As should be appreciated by one having ordinary skill in the art, the locating of the display 104 fosters simplicity and accuracy during certain procedures and testing. Beneficially, because the display 104 is on the module, the medical practitioner can look to the location where he/she is physically scanning and view the resultant image on the display 104 without looking away at a remote display. For instance, the display 104 could be attached to the back of a transducer in a manner that it can be easily rotated and tilted or can be located on the side of the module 103 in a so-called "flip-out" style configuration (similar to a consumer video camera) .

Moreover, the display 104 may be detachable so as to be positioned in a desired location separate from the body of the transducer and module. Among other benefits, this is useful in cases where another action is being effected simultaneously, such as placement of a needle for a biopsy, or insertion of a catheter in the body. The medical practitioner would be able to hold the assembly 100 in one hand, and guide the needle/catheter with the other using the image on the display 104 to facilitate the process and without having to look away to a remote monitor (not shown) .

The module 103 may be connected to a system (not shown) via connection 105. In representative embodiments, the connection 105 may be a wireless connection configured to operate under one of a variety of wireless protocols provided under standards. Such protocols are known to one having ordinary skill in the art and thus are not detailed in order to avoid obscuring the description of the representative embodiments. Notably, however, due to issues of confidentiality related to medical information, the selected protocol will likely have a competent level of security to ensure compliance with medical information confidentiality.

Alternatively, the connection 105 is shown to be a wired connection and may be compatible with one of a variety of standards. Illustratively, the connection may be a single differential serial pair such as universal serial bus (USB) or low-voltage differential signaling (LVDS). However, it is contemplated that other types of connections may be used.

As alluded to above, the transducer 102 is detachably mounted to the module 103. As described more fully herein, by providing for selective attachment and detachment of the transducer 102, a medical practitioner is accorded the ability to select a different transducer type based on the particular test/measurement undertaken; and without having to select and stock an entirely different assembly. As should be appreciated, this option beneficially allows the medical facility to reduce its capital expenditure by stocking one module for multiple types of transducers, rather than having to stock a complete ultrasound assembly for each type of transducer.

Similarly, the display 104 is illustratively detachably mounted to module 103. As mentioned above, the display 104 may be detached for optimal placement in the field of view of the sonographer during the imaging session. The data connection between the display 104 and the module 103 may be wired, as with USB or similar high-speed serial interface, or wireless, as with an ultra-wideband (UWB) protocol promoted by the WiMedia Alliance. If wireless, the display 104 should include a provision to provide power, such as a battery or DC input connector for an AC adapter.

Taking advantage of the detachable feature of the display 104, the medical facility is afforded the ability to reduce their overall capital investment or increase their aggregate ultrasound scanner reliability, or "up time", by separately stocking detachable display units. The display units may then be combined at will with one or more ultrasound transducers and modules as the patient workload changes, or as display units occasionally fail.

In representative embodiments, the transducer 102 is magnetically connected to the module 103. Alternatively, the transducer 102 may be mechanically connected to the module 103, such as by latching mechanisms (not shown) or friction-fit (i.e., 'snap-on') mechanisms. As described more fully below, the transducer 102 is connected electrically to the module by an interface (not shown in Fig. 1), which is operative to provide electrical power to the transducer 102 and to pass electrical signals from the transducer 102. Illustratively, the electrical-mechanical connection may comprise tabs (not shown) comprising copper with gold coating on a lower end (not shown) of the transducer 102 that mate to the electrical tabs (not shown) on the module 103 end. A skirt may be located around either the transducer 102 or module 103 sides that align the module to the opposite end. The connected structure is sealed such that it is resistant to fluid ingress. For example, the electrical-mechanical connection of the transducer 102 to the module 103 can be made similarly as described in US Patent 6,635,019, the disclosure of which is specifically incorporated herein by reference.

Notably however, and as described below, because of the microbeamf ormer placed in the transducer 102, the electrical connections needed to mate are much reduced since less analogue signals are required thus allowing for simpler mechanical connections such as "snap-on" mechanism where the mechanical tolerance required is much less. The is much more practically achievable allowing for easy connect /disconnect modules where the wear and tear over time would still allow a robust electrical connection.

Fig. 2 is a simplified schematic diagram of an ultrasound assembly 200 in accordance with a representative embodiment. The assembly 200 includes many common features to the assembly 100 described in connection with Fig. 1. Such common features are often not duplicatively described, but may be further elaborated upon.

The transducer 102 comprises transducer elements 102 as noted above. The transducer elements 101 may be linear array or a phased array, or a combination thereof, such as described in U.S. Patent 6,436,048. The beam from the transducer elements 101 may also be steered as described in U.S. Patent 7,037,264. As noted, the transducer elements 101 may be a curved linear (ID) array (CLA), such as described in US Patent 6,540,682. These patents are assigned to the present assignee and are all specifically incorporated herein by reference.

The transducer 102 also comprises a microbeamformer 201. The microbeamformer 201 may be as described in U.S. Patent 6,436,048. Echoes by the elements 101 of the transducer 102 are partially beamformed by a micro-beamformer 201. In a representative embodiment, the micro-beamformer 201 contains circuitry which controls the signals applied to groups of elements ("patches") of the transducer elements 101 and effects some processing of the echo signals received by elements of each group. Micro-beamforming in the transducer 102 beneficially reduces the number of conductors in the connection 105 between the assembly 100 and the ultrasound system (not shown). Additional details of the benefits derived from microbeamf orming may be found in commonly assigned U.S. Pat. No. 5,997,479, the disclosure of which is specifically incorporated herein by reference and in the ^048 patent.

In addition to the benefits derived from dividing the beamforming with a microbeamformer, the representative embodiments foster additional benefits because the microbeamformer 201 is co-located with the transducer elements 101 within the transducer 102. For example, superior electrical performance is realized because the electronics of the microbeamformer 201 are proximal to the elements 101, eliminating the need for complex interconnects, cabling, and the attendant signal distortions and power losses of long electrical connections .

Moreover, microbeamf orming may be specifically matched with the type of array of transducer elements 101, since the microbeamf orming is physically combined with the elements 101. Moreover, because of the matching of the microbeamf ormer 201 to the particular type of sensor array different versions of the microbeamformer 201 can be optimized for different sensor classes (e.g., sector, linear, CLA) and for different frequencies/impedances. Thus, rather than a generic microbeamformer that is configured to work acceptably with each of a number of transducer types, the present teachings allow for an improved if not optimal match of microbeamformer to the type of transducer array of each individual transducer 102.

Illustratively, the microbeamformer 201 may be matched in dimensions to the layout of the acoustic elements of sensor array 101 and then may be mounted directly to the sensor itself, saving space, simplifying the interconnection scheme between the microbeamformer 201 and the sensor, and reducing electrical noise and signal loss by minimizing signal trace lengths.

In addition, the microbeamformer 201 may be optimized to respond to the resonant frequency range of the acoustic sensor elements and to apply beamforming delays that match said frequency range with sufficient resolution for high quality imaging, but not so much resolution as to waste circuit components. Similarly, the microbeamformer circuitry may be optimized to match the characteristic impedance of the sensor elements 101.

As described above, the transducer 102 is connected to the module 103 via an interface 202; and the interface 202 comprises both a mechanical connection and an electrical connection. The mechanical connection enables attaching and detaching of the transducer 102 to the module 103 as described above. The electrical connection provides power to the transducer 102, in particular to its integrated microbeamf ormer; and signals from the microbeamf ormer 201 to the module 103 for further processing. The electrical mechanical connection can be made using a standard USB type latching connector or a custom mechanical latch type, snap fit, or magnetic type connection, such as described in co-pending US Patent Application Serial No. 60/941,427 entitled Wireless Ultrasound Probe Cable and filed on June 1, 2007. The disclosure of this application is specifically incorporated herein by reference.

The module 103 comprises a scan controller 203 and a main beamformer 204, such as described in U.S. Patent 6,436,048 or in U.S. Patent 7,037,264 for example. The module 103 may also comprise DSP circuitry 205 for the signal detection path in multiple modes (e.g., Greyscale, Flow, PW, CW) . In addition, the module 103 comprises a power supply 206 for powering the module 103, the transducer 102 and the display component 104. It also comprises a memory 207 for storing acquired images user presets scan control and beamforming coefficients user programs .

The power supply 206 may be an AC/DC converter operative to provide a desired DC voltage. Alternatively, the power supply 206 may be a known type of battery. The implementation of the latter provides certain benefits over known devices. First, because no cable is needed for power, the assembly 100 may be readily implemented according to a wireless protocol providing ease of portability and use. Moreover, a battery, which can be rechargeable, can be recharged simultaneously with data transfer over the same (wired) connection 105. For example, a USB connection may be used to realize both data and power for recharging.

The use of a battery also accords the benefit of powering the display 104 in a local manner. Thus, the display 104 does not require a remote power supply, and may have its own battery. As such, the display 104 can be compact and light. By contrast, a separate monitor or external display such as on a personal digital assistant (PDA) will require a power source and central processing unit (CPU), which add to the complexity of the system and reduce the ergonomic benefits derived from the self-contained assembly 100.

Furthermore, the rendering and formatting of images may be effected in the module 103, thus minimizing the need for processing at the display 104. This reduces not only the size and weight of the system, but also the cost of the display 104. The display 104 is easily connected or disconnected to the module 103 thus allowing for flexibility in positioning for the user. Due to the few electrical signals required, the mechanical - electrical connection can be made to be simple since the alignment and tolerance of the electrical tabs easily achievable. The electrical tabs of the module (described above) can mate to the electrical tabs of the display 104, such as by a magnetic connection, a friction fit or some other type of latching connection. This mechanical connection can allow for rotation and tilting of the display.

Fig. 3 is a simplified block diagram of a system 300 for ultrasound imaging in accordance with a representative embodiment. The system 300 comprises the assembly 100 and a system monitor 301 connected by connection 105 as shown. The system 300 includes many common features and details to those described in connection with the representative embodiments of Figs . 1 and 2 .

The system monitor 301 may be a stand-alone monitor used by the medical practitioner using the assembly 100 and may be in lieu of or in addition to the display 104. Alternatively, the system monitor 300 may be a central unit (e.g., a server) of a medical facility that provides access to the images from the assembly in real-time or via memory. Again, the link between the assembly 100 and the monitor 301 may be wired or wireless, as may the link from the monitor to other devices of a network connected thereto.

In view of this disclosure it is noted that the various ultrasound assemblies and systems ultrasound imaging may comprise a variety of devices, components, software, hardware and firmware. Moreover, applications other than medical imaging may benefit from the present teachings. Further, the various devices, components, software, hardware, firmware and parameters are included by way of example only and not in any limiting sense. In view of this disclosure, those skilled in the art can implement the present teachings in determining their own applications and needed devices, components, software, hardware and firmware to implement these applications, while remaining within the scope of the appended claims.

Claims :

1. An ultrasound assembly, comprising:

a module having an input side and an output side;

a ultrasound transducer comprising a micro-beamf ormer configured for attachment and detachment from the input side of the module; and

a display attached to the output side of the module.

2. An ultrasound assembly as claimed in claim 1, wherein the ultrasound transducer comprises a linear transducer array and the module is configured to receive input signals from the linear transducer array and to provide output signals to the display.

3. An ultrasound assembly as claimed in claim 1, wherein the ultrasound transducer comprises a phased array transducer array and the module is configured to receive input signals from the phased array transducer array and to provide output signals to the display.

4. An ultrasound assembly as claimed in claim 1, wherein the ultrasound transducer comprises a curved transducer array and the module is configured to receive input signals from the curved transducer array and to provide output signals to the display.

5. An ultrasound assembly as claimed in claim 1, wherein the module comprises a microcontroller and a memory and the

microcontroller is configured to acquire a transducer parameter from the memory.

6. An ultrasound assembly as claimed in claim 5, wherein the microcontroller is configured to receive data from the transducer array after acquiring the transducer parameter.

7. An ultrasound assembly as claimed in claim 5, wherein the microcontroller is configured to optimize calculating configuration and scanning coefficients of the ultrasound transducer.

8. An ultrasound assembly as claimed in claim 1, wherein the display is disposed over the module.

9. An ultrasound assembly as claimed in claim 1, wherein the module and the transducer are configured to mechanically attach and detach from one another.

10. An ultrasound assembly as claimed in claim 1, wherein the display is electrically connected to the assembly in a wired manner.

11. An ultrasound assembly as claimed in claim 1, wherein the module and the display are configured to magnetically attach and detach from one another.

12. An ultrasound assembly as claimed in claim 1, wherein the display is electrically connected to the assembly in a

wireless manner.

13. A system for ultrasound imaging, comprising:

an ultrasound assembly, comprising: a module having an input side and an output side; an ultrasound transducer comprising a micro-beamf ormer configured for attachment and detachment from the input side of the module; and a display attached to the output side of the module.

14. A system as claimed in claim 13, wherein the ultrasound transducer comprises a linear transducer array and the module is configured to receive input signals from the linear transducer array and to provide output signals to the display.

15. A system as claimed in claim 13, wherein the ultrasound transducer comprises a phased array transducer array and the module is configured to receive input signals from the phased array transducer array and to provide output signals to the display.

16. A system as claimed in claim 13, wherein the ultrasound transducer comprises a curved transducer array and the module is configured to receive input signals from the curved transducer array and to provide output signals to the display.

17. A system as claimed in claim 13, wherein the ultrasound transducer comprises a memory and the module

comprises a microcontroller configured to acquire a transducer parameter from the memory.

18. A system as claimed in claim 17, wherein the microcontroller is configured to receive data from the transducer array after acquiring the transducer parameter..

19. A system as claimed in claim 13, wherein the microcontroller is configured to optimize calculating configuration and scanning coefficients of the ultrasound transducer.

20. A system as claimed in claim 13, wherein the display is disposed over the module.

21. A system as claimed in claim 13, wherein the module and the transducer are configured to mechanically attach and detach from one another.

23. A system as claimed in claim 13, wherein the mechanical attachment is by friction-fit.

23. A system as claimed in claim 13, further comprising another display remote to the ultrasound assembly.

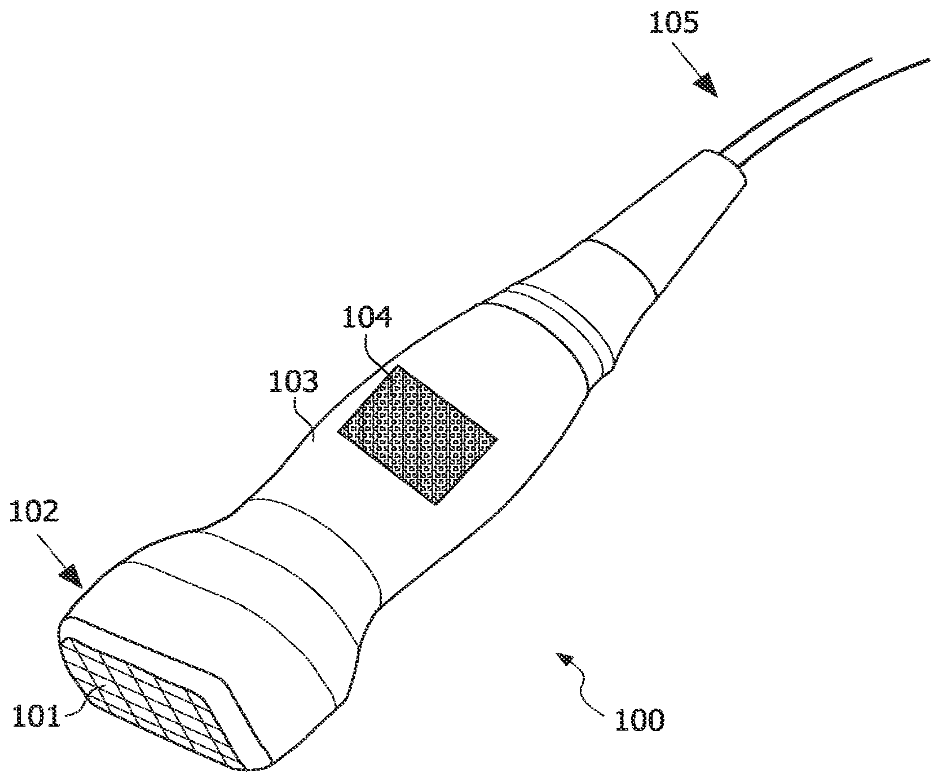

FIG. 1

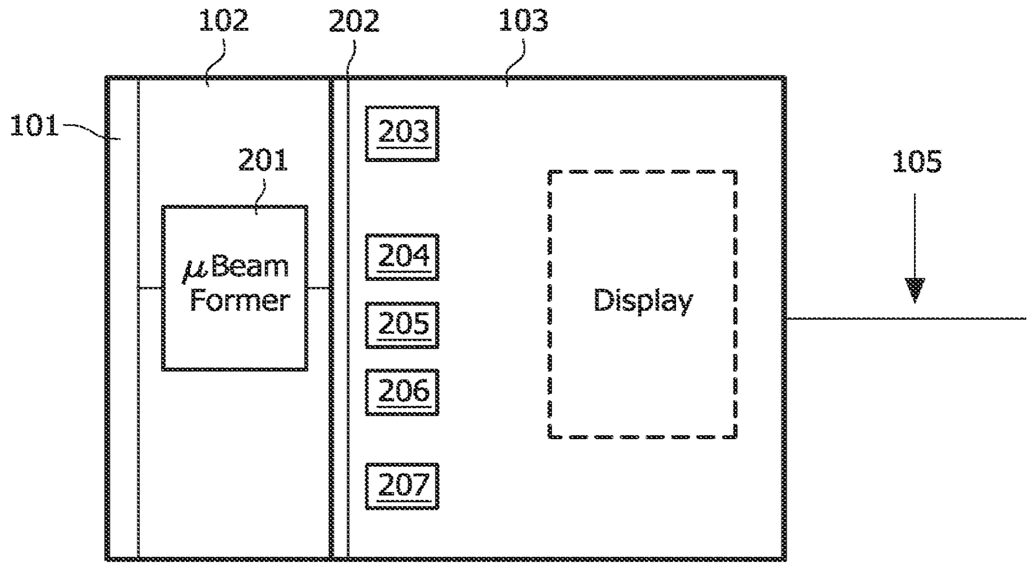
102
202
103
101
201
203
μBeam
Former
204
205
206
207
Display
105

FIG. 2

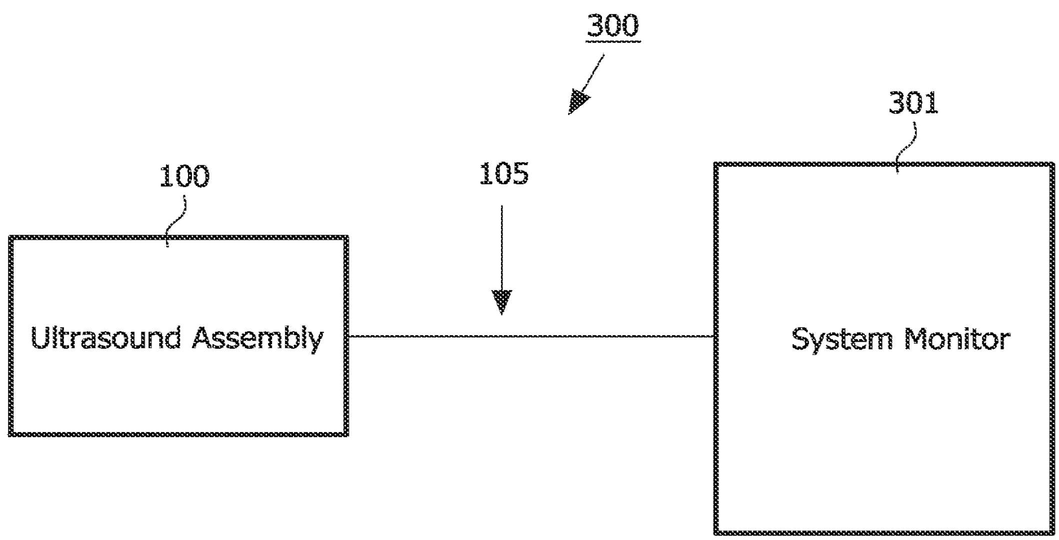
300
301
100
105
Ultrasound Assembly
System Monitor

FIG. 3

INTERNATIONAL SEARCH REPORT

International application No
PCT/IB2009/054999

A. CLASSIFICATION OF SUBJECT MATTER
INV. G01S7/521 G01S15/89

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
GOIS

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted dunng the international search (name of data base and, where practical, search terms used)

EPO-Internal

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No
X	US 2003/139664 A1 (HUNT ROBERT P [US] ET AL) 24 July 2003 (2003-07-24) figures 1,2A,3-5 paragraphs [0021], [0024], [0025] paragraphs [0030], [0031], [0035] paragraphs [0047], [0049] -----	1-23
X	US 2003/036702 A1 (DAVIDSEN RICHARD EDWARD [US]) 20 February 2003 (2003-02-20) abstract; figures 2,3 paragraphs [0023] - [0028] paragraphs [0030], [0034] -----	1-7, 9-19, 21-23

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[X] Further documents are listed in the continuation of Box C

[X] See patent family annex

* Special categoπes of cited documents

"A" document defining the general state of the art which is not considered to be of particular relevance
"E" earlier document but published on or after the international filing date
"L" document which may throw doubts on priority claιm(s) or which is cited to establish the publication date of another citation or other special reason (as specified)
"O" document referring to an oral disclosure, use, exhibition or other means
"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or pπoπty date and not in conflict with the application but cited to understand the pnnciple or theory underlying the invention
"X" document of particular relevance, the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone
"Y" document of particular relevance, the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art
"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
9 February 2010	16/02/2010

Name and mailing address of the ISA/	Authoπzed officer
European Patent Office, P B 5818 Patentlaan 2 NL - 2280 HV Rijswijk Tel (+31-70) 340-2040, Fax (+31-70) 340-3016	Knol l , Bernhard

Form PCT/ISA/210 (second sheet) (April 2005)

C(Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No
A	WO 01/13796 A1 (NOVASONICS INC [US]) 1 March 2001 (2001-03-01) figures 1,2,4,7,8 page 5, line 26 - line 30 line 3 - page 7, line 16 page 7, line 32 - page 8, line 6 page 10, line 19 - line 30 page 13, line 11 - line 23 page 14, line 27 - line 34 page 20, line 7 - page 21, line 23 -----	1-23
A	US 2007/262216 A1 (WANG DAVID [US]) 15 November 2007 (2007-11-15) the whole document -----	11

INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No
PCT/IB2009/054999

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
US 2003139664 A1	24-07-2003	NONE	
US 2003036702 A1	20-02-2003	NONE	
WO 0113796 A1	01-03-2001	AU 6910300 A	19-03-2001
		BR 0013436 A	30-04-2002
		CA 2382227 A1	01-03-2001
		CN 1376040 A	23-10-2002
		EP 1211982 A1	12-06-2002
		JP 2003507114 T	25-02-2003
		US 6251073 B1	26-06-2001
		US 2002038088 A1	28-03-2002
US 2007262216 A1	15-11-2007	NONE	

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(54) Autostereoscopic display

(57) An autostereoscopic display (1), in particular an autostereoscopic head-up display, is disclosed, comprising a pane (2), which is partly reflective and partly transmissive and a light source (3) for generation of an image consisting of a plurality of pixels (5,5a,5b), wherein for each pixel (5,5a,5b) a left/right light beam (6a,6b) is guided from the light source (3) to the left/right eye of the viewer via the pane (2). According to the invention, said guiding of the light beams (6a,6b) to the eyes is achieved only by pure reflection at said pane (2) (ie. there is no diffraction).

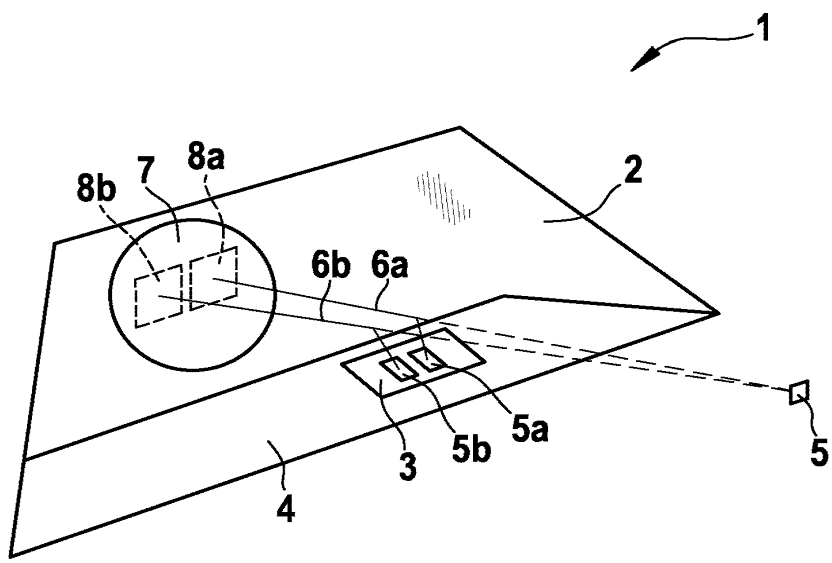

Fig. 1

EP 2 200 332 A1

Printed by Jouve, 75001 PARIS (FR)

Description

Technical Field

[0001] The invention relates to an autostereoscopic display. A autostereoscopic display is a device for displaying three-dimensional pictures without the need of additional equipment for the viewer, i.e. 3D-glasses such as anaglyphs, LCD-shutter glasses (LCD = Liquid Crystal Display), polarized glasses or prismatic glasses for example. In particular, the invention relates to head-up displays (HUD). A head-up display is any transparent display that presents data without requiring the user to look away from his or her usual viewpoint. Although they were initially developed for military aviation, HUDs are now used in commercial aircraft, automobiles, and other applications as well.

Prior Art

[0002] DE 101 35 342 C1 discloses a projection device having a projection unit and a relatively spaced projection surface, e.g. incorporated in the automobile dashboard, onto which an image is projected using a light beam for each image point. The projection surface has a beam widening device in front of a mirror reflecting the incident light beams to provide reflected beams converging in a planar viewing field in front of the automobile driver.

[0003] DE 101 31 720 Al discloses a head-up display system for presentation of an object outside the vehicle to a person in the vehicle, comprising means for determination of the position of vehicle occupants and means for location corrected display of the object relative to the position.

[0004] Furthermore, US 5,198,895 A discloses a head-up display used in a cockpit with a space for the pilot having two subspaces where the pilot's eyes will be located during flight. The head-up display includes a video display device for emitting light representative of a predetermined image, located in the cockpit and a second video display for emitting light representative of the predetermined image located in the cockpit. An angularly selective holographic optic element diffraction grating is provided for reflecting light emitted from the first video display into the first subspace, but not into the second subspace. Light emitted from second video display device is reflected into the second subspace but not into the first subspace.

[0005] In addition, US 5,973,727 A discloses a refractive index modulator consisting of a liquid crystal layer, which is arranged near a glass plate so that the liquid crystal molecules are arranged to have a refractive index that is either less than or greater than that of the glass plate to produce either a total internal reflection of a beam at the glass plate or to transmit a light beam through the glass plate.

[0006] Furthermore, US 2004/0239835 A1 discloses a three-dimension display apparatus which includes a liquid crystal display, a first polarizer on the rear surface of the liquid crystal display, a second polarizer on the front surface of the liquid crystal display, a liquid crystal polymer being on the second polarizer and including a chiral dopant and liquid crystal molecules. The liquid crystal polymer is divided into first regions through which incident light is not polarized and second regions through which the incident light is polarized at 90 degrees. A third polarizer on the liquid crystal polymer selectively transmits the incident light from the liquid crystal polymer.

[0007] Finally, EP 1 739 978 A2 discloses a three dimensional display device including an image display unit, which unit includes pixels having first sub-pixels corresponding to a left-eye image and second sub-pixels corresponding to a right-eye image. The three dimensional display device also includes a parallax barrier which is located proximately to the image display unit. The parallax barrier includes light interception portions and light transmission portions alternately and repeatedly arranged in a direction and also color filters arranged between the light interception portions and the light transmission portions, wherein the color filters control paths of lights from the pixels.

Object of the Invention

[0008] It is an object of the invention to provide an autostereoscopic display which is less complex and can be implemented with less technical effort. In particular, the object of the invention is to provide a head-up display which allows for a spatial impression.

Summary of the Invention

[0009] The object of the invention is achieved by a display according to claim 1, that is an autostereoscopic display, comprising

- a pane which is partly reflective and partly transmissive and
- a light source for generation of an image consisting of a plurality of pixels, wherein for each pixel a left/right light beam is guided from the light source to the left/right eye of the viewer via said pane,
- wherein said guiding of the light beams to the eyes is achieved only by pure reflection at said pane.

[0010] Advantageously, the guiding of the light beams at the pane (particularly a windscreen) is achieved only by pure reflection. That does not mean that there may be no transmissive part, that is to say parts of the light beams which cross the pane and do not reach the viewer's eyes. It means that the part, which reaches the viewer, is just reflected at the pane and not diffracted as it is the case in some prior art solutions, which use a diffraction grating in the windscreen.

[0011] A diffraction grating is an optical component with a regular pattern, which splits (diffracts) light into several beams travelling in different directions. The directions of these beams depend on the spacing of the grating and the wavelength of the light so that the grating acts as a dispersive element.

[0012] As one can imagine, the use of such a grating, especially in a relatively large pane such as a windscreen which in addition often have complex shapes, requires complex machinery to produce the same. By contrast, the inventive display does not need additional diffractive means in the pane. Accordingly, such a display can be produced with less technical effort.

[0013] It is beneficial if the light beams are reflected at a surface being inclined in relation to the pane. For example, this embodiment can be used for cars, in which a light source is installed on the roof of the car which emits light beams to the viewer's eyes via the surface and the pane. Mounting the light source on the roof requires less space in the region of the dashboard of a car. Just the space for a reflecting surface, basically a small mirror, is needed there.

[0014] It is advantageous if the light source is designed as one out of the group: LED-display (Light Emitting Diode), LCD-display (Liquid Crystal Display) or OLED-display (Organic Light Emitting Diode). Such displays are easy available, reliable and low priced. They can be used for generation of pictures by definition. To provide a spatial impression of the picture, parallax barriers, which are known per se, have to be provided. Examples are micro lenses and transmissive slits separated by opaque barrier regions.

[0015] In an advantageous embodiment of the invention, the light source is designed as a single laser light source for both light beams. Lasers are suitable means for generating pictures as known from laser shows for example. In this embodiment, both eyes have to share one light source. This is cost saving but may lead to limitations in brightness of the image and the frame rate. The latter is particularly important for animated pictures or videos.

[0016] It is also advantageous if the light source is designed as one laser light source for each light beam. Here the left channel and the right channel are drawn by a left and a right laser. Using two lasers is more expensive but provides for brighter images and an increased frame rate. The latter is important for the generation of less 'nervous' pictures or videos.

[0017] In a further advantageous embodiment, the pixels are generated by modulation of a movable laser beam. Often so-called 'scanners' are used for the generation of laser based pictures. Scanners comprise two galvanometers, i.e. two mirrors perpendicular to each other and electromagnetically actuated. The first mirror deflects the laser beam in horizontal direction, and the second mirror deflects it in vertical direction. By blanking and mixing colors in combination with said deflection, single pixels on a surface can be illuminated in a desired color and a desired brightness. If just one laser or scanner is used, it generates the pictures for the left and the right eye semi-parallel, wherein the projection of the image may be achieved interlaced, i.e. drawing the odd lines for the left eye and the even lines for the right eye and then vice versa, or picture by picture, i.e. drawing the complete picture for the left and the right eye in an alternating manner. If two lasers or scanners are used, the images are generated fully parallel. Using two lasers provides for an increased frame rate and thus for generation of less 'nervous' pictures.

[0018] In yet another preferred embodiment of the invention, the pixels are generated by modulation of a reflection of a laser beam. Here a laser beam, which may also stand still, is modulated by a reflective surface comprising pixels, whose reflective factor can be influenced. An example are very small mirrors, each representing one pixel and being electrically actuated, which can deflect the assigned part of the light beam past the viewer's eye so that the pixels appears dark. This provides just for black and white images but also more sophisticated modulations are imaginable.

[0019] It is beneficial if the reflection modulation is done at the pane. In this embodiment, the reflection modulator is attached to or part of the pane. Here, the light source may directly shine on the pane respectively windscreen, but one has to take care that said means (e.g. usually thin foils) do not influence the viewers perception of the world outside the car.

[0020] Furthermore, it is advantageous if the reflection modulation is done at said inclined surface. Here the problem of influencing the viewers perception (even when the display is switched off) is circumvented as the reflection modulator is attached to or built into said surface. Usually, the reflection modulator is mounted on a car's dashboard in this embodiment.

[0021] Furthermore, it is advantageous if a LCD-matrix is provided as reflection modulator. Such matrices are easy available, reliable and low priced. Basically, an LCD-matrix is a LCD-display without backlight. By contrast, the light for illuminating the pixels is generated in front of the matrix and a mirror is arranged behind the matrix. By darkening a LCD-pixel as known per se, light is no longer reflected. By means of an LCD-matrix also grayscale images can be generated quite easily. In the case of laser light being used, dedicated parallax barriers may be omitted as the laser beams for the left and the right channel can be guided to the viewer's eyes with high precession. However, one has to take care that the laser beam is widened a bit so that not a singular light point reaches the viewer's eyes but a beam having the size of, let us say the size of spectacles glass. In this sense, virtual glasses may be provided.

[0022] Finally, the display comprises means for detecting a position of the viewer, means for determining a desired position for the left/right light beam according to said position of the viewer and, means for adapting the left/right light beam to said desired position in a preferred embodiment. It may happen that the driver considerably moves his head in the line of sight and/or in a plane perpendicular to said line of sight during driving a car. Another reason for changing eye-positions are different users using the car. If the eyes of the viewer move out of the associated projecting areas, then the projecting areas are adapted to the current eye-position of the user in this embodiment. In this way, the viewer can see the projected image in any position and keeps on his 'virtual glasses' in this sense.

These and other aspects of the invention are apparent from and will be elucidated with reference to the embodiments described and shown in the schematic Figures hereinafter.

Brief Description of the Drawings

[0023]

Figure 1 shows a first embodiment of the invention with an active display on a surface on a car's dashboard;

Figure 2 shows a second embodiment with a laser scanner projecting the image directly via the windscreen of a car;

Figure 3 shows a third embodiment with a laser scanner projecting an image via a surface on a car's dashboard;

Figure 4 shows a fourth embodiment with a reflection modulator in the windscreen of a car.

Description of Embodiments

[0024] In the Figs. the same elements and elements with the same function are referenced with the same reference sign if not stated otherwise.

[0025] Fig. 1 depicts a first embodiment of the invention and shows an autostereoscopic display 1, comprising a pane 2, which is a windscreen of a car in this case, a light source 3 being arranged on a surface 4, which surface 4 is inclined in relation to the pane 2. For the sake of brevity just one pixel 5 of the light source 3 is shown, which pixel 5 consists of a left pixel 5a and a right pixel 5b. In addition, a left and a right light beam 6a and 6b is shown being emitted by the pixels 5a and 5b. Finally, Fig. 1 shows a driver's head 7.

[0026] The function of the display 1 as shown in Fig. 1 is as follows:

[0027] The left pixel 5a and the right pixel 5b are illuminated with a particular color and a particular brightness as the image to be projected requires. Thus, a left and a right light beam 6a and 6b are emitted, reflected at the pane 2 and finally reach the driver's head 7. The driver receives the left pixel 5a with the left eye and the right pixel 5b with right eye and thus gets the impression of a pixel 5 hovering in front or behind the pane 2. As can be seen, the angle of radiation for the beams 6a and 6b are chosen in such a way that the left and the right pixel 5a and 5b are visible in a particular left and right projecting areas 8a and 8b. Thus, small movements of the driver's head do not influence his spatial impression of the image. However, if he moves out of the target area, the spatial impression of the image is lost. This behavior of the light beams 6a and 6b can be seen as a provision of 'virtual glasses'.

[0028] The light source 3 may be an (active, meaning back lighted) LCD-display, a LED display or an OLED display. The way how pixels are activated is known per se for these devices and not explained any further. Said displays, however, need parallax barriers, which are known per se. Examples are micro lenses and transmissive slits separated by opaque barrier regions

[0029] Fig. 2 is quite similar to Fig. 1, the only difference is that the light source 3 is designed as a laser scanner. In this embodiment one single laser is used for the image generation, however, also two lasers can be used as the case may be. Furthermore, it is assumed that the images for the left and the right eye are sequentially generated, that means one by one. First, the laser generates the left light beam 6a and draws the image pixel by pixel and line by line quite similar as the cathode ray tubes do. After the left image has been completed, the laser generates the right light beam 6b and draws the right image in a similar way. Usually, 25 frames per second are chosen to project flowing pictures. Accordingly, the single laser should be capable of providing 50 frames per second so that flowing pictures for both the left and the right eye can be generated. If the contents of the pictures does not change very fast, also considerably lower frame rates may be applicable. An example is the speedometer which owing to the physics of a car cannot change very fast. As a laser beam can be guided or directed very precisely and as such may act as a parallax barrier, a further parallax barrier is not required. However, as laser light is so directional, means for widening the beams 6a and 6b a bit should be provided so that the pixels 5a and 5b are not just visible in a singular position of the driver's head but in a particular projecting area 8a and 8b as has been explained for the embodiment of Fig. 1 already. Additionally, a variable step width for the vertical scanning lines can compensate the double image introduced by a windscreen. According to prior art, a windscreen with 'wedged PVB' (Polyvinylbutyral) is used for this reason, which is a special windscreen providing for ghost-free automotive head-up displays. However, by employing variable step widths for the scanning lines also a 'normal' windscreen can be used.

[0030] Fig. 3 shows a modification of the embodiment shown in Fig. 2. Here the light source 3, again a laser scanner, is arranged on the roof of the car and emits the light beams 6a and 6b downwards to a reflecting surface 4 arranged inclined to the pane 1. However, the principle is the same as the one of Fig. 2. There is just another reflecting plane. The reflecting surface 4 may be a simple mirror in this embodiment, why the pixels 5a and 5b have a rather symbolical meaning. This variant of the invention is advantageous if there is just limited space on the dashboard.

[0031] A next embodiment is a variation of the embodiments shown in the Figs. 1 and 3. Here again, a light source 3 is arranged on the roof of the car, but is a fixed laser source in this case. In addition, the surface 4 comprises a reflection modulator, e.g. a LCD-matrix which is arranged right above the reflective surface 4. In this example, a left and a right light beam 6a and 6b are emitted by two lasers and reach two separated areas on the reflecting surface 4. As known per se, the LCD-matrix provides for darkening dedicated pixels and thus for the generation of grayscale images. By contrast to the last examples, the pixels 5a and 5b are 'real' here. The light beams 6a and 6b, which are already modulated now, propagate to the pane 2 and are deflected to the viewer's eyes there as has already been explained hereinbefore. Alternatively, a single laser beam can be emitted by the light source 3 which is then separated in a left and a right light beam 6a and 6b at the reflective surface 4.

[0032] In a fourth embodiment as shown in Fig. 4, the reflection modulator, e.g. a LCD-matrix again, is arranged on or in the pane 2. In principle, this arrangement would also work without external light- provided the LCD-matrix comprises a parallax barrier - but to provide proper function also in twilight or during night, the matrix is again illuminated as has been explained hereinbefore. The light source 3, which may be a fixed laser again, can be arranged on the roof if there is a reflective surface 4 (e.g. a mirror) on the dashboard or directly on the dashboard. In case of illuminating the LCD matrix with a laser, a parallax barrier may be omitted, but if the LCD-matrix is illuminated by 'normal' light, it has to be provided with a parallax barrier.

[0033] As one can imagine, the 'virtual glasses', i.e. the projecting areas 8a and 8b, have to move with the driver's head 7. Otherwise it can happen that the left eye receives the image for the right eye whereas the right eye receives no image at all and vice versa. In a worst case the driver's head 7 completely moves out of the reception area, in other words the projecting areas 8a and 8b and his eyes do not coincide. Accordingly, means for detecting the position of the driver's head or his eyes are provided in a preferred embodiment. Several possibilities are imaginable. First of all, the position detection may be achieved by visual detection, i.e. by means of a camera, which can operate in the visible light spectrum or in the infrared spectrum. Here the algorithms for 'face detection', which have been incorporated in recent digital consumer cameras, can be used. Another possibility is to use a number of weight sensors in the driver's seat so as to detect the position of the center of gravity of his body. As the driver normally seats upright or slightly inclined, the position of the eyes can easily be determined. In this context it should also be mentioned, that the projecting areas 8a and 8b are not necessarily square-shaped but may also be in the form of narrow upright rectangles so that it does not matter if the driver moves his head in vertical direction. Finally, distance sensors may be used, e.g. ultrasonic distance sensors, passive infrared sensors and so on. As these sensors are known per se, they are not explained in detail here.

[0034] Detecting the position of the driver's head 7 or his eyes is one part of the story. Advantageously, the inventive autostereoscopic display 1 comprises also means to shift the 'virtual glasses', i.e. the projecting areas 8a and 8b according to the detected position. If narrow, sufficiently high and upright rectangular projecting areas 8a and 8b are provided, a shift in the horizontal direction may be sufficient to follow the driver's eyes. If the vertical dimension is limited, i.e. does not cover the full vertical range of the eye's positions, then also a vertical shift of the projecting areas 8a and 8b may be employed. In case of a laser scanner, shifting of the projecting areas 8a and 8b is relatively simple as the image in principle can be projected at any desired position. In case of an active pixel matrix or a reflection modulator is used, things are more complicated.

[0035] If a reflection modulator in combination with a laser beam is employed, both the beam and the position on the modulator, where the image is generated, have to move. If an active pixel matrix is used, the position of the image generation has to move as well. Alternatively or in addition, a parallax barrier may move so that the position, from where the right and the left image can be viewed, varies. If the parallax barrier is formed by device, which allows for easy change of a 'picture', such as a LCD-matrix, the parallax barrier can easily be adapted to the detected position of the drive's head 7. In case of just a horizontal shift is needed, vertical stripes, whose transmission rate can individually be controlled, are proper means to adapt the projecting areas 8a and 8b to the actual eye-position. However, besides electronic shifting of the parallax barrier also mechanical shifting is imaginable. Here a predetermined structure, i.e. a sequence of transmissive parts and non-transmissive parts, is moved by a motor, usually a linear motor. The movement may be based on electromagnetic or piezoelectric effects for example.

[0036] So far, just movements of the driver's head 7 in a plane more or less perpendicular to the line of sight have been discussed. However, though it is less frequent, the head 7 may also move in direction of the line of sight and thus reduce or increase the distance between the eyes and the imaging device. Hand in hand with this movement the angle between the light beams generating the projecting areas 8a and 8b has to be adapted. If the distance is increased, the angle is decreased and vice versa. In case of a laser beam is used, the direction of the beam can be varied as discussed above. If systems are used, which need a dedicated parallax barrier, the parallax barrier has to be varied according to the distance between imaging system and driver.

[0037] It should be noted that all steps which are taken to detect the position of the driver's head 7 and to move the projecting areas 8a and 8b to said detected position may be performed once, on demand, or ongoing for example. Quite often, cars are used by just one user, who rarely changes his position once he has found a comfortable position. In this case, it may be sufficient to run the adaptation sequence just initially, when the car is used first or on demand if, for example, a dedicated function is chosen. On the other hand, there are cars, whose users change very often, for example rental cars. In this case or if the driver is rather nervous and changes its position very often also during driving the car, a continuous adaptation of the projecting areas 8a and 8b might be useful.

[0038] It should also be noted that, cars and their drivers are subject to strongly varying light conditions, like night, bright sunlight and also front lights of opposing traffic. Without further measures the projected image can get badly visible or even invisible. Accordingly, measures are taken in a preferred embodiment to reduce or even avoid the influence of disturbing light sources and in particular stray light from these light sources. Proper means range from simple covers and black, matt coatings to block light from undesired directions over semi-reflective layers to electrochromic layers and light diffusers.

[0039] Said semi-reflective layers can increase the fraction of the light beams 6a and 6b, which is reflected, and at the same time increase the fraction of reflected light coming from outside the car. In this way the influence of disturbing light sources can substantially be decreased. Such layers can, for example, be arranged in the region, where the light beams 6a and 6b are reflected on the pane 2. A further possibility to reduce the influence of external light is to arrange electrochromic layers in said region. If disturbing light sources, e.g. blinding lights from opposing traffic, shine through said region, the layer is darkened by applying a voltage as it is known per se. In this way, the fraction of light which gets into the car can be dramatically decreased. It is understood that also the driver cannot look outside the pane in this region. However, it is better to keep, for example, a speedometer visible than blinding lights. In a preferred embodiment, the darkening effect gradually disappears in the border region so that no ugly, dark rectangular is produced on the pane 2. Yet another possibility is to arrange diffusers in the region where the light beams 6a and 6b are reflected on the pane 2. In this way, in particular the influence of dot-shaped light sources, e.g. again blinding lights, is decreased as they are 'blurred' over a particular region. It should be understood, that only a small number of possibilities for reducing the influence of disturbing light sources can be presented here. However, one skilled in the art will easily choose the best solution or combination of solutions out of the possibilities presented here and other possibilities, which are known per se, when he implements an inventive autostereoscopic display 1.

[0040] Furthermore, it should be noted that the invention does not apply to head-up displays for cars only. It also applies to head-up displays for vehicles in general and also to autostereoscopic displays in general, meaning also to stationary devices.

[0041] Finally, it should be noted that the above-mentioned embodiments illustrate rather than limit the invention, and that those skilled in the art will be capable of designing many alternative embodiments without departing from the scope of the invention as defined by the appended claims. In the claims, any reference signs placed in parentheses shall not be construed as limiting the claims. The verb 'comprise' and its conjugations do not exclude the presence of elements or steps other than those listed in any claim or the specification as a whole. The singular reference of an element does not exclude the plural reference of such elements and vice-versa. In a device claim enumerating several means, several of these means may be embodied by one and the same item of software or hardware. The mere fact that certain measures are recited in mutually different dependent claims does not indicate that a combination of these measures cannot be used to advantage.

Claims

1. Autostereoscopic display (1), comprising

   - a pane (2) which is partly reflective and partly transmissive and
   - a light source (3) for generation of an image consisting of a plurality of pixels (5, 5a, 5b), wherein for each pixel (5, 5a, 5b) a left/right light beam (6a, 6b) is guided from the light source (3) to the left/right eye of the viewer via said pane (2),
   - wherein said guiding of the light beams (6a, 6b) to the eyes is achieved only by pure reflection at said pane (2).

2. Display (1) according to claim 1, wherein the light beams (6a, 6b) are reflected at a surface (4) being inclined in relation to the pane (2).

3. Display (1) according to any one of the claims 1 or 2, wherein the light source (3) is designed as one out of the group: LED-display, LCD-display or OLED-display.

4. Display (1) according to any one of the claims 1 or 2, wherein the light source (3) is designed as a single laser light source for both light beams (6a, 6b).

5. Display (1) according to any one of the claims 1 or 2, wherein the light source (3) is designed as one laser light source for each light beam (6a, 6b).

6. Display (1) according to any one of the claims 4 or 5, wherein the pixels (5, 5a, 5b) are generated by modulation of a movable laser beam.

7. Display (1) according to any one of the claims 4 or 5, wherein the pixels (5, 5a, 5b) are generated by modulation of a reflection of a laser beam.

8. Display (1) according to claim 7, wherein the reflection modulation is done at the pane (2).

9. Display (1) according to the claims 2 and 7, wherein the reflection modulation is done at said inclined surface (4).

10. Display (1) according to any one of the claims 7 to 9, wherein a LCD-matrix is provided as reflection modulator.

11. Display (1) according to any one of the preceding claims, comprising means for detecting a position of the viewer, means for determining a desired position for the left/right light beam (6a, 6b) according to said position of the viewer and, means for adapting the left/right light beam (6a, 6b) to said desired position.

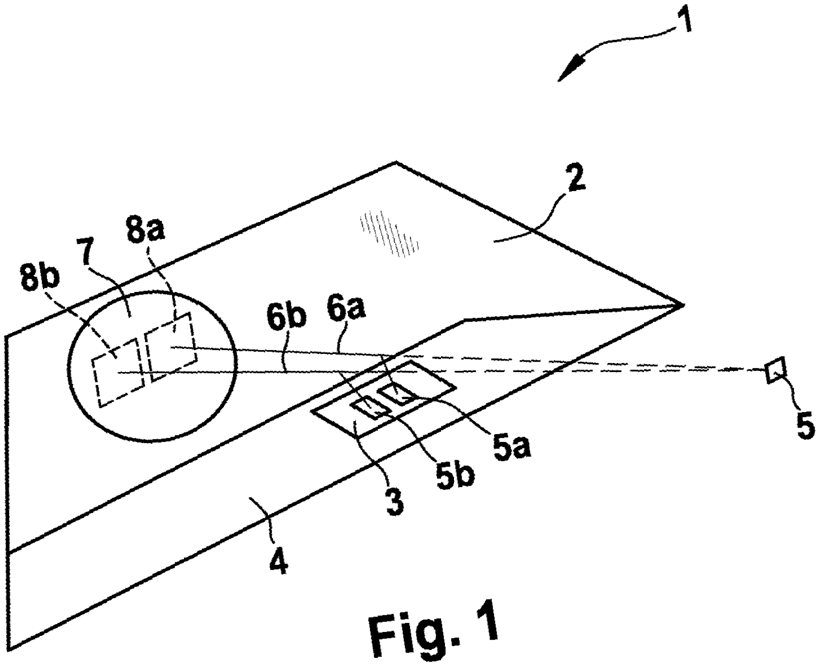

Fig. 1

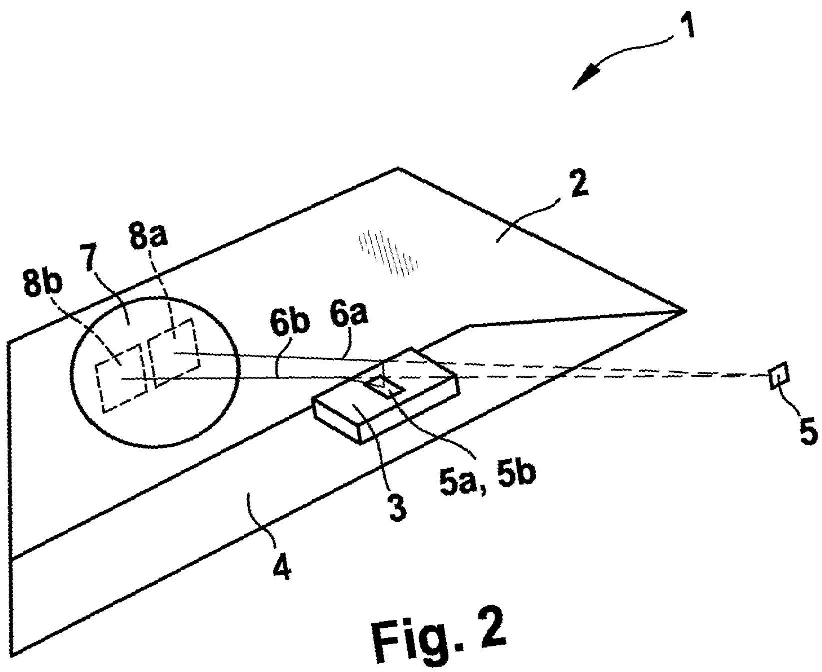

Fig. 2

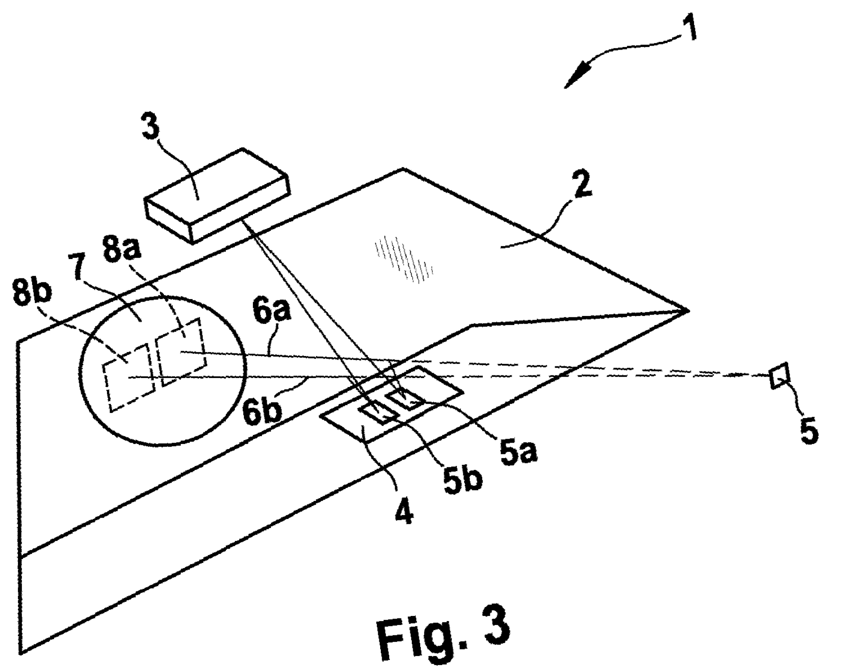

Fig. 3

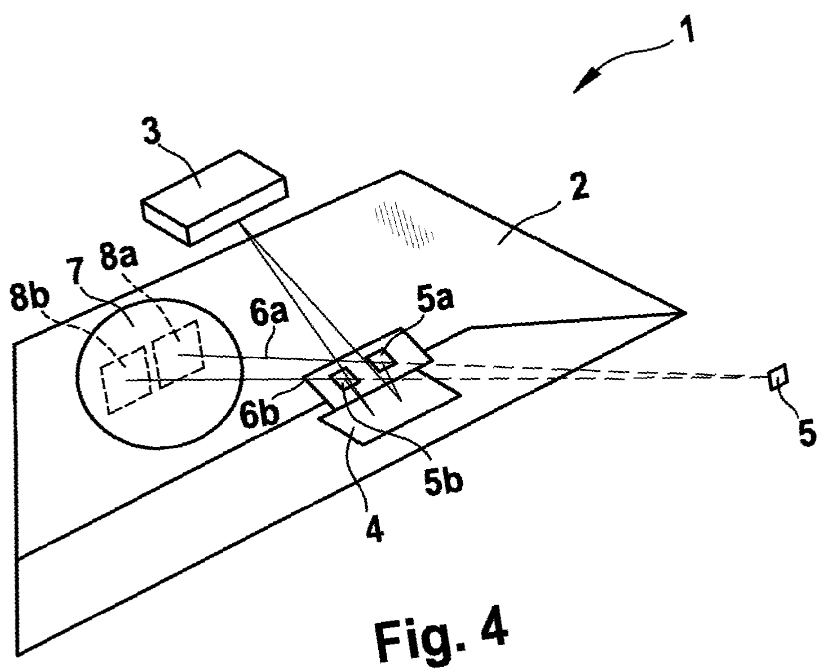

Fig. 4

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EUROPEAN SEARCH REPORT

Application Number
EP 08 10 5999

DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (IPC)
X Y	US 2005/052617 A1 (FUJIKAWA TAKAYUKI [JP] ET AL) 10 March 2005 (2005-03-10) * abstract * * paragraphs [0002], [0003], [0023], [0026], [0027] * * paragraphs [0043] - [0053]; figure 1 * * paragraphs [0081], [0082], [0085], [0090]; figure 7 *	1-7,11 8-10	INV. H04N13/04
X	US 2008/143895 A1 (PETERKA THOMAS [US] ET AL) 19 June 2008 (2008-06-19) * abstract * * paragraphs [0007], [0013] * * paragraph [0041]; figure 3 * * paragraphs [0120], [0121], [0124]; figure 12 *	1,3,11	
Y	EP 0 589 179 A (TEXAS INSTRUMENTS INC [US]) 30 March 1994 (1994-03-30) * column 2, lines 15-20,52-56; figure 1 *	8-10	
D,A	DE 101 35 342 C1 (SCHNEIDER LASER TECHNOLOGIES A [DE]; BOSCH GMBH ROBERT [DE]) 31 October 2002 (2002-10-31) * figures 9,10 *	2	TECHNICAL FIELDS SEARCHED (IPC) H04N B60K B60R

The present search report has been drawn up for all claims

Place of search	Date of completion of the search	Examiner
The Hague	22 April 2009	Mao, Pauline

CATEGORY OF CITED DOCUMENTS

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Patent document cited in search report	Publication date	Patent family member(s)	Publication date
US 2005052617 A1	10-03-2005	DE 102004040538 A1	17-03-2005
		JP 2005070255 A	17-03-2005
US 2008143895 A1	19-06-2008	NONE	
EP 0589179 A	30-03-1994	CN 1083932 A	16-03-1994
		DE 69317027 D1	26-03-1998
		DE 69317027 T2	23-07-1998
		JP 6208089 A	26-07-1994
		US 5313479 A	17-05-1994
DE 10135342 C1	31-10-2002	AU 2002321250 A1	03-03-2003
		WO 03016982 A2	27-02-2003
		EP 1410096 A2	21-04-2004
		JP 4159466 B2	01-10-2008
		JP 2005500567 T	06-01-2005

EPO FORM P0459

For more details about this annex : see Official Journal of the European Patent Office, No. 12/82

REFERENCES CITED IN THE DESCRIPTION

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Patent documents cited in the description

- DE 10135342 C1 **[0002]**
- DE 10131720 A1 **[0003]**
- US 5198895 A **[0004]**
- US 5973727 A **[0005]**
- US 20040239835 A1 **[0006]**
- EP 1739978 A2 **[0007]**

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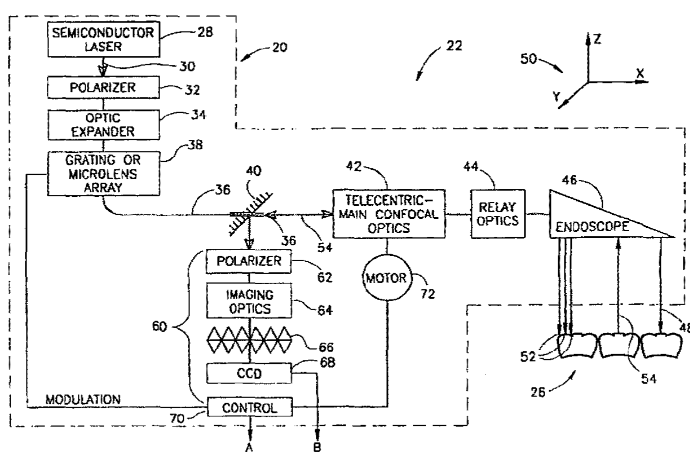
(54) **Title:** IMAGING A THREE-DIMENSIONAL STRUCTURE BY CONFOCAL FOCUSSING AN ARRAY OF LIGHT BEAMS



(57) **Abstract**

Determining surface topology of a portion (26) of a three-dimensional structure is provided. An array of incident light beams (36) passing through a focusing optics (42) and a probing face is shone on said portion. The focusing optics defines one or more focal planes forward the probing face in a position which can be changed (72) by the focusing optics. The beams generate illuminated spots (52) on the structure and the intensity of returning light rays propagating in an optical path opposite to that of the incident light rays is measured (60) at various positions of the focal plane(s). By determining spot-specific positions yielding a maximum intensity of the returned light beams, data is generated which is representative of said topology. Measurement of teeth. Light beams by grating of matrix of pinholes, micro lens array. Simultaneous imaging from three angles. Quicker with three different light components.

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IMAGING A THREE-DIMENSIONAL STRUCTURE BY CONFOCAL FOCUSSING AN ARRAY OF LIGHT BEAMS

FIELD OF THE INVENTION

This invention in the field of imaging techniques and relates to a method and an apparatus for non-contact imaging of three-dimensional structures, particularly useful for direct surveying of teeth.

BACKGROUND OF THE INVENTION

A great variety of methods and systems have been developed for direct optical measurement of teeth and the subsequent automatic manufacture of dentures. The term *"direct optical measurement"* signifies surveying of teeth in the oral cavity of a patient. This facilitates the obtainment of digital constructional data necessary for the computer-assisted design (CAD) or computer-assisted manufacture (CAM) of tooth replacements without having to make any cast impressions of the teeth. Such systems typically includes an optical probe coupled to an optical pick-up or receiver such as charge coupled device (CCD) and a processor implementing a suitable image processing technique to design and fabricate virtually the desired product.

One conventional technique of the kind specified is based on a laser-triangulation method for measurement of the distance between the surface of the tooth and the optical distance probe, which is inserted into the oral cavity of the patient. The main drawback of this technique consists of the following. It is assumed that the surface of the tooth reflects optimally, e.g. Lambert's reflection. Unfortunately, this is not the case in practice and often the data that is obtained is not accurate.

Other techniques, which are embodied in CEREC-1 and CEREC-2 systems commercially available from Siemens GmbH or Sirona Dental Systems, utilize the light-section method and phase-shift method, respectively. Both systems employ a specially designed hand-held probe to measure the three-dimensional coordinates of a prepared tooth. However, the methods require a specific coating (i.e. measurement powder and white-pigments suspension, respectively) to be deposited to the tooth. The thickness of the coating layer should meet specific, difficult to control requirements, which leads to inaccuracies in the measurement data.

By yet another technique, mapping of teeth surface is based on physical scanning of the surface by a probe and by determining the probe's position, e.g. by optical or other remote sensing means, the surface may be imaged.

U.S. Patent No. 5,372,502 discloses an optical probe for three-dimensional surveying. The operation of the probe is based on the following. Various patterns are projected onto the tooth or teeth to be measured and corresponding plurality of distorted patterns are captured by the probe. Each interaction provides refinement of the topography.

SUMMARY OF THE INVENTION

The present invention is directed to a method and apparatus for imaging three-dimensional structures. A preferred, non-limiting embodiment, is concerned with the imaging of a three-dimensional topology of a teeth segment, particularly such where one or more teeth are missing. This may allow the generation of data for subsequent use in design and manufacture of, for example, prosthesis of one or more teeth for incorporation into said teeth segment. Particular examples are the manufacture of crowns or bridges.

The present invention provides, by a first of its aspects, a method for determining surface topology of a portion of a three-dimensional structure, comprising:

(a) providing an array of incident light beams propagating in an optical path leading through a focusing optics and a probing face; the focusing optics defining one or more focal planes forward said probing face in a position changeable by said optics, each light beam having its focus on one of said one or more focal plane; the beams generating a plurality of illuminated spots on the structure;

(b) detecting intensity of returned light beams propagating from each of these spots along an optical path opposite to that of the incident light;

(c) repeating steps (a) and (b) a plurality of times, each time changing position of the focal plane relative to the structure; and

(d) for each of the illuminated spots, determining a spot-specific position, being the position of the respective focal plane, yielding a maximum measured intensity of a respective returned light beam; and

(e) based on the determined spot-specific positions, generating data representative of the topology of said portion.

By a further of its aspects, the present invention provides an apparatus for determining surface topology of a portion of a three-dimensional structure, comprising:

- a probing member with a sensing face;
- an illumination unit for providing an array of incident light beams transmitted towards the structure along an optical path through said probing unit to generate illuminated spots on said portion;

- a light focusing optics defining one or more focal planes forward said probing face at a position changeable by said optics, each light beam having its focus on one of said one or more focal plane ;
- a translation mechanism coupled to said focusing optics for displacing said focal plane relative to the structure along an axis defined by the propagation of the incident light beams;
- a detector having an array of sensing elements for measuring intensity of each of a plurality of light beams returning from said spots propagating through an optical path opposite to that of the incident light beams;
- a processor coupled to said detector for determining for each light beam a spot-specific position, being the position of the respective focal plane of said one or more focal planes yielding maximum measured intensity of the returned light beam, and based on the determined spot-specific positions, generating data representative of the topology of said portion.

The probing member, the illumination unit and the focusing optics and the translation mechanism are preferably included together in one device, typically a hand-held device. The device preferably includes also the detector.

The determination of the spot-specific positions in fact amounts to determination of the in-focus distance. The determination of the spot-specific position may be by measuring the intensity *per se*, or typically is performed by measuring the displacement (S) derivative of the intensity (I) curve (dI/dS) and determining the relative position in which this derivative function indicates a maximum maximum intensity. The term *"spot-specific position (SSP)"* will be used to denote the relative in-focus position regardless of the manner in which it is determined. It should be understood that the SSP is always a relative position as the absolute position depends on the position of the sensing face. However the generation of the surface topology does not require knowledge of the absolute position, as all dimensions in the cubic field of view are absolute.

The SSP for each illuminated spot will be different for different spots. The position of each spot in an **X-Y** frame of reference is known and by knowing the relative positions of the focal plane needed in order to obtain maximum intensity (namely by determining the SSP) , the **Z** or depth coordinate can be associated with each spot and thus by knowing the **X-Y-Z** coordinates of each spot the surface topology can be generated.

In accordance with one embodiment, in order to determine the **Z** coordinate (namely the SSP) of each illuminated spot the position of the focal plane is scanned over the entire range of depth or **Z** component possible for the measured surface portion. In accordance with another embodiment the beams have components which each has a different focal plane. Thus, in accordance with this latter embodiment by independent determination of SSP for the different light components, e.g. 2 or 3 with respective corresponding 2 or 3 focal planes, the position of the focal planes may be changed by the focusing optics to scan only part of the possible depth range, with all focal planes together covering the expected depth range. In accordance with yet another embodiment, the determination of the SSP involves a focal plane scan of only part of the potential depth range and for illuminated spots where a maximum illuminated intensity was not reached, the SSP is determined by extrapolation from the measured values or other mathematical signal processing methods.

The method and apparatus of the invention are suitable for determining a surface topology of a wide variety of three-dimensional structures. A preferred implementation of method and apparatus of the invention are in determining surface topology of a teeth section.

In accordance with one embodiment of the invention, the method and apparatus are used to construct an object to be fitted within said structure. In accordance with the above preferred embodiment, such an object is at least one tooth or a portion of a tooth missing in the teeth section. Specific examples include a crown to be fitted on a tooth stump or a bridge to be fitted within teeth.

By one embodiment of the invention, the plurality of incident light beams are produced by splitting a parent beam. Alternatively, each incident light beam or a group of incident light beams may be emitted by a different light emitter. In accordance with a preferred embodiment, light emitted from a light emitter passes through a diffraction or refraction optics to obtain the array of light beams.

In accordance with one embodiment, the parent light beam is light emitted from a single light emitter. In accordance with another embodiment, the parent light beam is composed of different light components, generated by different light emitters, the different light components differing from one another by at least one detectable parameter. Such a detectable parameter may, for example be wavelength, phase, different duration or pulse pattern, etc. Typically, each of said light components has its focus in a plane differently distanced from the structure than other light components. In such a case, when the focal plane of the optics is changed, simultaneously the different ranges of depth (or **Z** component) will be scanned. Thus, in such a case, for each illuminated spot there will be at least one light component which will yield a maximum intensity, and the focal distance associated with this light component will then define the **Z** component of the specific spot.

In accordance with an embodiment of the invention the incident light beams are polarized. In accordance with this embodiment, typically the apparatus comprises a polarization filter for filtering out, from the returned light beams, light components having the polarization of the incident light, whereby light which is detected is that which has an opposite polarization to that of the incident light.

The data representative of said topology may be used for virtual reconstruction of said surface topology, namely for reconstruction within the computer environment. The reconstructed topology may be represented on a screen, may be printed, etc., as generally known *per se*. Furthermore, the data representative of said topology may also be used for visual or physical construction of an object to be fitted within said structure. In the case of the preferred embodiment noted above, where said structure is a teeth section with at least one missing tooth or tooth portion, said object is a prosthesis of one or more tooth, e.g. a crown or a bridge.

By determining surface topologies of adjacent portions, at times from two or more different angular locations relative to the structure, and then combining such surface topologies, e.g in a manner known *per se*, a complete three-dimensional representation of the entire structure may be obtained. Data representative of such a representation may, for example, be used for virtual or physical reconstruction of the structure, may be transmitted to another apparatus or system for such reconstruction, e.g. to a CAD/CAM apparatus. Typically, but not exclusively, the apparatus of the invention comprises a communication port for connection to a communication network which may be a computer network, a telephone network, a wireless communication network, etc.

BRIEF DESCRIPTION OF THE DRAWINGS

In order to understand the invention and to see how it may be carried out in practice, a preferred embodiment will now be described, by way of non-limiting example only, with reference to the accompanying drawings, in which:

Figs. 1A and **1B** are a schematic illustration by way of a block diagram of an apparatus in accordance with an embodiment of the invention (Fig. 1B is a continuation of Fig. 1A);

Fig. 2A is a top view of a probing member in accordance with an embodiment of the invention;

Fig. 2B is a longitudinal cross-section through line II-II in Fig. 2A, depicting also some exemplary rays passing therethrough;

Fig. 3 is a schematic illustration of another embodiment of a probing member ; and

Fig. 4 is a schematic illustration of an embodiment where the parent light beam, and thus each of the incident light beams, is composed of several light components, each originating from a different light emitter.

DETAILED DESCRIPTION OF A PREFERRED EMBODIMENT

Reference is first being made to Figs. 1A and 1B illustrating, by way of a block diagram an apparatus generally designated 20, consisting of an optical device 22 coupled to a processor 24. The embodiment illustrated in Fig. 1 is particularly useful for determining the three-dimensional structure of a teeth segment 26, particularly a teeth segment where at least one tooth or portion of tooth is missing for the purpose of generating data of such a segment for subsequent use in design or manufacture of a prosthesis of the missing at least one tooth or portion, e.g. a crown or a bridge. It should however be noted, that the invention is not limited to this embodiment, and applies, *mutatis mutandis*, also to a variety of other applications of imaging of three-dimensional structure of objects, e.g. for the recordal or archeological objects, for imaging of a three-dimensional structure of any of a variety of biological tissues, etc.

Optical device **22** comprises, in this specific embodiment, a semiconductor laser unit **28** emitting a laser light, as represented by arrow **30**. The light passes through a polarizer **32** which gives rise to a certain polarization of the light passing through polarizer **32**. The light then enters into an optic expander **34** which improves the numerical aperture of the light beam **30**. The light beam **30** then passes through a module **38**, which may, for example, be a grating or a micro lens array which splits the parent beam **30** into a plurality of incident light beams **36**, represented here, for ease of illustration, by a single line. The operation principles of module **38** are known *per se* and the art and these principles will thus not be elaborated herein.

The light unit **22** further comprises a partially transparent mirror **40** having a small central aperture. It allows transfer of light from the laser source through the downstream optics, but reflects light travelling in the opposite direction. It should be noted that in principle, rather than a partially transparent mirror other optical components with a similar function may also be used, e.g. a beam splitter. The aperture in the mirror **40** improves the measurement accuracy of the apparatus. As a result of this mirror structure the light beams will yield a light annulus on the illuminated area of the imaged object as long as the area is not in focus; and the annulus will turn into a completely illuminated spot once in focus. This will ensure that a difference between the measured intensity when out-of- and in-focus will be larger. Another advantage of a mirror of this kind, as opposed to a beam splitter, is that in the case of the mirror internal reflections which occur in a beam splitter are avoided, and hence the signal-to-noise ratio improves.

The unit further comprises a confocal optics **42**, typically operating in a telecentric mode, a relay optics **44**, and an endoscopic probing member **46**. Elements **42, 44** and **46** are generally as known *per se.* It should however be noted that telecentric confocal optics avoids distance-introduced magnification changes and maintains the same magnification of the image over a wide range of distances in the **Z** direction (the **Z** direction being the direction of beam propagation). The relay optics enables to maintain a certain numerical aperture of the beam's propagation.

The endoscopic probing member typically comprises a rigid, light-transmitting medium, which may be a hollow object defining within it a light transmission path or an object made of a light transmitting material, e.g. a glass body or tube. At its end, the endoscopic probe typically comprises a mirror of the kind ensuring a total internal reflection and which thus directs the incident light beams towards the teeth segment **26**. The endoscope **46** thus emits a plurality of incident light beams **48** impinging on to the surface of the teeth section.

Incident light beams **48** form an array of light beams arranged in an **X-Y** plane, in the Cartasian frame **50**, propagating along the **Z** axis. As the surface on which the incident light beams hits is an uneven surface, the illuminated spots **52** are displaced from one another along the **Z** axis, at different (X_i,Y_i) locations. Thus, while a spot at one location may be in focus of the optical element **42**, spots at other locations may be out-of-focus. Therefore, the light intensity of the returned light beams (see below) of the focused spots will be at its peak, while the light intensity at other spots will be off peak. Thus, for each illuminated spot, a plurality of measurements of light intensity are made at different positions along the Z-axis and for each of such (X_i,Y_i) location, typically the derivative of the intensity over distance (Z) will be made, the Z_i yielding maximum derivative, Z_0, will be the in-focus distance. As pointed out above, where, as a result of use of the punctured mirror **40**, the incident light forms a light disk on the surface when out of focus and a complete light spot only when in focus, the distance derivative will be larger when approaching in-focus position thus increasing accuracy of the measurement.

The light scattered from each of the light spots includes a beam travelling initially in the **Z** axis along the opposite direction of the optical path traveled by the incident light beams. Each returned light beam **54** corresponds to one of the incident light beams **36**. Given the unsymmetrical properties of mirror **40**, the returned light beams are reflected in the direction of the detection optics generally designated **60**. The detection optics comprises a polarizer **62** that has a plane of preferred polarization oriented normal to the plane polarization of polarizer **32**. The returned polarized light beam **54** pass through an imaging optic **64**, typically a lens or a plurality of lenses, and then through a matrix **66** comprising an array of pinholes. CCD camera has a matrix or sensing elements each representing a pixel of the image and each one corresponding to one pinhole in the array **66**.

The CCD camera is connected to the image-capturing module **80** of processor unit **24**. Thus, each light intensity measured in each of the sensing elements of the CCD camera, is then grabbed and analyzed, in a manner to be described below, by processor **24**.

Unit **22** further comprises a control module **70** connected to a controlling operation of both semi-conducting laser **28** and a motor **72**. Motor **72** is linked to telecentric confocal optics **42** for changing the relative location of the focal plane of the optics **42** along the Z-axis. In a single sequence of operation, control unit **70** induces motor **72** to displace the optical element **42** to change the focal plane location and then, after receipt of a feedback that the location has changed, control module **70** will induce laser **28** to generate a light pulse. At the same time it will synchronize image-capturing module **80** to grab data representative of the light intensity from each of the sensing elements. Then in subsequent sequences the focal plane will change in the same manner and the data capturing will continue over a wide focal range of optics **44, 44**.

Image capturing module **80** is connected to a CPU **82** which then determines the relative intensity in each pixel over the entire range of focal planes of optics **42, 44**. As explained above, once a certain light spot is in focus, the measured intensity will be maximal. Thus, by determining the Z_i corresponding to the maximal light intensity or by determining the maximum displacement derivative of the light intensity, for each pixel, , the relative position of each light spot along the **Z** axis can be determined. Thus, data representative of the three-dimensional pattern of a surface in the teeth segment, can be obtained. This three-dimensional representation may be displayed on a display **84** and manipulated for viewing, e.g. viewing from different angles, zooming-in or out, by the user control module **86** (typically a computer keyboard). In addition, the data representative of the surface topology may be transmitted through an appropriate data port, e.g. a modem **88**, through any communication network, e.g. telephone line **90**, to a recipient (not shown) e.g. to an off-site CAD/CAM apparatus (not shown).

By capturing, in this manner, an image from two or more angular locations around the structure, e.g. in the case of a teeth segment from the buccal direction, from the lingal direction and optionally from above the teeth, an accurate three-dimensional representation of the teeth segment may be reconstructed. This may allow a virtual reconstruction of the three-dimensional structure in a computerized environment or a physical reconstruction in a CAD/CAM apparatus.

As already pointed out above, a particular and preferred application is imaging of a segment of teeth having at least one missing tooth or a portion of a tooth, and the image can then be used for the design and subsequent manufacture of a crown or any other prosthesis to be fitted into this segment.

Reference is now being made to Figs. 2A AND 2B illustrating a probing member **90** in accordance with one, currently preferred, embodiment of the invention. The probing member **90** is made of a light transmissive material, typically glass and is composed of an anterior segment **91** and a posterior segment **92**, tightly glued together in an optically transmissive manner at **93**. Slanted face **94** is covered by a totally reflective mirror layer **95.** Glass disk **96** defining a sensing surface **97** is disposed at the bottom in a manner leaving an air gap **98**. The disk is fixed in position by a holding structure which is not shown. Three light rays are

99 are represented schematically. As can be seen, they bounce at the walls of the probing member at an angle in which the walls are totally reflective and finally bounce on mirror 94 and reflected from there out through the sensing face **97**. The light rays focus on focusing plane **100**, the position of which can be changed by the focusing optics (not shown in this figure).

Reference is now being made to Fig. 3, which is a schematic illustration of an endoscopic probe in accordance with an embodiment of the invention. The endoscopic probe, generally designated **101**, has a stem **102** defining a light transmission path (e.g., containing a void elongated space, being made of or having an interior made of a light transmitting material. Probe **102** has a trough-like probe end **104** with two lateral probe members **106** and **108** and a top probe member **110**. The optical fibers have light emitting ends in members **106, 108** and **110** whereby the light is emitted in a direction normal to the planes defined by these members towards the interior of the trough-like structure **104**. The probe is placed over a teeth segment **120**, which in the illustrated case consists of two teeth **122** and **124**, and a stamp **126** of a tooth for placement of a crown thereon. Such a probe will allow the simultaneous imaging of the surface topology of the teeth segment from three angles and subsequently the generation of a three-dimensional structure of this segment.

Reference is now being made to Fig. 4. In this figure, a number of components of an apparatus generally designated **150** in accordance with another embodiment are shown. Other components, not shown, may be similar to those of the embodiment shown in Fig. 1. In this apparatus a parent light beam **152** is a combination of light emitted by a number of laser light emitters **154A, 154B** and **154C**. Optic expander unit **156** then expands the single parent beam into an array of incident light beams **158**. Incident light beams pass through unidirectional mirror **160**, then through optic unit **162** towards object **164**.

The different light components composing parent beam **152** may for example be different wavelengths, a different one transmitted from each of laser emitters **154A-C**. Thus, parent light beam **152** and each of incident light beams **158** will be composed of three different light components. The image of the optics, or an optical arrangement associated with each of light emitters may be arranged such that each light component focuses on a different plane, $\mathbf{P_A}$, $\mathbf{P_B}$ and $\mathbf{P_C}$, respectively. Thus in the position shown in Fig. 3, incident light beam **158A** bounces on the surface at spot **170A** which in the specific optical arrangement of optics **162** is in the focal point for light component **A** (emitted by light emitter **154A**). Thus, the returned light beam **172A**, passing through detection optics **174** yield maximum measured intensity of light component **A** measured by two-dimensional array of spectrophotometers **176, e.g. a 3 CHIP CCD camera**. Similarly, different maximal intensity will be reached for spots **170B** and **170C** for light components **B** and **C**, respectively.

Thus, by using different light components each one focused simultaneously at a different plane, the time measurement can be reduced as different focal plane ranges can simultaneously be measured.

CLAIMS:

1. A method for determining surface topology of a portion of a three-dimensional structure, comprising:

(a) providing an array of incident light beams propagating in an optical path leading through a focusing optics and through a probing face; the focusing optics defining one or more focal planes forward said probing face in a position changeable by said optics, each light beam having its focus on one of said one or more focal plane; the beams generating a plurality of illuminated spots on the structure;

(b) detecting intensity of returned light beams propagating from each of these spots along an optical path opposite to that of the incident light;

(c) repeating steps (a) and (b) a plurality of times, each time changing position of the focal plane relative to the structure;

(d) for each of the illuminated spots, determining a spot-specific position, being the position of the respective focal plane yielding a maximum measured intensity of a respective returned light beam; and

(e) generating data representative of the topology of said portion.

2. The method according to Claim 1, wherein the plurality of incident light beams are produced by splitting a single parent beam.

3. The method according to Claim 1, wherein step (a) comprises polarizing the incident light beams.

4. The method according to Claim 3, wherein step (b) comprises filtering light having polarization same as the incident light and measuring light of opposite polarization.

5. The method according to any one of Claims 1-4, wherein each of said beams is composed of at least two light components different in at least one parameter.

6. The method according to Claim 5, wherein said at least one parameter is selected from the group consisting of wavelength, phase, light pulse duration and pattern.

7. The method according to Claim 5, comprising. in step (b), determining intensity independently for each of said at least two light components in the return light beams.

8. The method according to Claim 7, wherein each of said at least two light components focuses in a plane differently distanced from the sensing surface.

9. The method according to any one of Claims 1-8, wherein the data representative of said topology is used for constructing an object to be fitted within said structure.

10. The method according to any one of Claims 1-9, wherein the data representative of said topology is converted into a form transmissible through a communication medium to recipient.

11. The method according to any one of the preceding claims, wherein said structure is a teeth segment.

12. The method according to Claim 12, wherein said structure is a teeth segment with at least one missing tooth or a portion of a tooth and said object is said at least one missing tooth or the portion of the tooth.

13. A method for reconstruction of topology of a three-dimensional structure comprising:

(i) determining surface topologies from at least two different positions or angular locations relative to the structure, by the method defined in any one of Claims 1-12;

(ii) combining the surface topologies to obtain data representative of said structure.

14. The method according to Claim 13, for reconstruction of topology of a teeth portion, comprising:

- determining surface topologies of at least a buccal surface and a lingual surface of the teeth portion;
- combining the surface topologies to obtain data representative of a three-dimensional structure of said teeth portion.

15. The method according to Claim 14, for obtaining data representative of a three-dimensional structure of a teeth portion with at least one missing tooth or a portion of a tooth.

16. The method according to Claim 15, wherein said data is used in a process of designing or manufacturing of a prostheses of said at least one missing tooth or a portion of a tooth.

17. The method according to Claim 16, wherein said prostheses is a crown or a bridge.

18. An apparatus for determining surface topology of a portion of a three-dimensional structure, comprising:

- a probing member with a sensing face;
- an illumination unit for providing an array of incident light beams transmitted towards the structure along an optical path through said probing unit to generate illuminated spots on said portion ;
- a light focusing optics defining one or more focal planes forward said probing face at a position changeable by said optics, each light beam having its focus on one of said one or more focal plane;
- a translation mechanism for displacing said focal plane relative to the structure along an axis defined by the propagation of the incident light beams;

- a detector having an array of sensing elements for measuring intensity of each of a plurality of light beamsreturning from said spots propagating through an optical path opposite to that of the incident light beams;
- a processor coupled to said detector for determining for each light beam a spot-specific position, being the position of the respective focal plane of said one or more focal planes yielding maximum measured intensity of the returned light beam, and based on the determined spot-specific positions, generating data representative of the topology of portion.

19. The apparatus according to Claim 18, wherein said illumination unit comprises a source emitting a parent light beam and a beam splitter for splitting the parent beam into said array of incident light beams.

20. The apparatus according to Claim 19, wherein said illumination unit comprises a grating or microlens array.

21. The apparatus according to any one of Claims 18-20, comprising a polarizer for polarizing said incident light beams are polarized.

22. The apparatus according to Claim 21, comprising a polarization filter for filtering out from the returned light beams light components having the polarization of the incident light beams.

23. The apparatus according to any one of Claim 18-22, wherein the illumination unit comprises at least two light sources and each of said incident beams is composed of light components from the at least two light sources.

24. The apparatus according to Claim 23, wherein the at least two light sources emit each a light component of different wavelength.

25. The apparatus according to Claim 24, wherein said light directing optics defines a different focal plane for each light component and the detector independently detects intensity of each light components.

26. The apparatus according to Claim 23, wherein the at least two light sources are located so as to define optical paths of different lengths for the incident light beams emitted by each of the at least two light sources.

27. The apparatus according to any one of Claims 18-26, wherein said focusing optics operates in a telecentric confocal mode.

28. The apparatus according to any one of Claims 18-27, wherein said light directing optics comprises optical fibers.

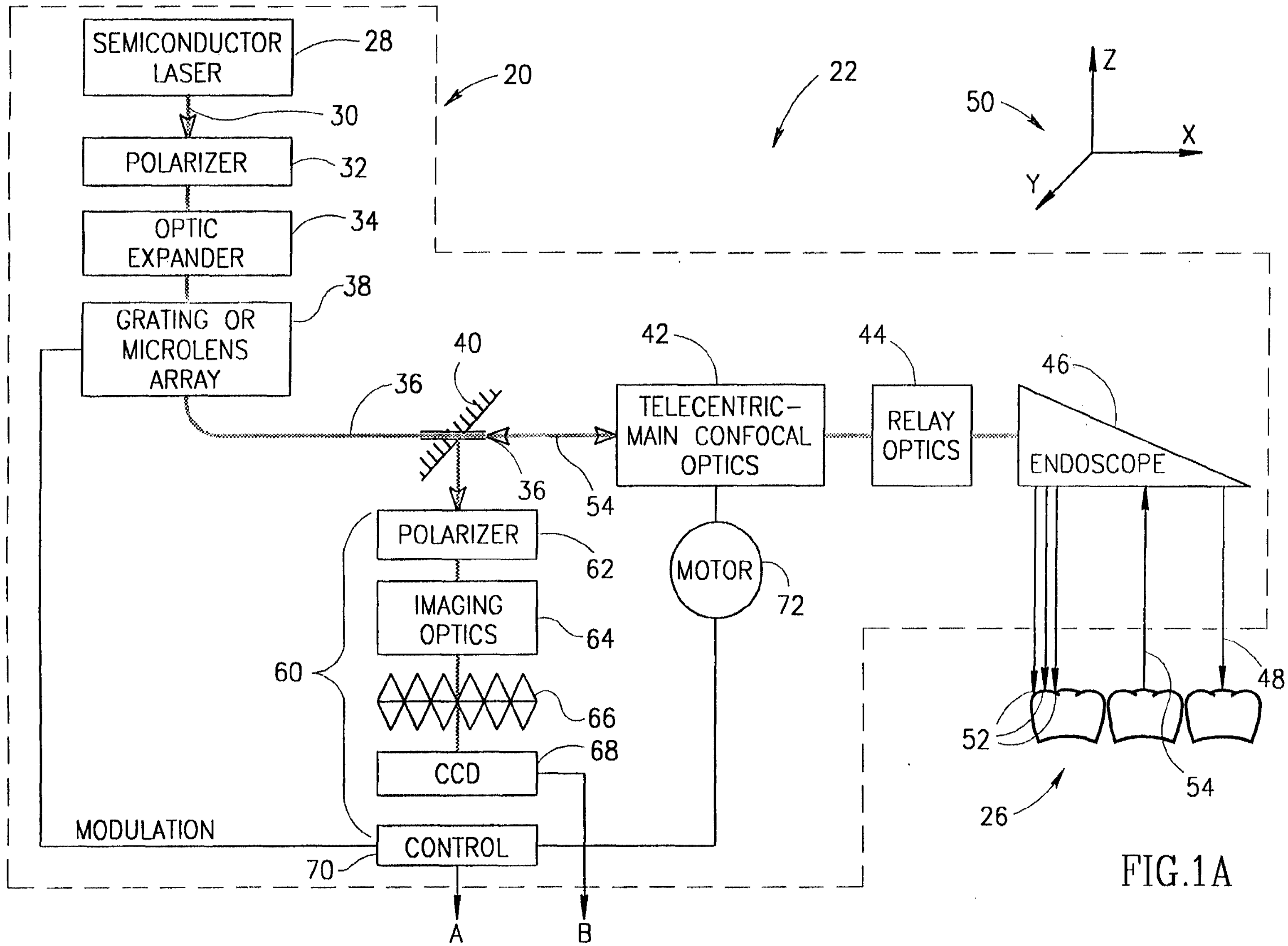
29. The apparatus according to any one of Claims 18-28, wherein said sensing elements are an array of charge coupled devices (CCD).

30. The apparatus according to Claim 29, wherein, said detector unit comprises a pinhole array, each pinhole corresponding to one of the CCDs in the CCD array.

31. The apparatus according to any one of Claims 18-30, comprising a unit for generating data for transmission to CAD/CAM device.

32. The apparatus according to Claim 31, comprising a communication port of a communication medium.

33. The apparatus according to any one of Claims 18-32, for determining surface topology of a teeth portion, comprising an optical probing memeber for placing proximal to the teeth.



SEMICONDUCTOR LASER
28
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POLARIZER
32
OPTIC EXPANDER
34
GRATING OR MICROLENS ARRAY
38
40
42
44
46
36
TELECENTRIC-MAIN CONFOCAL OPTICS
RELAY OPTICS
ENDOSCOPE
36
54
POLARIZER
62
MOTOR
72
IMAGING OPTICS
64
60
48
66
52
68
CCD
54
26
MODULATION
CONTROL
70
A
B

FIG.1A

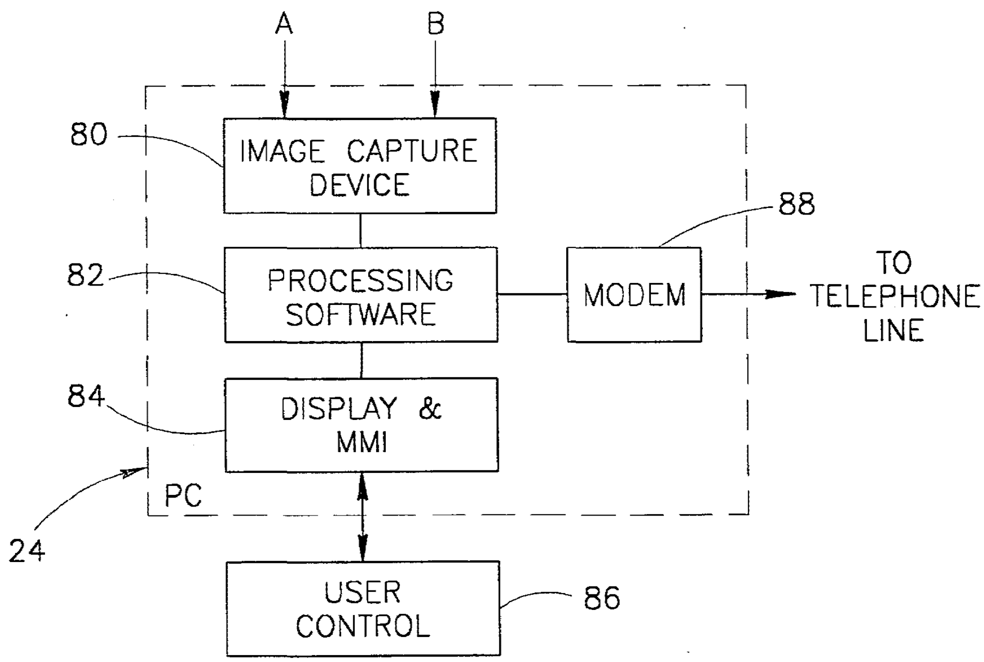
A
B
80
IMAGE CAPTURE DEVICE
88
82
PROCESSING SOFTWARE
MODEM
TO TELEPHONE LINE
84
DISPLAY & MMI
PC
24
USER CONTROL
86

FIG.1B

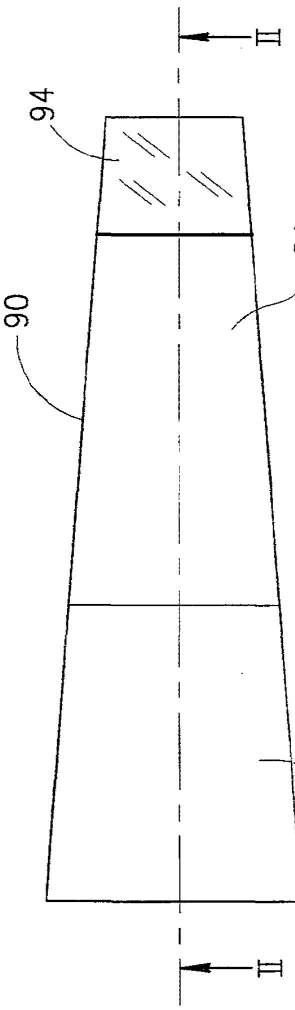

FIG.2A

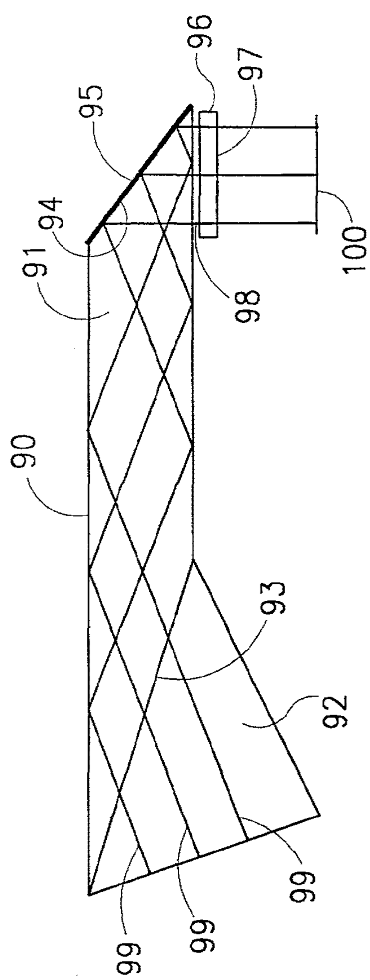

FIG.2B

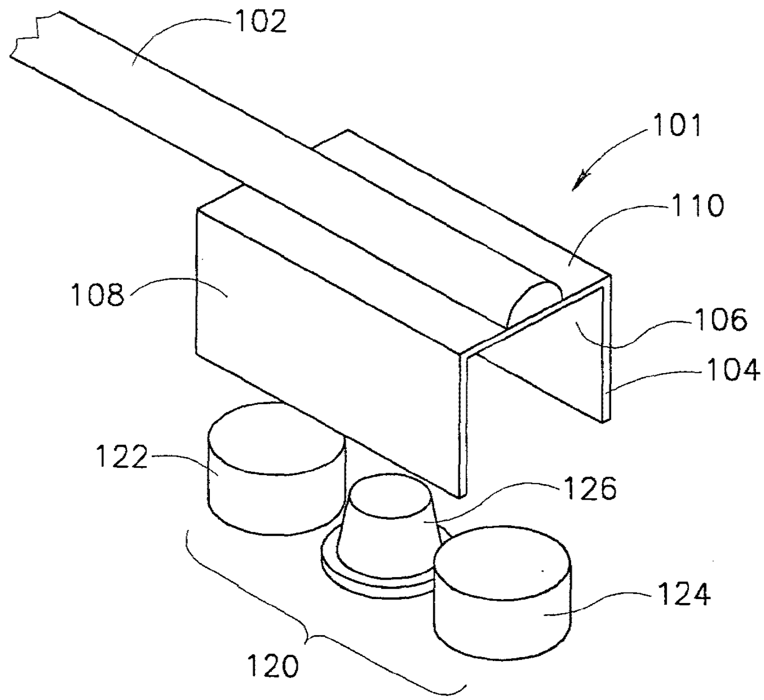

FIG.3

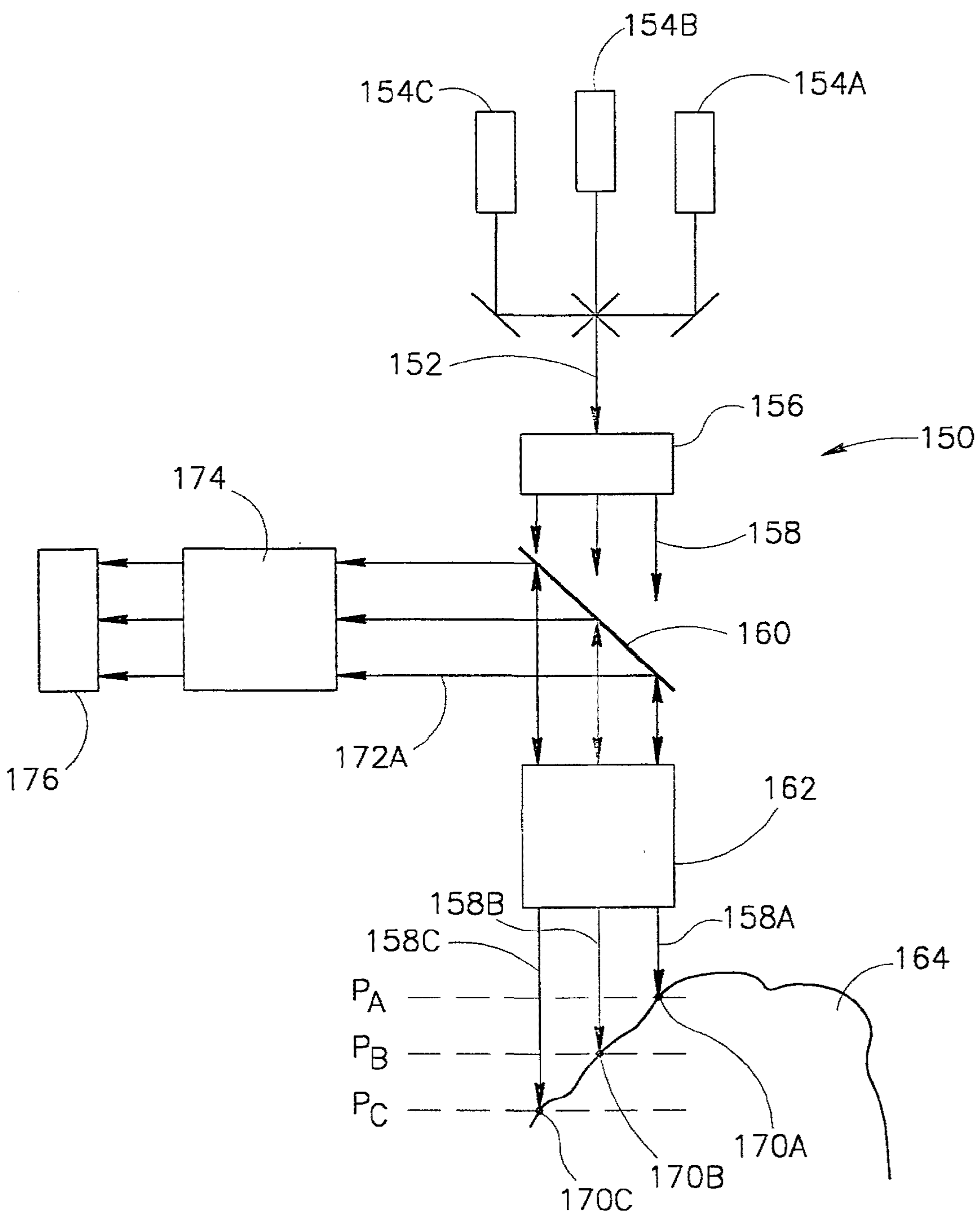
154B
154C
154A
152
156
150
174
158
160
176
172A
162
158B
158C
158A
164
P_A
P_B
P_C
170A
170B
170C

FIG.4

INTERNATIONAL SEARCH REPORT

Interı nal Application No
PCT/IL 99/00431

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According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
IPC 7 G01B A61C

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category °	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	EP 0 679 864 A (KOMATSU) 2 November 1995 (1995-11-02) column 2, line 9 - line 27; figure 25 ---	1,18
X	GB 2 321 517 A (YOKOGAWA) 29 July 1998 (1998-07-29) figures 3,6,7 ---	1-3, 18-21
A	DE 196 38 758 A (RUBBERT) 19 March 1998 (1998-03-19) figure 4 ---	1,18
A	US 4 575 805 A (MOERMANN ET AL.) 11 March 1986 (1986-03-11) column 9, line 61 -column 10, line 42 --- -/--	13

[X] Further documents are listed in the continuation of box C.

[X] Patent family members are listed in annex.

° Special categories of cited documents :

"A" document defining the general state of the art which is not considered to be of particular relevance

"E" earlier document but published on or after the international filing date

"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)

"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art.

"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
30 November 1999	06/12/1999

Name and mailing address of the ISA	Authorized officer
European Patent Office, P.B. 5818 Patentlaan 2 NL – 2280 HV Rijswijk Tel. (+31–70) 340–2040, Tx. 31 651 epo nl, Fax: (+31–70) 340–3016	Mielke, W

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INTERNATIONAL SEARCH REPORT

Inte[illegible]onal Application No
PCT/IL 99/00431

C.(Continuation) DOCUMENTS CONSIDERED TO BE RELEVANT

Category °	Citation of document, with indication,where appropriate, of the relevant passages	Relevant to claim No.
A	GB 2 144 537 A (ISTITUTO) 6 March 1985 (1985-03-06) page 2, line 26 - line 49; figure 2 ---	5,23
A	US 5 737 084 A (TAKAOKA) 7 April 1998 (1998-04-07) figures 5-7 ---	20
A	DE 196 50 391 A (LEICA) 10 June 1998 (1998-06-10) figure 1 ---	
A	DE 196 40 495 A (LEICA) 9 April 1998 (1998-04-09) figure 1 ---	
A	WO 97 37264 A (KOMATSU) 9 October 1997 (1997-10-09) figure 1 ---	
A	US 5 381 236 A (OXFORD SENSOR) 10 January 1995 (1995-01-10) column 3, line 21 - line 44; figure 1 -----	

2

Form PCT/ISA/210 (continuation of second sheet) (July 1992)

INTERNATIONAL SEARCH REPORT

Information on patent family members

International Application No
PCT/IL 99/00431

Patent document cited in search report		Publication date	Patent family member(s)		Publication date
EP 0679864	A	02-11-1995	US	5659420 A	19-08-1997
			WO	9509346 A	06-04-1995
			JP	7181023 A	18-07-1995
GB 2321517	A	29-07-1998	NONE		
DE 19638758	A	19-03-1998	AU	4111497 A	02-04-1998
			WO	9811403 A	19-03-1998
			EP	0935736 A	18-08-1999
US 4575805	A	11-03-1986	AT	14073 T	15-07-1985
			EP	0054785 A	30-06-1982
			JP	1665145 C	19-05-1992
			JP	3017494 B	08-03-1991
			JP	57173053 A	25-10-1982
GB 2144537	A	06-03-1985	IT	1198660 B	21-12-1988
			DE	3428593 A	14-02-1985
			FR	2550332 A	08-02-1985
US 5737084	A	07-04-1998	JP	9096512 A	08-04-1997
			JP	9126739 A	16-05-1997
			JP	9257440 A	03-10-1997
			US	5946100 A	31-08-1999
DE 19650391	A	10-06-1998	WO	9825171 A	11-06-1998
			EP	0943113 A	22-09-1999
DE 19640495	A	09-04-1998	WO	9814132 A	09-04-1998
WO 9737264	A	09-10-1997	JP	9264720 A	07-10-1997
US 5381236	A	10-01-1995	AU	1195892 A	07-09-1992
			DE	69207176 D	08-02-1996
			DE	69207176 T	04-07-1996
			EP	0571431 A	01-12-1993
			WO	9214118 A	20-08-1992
			JP	6505096 T	09-06-1994
			JP	6506287 T	14-07-1994

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— *of inventorship (Rule 4.17(iv))*

Published:

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WO 2010/145669 A1

(54) **Title:** FOCUS SCANNING APPARATUS

(57) **Abstract:** Disclosed is a handheld scanner for obtaining and/or measuring the 3D geometry of at least a part of the surface of an object using confocal pattern projection techniques. Specific embodiments are given for intraoral scanning and scanning of the interior part of a human ear.

Focus scanning apparatus

The present invention relates to an apparatus and a method for optical 3D scanning of surfaces. The principle of the apparatus and method according to the invention may be applied in various contexts. One specific embodiment of the invention is particularly suited for intraoral scanning, i.e. direct scanning of teeth and surrounding soft-tissue in the oral cavity. Other dental related embodiments of the invention are suited for scanning dental impressions, gypsum models, wax bites, dental prosthetics and abutments. Another embodiment of the invention is suited for scanning of the interior and exterior part of a human ear or ear channel impressions. The invention may find use within scanning of the 3D structure of skin in dermatological or cosmetic / cosmetological applications, scanning of jewelry or wax models of whole jewelry or part of jewelry, scanning of industrial parts and even time resolved 3D scanning, such as time resolved 3D scanning of moving industrial parts.

Background of the invention

The invention relates to three dimensional (3D) scanning of the surface geometry of objects. Scanning an object surface in 3 dimensions is a well known field of study and the methods for scanning can be divided into contact and non-contact methods. An example of contact measurements methods are Coordinate Measurement Machines (CMM), which measures by letting a tactile probe trace the surface. The advantages include great precision, but the process is slow and a CMM is large and expensive. Non-contact measurement methods include x-ray and optical probes.

Confocal microscopy is an optical imaging technique used to increase micrograph contrast and/or to reconstruct three-dimensional images by using a spatial pinhole to eliminate out-of-focus light or flare in specimens that are thicker than the focal plane.

A confocal microscope uses point illumination and a pinhole in an optically conjugate plane in front of the detector to eliminate out-of-focus information. Only the light within the focal plane can be detected. As only one point is illuminated at a time in confocal microscopy, 2D imaging requires raster scanning and 3D imaging requires raster scanning in a range of focus planes.

In WO 00/08415 the principle of confocal microscopy is applied by illuminating the surface with a plurality of illuminated spots. By varying the focal plane in-focus spot-specific positions of the surface can be determined. However, determination of the surface structure is limited to the parts of the surface that are illuminated by a spot.

WO 2003/060587 relates to optically sectioning of a specimen in microscopy wherein the specimen is illuminated with an illumination pattern. Focus positions of the image plane are determined by characterizing an oscillatory component of the pattern. However, the focal plane can only be adjusted by moving the specimen and the optical system relative to each other, i.e. closer to or further away from each other. Thus, controlled variation of the focal plane requires a controlled spatial relation between the specimen and the optical system, which is fulfilled in a microscope. However, such a controlled spatial relation is not applicable to e.g. a hand held scanner.

US2007/01 09559 A 1 describes a focus scanner where distances are found from the focus lens positions at which maximum reflective intensity of light beams incident on the object being scanned is observed. In contrast to the invention disclosed here, this prior art exploits no pre-determined measure of the illumination pattern and exploits no contrast detection, and therefore, the signal-to-noise ratio is sub-optimal.

In WO 2008/1 25605, means for generating a time-variant pattern composed of alternating split images are described. This document describes a scanning method to obtain an optical section of a scan object by means of two different illumination profiles, e.g. two patterns of opposite phases. These two images are used to extract the optical section, and the method is limited to acquisition of images from only two different illumination profiles. Furthermore, the method relies on a predetermined calibration that determines the phase offset between the two illumination profiles.

Summary of the invention

Thus, an object of the invention is to provide a scanner which may be integrated in a manageable housing, such as a handheld housing. Further objects of the invention are: discriminate out-of-focus information and provide a fast scanning time.

This is achieved by a method and a scanner for obtaining and/or measuring the 3D geometry of at least a part of the surface of an object, said scanner comprising:

- at least one camera accommodating an array of sensor elements,
- means for generating a probe light incorporating a spatial pattern,
- means for transmitting the probe light towards the object thereby illuminating at least a part of the object with said pattern in one or more configurations,
- means for transmitting at least a part of the light returned from the object to the camera,
- means for varying the position of the focus plane of the pattern on the object while maintaining a fixed spatial relation of the scanner and the object,
- means for obtaining at least one image from said array of sensor elements,
- means for evaluating a correlation measure at each focus plane position between at least one image pixel and a weight function, where the weight function is determined based on information of the configuration of the spatial pattern;
- data processing means for:
    a) determining by analysis of the correlation measure the in-focus position(s) of:
        - each of a plurality of image pixels for a range of focus plane positions, or
        - each of a plurality of groups of image pixels for a range of focus plane positions, and
    b) transforming in-focus data into 3D real world coordinates.

The method and apparatus described in this invention is for providing a 3D surface registration of objects using light as a non-contact probing agent. The light is provided in the form of an illumination pattern to provide a light oscillation on the object. The variation / oscillation in the pattern may be spatial, e.g. a static checkerboard pattern, and/or it may be time varying, for example by moving a pattern across the object being scanned. The invention provides for a variation of the focus plane of the pattern over a range of focus plane positions while maintaining a fixed spatial relation of the scanner and the object. It does not mean that the scan must be provided with a fixed spatial relation of the scanner and the object, but merely that the focus plane can be varied (scanned) with a fixed spatial relation of the scanner and the object. This provides for a hand held scanner solution based on the present invention.

In some embodiments the signals from the array of sensor elements are light intensity.

One embodiment of the invention comprises a first optical system, such as an arrangement of lenses, for transmitting the probe light towards the object and a second optical system for imaging light returned from the object to the camera. In the preferred embodiment of the invention only one optical system images the pattern onto the object and images the object, or at least a part of the object, onto the camera, preferably along the same optical axis, however along opposite optical paths.

In the preferred embodiment of the invention an optical system provides an imaging of the pattern onto the object being probed and from the object being probed to the camera. Preferably, the focus plane is adjusted in such a way that the image of the pattern on the probed object is shifted along the optical axis, preferably in equal steps from one end of the scanning region to the other. The probe light incorporating the pattern provides a pattern of light and darkness on the object. Specifically, when the pattern is varied in time for a fixed focus plane then the in-focus regions on the object will display an oscillating pattern of light and darkness. The out-of-focus regions will display smaller or no contrast in the light oscillations.

Generally we consider the case where the light incident on the object is reflected diffusively and/or specularly from the object's surface. But it is understood that the scanning apparatus and method are not limited to this situation. They are also applicable to e.g. the situation where the incident light penetrates the surface and is reflected and/or scattered and/or gives rise to fluorescence and/or phosphorescence in the object. Inner surfaces in a sufficiently translucent object may also be illuminated by the illumination pattern and be imaged onto the camera. In this case a volumetric scanning is possible. Some planktic organisms are examples of such objects.

When a time varying pattern is applied a single sub-scan can be obtained by collecting a number of 2D images at different positions of the focus plane and at different instances of the pattern. As the focus plane coincides with the scan surface at a single pixel position, the pattern will be projected onto the surface point in-focus and with high contrast, thereby giving rise to a large variation, or amplitude, of the pixel value over time. For each pixel it is thus possible to identify individual settings of the focusing plane for which each pixel will be in focus. By using knowledge of the optical system used, it is possible to transform the contrast information vs. position of the focus plane into 3D surface information, on an individual pixel basis.

Thus, in one embodiment of the invention the focus position is calculated by determining the light oscillation amplitude for each of a plurality of sensor elements for a range of focus planes.

For a static pattern a single sub-scan can be obtained by collecting a number of 2D images at different positions of the focus plane. As the focus plane coincides with the scan surface, the pattern will be projected onto the surface point in-focus and with high contrast. The high contrast gives rise to a large spatial variation of the static pattern on the surface of the object, thereby providing a large variation, or amplitude, of the pixel values over a group of adjacent pixels. For each group of pixels it is thus possible to identify individual settings of the focusing plane for which each group of pixels will be in focus. By using knowledge of the optical system used, it is possible to transform the contrast information vs. position of the focus plane into 3D surface information, on an individual pixel group basis.

Thus, in one embodiment of the invention the focus position is calculated by determining the light oscillation amplitude for each of a plurality of groups of the sensor elements for a range of focus planes.

The 2D to 3D conversion of the image data can be performed in a number of ways known in the art. I.e. the 3D surface structure of the probed object can be determined by finding the plane corresponding to the maximum light oscillation amplitude for each sensor element, or for each group of sensor elements, in the camera's sensor array when recording the light amplitude for a range of different focus planes. Preferably, the focus plane is adjusted in equal steps from one end of the scanning region to the other. Preferably the focus plane can be moved in a range large enough to at least coincide with the surface of the object being scanned.

The present invention distinguishes itself from WO 2008/1 25605, because in the embodiments of the present invention that use a time-variant pattern, input images are not limited to two illumination profiles and can be obtained from any illumination profile of the pattern. This is because the orientation of the reference image does not rely entirely on a predetermined calibration, but rather on the specific time of the input image acquisition.
Thus WO 2008/125605 applies specifically exactly two patterns, which are realized physically by a chrome-on-glass mask as illuminated from either side, the reverse side being reflective. WO 2008/1 25605 thus has the advantage of using no moving parts, but the disadvantage of a comparatively poorer signal-to-noise ratio. In the present invention there is the possibility of using any number of pattern configurations, which makes computation of the light oscillation amplitude or the correlation measure more precise.

Definitions

Pattern: A light signal comprising an embedded spatial structure in the lateral plane. May also be termed "illumination pattern".

Time varying pattern: A pattern that varies in time, i.e. the embedded spatial structure varies in time. May also be termed "time varying illumination pattern". In the following also termed "fringes".

Static pattern: A pattern that does not vary in time, e.g. a static checkerboard pattern or a static line pattern.

Pattern configuration: The state of the pattern. Knowledge of the pattern configuration at a certain time amounts to knowing the spatial structure of the illumination at that time. For a periodic pattern the pattern configuration will include information of the pattern phase. If a surface element of the object being scanned is imaged onto the camera then knowledge of the pattern configuration amounts to knowledge of what part of the pattern is illuminating the surface element.

Focus plane: A surface where light rays emitted from the pattern converge to form an image on the object being scanned. The focus plane does not need to be flat. It may be a curved surface.

Optical system: An arrangement of optical components, e.g. lenses, that transmit, collimate and/or images light, e.g. transmitting probe light towards the object, imaging the pattern on and/or in the object, and imaging the object, or at least a part of the object, on the camera.

Optical axis: An axis defined by the propagation of a light beam. An optical axis is preferably a straight line. In the preferred embodiment of the invention the optical axis is defined by the configuration of a plurality of optical components, e.g. the configuration of lenses in the optical system. There may be more than one optical axis, if for example one optical system transmits probe light to the object and another optical system images the object on the camera. But preferably the optical axis is defined by the propagation of the light in the optical system transmitting the pattern onto the object and imaging the object onto the camera. The optical axis will often coincide with the longitudinal axis of the scanner.

Optical path: The path defined by the propagation of the light from the light source to the camera. Thus, a part of the optical path preferably coincides with the optical axis. Whereas the optical axis is preferably a straight line, the optical path may be a non-straight line, for example when the light is reflected, scattered, bent, divided and/or the like provided e.g. by means of beam splitters, mirrors, optical fibers and the like.

Telecentric system: An optical system that provides imaging in such a way that the chief rays are parallel to the optical axis of said optical system. In a telecentric system out-of-focus points have substantially same magnification as in-focus points. This may provide an advantage in the data processing. A perfectly telecentric optical system is difficult to achieve, however an optical system which is substantially telecentric or near telecentric may be provided by careful optical design. Thus, when referring to a telecentric optical system it is to be understood that it may be only near telecentric.

Scan length: A lateral dimension of the field of view. If the probe tip (i.e. scan head) comprises folding optics to direct the probe light in a direction different such as perpendicular to the optical axis then the scan length is the lateral dimension parallel to the optical axis.

Scan object: The object to be scanned and on which surface the scanner provides information. "The scan object" may just be termed "the object".

Camera: Imaging sensor comprising a plurality of sensors that respond to light input onto the imaging sensor. The sensors are preferably ordered in a 2D array in rows and columns.

Input signal: Light input signal or sensor input signal from the sensors in the camera. This can be integrated intensity of light incident on the sensor during the exposure time or integration of the sensor. In general, it translates to a pixel value within an image. May also be termed "sensor signal".

Reference signal: A signal derived from the pattern. A reference signal may also be denoted a weight function or weight vector or reference vector.

Correlation measure: A measure of the degree of correlation between a reference and input signal. Preferably the correlation measure is defined such that if the reference and input signal are linearly related to each other then the correlation measure obtains a larger magnitude than if they are not.
In some cases the correlation measure is a light oscillation amplitude.

Image: An image can be viewed as a 2D array of values (when obtained with a digital camera) or in optics, an image indicates that there exists a relation between an imaged surface and an image surface where light rays emerging from one point on said imaged surface substantially converge on one point on said image surface.

Intensity: In optics, intensity is a measure of light power per unit area. In image recording with a camera comprising a plurality of individual sensing elements, intensity may be used to term the recorded light signal on the individual sensing elements. In this case intensity reflects a time integration of light power per unit area on the sensing element over the exposure time involved in the image recording.

Mathematical notation

A	A correlation measure between the weight function and the recorded light signal. This can be a light oscillation amplitude.
I	Light input signal or sensor input signal. This can be integrated intensity of light incident on the sensor during the exposure time or integration of the sensor. In general, it translates to a pixel value within an image.
f	Reference signal. May also be called weight value.
n	The number of measurements with a camera sensor and/or several camera sensors that are used to compute a correlation measure.
H	Image height in number of pixels
W	Image width in number of pixels

Symbols are also explained as needed in the text.

Detailed description of the invention

The scanner preferably comprises at least one beam splitter located in the optical path. For example, an image of the object may be formed in the camera by means of a beam splitter. Exemplary uses of beam splitters are illustrated in the figures.

In a preferred embodiment of the invention light is transmitted in an optical system comprising a lens system. This lens system may transmit the pattern towards the object and images light reflected from the object to the camera.

In a telecentric optical system, out-of-focus points have the same magnification as in-focus points. Telecentric projection can therefore significantly ease the data mapping of acquired 2D images to 3D images. Thus, in a preferred embodiment of the invention the optical system is substantially telecentric in the space of the probed object. The optical system may also be telecentric in the space of the pattern and camera.

Varying focus

A pivotal point of the invention is the variation, i.e. scanning, of the focal plane without moving the scanner in relation to the object being scanned. Preferably the focal plane may be varied, such as continuously varied in a periodic fashion, while the pattern generation means, the camera, the optical system and the object being scanned is fixed in relation to each other. Further, the 3D surface acquisition time should be small enough to reduce the impact of relative movement between probe and teeth, e.g. reduce effect of shaking. In the preferred embodiment of the invention the focus plane is varied by means of at least one focus element. Preferably the focus plane is periodically varied with a predefined frequency. Said frequency may be at least 1 Hz, such as at least 2 Hz, 3, 4, 5, 6, 7, 8, 9 or at least 10 Hz, such as at least 20, 40, 60, 80 or at least 100 Hz.

Preferably the focus element is part of the optical system. I.e. the focus element may be a lens in a lens system. A preferred embodiment comprises means, such as a translation stage, for adjusting and controlling the position of the focus element. In that way the focus plane may be varied, for example by translating the focus element back and forth along the optical axis.

If a focus element is translated back and forth with a frequency of several Hz this may lead to instability of the scanner. A preferred embodiment of the invention thus comprises means for reducing and/or eliminating the vibration and/or shaking from the focus element adjustment system, thereby increasing the stability of the scanner. This may at least partly be provided by means for fixing and/or maintaining the centre of mass of the focus element adjustment system, such as a counter-weight to substantially counter-balance movement of the focus element; for example, by translating a counter-weight opposite to the movement of the focus element. Ease of operation may be achieved if the counter-weight and the focus element are connected and driven by the same translation means. This may however, only substantially reduce the vibration to the first order. If a counter-weight balanced device is rotated around the counter-weight balanced axis, there may be issues relating to the torque created by the counter-weights. A further embodiment of the invention thus comprises means for reducing and/or eliminating the first order, second order, third order and/or higher order vibration and/or shaking from the focus element adjustment system, thereby increasing the stability of the scanner.

In another embodiment of the invention more than one optical element is moved to shift the focal plane. In that embodiment it is desirable that these elements are moved together and that the elements are physically adjacent.

In the preferred embodiment of the invention the optical system is telecentric, or near telecentric, for all focus plane positions. Thus, even though one or more lenses in the optical system may be shifted back and forth to change the focus plane position, the telecentricity of the optical system is maintained.

The preferred embodiment of the invention comprises focus gearing. Focus gearing is the correlation between movement of the lens and movement of the focus plane position. E.g. a focus gearing of 2 means that a translation of the focus element of 1 mm corresponds to a translation of the focus plane position of 2 mm. Focus gearing can be provided by a suitable design of the optical system. The advantage of focus gearing is that a small movement of the focus element may correspond to a large variation of the focus plane position. In specific embodiments of the invention the focus gearing is between 0.1 and 100, such as between 0.1 and 1, such as between 1 and

10, such as between 2 and 8, such as between 3 and 6, such as least 10, such as at least 20.

In another embodiment of the invention the focus element is a liquid lens. A liquid lens can control the focus plane without use of any moving parts.

Camera

The camera may be a standard digital camera accommodating a standard CCD or CMOS chip with one A/D converter per line of sensor elements (pixels). However, to increase the frame rate the scanner according to the invention may comprise a high-speed camera accommodating multiple A/D converters per line of pixels, e.g. at least 2, 4, 8 or 16 A/D converters per line of pixels.

Pattern

Another central element of the invention is the probe light with an embedded pattern that is projected on to the object being scanned. The pattern may be static or time varying. The time varying pattern may provide a variation of light and darkness on and/or in the object. Specifically, when the pattern is varied in time for a fixed focus plane then the in-focus regions on the object will display an oscillating pattern of light and darkness. The out-of-focus regions will display smaller or no contrast in the light oscillations. The static pattern may provide a spatial variation of light and darkness on and/or in the object. Specifically, the in-focus regions will display an oscillating pattern of light and darkness in space. The out-of-focus regions will display smaller or no contrast in the spatial light oscillations.

Light may be provided from an external light source, however preferably the scanner comprises at least one light source and pattern generation means to produce the pattern. It is advantageous in terms of signal-to-noise ratio to design a light source such that the intensity in the non-masked parts of the pattern is as close to uniform in space as possible. In another embodiment the light source and the pattern generation means is integrated in a single component, such as a segmented LED. A segmented LED may provide a static pattern and/or it may provide a time varying pattern in itself by turning on and off the different segments in sequence. In one embodiment of the invention the time varying pattern is periodically varying in time. In another embodiment of the invention the static pattern is periodically varying in space.

Light from the light source (external or internal) may be transmitted through the pattern generation means thereby generating the pattern. For example the pattern generation means comprises at least one translucent and/or transparent pattern element. For generating a time varying pattern a wheel, with an opaque mask can be used. E.g. the mask comprises a plurality of radial spokes, preferably arranged in a symmetrical order. The scanner may also comprise means for rotating and/or translating the pattern element. For generating a static pattern a glass plate with an opaque mask can be used. E.g. the mask comprises a line pattern or checkerboard pattern. In general said mask preferably possesses rotational and/or translational periodicity. The pattern element is located in the optical path. Thus, light from the light source may be transmitted through the pattern element, e.g. transmitted transversely through the pattern element. The time varying pattern can then be generated by rotating and/or translating the pattern element. A pattern element generating a static pattern does not need to be moved during a scan.

Correlation

One object of the invention is to provide short scan time and real time processing, e.g. to provide live feedback to a scanner operator to make a fast scan of an entire tooth arch. However, real time high resolution 3D scanning creates an enormous amount of data. Therefore data processing should be provided in the scanner housing, i.e. close to the optical components, to reduce data transfer rate to e.g. a cart, workstation or display. In order to speed up data processing time and in order to extract in-focus information with an optimal signal-to-noise ratio various correlation techniques may be embedded / implemented. This may for example be implemented in the camera electronics to discriminate out-of-focus information. The pattern is applied to provide illumination with an embedded spatial structure on the object being scanned. Determining in-focus information relates to calculating a correlation measure of this spatially structured light signal (which we term input signal) with the variation of the pattern itself (which we term reference signal). In general the magnitude of the correlation measure is high if the input signal coincides with the reference signal. If the input signal displays little or no variation then the magnitude of the correlation measure is low. If the input signal displays a large spatial variation but this variation is different than the variation in the reference signal then the magnitude of the correlation measure is also low. In a further embodiment of the invention the scanner and/or the scanner head may be wireless, thereby simplifying handling and operation of the scanner and increasing accessibility under difficult scanning situations, e.g. intra-oral or in the ear scanning. However, wireless operation may further increase the need for local data processing to avoid wireless transmission of raw 3D data.

The reference signal is provided by the pattern generating means and may be periodic. The variation in the input signal may be periodic and it may be confined to one or a few periods. The reference signal may be determined independently of the input signal. Specifically in the case of a periodic variation, the phase between the oscillating input and reference signal may be known independently of the input signal. In the case of a periodic variation the correlation is typically related to the amplitude of the variation. If the phase between the oscillating input and reference signals is not known it is necessary to determine both cosine and sinusoidal part of the input signal before the input signal's amplitude of variation can be determined. This is not necessary when the phase is known.

One way to define the correlation measure mathematically with a discrete set of measurements is as a dot product computed from a signal vector, $I = (I_i, \ldots, I_n)$, with $n > 1$ elements representing sensor signals and a reference vector, $f = (f_1, \ldots, f_n)$, *oi* same length as said signal vector of reference weights. The correlation measure A is then given by

$$A = \boldsymbol{f} \cdot \boldsymbol{I} = \sum_{i=1}^{n} f_i I_i$$

The indices on the elements in the signal vector represent sensor signals that are recorded at different times and/or at different sensors. In the case of a continuous measurement the above expression is easily generalized to involve integration in place of the summation. In that case the integration parameter is time and/or one or more spatial coordinates.

A preferred embodiment is to remove the DC part of the correlation signal or correlation measure, i.e., when the reference vector elements sums to zero ($\sum_{i=1}^{n} f_i = 0$). The focus position can be found as an extremum of the correlation measure computed over all focus element positions. We note that in this case the correlation measure is proportional to the sample Pearson correlation coefficient between two variables. If the

DC part is not removed, there may exist a trend in DC signal over all focus element positions, and this trend can be dominating numerically. In this situation, the focus position may still be found by analysis of the correlation measure and/or one or more of its derivatives, preferably after trend removal.

Preferably, the global extremum should be found. However, artifacts such as dirt on the optical system can result in false global maxima. Therefore, it can be advisable to look for local extrema in some cases. If the object being scanned is sufficiently translucent it may be possible to identify interior surfaces or surface parts that are otherwise occluded. In such cases there may be several local extrema that corresponds to surfaces and it may be advantageous to process several or all extrema.

The correlation measure can typically be computed based on input signals that are available as digital images, i.e., images with a finite number of discrete pixels. Therefore conveniently, the calculations for obtaining correlation measures can be performed for image pixels or groups thereof. Correlation measures can then be visualized in as pseudo-images.

The correlation measure applied in this invention is inspired by the principle of a lock-in amplifier, in which the input signal is multiplied by the reference signal and integrated over a specified time. In this invention, a reference signal is provided by the pattern.

Temporal correlation

Temporal correlation involves a time-varying pattern. The light signal in the individual light sensing elements in the camera is recorded several times while the pattern configuration is varied. The correlation measure is thus at least computed with sensor signals recorded at different times.

A principle to estimate light oscillation amplitude in a periodically varying light signal is taught in WO 98/45745 where the amplitude is calculated by first estimating a cosine and a sinusoidal part of the light intensity oscillation. However, from a statistical point of view this is not optimal because two parameters are estimated to be able to calculate the amplitude.

In this embodiment of the invention independent knowledge of the pattern configuration at each light signal recording allows for calculating the correlation measure at each light sensing element.

In some embodiments of the invention the scanner comprises means for obtaining knowledge of the pattern configuration. To provide such knowledge the scanner preferably further comprises means for registering and/or monitoring the time varying pattern.

Each individual light sensing element, i.e. sensor element, in the camera sees a variation in the light signal corresponding to the variation of the light illuminating the object.

One embodiment of the invention obtains the time variation of the pattern by translating and/or rotating the pattern element. In this case the pattern configuration may be obtained by means of a position encoder on the pattern element combined with prior knowledge of the pattern geometry that gives rise to a pattern variation across individual sensing elements. Knowledge of the pattern configuration thus arises as a combination of knowledge of the pattern geometry that results in a variation across different sensing elements and pattern registration and/or monitoring during the 3D scan. In case of a rotating wheel as the pattern element the angular position of the wheel may then be obtained by an encoder, e.g. mounted on the rim.

One embodiment of the invention involves a pattern that possesses translational and/or rotational periodicity. In this embodiment there is a well-defined pattern oscillation period if the pattern is substantially translated and/or rotated at a constant speed.

One embodiment of the invention comprises means for sampling each of a plurality of the sensor elements a plurality of times during one pattern oscillation period, preferably sampled an integer number of times, such as sampling 2, 3, 4, 5, 6, 7 or 8 times during each pattern oscillation period, thereby determining the light variation during a period.

The temporal correlation measure between the light variation and the pattern can be obtained by recording several images on the camera during one oscillation period (or at least one oscillation period). The number of images recorded during one oscillation