UNITED STATES PATENT AND TRADEMARK OFFICE

UNITED STATES DEPARTMENT OF COMMERCE
United States Patent and Trademark Office
Address: COMMISSIONER FOR PATENTS
P.O. Box 1450
Alexandria, Virginia 22313-1450
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APPLICATION NO.	ISSUE DATE	PATENT NO.	ATTORNEY DOCKET NO.	CONFIRMATION NO.
14/386,823	01/03/2017	9538152	COREPH-0072 US NP	1857

92342 7590 12/14/2016

Nathan & Associates Patent Agents Ltd
P.O.Box 10178
Tel Aviv, 6110101
ISRAEL

ISSUE NOTIFICATION

The projected patent number and issue date are specified above.

Determination of Patent Term Adjustment under 35 U.S.C. 154 (b)
(application filed on or after May 29, 2000)

The Patent Term Adjustment is 177 day(s). Any patent to issue from the above-identified application will include an indication of the adjustment on the front page.

If a Continued Prosecution Application (CPA) was filed in the above-identified application, the filing date that determines Patent Term Adjustment is the filing date of the most recent CPA.

Applicant will be able to obtain more detailed information by accessing the Patent Application Information Retrieval (PAIR) WEB site (http://pair.uspto.gov).

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):

Gal Shabtay, Tel-Aviv, ISRAEL;
Corephotonics Ltd., Tel-Aviv, ISRAEL;
Noy Cohen, Tel-Aviv, ISRAEL;
Oded Gigushinski, Herzlia, ISRAEL;
Ephraim Goldenberg, Ashdod, ISRAEL;

PART B - FEE(S) TRANSMITTAL

Complete and send this form, together with applicable fee(s), to: Mail **Mail Stop ISSUE FEE**
Commissioner for Patents
P.O. Box 1450
Alexandria, Virginia 22313-1450
or Fax (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)

92342 7590 11/25/2016

Nathan & Associates Patent Agents Ltd
P.O.Box 10178
Tel Aviv, 6110101
ISRAEL

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 facsimile transmitted to the USPTO (571) 273-2885, on the date indicated below.

(Depositor's name)

(Signature)

(Date)

APPLICATION NO.	FILING DATE	FIRST NAMED INVENTOR	ATTORNEY DOCKET NO.	CONFIRMATION NO.
14/386,823	09/22/2014	Gal Shabtay	COREPH-0072 US NP	1857

TITLE OF INVENTION: HIGH RESOLUTION THIN MULTI-APERTURE IMAGING SYSTEMS

APPLN. TYPE	ENTITY STATUS	ISSUE FEE DUE	PUBLICATION FEE DUE	PREV. PAID ISSUE FEE	TOTAL FEE(S) DUE	DATE DUE
nonprovisional	SMALL	$480	$0	$0	$480	02/27/2017

EXAMINER	ART UNIT	CLASS-SUBCLASS
COWAN, EUEL K	2664	348-336000

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 03-02 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 Nathan & Associates Patent Agents Ltd
   2 Menachem Nathan
   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 has been filed for recordation as set forth in 37 CFR 3.11. Completion of this form is NOT a substitute for filing an assignment.

(A) NAME OF ASSIGNEE: Corephotonics Ltd.

(B) RESIDENCE: (CITY and STATE OR COUNTRY): Tel Aviv, Israel

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

4a. The following fee(s) are submitted:
- ☒ Issue Fee
- ☐ Publication Fee (No small entity discount permitted)
- ☐ Advance Order - # of Copies ____________

4b. Payment of Fee(s): **(Please first reapply any previously paid issue fee shown above)**
- ☐ A check is enclosed.
- ☒ Payment by credit card. ~~Form PTO-2038 is attached.~~ Via EFS-Web
- ☐ The director is hereby authorized to charge the required fee(s), any deficiency, or credits any overpayment, to Deposit Account Number ____________ (enclose an extra copy of this form).

5. **Change in Entity Status** (from status indicated above)
- ☐ Applicant certifying micro entity status. See 37 CFR 1.29 — 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.
- ☐ Applicant asserting small entity status. See 37 CFR 1.27 — 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.
- ☐ Applicant changing to regular undiscounted fee 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 / Menachem Nathan / Date 11/27/2016

Typed or printed name MENACHEM NATHAN Registration No. 65392

PTOL-85 Part B (10-13) Approved for use through 10/31/2013. OMB 0651-0033 U.S. Patent and Trademark Office; U.S. DEPARTMENT OF COMMERCE

Electronic Patent Application Fee Transmittal

Application Number:	14386823
Filing Date:	22-Sep-2014
Title of Invention:	HIGH RESOLUTION THIN MULTI-APERTURE IMAGING SYSTEMS
First Named Inventor/Applicant Name:	Gal Shabtay
Filer:	Menachem Nathan
Attorney Docket Number:	COREPH-0072 US NP

Filed as Small Entity

Filing Fees for U.S. National Stage under 35 USC 371

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:				
UTILITY APPL ISSUE FEE	2501	1	480	480

Description	Fee Code	Quantity	Amount	Sub-Total in USD($)
Extension-of-Time:				
Miscellaneous:				
		Total in USD ($)		**480**

Electronic Acknowledgement Receipt

EFS ID:	27614373
Application Number:	14386823
International Application Number:	
Confirmation Number:	1857
Title of Invention:	HIGH RESOLUTION THIN MULTI-APERTURE IMAGING SYSTEMS
First Named Inventor/Applicant Name:	Gal Shabtay
Customer Number:	92342
Filer:	Menachem Nathan
Filer Authorized By:	
Attorney Docket Number:	COREPH-0072 US NP
Receipt Date:	27-NOV-2016
Filing Date:	22-SEP-2014
Time Stamp:	05:02:42
Application Type:	U.S. National Stage under 35 USC 371

Payment information:

Submitted with Payment	yes
Payment Type	CARD
Payment was successfully received in RAM	$480
RAM confirmation Number	112816INTEFSW05041400
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.pdf	1332483 0dd9b13abbc86ac98cbe479c6546768c43b339fc	no	1
Warnings:					
Information:					
2	Fee Worksheet (SB06)	fee-info.pdf	30142 022d1109d0a580b63b5f980274233a051151ce6d	no	2
Warnings:					
Information:					
			Total Files Size (in bytes):	1362625	

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.

UNITED STATES PATENT AND TRADEMARK OFFICE

UNITED STATES DEPARTMENT OF COMMERCE
United States Patent and Trademark Office
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www.uspto.gov

NOTICE OF ALLOWANCE AND FEE(S) DUE

92342 7590 11/25/2016

Nathan & Associates Patent Agents Ltd
P.O.Box 10178
Tel Aviv, 6110101
ISRAEL

EXAMINER	
COWAN, EUEL K	
ART UNIT	PAPER NUMBER
2664	

DATE MAILED: 11/25/2016

APPLICATION NO.	FILING DATE	FIRST NAMED INVENTOR	ATTORNEY DOCKET NO.	CONFIRMATION NO.
14/386,823	09/22/2014	Gal Shabtay	COREPH-0072 US NP	1857

TITLE OF INVENTION: HIGH RESOLUTION THIN MULTI-APERTURE IMAGING SYSTEMS

APPLN. TYPE	ENTITY STATUS	ISSUE FEE DUE	PUBLICATION FEE DUE	PREV. PAID ISSUE FEE	TOTAL FEE(S) DUE	DATE DUE
nonprovisional	SMALL	$480	$0	$0	$480	02/27/2017

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: Utility patents issuing on applications filed on or after Dec. 12, 1980 may require payment of maintenance fees. It is patentee's responsibility to ensure timely payment of maintenance fees when due.

PART B - FEE(S) TRANSMITTAL

Complete and send this form, together with applicable fee(s), to: Mail **Mail Stop ISSUE FEE**
Commissioner for Patents
P.O. Box 1450
Alexandria, Virginia 22313-1450
or Fax (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)

92342 7590 11/25/2016

Nathan & Associates Patent Agents Ltd
P.O.Box 10178
Tel Aviv, 6110101
ISRAEL

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 facsimile transmitted to the USPTO (571) 273-2885, on the date indicated below.

(Depositor's name)
(Signature)
(Date)

APPLICATION NO.	FILING DATE	FIRST NAMED INVENTOR	ATTORNEY DOCKET NO.	CONFIRMATION NO.
14/386,823	09/22/2014	Gal Shabtay	COREPH-0072 US NP	1857

TITLE OF INVENTION: HIGH RESOLUTION THIN MULTI-APERTURE IMAGING SYSTEMS

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nonprovisional	SMALL	$480	$0	$0	$480	02/27/2017

EXAMINER	ART UNIT	CLASS-SUBCLASS
COWAN, EUEL K	2664	348-336000

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 03-02 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____________________
   2____________________
   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 has been filed for recordation as set forth in 37 CFR 3.11. Completion of this form is NOT a substitute for filing an assignment.

(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. The following fee(s) are submitted:
- ❑ Issue Fee
- ❑ Publication Fee (No small entity discount permitted)
- ❑ Advance Order - # of Copies ________________

4b. Payment of Fee(s): **(Please first reapply any previously paid issue fee shown above)**
- ❑ A check is enclosed.
- ❑ Payment by credit card. Form PTO-2038 is attached.
- ❑ The director is hereby authorized to charge the required fee(s), any deficiency, or credits any overpayment, to Deposit Account Number __________ (enclose an extra copy of this form).

5. **Change in Entity Status** (from status indicated above)
- ❑ Applicant certifying micro entity status. See 37 CFR 1.29

  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.
- ❑ Applicant asserting small entity status. See 37 CFR 1.27

  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.
- ❑ Applicant changing to regular undiscounted fee 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 ____________________ Date ____________________

Typed or printed name ____________________ Registration No. ____________________

UNITED STATES PATENT AND TRADEMARK OFFICE

UNITED STATES DEPARTMENT OF COMMERCE
United States Patent and Trademark Office
Address: COMMISSIONER FOR PATENTS
P.O. Box 1450
Alexandria, Virginia 22313-1450
www.uspto.gov

APPLICATION NO.	FILING DATE	FIRST NAMED INVENTOR	ATTORNEY DOCKET NO.	CONFIRMATION NO.
14/386,823	09/22/2014	Gal Shabtay	COREPH-0072 US NP	1857

92342 7590 11/25/2016

Nathan & Associates Patent Agents Ltd
P.O.Box 10178
Tel Aviv, 6110101
ISRAEL

EXAMINER	
COWAN, EUEL K	
ART UNIT	**PAPER NUMBER**
2664	

DATE MAILED: 11/25/2016

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

(Applications filed on or after May 29, 2000)

The Office has discontinued providing a Patent Term Adjustment (PTA) calculation with the Notice of Allowance.

Section 1(h)(2) of the AIA Technical Corrections Act amended 35 U.S.C. 154(b)(3)(B)(i) to eliminate the requirement that the Office provide a patent term adjustment determination with the notice of allowance. See Revisions to Patent Term Adjustment, 78 Fed. Reg. 19416, 19417 (Apr. 1, 2013). Therefore, the Office is no longer providing an initial patent term adjustment determination with the notice of allowance. The Office will continue to provide a patent term adjustment determination with the Issue Notification Letter that is mailed to applicant approximately three weeks prior to the issue date of the patent, and will include the patent term adjustment on the patent. Any request for reconsideration of the patent term adjustment determination (or reinstatement of patent term adjustment) should follow the process outlined in 37 CFR 1.705.

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.

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 12 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. 14/386,823	Applicant(s) SHABTAY ET AL.	
	Examiner EUEL COWAN	Art Unit 2664	AIA (First Inventor to File) 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 *interview on 11/10/2016*.
   ☐ 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 *44, 53, 62 & 63*. 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. ______ .
   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 _____
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 _____.

/AUNG S. MOE/ Primary Examiner, Art Unit 2664	/EUEL COWAN/ Examiner, Art Unit 2664

DETAILED ACTION

Examiner's Amendment

1. An examiner's amendment to the record appears below. Should the changes and/or additions be unacceptable to applicant, an amendment may be filed as provided by 37 CFR 1.312. To ensure consideration of such an amendment, it MUST be submitted no later than the payment of the issue fee.

Authorization for this examiner's amendment was given in an interview with Menachem Nathan on 11/10/2016.

The application has been amended as follows:

Delete claims 1, 4, 10, 13, 45-51, & 54-60.

Claim 44. (Currently amended) A multi-aperture imaging system comprising:

a) a first camera ~~subset~~ that provides a first image, the first camera ~~subset~~ having a first field of view (FOV_1) and a first sensor with a first plurality of sensor pixels covered at least in part with a standard color filter array (CFA);

b) a second camera ~~subset~~ that provides a second image, the second camera ~~subset~~ having a second field of view (FOV_2) such that $FOV_2 < FOV_1$ and a second sensor with a second plurality of sensor pixels, the second plurality of sensor pixels being either Clear or covered with a standard CFA, the second image having an overlap area with the first image; and

c) a processor configured to provide an output image from a point of view of ~~either~~ the first ~~or the second~~ camera ~~subset~~ based on a zoom factor (ZF) input that defines a respective field of view (FOV_{ZF}), the first image being a primary image and the second image being a non-primary image, wherein if $FOV_2 < FOV_{ZF} < FOV_1$ then the point of view of the output image is that of the first camera, the processor further configured to register the overlap area of the second image as non-primary image to the first image as primary image to obtain the output image.

Claim 53. (Currently amended) A method of acquiring images by a multi-aperture imaging system, the method comprising:

a) providing a first image generated by a first camera ~~subset~~ of the imaging system, the first camera ~~subset~~ having a first field of view (FOV_1) and a first sensor with a first plurality of sensor pixels covered at least in part with a standard color filter array (CFA);

b) providing a second image generated by a second camera ~~subset~~ of the imaging system, the second camera ~~subset~~ having a second field of view (FOV_2) such that $FOV_2 < FOV_1$ and a second sensor with a second plurality of sensor pixels, the second plurality of sensor pixels being either Clear or covered with a standard CFA, the second image having an overlap area with the first image; ~~and~~

c) using a processor ~~for generating~~ to provide an output image from a point of view of ~~either~~ the first ~~or the second~~ camera ~~subset~~ based on a zoom factor (ZF) input that defines a respective field of view (FOV_{ZF}), the first image being a primary image and the second image being a non-primary image, wherein if $FOV_2 < FOV_{ZF} < FOV_1$ then the point of view of the output image is that of the first camera; and

d) using the processor to register the overlap area of the second image as non-primary image to the first image as primary image to obtain the output image.

Claim 62. (New) The multi-aperture imaging system of claim 44, wherein, if $FOV_2 \geq FOV_{ZF}$, then the processor is further configured to provide an output image from a point of view of the second camera.

Claim 63. (New) The method of claim 53, further comprising, if $FOV_2 \geq FOV_{ZF}$, using the processor to provide an output image from a point of view of the second camera.

Allowable Subject Matter

2. Claims 44, 53, 62 & 63 are allowed.
3. The following is an examiner's statement of reasons for allowance: The prior art teaches switching the point of view from different cameras or sensors based on an adjusted zoom level and also fusing images. It does not explicitly teach or suggest a relationship of the zoom factor to a first and second FOV that dictates which

corresponding image is used as the primary image when the images are fused, in conjunction with other elements.

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."

Conclusion

Any inquiry concerning this communication or earlier communications from the examiner should be directed to EUEL COWAN whose telephone number is (571)270-5093. The examiner can normally be reached on Mon. - Thur: 8am - 5pm est.

If attempts to reach the examiner by telephone are unsuccessful, the examiner's supervisor, Lin Ye can be reached on 571 272 7372. 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 http://pair-direct.uspto.gov. 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.

/EUEL COWAN/
Examiner, Art Unit 2664

/AUNG S. MOE/
Primary Examiner, Art Unit 2664

Examiner-Initiated Interview Summary	**Application No.** 14/386,823	**Applicant(s)** SHABTAY ET AL.	
	Examiner EUEL COWAN	**Art Unit** 2664	

All participants (applicant, applicant's representative, PTO personnel):

(1) *EUEL COWAN*. (3)______.

(2) *Menachem Nathan*. (4)______.

Date of Interview: *10 November 2016*.

Type: ☒ Telephonic ☐ Video Conference
☐ Personal [copy given to: ☐ applicant ☐ applicant's representative]

Exhibit shown or demonstration conducted: ☐ Yes ☒ No.
If Yes, brief description: ______.

Issues Discussed ☐101 ☐112 ☐102 ☒103 ☒Others
(For each of the checked box(es) above, please describe below the issue and detailed description of the discussion)

Claim(s) discussed: *1,44 and 53*.

Identification of prior art discussed: *Border, US 2008/0218612 & Williams, US 2013/0141525*.

Substance of Interview
(For each issue discussed, provide a detailed description and indicate if agreement was reached. Some topics may include: identification or clarification of a reference or a portion thereof, claim interpretation, proposed amendments, arguments of any applied references etc...)

Applicant agreed to make amendments to claims 1, 44 & 53 to inlcude the relationship of the zoom factor to the first and second field of view that dictates at least the switching of the point of view, via Examiner's Amendment in order to issue the case.

Applicant recordation instructions: It is not necessary for applicant to provide a separate record of the substance of interview.

Examiner recordation instructions: Examiners must summarize the substance of any interview of record. A complete and proper recordation of the substance of an interview should include the items listed in MPEP 713.04 for complete and proper recordation including the identification of the general thrust of each argument or issue discussed, a general indication of any other pertinent matters discussed regarding patentability and the general results or outcome of the interview, to include an indication as to whether or not agreement was reached on the issues raised.

☐ Attachment

/EUEL COWAN/
Examiner, Art Unit 2664

Search Notes	Application/Control No.	Applicant(s)/Patent Under Reexamination
	14386823	SHABTAY ET AL.
	Examiner	Art Unit
	EUEL COWAN	2664

CPC- SEARCHED

Symbol	Date	Examiner

CPC COMBINATION SETS - SEARCHED

Symbol	Date	Examiner
G06T2207/10004, G06T2207/20212, H04N7/00, H04N5/04, H04N5/2258, H04N5/2259, H04N5/23216, H04N5/23229, H04N5/23296 , HO4N9/735, HO4N5/2258, HO4N5/23232, HO4N5/23296, HO4N9/045	11/10/2016	Euel Cowan

US CLASSIFICATION SEARCHED

Class	Subclass	Date	Examiner
348	348/211.9,211.11,240.99-240.3,237,267,273-280,350,376	11/10/2016	Euel Cowan
396	72,76,77	11/10/2016	Euel Cowan

SEARCH NOTES

Search Notes	Date	Examiner
text limited search in the following US class/subclass: 348/240.99-240.3,237,267,273-280,350,376.	5/10/2016	Euel Cowan
text limited search in the following CPC group: G08B13/19689| G08B13/1963| G06T2207/20221| B60R2300/304	5/10/2016	Euel Cowan
inventor search	5/10/2016	Euel Cowan
text search in 348/211.9,211.11,240.99-240.3,237,267,273-280,350,376 & 396/72,76,77	11/10/2016	Euel Cowan
text search in G06T2207/10004, G06T2207/20212, H04N7/00, H04N5/04, H04N5/2258, H04N5/2259, H04N5/23216, H04N5/23229, H04N5/23296 , HO4N9/735, HO4N5/2258, HO4N5/23232, HO4N5/23296, HO4N9/045	11/10/2016	Euel Cowan
inventor search	11/10/2016	Euel Cowan

INTERFERENCE SEARCH			
US Class/ CPC Symbol	**US Subclass / CPC Group**	**Date**	**Examiner**
All	PG Pub text search	11/10/2016	Euel Cowan

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BIB DATA SHEET

CONFIRMATION NO. 1857

SERIAL NUMBER	FILING or 371(c) DATE	CLASS	GROUP ART UNIT	ATTORNEY DOCKET NO.
14/386,823	09/22/2014 RULE	348	2664	COREPH-0072 US NP

APPLICANTS
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Oded Gigushinski, Herzlia, ISRAEL;
Ephraim Goldenberg, Ashdod, ISRAEL;

** **CONTINUING DATA** *************************
This application is a 371 of PCT/IB2013/060356 11/23/2013
which claims benefit of 61/730,570 11/28/2012

** **FOREIGN APPLICATIONS** *************************

** **IF REQUIRED, FOREIGN FILING LICENSE GRANTED** ** ** SMALL ENTITY **
12/15/2014

Foreign Priority claimed ☑ Yes ☐ No 35 USC 119(a-d) conditions met ☑ Yes ☐ No Verified and Acknowledged /EUEL K COWAN/ Examiner's Signature	☐ Met after Allowance Initials	STATE OR COUNTRY	SHEETS DRAWINGS	TOTAL CLAIMS	INDEPENDENT CLAIMS
		ISRAEL	7	16	3

ADDRESS

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TITLE

HIGH RESOLUTION THIN MULTI-APERTURE IMAGING SYSTEMS

FILING FEE RECEIVED	FEES	
850	FEES: Authority has been given in Paper No.____________ to charge/credit DEPOSIT ACCOUNT No.____________ for following:	☐ All Fees ☐ 1.16 Fees (Filing) ☐ 1.17 Fees (Processing Ext. of time) ☐ 1.18 Fees (Issue) ☐ Other ________________ ☐ Credit

BIB (Rev. 05/07).

EAST Search History

EAST Search History (Prior Art)

Ref #	Hits	Search Query	DBs	Default Operator	Plurals	Time Stamp
L3	408	("3" or "4" or "5" or "2") & (switch$3 or choos$3 or select$3 or chosen or designat$3 or chang$3) near4 (image or sensor or camera or region or array) with zoom factor	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	ADJ	ON	2016/11/11 11:30
L4	163	"7" AND ((H04N5/2258 OR H04N5/23296).CPC. AND (348/262 OR 348/E5.028).CCLS.)	US-PGPUB; USPAT; USOCR	ADJ	ON	2016/11/11 11:30
S1	1	14/386823	US-PGPUB; USPAT; USOCR	ADJ	ON	2016/04/11 09:52
S2	17	("20080030592" | "20100277619" | "20110064327" | "20110121421" | "20110285730" | "20110292258" | "7305180" | "7561191" | "7676146" | "8094208" | "8134115" | "8149327" | "8179457" | "8439265" | "8542287" | "8553106" | "8660420").PN.	US-PGPUB; USPAT; USOCR	ADJ	ON	2016/04/17 21:36
S3	0	(HO4N9/735 OR HO4N5/2258 OR HO4N5/23232 OR HO4N5/23296 OR HO4N9/045 OR HO4N9/097 OR HO4N2209/045).CPC.	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	ADJ	ON	2016/04/17 22:31
S4	0	(HO4N9/735 OR HO4N5/2258 OR HO4N5/23232 OR HO4N5/23296 OR HO4N9/045 OR HO4N9/097).CPC.	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	ADJ	ON	2016/05/03 11:01
S5	6686	348/240.99-240.3,237,267,273-280,350,376.ccls.	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	ADJ	ON	2016/05/03 11:06
S6	1	14/386823 & bbrr	US-PGPUB; USPAT; USOCR	ADJ	ON	2016/05/05 14:21
S7	17	("20080030592" | "20100277619" | "20110064327" | "20110121421" | "20110285730" | "20110292258" | "7305180" | "7561191" | "7676146" | "8094208" | "8134115" | "8149327" | "8179457" | "8439265" | "8542287" |	US-PGPUB; USPAT; USOCR	ADJ	ON	2016/05/06 08:37

		"8553106" | "8660420").PN.				
S9	0	S7 & (request$3 or chang$3 or $2creas$3) near3 zoom same (first or second) camera	US-PGPUB; USPAT; USOCR	ADJ	ON	2016/05/06 08:39
S10	1	14/283957	US-PGPUB; USPAT; USOCR	ADJ	ON	2016/05/06 15:24
S11	17	("20080030592" | "20100277619" | "20110064327" | "20110121421" | "20110285730" | "20110292258" | "7305180" | "7561191" | "7676146" | "8094208" | "8134115" | "8149327" | "8179457" | "8439265" | "8542287" | "8553106" | "8660420").PN.	US-PGPUB; USPAT; USOCR	ADJ	ON	2016/05/06 16:44
S12	6	S11 & (request$3 or chang$3 or $2creas$3) near3 zoom	US-PGPUB; USPAT; USOCR	ADJ	ON	2016/05/06 16:44
S13	17	("20080030592" | "20100277619" | "20110064327" | "20110121421" | "20110285730" | "20110292258" | "7305180" | "7561191" | "7676146" | "8094208" | "8134115" | "8149327" | "8179457" | "8439265" | "8542287" | "8553106" | "8660420").PN.	US-PGPUB; USPAT; USOCR	ADJ	ON	2016/05/07 15:43
S14	10	S13 & (request$3 or chang$3 or $2creas$3 or select$3) near5 (focal length or zoom)	US-PGPUB; USPAT; USOCR	ADJ	ON	2016/05/07 15:43
S15	17	("20080030592" | "20100277619" | "20110064327" | "20110121421" | "20110285730" | "20110292258" | "7305180" | "7561191" | "7676146" | "8094208" | "8134115" | "8149327" | "8179457" | "8439265" | "8542287" | "8553106" | "8660420").PN.	US-PGPUB; USPAT; USOCR	ADJ	ON	2016/05/07 20:14
S16	3	S15 & (register$3 or registration) near5 pixel	US-PGPUB; USPAT; USOCR	ADJ	ON	2016/05/07 20:14
S17	8818	(switch$3 or chang$3) near4 (camera or sensor or point near3 view) with (focal length or zoom$3)	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	ADJ	ON	2016/11/09 09:42
S18	721	(switch$3 or chang$3) near4 (first or second or top or bottom or left or right or wide or tele) near4 (camera or sensor or point near3 view) with (focal length or zoom$3)	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	ADJ	ON	2016/11/09 09:43
S19	446	S18 & ("348" or "396").clas.	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	ADJ	ON	2016/11/09 09:45
S20	0	S19 and camera with subarray	US-PGPUB; USPAT;	ADJ	ON	2016/11/09 09:48

			USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB			
S21	6	S19 and (sensor or camera) with (sub(array or region or camera) or (second or two) (regions or array or section))	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	ADJ	ON	2016/11/09 09:54
S22	86	S19 AND (G06T2207/10004 OR G06T2207/20212 OR H04N7/00 OR H04N5/04 OR H04N5/2258 OR H04N5/2259 OR H04N5/23216 OR H04N5/23229 OR H04N5/23296 or HO4N9/735 OR HO4N5/2258 OR HO4N5/23232 OR HO4N5/23296 OR HO4N9/045 OR HO4N9/097 OR HO4N2209/045).CPC.	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	ADJ	ON	2016/11/09 10:44
S23	409	(switch$3 or chang$3) near4 (first or second or top or bottom or left or right or wide or tele) near4 (switch$3 or chang$3) near4 (camera or sensor or point near3 view) with (focal length or zoom$3)	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	ADJ	ON	2016/11/09 10:45
S24	718	(switch$3 or chang$3) near4 (first or second or top or bottom or left or right or wide or tele) with (switch$3 or chang$3) near4 (camera or sensor or point near3 view) with (focal length or zoom$3)	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	ADJ	ON	2016/11/09 10:45
S25	602	(switch$3 or chang$3) near4 (first or second or top or bottom or left or right or wide or tele) with (switch$3 or chang$3 or adjust$3) near3 (camera or sensor or point near3 view) with (focal length or zoom$3)	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	ADJ	ON	2016/11/09 10:47
S26	75	S25 AND (G06T2207/10004 OR G06T2207/20212 OR H04N7/00 OR H04N5/04 OR H04N5/2258 OR H04N5/2259 OR H04N5/23216 OR H04N5/23229 OR H04N5/23296 or HO4N9/735 OR HO4N5/2258 OR HO4N5/23232 OR HO4N5/23296 OR HO4N9/045 OR HO4N9/097 OR HO4N2209/045).CPC.	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	ADJ	ON	2016/11/09 10:47
S27	602	(switch$3 or chang$3) near4 (first or second or top or bottom or left or right or wide or tele) with (switch$3 or chang$3 or adjust$3) near3 (camera or sensor or point near3 view) with (focal length or zoom$3)	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	ADJ	ON	2016/11/09 13:47
S28	0	S27 and (switch$3 or chang$3 or choos$3 or chosen) near3 primary (image or sensor)	US-PGPUB; USPAT; USOCR;	ADJ	ON	2016/11/09 13:47

			FPRS; EPO; JPO; DERWENT; IBM_TDB			
S29	313	(switch$3 or chang$3 or choos$3 or chosen) near4 (first or second or top or bottom or left or right or wide or tele) near3 (sensor or camera) with (switch$3 or chang$3 or adjust$3) near4 (focal length or zoom$3)	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	ADJ	ON	2016/11/09 14:12
S30	320	(switch$3 or chang$3 or choos$3 or chosen) near4 (first or second or top or bottom or left or right or wide or tele) near3 (sensor or camera) with (switch$3 or chang$3 or adjust$3 or choos$3 or select$3) near4 (focal length or zoom$3)	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	ADJ	ON	2016/11/09 14:15
S31	0	S30 & (first or second or top or bottom or left or right or wide or tele) near3 primary near3 (iamge or sensor or camera) with (switch$3 or chang$3 or adjust$3 or choos$3) near4 (focal length or zoom$3)	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	ADJ	ON	2016/11/09 14:16
S32	2	S30 & (first or second or top or bottom or left or right or wide or tele) near3 (main or primary) near3 (iamge or sensor or camera) with (switch$3 or chang$3 or adjust$3 or choos$3) near4 (focal length or zoom$3)	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	ADJ	ON	2016/11/09 14:19
S33	17060	(sensor or camera) with (sub(array or region or camera) or (second or two) (regions or array or section))	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	ADJ	ON	2016/11/09 14:22
S34	1	S33 & (switch$3 or choos$3 or select$3 or chosen or designat$3) near4 (main or primary) near3 (image or sensor or camera) with (switch$3 or chang$3 or adjust$3 or choos$3) near4 (focal length or zoom$3)	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	ADJ	ON	2016/11/09 14:24
S35	1	S33 & (switch$3 or choos$3 or select$3 or chosen or designat$3) near4 (main or primary) near3 (image or sensor or camera or region or array) with (switch$3 or chang$3 or adjust$3 or choos$3) near4 (focal length or zoom$3)	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	ADJ	ON	2016/11/09 14:25
S36	165	(switch$3 or choos$3 or select$3 or chosen or designat$3) near3 (main or primary) near3 (image or sensor or camera or region or array) with (switch$3 or chang$3 or adjust$3 or choos$3) near3 (focal length or zoom$3)	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	ADJ	ON	2016/11/09 14:42
S37	42	S36 and (fus$3 or combin$3 or	US-PGPUB;	ADJ	ON	2016/11/09

		synthesiz$3)	USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB			14:44
S38	9	S36 and (fus$3 or combin$3 or synthesiz$3) near3 image	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	ADJ	ON	2016/11/09 14:44
S39	165	(switch$3 or choos$3 or select$3 or chosen or designat$3) near3 (main or primary) near3 (image or sensor or camera or region or array) with (switch$3 or chang$3 or adjust$3 or choos$3) near3 (focal length or zoom$3)	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	ADJ	ON	2016/11/10 12:31
S40	17	("20080030592" | "20100277619" | "20110064327" | "20110121421" | "20110285730" | "20110292258" | "7305180" | "7561191" | "7676146" | "8094208" | "8134115" | "8149327" | "8179457" | "8439265" | "8542287" | "8553106" | "8660420").PN.	US-PGPUB; USPAT; USOCR	ADJ	ON	2016/11/10 12:31
S43	8	S39 AND (348/211.9,211.11,240.99-240.3,237,267,273-280,350,376.ccls. or (G06T2207/10004 OR G06T2207/20212 OR H04N7/00 OR H04N5/04 OR H04N5/2258 OR H04N5/2259 OR H04N5/23216 OR H04N5/23229 OR H04N5/23296 or HO4N9/735 OR HO4N5/2258 OR HO4N5/23232 OR HO4N5/23296 OR HO4N9/045 OR HO4N9/097 OR HO4N2209/045).CPC.)	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	ADJ	ON	2016/11/10 12:33
S44	69	(("SHABTAY") near3 ("Gal")).INV.	US-PGPUB; USPAT; USOCR	ADJ	ON	2016/11/10 14:01
S45	39	(("COHEN") near3 ("Noy")).INV.	US-PGPUB; USPAT; USOCR	ADJ	ON	2016/11/10 14:01
S46	10	(("GIGUSHINSKI") near3 ("Oded")).INV.	US-PGPUB; USPAT; USOCR	ADJ	ON	2016/11/10 14:01
S47	55	(("GOLDENBERG") near3 ("Ephraim")).INV.	US-PGPUB; USPAT; USOCR	ADJ	ON	2016/11/10 14:01
S48	165	(switch$3 or choos$3 or select$3 or chosen or designat$3) near3 (main or primary) near3 (image or sensor or camera or region or array) with (switch$3 or chang$3 or adjust$3 or choos$3) near3 (focal length or zoom$3)	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	ADJ	ON	2016/11/10 14:32
S49	17	S48 AND ((348/211.9,211.11,240.99-240.3,237,267,273-280,350,376 396/72,76,77).ccls. or (G06T2207/10004 OR G06T2207/20212 OR H04N7/00 OR	US-PGPUB; USPAT; USOCR; FPRS;	ADJ	ON	2016/11/10 14:32

		H04N5/04 OR H04N5/2258 OR H04N5/2259 OR H04N5/23216 OR H04N5/23229 OR H04N5/23296 or HO4N9/735 OR HO4N5/2258 OR HO4N5/23232 OR HO4N5/23296 OR HO4N9/045 OR HO4N9/097 OR HO4N2209/045).CPC.)	EPO; JPO; DERWENT; IBM_TDB			
S50	0	(S45 or S46 or S47 or S44) & (switch$3 or choos$3 or select$3 or chosen or designat$3) near3 (main or primary) near3 (image or sensor or camera or region or array) with (switch$3 or chang$3 or adjust$3 or choos$3) near3 (focal length or zoom$3)	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	ADJ	ON	2016/11/10 14:34
S51	14	(S45 or S46 or S47 or S44) & (switch$3 or choos$3 or select$3 or chosen or designat$3 or chang$3) near4 (image or sensor or camera or region or array) with (switch$3 or chang$3 or adjust$3 or choos$3) near3 (focal length or zoom$3)	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	ADJ	ON	2016/11/10 14:35
S52	5	(S45 or S46 or S47 or S44) & (switch$3 or choos$3 or select$3 or chosen or designat$3 or chang$3) near4 (image or sensor or camera or region or array) same point near3 view	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	ADJ	ON	2016/11/10 14:36

EAST Search History (Interference)

Ref #	Hits	Search Query	DBs	Default Operator	Plurals	Time Stamp
S53	0	((switch$3 or choos$3 or select$3 or chosen or designat$3 or chang$3) and (image or sensor or camera or region or array) same point near3 view and first and second and sub(set or aray or imager) and (cfa or color filter) and camera and sensor and pixel and clear and processor and output and image and less than and more than near4 zoom and primary image and overlap$4 and (region or area or section) and (fus$ or join$3 or synthesiz$3 or combin$3)).clm.	US-PGPUB; USPAT	ADJ	ON	2016/11/10 14:40

11/11/2016 11:31:34 AM
C:\Users\ecowan\Documents\EAST\Workspaces\14386823a.wsp

Issue Classification	Application/Control No.	Applicant(s)/Patent Under Reexamination
	14386823	SHABTAY ET AL.
	Examiner	**Art Unit**
	EUEL COWAN	2664

CPC					
Symbol				**Type**	**Version**
H04N	9	/	735	F	2013-01-01
H04N	5	/	2258	I	2013-01-01
H04N	5	/	23232	I	2013-01-01
H04N	9	/	045	I	2013-01-01
H04N	2209	/	045	A	2013-01-01
H04N	5	/	23296	I	2013-01-01
H04N	9	/	097	I	2013-01-01
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CPC Combination Sets							
Symbol				**Type**	**Set**	**Ranking**	**Version**
		/					
		/					

/EUEL COWAN/ Examiner.Art Unit 2664 (Assistant Examiner)	11/10/2016 (Date)	**Total Claims Allowed:** 4	
/AUNG S MOE/ Primary Examiner.Art Unit 2664 (Primary Examiner)	11/13/2016 (Date)	O.G. Print Claim(s) 1	O.G. Print Figure 1b

Issue Classification	Application/Control No.	Applicant(s)/Patent Under Reexamination
	14386823	SHABTAY ET AL.
	Examiner	**Art Unit**
	EUEL COWAN	2664

US ORIGINAL CLASSIFICATION	
CLASS	**SUBCLASS**
348	240.99

CROSS REFERENCE(S)

CLASS	SUBCLASS (ONE SUBCLASS PER BLOCK)				
348	211.9	240.3	211.11		

INTERNATIONAL CLASSIFICATION

CLAIMED					NON-CLAIMED
H	0	4	N	5 / 262 (2006.0)	
H	0	4	N	5 / 232 (2006.0)	
H	0	4	N	5 / 262 (2006.0)	
H	0	4	N	5 / 232 (2006.0)	

/EUEL COWAN/ Examiner.Art Unit 2664 (Assistant Examiner)	11/10/2016 (Date)	**Total Claims Allowed:** 4	
/AUNG S MOE/ Primary Examiner.Art Unit 2664 (Primary Examiner)	11/13/2016 (Date)	O.G. Print Claim(s) 1	O.G. Print Figure 1b

Issue Classification

Application/Control No.	Applicant(s)/Patent Under Reexamination
14386823	SHABTAY ET AL.
Examiner	**Art Unit**
EUEL COWAN	2664

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

Final	Original	Final	Original	Final	Original	Final	Original	Final	Original	Final	Original	Final	Original	Final	Original
	1		17		33		49								
	2		18		34		50								
	3		19		35		51								
	4		20		36		52								
	5		21		37	3	53								
	6		22		38		54								
	7		23		39		55								
	8		24		40		56								
	9		25		41		57								
	10		26		42		58								
	11		27		43		59								
	12		28	1	44		60								
	13		29		45		61								
	14		30		46	2	62								
	15		31		47	4	63								
	16		32		48										

/EUEL COWAN/ Examiner.Art Unit 2664 (Assistant Examiner)	11/10/2016 (Date)	**Total Claims Allowed:** 4	
/AUNG S MOE/ Primary Examiner.Art Unit 2664 (Primary Examiner)	11/13/2016 (Date)	O.G. Print Claim(s) 1	O.G. Print Figure 1b

IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

In re Applicant: § Confirmation No: 1857

§

Gal Shabtay §

§ Art Unit: 2664

Serial No.: 14/386,823

Title: **HIGH RESOLUTION THIN MULTI-APERTURE IMAGING SYSTEMS**

Filed: 09/22/2014 §

§ Attorney Docket: Coreph-0072 US NP

Examiner: COWAN, EUEL K

Commissioner for Patents
P.O. Box 1450
Alexandria, VA 22313-1450

RESPONSE

This is in response to the Office Action having a Notification Date of 05/17/2016, which response is made timely. Please amend the application as follows:

IN THE CLAIMS:

1. (Original) A multi-aperture imaging system comprising:

a) a first camera subset that provides a first image, the first camera subset having a first sensor with a first plurality of sensor pixels covered at least in part with a non-standard color filter array (CFA), the non-standard CFA used to increase a specific color sampling rate relative to a same color sampling rate in a standard CFA;

b) a second camera subset that provides a second image, the second camera subset having a second sensor with a second plurality of sensor pixels, the second plurality of sensor pixels being either Clear or covered with a standard CFA; and

c) a processor configured to process the first and second images into a combined output image.

2. (Previously Cancelled)

3. (Previously Cancelled)

4. (Original) The imaging system of claim 1, wherein the non-standard CFA includes a repetition of a 4x4 micro-cell in which a color filter order is BBRR-RBBR-RRBB-BRRB.

5-9. (Previously Cancelled)

10. (Previously Presented) The imaging system of claim 1, wherein the processor is further configured to register respective first and second Luma images obtained from the first and second images during the processing of the first and second images into a combined output image, the registered first and second Luma images used together with color information to form the combined output image.

11. (Previously Cancelled)

12. (Previously Cancelled)

13. (Previously Presented) The imaging system of claim 1, wherein the first camera subset has a first field of view (FOV), wherein the second camera subset has a second, smaller FOV than the first FOV, and wherein the non-standard CFA covers substantially only

an overlap area on the first sensor that captures the second FOV, thereby providing both optical zoom and increased color resolution.

14-31. (Previously Cancelled)

32-43. (Previously Cancelled)

44. (Previously Presented) A multi-aperture imaging system comprising:

a) a first camera subset that provides a first image, the first camera subset having a first field of view (FOV_1) and a first sensor with a first plurality of sensor pixels covered at least in part with a standard color filter array (CFA);

b) a second camera subset that provides a second image, the second camera subset having a second field of view (FOV_2) such that $FOV_2 < FOV_1$ and a second sensor with a second plurality of sensor pixels, the second plurality of sensor pixels being either Clear or covered with a standard CFA; and

c) a processor configured to provide an output image from a point of view of either the first or the second camera subset based on a zoom factor (ZF) input that defines a respective field of view (FOV_{ZF}).

45. (Previously Presented) The imaging system of claim 44, wherein if $FOV_2 < FOV_{ZF} \leq FOV_1$, then the point of view of the output image is that of the first camera and if $FOV_2 \geq FOV_{ZF}$, then the point of view of the output image is that of the second camera.

46. (Previously Presented) The imaging system of claim 45, wherein the processor is further configured to form the output image by processing the first and second images into a combined output image.

47. (Previously Presented) The imaging system of claim 46, wherein the processing of the first and second images into a combined output image includes a registration process for registering respective pixels from the first and second images to form the combined output image.

48. (Previously Presented) The imaging system of claim 47, wherein if $FOV_2 < FOV_{ZF} \leq FOV_1$ then the registration process includes finding in an overlap area a corresponding pixel in the second image for each pixel in the first image, wherein the processor is further configured to form the combined output image by modifying values of the first image pixels according to values of the corresponding pixels in the second image, thereby providing a point of view of the output image of the first camera, and if $FOV_2 \geq FOV_{ZF}$ then the registration includes finding a corresponding pixel in the first image for each pixel in the second image, wherein the processor is further configured to form a combined output image by modifying values of the second image pixels according to values of the corresponding pixels in the first image, thereby providing a point of view of the output image of the second camera.

49. (Previously Presented) The imaging system of claim 48, wherein the modified values are Luma pixel values in the first or second image modified according to corresponding Luma pixel values in, respectively, the second or first image.

50. (Previously Presented) The imaging system of claim 47, wherein if $FOV_2 < FOV_{ZF} \leq FOV_1$ then a registration process includes finding in an overlap area a corresponding pixel in the second image for each pixel in the first image, wherein the processor is further configured to form the combined output image by modifying values of the first image pixels according to values of the corresponding pixels in the second image, thereby providing a point of view of the output image of the first camera, and if $FOV_2 \geq FOV_{ZF}$ then the processor is further configured to form a combined output image using only pixel values from the second image, thereby providing a point of view of the output image of the second camera.

51. (Previously Presented) The imaging system of claim 50, wherein the modified values are first image Luma pixel values modified according to corresponding second image Luma pixel values.

52. (Cancelled)

53. (Previously Presented) A method of acquiring images by a multi-aperture imaging system, the method comprising:

a) providing a first image generated by a first camera subset of the imaging system, the first camera subset having a first field of view (FOV_1) and a first sensor with a first plurality of sensor pixels covered at least in part with a standard color filter array (CFA);

b) providing a second image generated by a second camera subset of the imaging system, the second camera subset having a second field of view (FOV_2) such that $FOV_2 < FOV_1$ and a second sensor with a second plurality of sensor pixels, the second plurality of sensor pixels being either Clear or covered with a standard CFA; and

c) using a processor for generating an output image from a point of view of either the first or the second camera subset based on a zoom factor (ZF) input that defines a respective field of view (FOV_{ZF}).

54. (Previously Presented) The method of claim 53, further comprising: if $FOV_2 < FOV_{ZF} \leq FOV_1$, generating an output image from a point of view of the first camera; and if $FOV_2 \geq FOV_{ZF}$, generating an output image from a point of view of the second camera.

55. (Previously Presented) The method of claim 54, further comprising generating the output image by processing the first and second images into a combined output image.

56. (Previously Presented) The method of claim 55, wherein the processing of the first and second images into a combined output image includes executing a registration process for registering respective pixels from the first and second images to form the combined output image.

57. (Previously Presented) The method of claim 56, wherein the registration process comprises: if $FOV_2 < FOV_{ZF} \leq FOV_1$, finding in an overlap area a corresponding pixel in the second image for each pixel in the first image and generating the combined output image by modifying values of the first image pixels according to corresponding pixel values in the second image, thereby providing a point of view of the output image of the first camera, and

if $FOV_2 \geq FOV_{ZF}$, finding a corresponding pixel in the first image for each pixel in the second image and generating a combined output image by modifying values of the second image pixels according to corresponding pixel values in the first image, thereby providing a point of view of the output image of the second camera.

58. (Previously Presented) The method of claim 57, wherein the modified values in the first or second image are Luma pixel values modified according to corresponding Luma pixel values in, respectively, the second or first image.

59. (Previously Presented) The method of claim 56, wherein the registration process comprises: if $FOV_2 < FOV_{ZF} \leq FOV_1$, finding in an overlap area a corresponding pixel in the second image for each pixel in the first image and generating the combined output image by modifying values of the first image pixels according to corresponding pixel values in the second image, thereby providing a point of view of the output image of the first camera; and if $FOV_2 \geq FOV_{ZF}$, generating a combined output image using only pixel values from the second image, thereby providing a point of view of the output image of the second camera.

60. (Previously Presented) The method of claim 59, wherein the modified values are first image Luma pixel values modified according to corresponding second image Luma pixel values.

61. (Cancelled)

RESPONSE

General

Claims 1, 10, 13, 44-61 are pending in the application. In the Office Action, all claims were rejected. The rejection is respectfully traversed. Claims 52 and 61 are cancelled with this response without prejudice to or disclaimer of the subject matter contained therein, rendering their rejection moot.

Applicant respectfully requests Examiner to reconsider and to withdraw all rejections.

Claim Rejections - 35 USC § 103

Claims 1, 10, 13, 44-61 were rejected under pre-AIA 35 U.S.C. 103(a) as being unpatentable over Dagher, US 2011/0064327 in view of Koskinen, US 8179457. The rejection is respectfully traversed.

Regarding **claim 1**, Examiner states that Dagher discloses a multi-aperture imaging system comprising elements (a)-(c) but does not explicitly disclose a non-standard color filter array CFA. Examiner further states that Koskinen in the same art of imaging has a non-standard color filter array CFA. Koskinen allows for the color filter array may be designed much more freely than conventional color filter arrays. Contrasting Fig. 3 with FIG. 1, the optical filters ... enable a plurality of different filter types to be used in any desired combinations, Col. 3, lines 59-63, Fig.3; It should be noted that the color filters do not have to be separate for each receptor (2)... each of three different filter types is shown overlaying a plurality of the receptors Col.7 ln.51-55, Fig.7, Fig.9. Examiner concludes that it would have been have been an obvious design choice to one of ordinary skill in the art at the time of the invention to combine a non-Bayer filter as taught by Koskinen with the invention of Dagher since it allows the designer much more freedom than a standard Bayer color filter array (Koskinen, col. 1 line 46-56, col. 3 lines 41-48, col. 3 lines 59-63, Figs. 1 and 3).

Applicant respectfully traverses the rejection and argues as follows:

Regarding **claim 1**, the claim recites:

> (a) a first camera subset that provides a first image, the first camera subset having a first sensor with a first plurality of sensor pixels covered at least in part with a non-standard color filter array (CFA), the non-standard CFA used to increase a specific color sampling rate relative to a same color sampling rate in a standard CFA"

Koskinen's invention is concerned with color filters for sub-diffraction limit-sized light sensors in a single camera. In this context, Koskinen mentions optimization between "resolution" and color fidelity and sensitivity, as follows:

> "A dynamic optimization between resolution and color fidelity and sensitivity may be achieved by creating the data elements from different numbers of receptors".

Koskinen's "receptors" are sub-diffraction limit sized sensor pixels. In Applicant's disclosure as well as in Dagher there are no such sub-diffraction limit-sized sensor pixels and there is no "data element" created from different numbers of receptors. More importantly, Examiner's stated motivation, backed by text from Koskinen (Koskinen, col. 1 lines 46-56, col. 3, lines 41-48, col. 3, lines 59-63, FIGS. 1 and 3) that the combination of Koskinen and Dagher "would be an obvious design choice that allows the designer much more freedom than a standard Bayer color filter array" is completely unrelated to Applicant's motivation presented in the Background of his disclosure:

> "Therefore, there is a need for, and it would be advantageous to have thin MAI (multi-aperture imaging) systems that produce an image with high resolution (and specifically high color resolution) together with zoom functionality".

Thus, Applicant's disclosure clearly states a different problem to be solved and a different motivation than just a design choice to allow more freedom than a standard Bayer color filter array. Moreover and as mentioned, in Dagher's image sensor there are no "receptors" or "data elements" taught by Koskinen. Applicant respectfully submits that there would be no motivation, and in fact it would make no sense to one of ordinary skill in the art, to combine Koskinen's color filters with Dagher's sensor and that consequently Examiner has failed to present even a *prima facie* case of obviousness for claim 1.

In summary, the combination of Dagher and Koskinen fails to render claim 1 obvious because there would be no motivation to combine the two references and reasonably expect a successful outcome that will lead to the system claimed in claim 1.

Regarding **claim 10**, the claim depends directly from claim 1 and includes all of its limitations. Applicant therefore argues, as for claim 1, that Examiner has failed to present even a *prima facie* case of obviousness for claim 10.

Regarding **claim 13**, Applicant has already argued above the difference between "receptors" in Koskinen and sensor pixels in Dagher and in Applicant's invention. Therefore, Applicant respectfully traverses Examiner's finding that the color filters do not have to be separate for each receptor (2)... each of three different filter types is shown overlaying a plurality of the receptors Col.7 ln.51 55, Fig. 7, Fig. 9), thereby providing both optical zoom and increased color resolution (as taught by Dagher in at least [58] and [98]). Further, as claim 13 depends directly from claim 1 and includes all of its limitations. Applicant argues, as for claim 1, that Examiner has failed to present even a *prima facie* case of obviousness for claim 13.

Regarding **claims 44-61**, of which claims 44, 52, 53 and 61 are independent, Applicant respectfully points out that although the 35 USC § 103 rejection above is based on the combination of Dagher and Koskinen, <u>Koskinen is not mentioned anymore in Examiner's arguments and reasons for the rejection.</u>

Regarding **claim 44**, Examiner states that Dagher renders the claim obvious by disclosing elements (a) and (b) as well as (c) a processor configured to provide an output image from a point of view of either the first or the second camera subset based on a zoom factor (ZF) input that defines a respective field of view FOV_{ZF} (during the processing of the first and second images into a combined output image the first and second sets of image data may be configured for combining or fused based on a zoom factor (ZF) input by changing the focal length of an optical system , paragraph 4 ... "allows the user to choose any level of zoom and to utilize the multi-aperture camera as a continuous zoom camera" paragraph 62, thus including a point of view from either camera).

The rejection is respectfully traversed. Paragraph 62 in Dagher reads:

> [0062] In certain of the image fusion processes presented herein, a resulting image is either a *full-size* wide image or a *full-size* tele image, produced using upsampling/interpolation of the original tele image. The term "*full-size*," in the case where sub-cameras in a multi-aperture camera *share a single sensor*, means that a resulting image size corresponds to an image that would be produced using substantially all of the pixels available on the sensor, were it not shared. This does not preclude a user from choosing an *intermediate level of zoom between wide and tele fields of view*. Further cropping and re-sampling of target image 310, for example, allows the user to choose any level of zoom and to utilize the multi-aperture camera as a continuous zoom camera.

Applicant disclosure refers to "point of view" as follows:

> The output image point of view is determined according to the primary image point of view (camera angle).

Further, Applicant's disclosure refers to FIG. 1 as follows:

> "If the ZF is such that the output FOV is equal to, or smaller than the Tele FOV, the primary sensor is the Tele sensor and the auxiliary sensor is the Wide sensor. The point of view defined by the output image is that of the primary sensor".

To clarify, in the instant invention, the output image may be based on a primary image obtained either with the Wide sensor (or camera) or with the Tele sensor (or camera), depending on the zoom level. *Applicant argues that the output image in Dagher, even if it includes image data from only the Tele camera, is output from the point of view of the Wide camera.*

Applicant submits that Dagher teaches high, low, and intermediate zoom in terms of number of pixels used, but does not teach an output image being related to a zoom factor and a point of view. His paragraph 62 refers to specifics of the image fusion, not of the output image point of view being determined according to a primary image point of view (i.e. the output image being based either on the Wide image or on the Tele image, depending on the zoom level). Specifically, while Dagher mentions the word "zoom" 44 times, Dagher does not teach a processor configured to provide an output image from a point of view of either the first or the second camera subset based on a zoom factor (ZF) input that defines a respective field of view (FOV_{ZF}), as recited in (c). Dagher does not use a zoom factor to define FOV_{ZF} and consequently to determine whether the output image is provided from the point of view of the first or the second camera, depending on the defined FOV_{ZF}. Dagher's output image is always based on the Wide camera point of view, with the Tele image data sets contributing to the fused output image according to the zoom level (with a full Tele image representing 100% Tele image data contribution, but still represented from the Wide camera point of view). Consequently, Applicant submits that Dagher does not teach all of the limitations of claim 44 and therefore cannot and does not render claim 44 obvious. Applicant further submits that Examiner has failed to present even a *prima facie* case of obviousness for claim 44.

Regarding **claim 45**, Examiner states that Dagher discloses that if $FOV_2 < FOV_{ZF} \leq FOV_1$, then the point of view of the output image is that of the first camera (this requires a request to increase zoom. Dagher discusses in paragraph 4..."zoom may be understood as a capability to provide different magnifications of the same scene and/or object by changing the focal length of an optical system" thus a situation where the current zoom factor is based on camera 12 (narrow FOV) in fig. 1, a request to increase the zoom, moves it above the initial position to that of at least the FOV of camera 10) and if $FOV_2 \geq FOV_{ZF}$, then the point of view of the output image is that of the second camera (same logic for the reverse request).

Applicant respectfully traverses and argues that nothing in the text above or anywhere else in Dagher indicates that Dagher uses anything but a single point of view (of the same Wide camera) for the output image at all zoom levels. While the sentence used by Examiner provides a (well known) definition of zoom, it does not associate a level of zoom with an output image being provided from the point of view of a Tele camera based on a zoom factor. Dagher associates a level of zoom with image data set inputs to be used in the fusion process to produce the output image, not with the output image being based on the point of view of the Tele camera at certain zoom levels (e.g. at $FOV_2 \geq FOV_{ZF}$). Consequently, Applicant submits that Dagher does not teach all of the limitations of claim 45 and that Examiner has failed to present even a *prima facie* case of obviousness for claim 45.

Regarding **claim 46,** the claim depends indirectly from claim 44 through claim 45 and includes all of their limitations. Applicant therefore submits that Dagher does not teach all of the limitations of claim 46 and that Examiner has failed to present even a *prima facie* case of obviousness for claim 46.

Regarding **claim 47,** the claim depends indirectly from claims 44 and 45 and includes all of their limitations. Applicant therefore submits that Dagher does not teach all of the limitations of claim 47 and that Examiner has failed to present even a *prima facie* case of obviousness for claim 47.

Regarding **claim 48,** the claim depends indirectly from claims 44 and 45 and includes all of their limitations. The claim further recites "wherein if $FOV_2 < FOV_{ZF} \leq FOV_1$ then the registration process includes finding in an overlap area a corresponding pixel in the second image for each pixel in the first image, wherein the processor is further configured to form the combined output image by modifying values of the first image pixels according to values of the corresponding pixels in the second image, thereby providing a point of view of the output image of the first camera, and if $FOV_2 \geq FOV_{ZF}$ then the registration includes finding a corresponding pixel in the first image for each pixel in the second image, wherein the processor is further configured to form a combined output image by modifying values of the second image pixels according to values of the corresponding pixels in the first image, thereby providing a point of view of the output image of the second camera". Examiner refers specifically to paragraphs 73-74 and 83 in Dagher. These refer to image registration and fusion, but say nothing of the point of view of the output image being of the second camera if $FOV_2 \geq FOV_{ZF}$. Applicant therefore submits that Dagher does not teach all of the limitations of claim 48 and that Examiner has failed to present even a *prima facie* case of obviousness for claim 48.

Regarding **claim 49,** the claim depends indirectly from claims 44, 45 and 48 and includes all of their limitations. Applicant therefore submits that Dagher does not teach all of the limitations of claim 49 and that Examiner has failed to present even a *prima facie* case of obviousness for claim 49.

Regarding **claim 50,** the claim depends indirectly from claims 44, 45 and 47 and includes all of their limitations. Further and similar to the argument presented re. claim 48 above, Applicant submits that Dagher does not teach at least "if $FOV_2 \geq FOV_{ZF}$ then the processor is further configured to form a combined output image using only pixel values from the second image, thereby providing a point of view of the output image of the second camera", because Dagher does not teach an output image from the point of view of a second Tele camera. Applicant therefore submits that Dagher does not teach all of the limitations of claim 50 and that Examiner has failed to present even a *prima facie* case of obviousness for claim 50.

Regarding **claim 51**, the claim depends indirectly from claims 44, 45, 47 and 50 and includes all of their limitations. Applicant therefore submits that Dagher does not teach all of the limitations of claim 51 and that Examiner has failed to present even a *prima facie* case of obviousness for claim 51.

Regarding **claim 52**, since the claim is cancelled herewith without prejudice to or disclaimer of the subject matter contained therein, its rejection is moot.

Regarding **claim 53**, which was rejected using the same rationale as in the rejections of claims 52 and 44, Applicant respectfully traverses the rejection and submits that Examiner has failed to present even a *prima facie* case of obviousness for claim 53, for the reasons argued against the rejection of claim 44.

Regarding **claim 54**, Examiner states the claim recites similar limitations as claim 45 and was rejected for the same rationale. Applicant respectfully traverses the rejection and submits that Examiner has failed to present even a *prima facie* case of obviousness for claim 54, for the reasons argued against the rejection of claim 45.

Regarding **claim 55**, Examiner states the claim recites similar limitations as claim 46 and was rejected for the same rationale. Applicant respectfully traverses the rejection and submits that Examiner has failed to present even a *prima facie* case of obviousness for claim 55, for the reasons argued against the rejection of claim 46.

Regarding **claim 56**, Examiner states the claim recites similar limitations as claim 46 and was rejected for the same rationale. Applicant respectfully traverses the rejection and submits that Examiner has failed to present even a *prima facie* case of obviousness for claim 56, for the reasons argued against the rejection of claim 46.

Regarding **claims 57-60**, Examiner states the claims recite similar limitations as claims 48-51 and were rejected for the same rationale. Applicant respectfully traverses the rejection and submits that Examiner has failed to present even a *prima facie* case of obviousness for claims 57-60, for the reasons argued against the rejection of claims 48-51.

Regarding **claim 61**, since the claim is cancelled herewith without prejudice to or disclaimer of the subject matter contained therein, its rejection is moot.

Claim 4 was rejected under pre-AIA 35 U.S.C. 103(a) as being unpatentable over Dagher, US2011/0064327 in view of Koskinen, US 8179457 in view of Myhrvold, US 8094208.

The rejection of **claim 4** is respectfully traversed. Claim 4 depends directly from claim 1 and includes all of its limitations. Since Myhrvold does not teach recited limitations similarly not taight by Dagher and Koskinen, the combination of Dagher, Koskinen and Myhrvold cannot and does not render claim 4 obvious. Applicant submits, as for claim 1, that Examiner has failed to present even a *prima facie* case of obviousness for claim 4.

In view of the above amendments and remarks it is respectfully submitted that claims 1, 4, 10, 13 and 44-51 and 53-60 are in condition for allowance. Prompt notice of allowance is respectfully and earnestly solicited.

Respectfully submitted,

/Menachem Nathan/

Menachem Nathan
Agent for Applicant
Registration No. 65392

Date: August 8, 2016

Electronic Acknowledgement Receipt

EFS ID:	26596825
Application Number:	14386823
International Application Number:	
Confirmation Number:	1857
Title of Invention:	HIGH RESOLUTION THIN MULTI-APERTURE IMAGING SYSTEMS
First Named Inventor/Applicant Name:	Gal Shabtay
Customer Number:	92342
Filer:	Menachem Nathan
Filer Authorized By:	
Attorney Docket Number:	COREPH-0072 US NP
Receipt Date:	10-AUG-2016
Filing Date:	22-SEP-2014
Time Stamp:	05:24:26
Application Type:	U.S. National Stage under 35 USC 371

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	Amendment/Req. Reconsideration-After Non-Final Reject	OA_response.pdf	106122 4642398df03be948f49fad458bb0042d5013b49d	no	13

Warnings:

Information:	
Total Files Size (in bytes):	106122

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.

PTO/SB/06 (09-11)
Approved for use through 1/31/2014. OMB 0651-0032
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PATENT APPLICATION FEE DETERMINATION RECORD

Substitute for Form PTO-875

Application or Docket Number	Filing Date	
14/386,823	09/22/2014	☐ To be Mailed

ENTITY: ☐ LARGE ☒ SMALL ☐ MICRO

APPLICATION AS FILED – PART I

FOR	NUMBER FILED (Column 1)	NUMBER EXTRA (Column 2)	RATE ($)	FEE ($)
☐ BASIC FEE (37 CFR 1.16(a), (b), or (c))	N/A	N/A	N/A	
☐ SEARCH FEE (37 CFR 1.16(k), (i), or (m))	N/A	N/A	N/A	
☐ EXAMINATION FEE (37 CFR 1.16(o), (p), or (q))	N/A	N/A	N/A	
TOTAL CLAIMS (37 CFR 1.16(i))	minus 20 =	*	X $ =	
INDEPENDENT CLAIMS (37 CFR 1.16(h))	minus 3 =	*	X $ =	
☐ APPLICATION SIZE FEE (37 CFR 1.16(s))	If the specification and drawings exceed 100 sheets of paper, the application size fee due is $310 ($155 for small entity) for each additional 50 sheets or fraction thereof. See 35 U.S.C. 41(a)(1)(G) and 37 CFR 1.16(s).			
☐ MULTIPLE DEPENDENT CLAIM PRESENT (37 CFR 1.16(j))				
* If the difference in column 1 is less than zero, enter "0" in column 2.			TOTAL	

APPLICATION AS AMENDED – PART II

AMENDMENT

08/10/2016	CLAIMS REMAINING AFTER AMENDMENT (Column 1)		HIGHEST NUMBER PREVIOUSLY PAID FOR (Column 2)	PRESENT EXTRA (Column 3)	RATE ($)	ADDITIONAL FEE ($)
Total (37 CFR 1.16(i))	* 20	Minus	** 22	= 0	x $40 =	0
Independent (37 CFR 1.16(h))	* 3	Minus	***3	= 0	x $210 =	0
☐ Application Size Fee (37 CFR 1.16(s))						
☐ FIRST PRESENTATION OF MULTIPLE DEPENDENT CLAIM (37 CFR 1.16(j))						
					TOTAL ADD'L FEE	**0**

AMENDMENT

	CLAIMS REMAINING AFTER AMENDMENT (Column 1)		HIGHEST NUMBER PREVIOUSLY PAID FOR (Column 2)	PRESENT EXTRA (Column 3)	RATE ($)	ADDITIONAL FEE ($)
Total (37 CFR 1.16(i))	*	Minus	**	=	X $ =	
Independent (37 CFR 1.16(h))	*	Minus	***	=	X $ =	
☐ Application Size Fee (37 CFR 1.16(s))						
☐ FIRST PRESENTATION OF MULTIPLE DEPENDENT CLAIM (37 CFR 1.16(j))						
					TOTAL ADD'L FEE	

* If the entry in column 1 is less than the entry in column 2, write "0" in column 3.
** If the "Highest Number Previously Paid For" IN THIS SPACE is less than 20, enter "20".
*** If the "Highest Number Previously Paid For" IN THIS SPACE is less than 3, enter "3".
The "Highest Number Previously Paid For" (Total or Independent) is the highest number found in the appropriate box in column 1.

LIE
/LINDA A. WASHINGTON/

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APPLICATION NO.	FILING DATE	FIRST NAMED INVENTOR	ATTORNEY DOCKET NO.	CONFIRMATION NO.
14/386,823	09/22/2014	Gal Shabtay	COREPH-0072 US NP	1857

92342 7590 05/17/2016
Nathan & Associates Patent Agents Ltd
P.O.Box 10178
Tel Aviv, 6110101
ISRAEL

EXAMINER	
COWAN, EUEL K	

ART UNIT	PAPER NUMBER
2664	

NOTIFICATION DATE	DELIVERY MODE
05/17/2016	ELECTRONIC

Please find below and/or attached an Office communication concerning this application or proceeding.

The time period for reply, if any, is set in the attached communication.

Notice of the Office communication was sent electronically on above-indicated "Notification Date" to the following e-mail address(es):

info@natpatent.com
mnathan@post.tau.ac.il
talya.nathan@gmail.com

Office Action Summary	Application No. 14/386,823	Applicant(s) SHABTAY ET AL.	
	Examiner EUEL COWAN	Art Unit 2664	AIA (First Inventor to File) Status No

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

Period for Reply

A SHORTENED STATUTORY PERIOD FOR REPLY IS SET TO EXPIRE *3* MONTHS FROM THE MAILING DATE OF THIS COMMUNICATION.

- Extensions of time may be available under the provisions of 37 CFR 1.136(a). In no event, however, may a reply be timely filed after SIX (6) MONTHS from the mailing date of this communication.
- If NO period for reply is specified above, the maximum statutory period will apply and will expire SIX (6) MONTHS from the mailing date of this communication.
- Failure to reply within the set or extended period for reply will, by statute, cause the application to become ABANDONED (35 U.S.C. § 133). Any reply received by the Office later than three months after the mailing date of this communication, even if timely filed, may reduce any earned patent term adjustment. See 37 CFR 1.704(b).

Status

1)☒ Responsive to communication(s) filed on *9/22/2014*.

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

2a)☐ This action is **FINAL**. 2b)☒ This action is non-final.

3)☐ 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.

4)☐ Since this application is in condition for allowance except for formal matters, prosecution as to the merits is closed in accordance with the practice under *Ex parte Quayle*, 1935 C.D. 11, 453 O.G. 213.

Disposition of Claims*

5)☒ Claim(s) *1,4,10,13 and 44-61* is/are pending in the application.

5a) Of the above claim(s) _____ is/are withdrawn from consideration.

6)☐ Claim(s) _____ is/are allowed.

7)☒ Claim(s) *1,4,10,13 and 44-61* is/are rejected.

8)☐ Claim(s) _____ is/are objected to.

9)☐ Claim(s) _____ are subject to restriction and/or election requirement.

* If any claims have been determined allowable, 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.

Application Papers

10)☐ The specification is objected to by the Examiner.

11)☒ The drawing(s) filed on *9/22/2014* is/are: a)☒ accepted or b)☐ objected to by the Examiner.

Applicant may not request that any objection to the drawing(s) be held in abeyance. See 37 CFR 1.85(a).

Replacement drawing sheet(s) including the correction is required if the drawing(s) is objected to. See 37 CFR 1.121(d).

Priority under 35 U.S.C. § 119

12)☒ 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. _____.

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)).

** See the attached detailed Office action for a list of the certified copies not received.

Attachment(s)

1) ☒ Notice of References Cited (PTO-892)

2) ☒ Information Disclosure Statement(s) (PTO/SB/08a and/or PTO/SB/08b) Paper No(s)/Mail Date _____.

3) ☐ Interview Summary (PTO-413) Paper No(s)/Mail Date. _____ .

4) ☐ Other: _____.

DETAILED ACTION

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

Claim Rejections - 35 USC § 103

2. The following is a quotation of pre-AIA 35 U.S.C. 103(a) which forms the basis for all obviousness rejections set forth in this Office action:

> (a) A patent may not be obtained though the invention is not identically disclosed or described as set forth in section 102 of this title, if the differences between the subject matter sought to be patented and the prior art are such that the subject matter as a whole would have been obvious at the time the invention was made to a person having ordinary skill in the art to which said subject matter pertains. Patentability shall not be negatived by the manner in which the invention was made.

3. Claims 1, 10, 13, 44-61 are rejected under pre-AIA 35 U.S.C. 103(a) as being unpatentable over Dagher, US 2011/0064327 in view of Koskinen, US 8179457.

Regarding claim 1, Dagher discloses a multi-aperture imaging system (paragraphs [0041]-[0042], Fig.1; multi-aperture camera Fig.3) comprising: a) a first camera subset (fig. 1 camera 10) that provides a first image, the first camera subset having a first sensor with a first plurality of sensor pixels (paragraph 46, first pixels images FOV 20 wide view as in fig. 4 also; the sensors of sub-cameras of a single multi-aperture camera may be shared in any manner... blocks of pixels adjacent one another in a single sensor chip... not limited to having identical shapes or sizes [0049], Fig.2;... multi-aperture camera (100), each of first and second optical sub-systems (110) and (120) is shown imaging onto its own sensor (i.e., sensors (130) and (140), respectively) [0067], Fig.2) covered at least in part with a color filter array CFA (paragraph 63, Image sensors often utilize a Red-Green-Blue ("RGB") color filter array, such as a Bayer pattern... in FIG. 8, both the tele and the wide images are converted from RGB to YUV [0063], Fig.8; ... a CFA such as a Bayer filter, or be formed of individual color sensor elements (e.g., RGB or Cyan-Magenta-Yellow ("CMY")) [0067]), the CFA used to increase a specific color sampling rate relative to a same color sampling rate in a standard CFA (... upsampling and interpolation of the first and second sets of image data... increasing the sampling frequency... higher level of image quality... higher resolution [0054], Fig.4, Fig.5, Fig.6);

b) a second camera subset (fig. 1 camera 12; paragraph 46) that provides a second image, the second camera subset having a second sensor with a second plurality of sensor pixels (Fig.1, pixels of second camera produce image 22, the second plurality of sensor pixels being either Clear or covered with a standard CFA (... Image sensors often utilize a Red-Green-Blue ("RGB") color filter array ("CFA"), such as a Bayer pattern... in FIG. 8, both the tele and the wide images are converted from RGB to YUV... the tele sub-camera may utilize an image sensor that does not have a color filter array... to utilize its entire sensor area [0063], Fig.8); and

c) a processor configured to process the first and second images into a combined-output image (... Multi aperture camera (100) provides first and second sets of image data (301) and (302) to a processor (166) which may, for example, be configured for combining or "fusing" the image data sets... to an image output device (167) [0053], Fig.3).

Dagher does not explicitly disclose a non-standard color filter array CFA. **Koskinen** in the same art of imaging has a non-standard color filter array CFA. (filter types include, CYGM filters... and RGBE filters Col.1 ln.46-56. Koskinen allows for the color filter array may be designed much more freely than conventional color filter arrays Col.3 ln.41-48, Fig.3; Contrasting FIG. 3 with FIG. 1, the optical filters... enable a plurality of different filter types to be used in any desired combinations Col. 3 ln. 59-63 Fig.3; It should be noted that the color filters do not have to be separate for each receptor (2)... each of three different filter types is shown overlaying a plurality of the receptors Col.7 ln.51-55, Fig.7, Fig.9). It would have been have been an obvious design choice to one of ordinary skill in the art at the time of the invention to combine a non-Bayer filter as taught by Koskinen with the invention of Dagher since it allows the designer much more freedom than a standard Bayer color filter array (Koskinen, col. 1 line 46-56, col. 3 lines 41-48, col. 3 lines 59-63, figs. 1 & 3).

Regarding claim 10, the Dagher- Koskinen combination teaches the invention as per claim 1 wherein Dagher teaches combining or "fusing" the image data sets... to an image output device 167, [0053], fig.3) is further configured to register respective first and second Luma images obtained from the first and second images during the processing of the first and second images into a combined output image, the registered first and second Luma images used together with color information to form the combined output image (... FIG.8, both the tele and wide images are converted from RGB to YUV... one luminance (Y) channel and two chrominance channels (U, V) [0063], fig.8; ... Process (338)... may be applied to full color images... an image registration procedure (342) is applied [0065], fig.9; ... fusion of image data... may involve addition of color information from a color sub-camera image to luminance information from a grayscale sub-camera image... a complementary operation may be performed where luminance information from the grayscale sub-camera is added to the color image from the color sub-camera... FIG. 11, which illustrates an exemplary process (365) that utilizes processor (166) (see FIG. 3) for fusion of image data [0073]-[0077], Fig.11; ... a grayscale sub-camera generally produces only a luminance signal (e.g., Y information [0067]).

Regarding claim 13, the Dagher-Koskinen combination teaches the invention as per claim 1 wherein Dagher teaches the first camera subset has a first field of view FOV (fig. 1 part 20 from camera 10), wherein the second camera subset has a second, narrower FOV than the first FOV (view 22 from camera 12 has a smaller FOV that camera 10 in fig. 1), and Koskinen teaches that the non-standard CFA (col. 3 lines 41-

48 the filter arrays may be designed more freely than conventional color filter arrays) covers substantially only an overlap area on the first sensor that captures the second FOV (the optical filters... enable a plurality of different filter types to be used in any desired combinations Col.3 ln.58-63, Fig.3) covers an overlap area on the first sensor that captures the second FOV (It should be noted that the color filters do not have to be separate for each receptor (2)... each of three different filter types is shown overlaying a plurality of the receptors Col.7 ln.51-55, Fig.7, Fig.9), thereby providing both optical zoom and increased color resolution (as taught by Dagher in at least [59] & [98]).

Regarding claim 44, Dagher discloses a multi-aperture imaging system comprising: a) a first camera subset that provides a first image, the first camera subset having a first field of view FOV_1 (as described in claim 1 where a first FOV can be fig. 1 part 10) and a first sensor (from camera 10) with a first plurality of sensor pixels (fig. 4 part 171) covered at least in part with a standard color filter array CFA (fig paragraph 63, Image sensors often utilize a Red-Green-Blue ("RGB") color filter array;

b) a second camera subset that provides a second image (fig. 1 camera 12), the second camera subset having a second field of view (FOV_2) such that $FOV_2 < FOV_1$ (fig. 1 camera 20 has a narrower FOV than camera 10) and a second sensor with a second plurality of sensor pixels (from camera 12), the second plurality of sensor pixels being either Clear or covered with a standard CFA (paragraph 63, the tele sub-camera may utilize an image sensor that does not have a color filter array... to utilize its entire sensor area) ; and

c) a processor configured to provide an output image from a point of view of either the first or the second camera subset based on a zoom factor (ZF) input that defines a respective field of view FOV_{zf} (during the processing of the first and second images into a combined output image the first and second sets of image data may be configured for combining or fused based on a zoom factor (ZF) input by changing the focal length of an optical system , paragraph 4 ... "*allows the user to choose any level of zoom and to utilize the multi-aperture camera as a continuous zoom camera*" paragraph 62, thus including a point of view from either camera).

Regarding claim 45, Dagher discloses that if $FOV_2 < FOV_{zf} < FOV_1$, then the point of view of the output image is that of the first camera (this requires a request to increase zoom. Dagher discusses in paragraph 4..."*zoom may be understood as a capability to provide different magnifications of the same scene and/or object by changing the focal length of an optical system*" thus a situation where the current zoom factor is based on camera 12 (narrow FOV) in fig. 1, a request to increase the zoom, moves it above the initial position to that of at least the FOV of camera 10) and if $FOV_2 > FOV_{zf}$, then the point of view of the output image is that of the second camera (same logic for the reverse request).

Regarding claim 46, Dagher discloses that the processor is further configured to form the output image by processing the first and second images into a combined output image (paragraph 74, using processor 166).

Regarding claim 47, Dagher discloses that the processing of the first and second images into a combined output image includes a registration process for registering respective pixels from the first and second images to form the combined output image (image registration is used, paragraph 65).

Regarding claim 48, Dagher discloses that if $FOV_2 < FOV_{zf} < FOV_1$ (which is a request for zoom change between the lowest and highest magnification change) then the registration process includes finding in an overlap area a corresponding pixel in the second image for each pixel in the first image (... image may be divided into overlapping or non-overlapping blocks of size Kx x Ky, for i.e., Kx pixels in an x-direction and Ky pixels in a y-direction, paragraph 83. Also some overlap is required for images that are to be registered, [81]), wherein the processor is further configured to form the combined output image by modifying values of the first image pixels according to values of the corresponding pixels in the second image, thereby providing a point of view of the output image of the first camera, and if $FOV_2 < FOV_{zf}$ then the registration includes finding a corresponding pixel in the first image for each pixel in the second image, wherein the processor is further configured to form a combined output image by modifying values of the second image pixels according to values of the corresponding pixels in the first image, thereby providing a point of view of the output image of the second camera (for either zoom selection both images can be changed from RGB domain to YUV in the fusion process, [73-74].

Regarding claim 49, Dagher discloses that the modified values are Luma pixel values in the first or second image modified according to corresponding Luma pixel values in, respectively, the second or first image (since the order of certain steps can be reordered, the Luma pixels of either image may be replaced/transferred with the other or cropped, [62, 66].

Regarding claim 50, Dagher discloses that if $FOV_2 < FOV_{zf} < FOV_1$ then a registration process includes finding in an overlap area a corresponding pixel in the second image for each pixel in the first image (... image may be divided into overlapping or non-overlapping blocks of size Kx x Ky, for i.e., Kx pixels in an x-direction and Ky pixels in a y-direction, paragraph 83. Also some overlap is required for images that are to be registered, [81]), wherein the processor is further configured to form the combined output image by modifying values of the first image pixels according to values of the corresponding pixels in the second image (the Luma pixels of one image may be replaced/transferred with the other or cropped, [62, 66]), thereby providing a point of view of the output image of the first camera (since the order of certain steps can be reordered either point of view can be represented based on zoom selection), and if $FOV_2 > FOV_{zf}$ then the processor is further configured to form a combined output image using only pixel values from the second image, thereby providing a point of view of the output image of the second camera (this would represent the reverse of the first part of the claim).

Regarding claim 51, Dagher discloses that the modified values are first image Luma pixel values modified according to corresponding second image Luma pixel values (since the order of certain steps can be reordered, the Luma pixels of either image may be replaced/transferred to the other and cropped, [62, 66]).

Regarding claim 52, Dagher discloses the limitations of the claim similar to that of claim 44 wherein he also discloses wherein the processing includes registering the first and second images and finding respective pixels in the first and second images and wherein the registering includes applying low pass filtering to the second image, thereby improving registration performance (paragraph 98, "using image registration information...color information may be fused…only low passed color information is used from the color channels).

Claim 53 recites similar limitations as claims 52 and 44 and is rejected for the same rationale.

Claim 54 recites similar limitations as claim 45 and is rejected for the same rationale.

Claim 55 recites similar limitations as claim 46 and is rejected for the same rationale.

Claim 56 recites similar limitations as claim 47 and is rejected for the same rationale.

Claims 57-60 recite similar limitations as claims 48-51 and are rejected for the same rationale.

Claim 61 is a method claim corresponding to the device of claim 52 and is rejected for the same rationale.

4. Claim 4 is rejected under pre-AIA 35 U.S.C. 103(a) as being unpatentable over Dagher, US2011/0064327 in view of Koskinen, US 8179457 in view of Myhrvold, US 8094208.

Regarding claim 4, the Dagher- Koskinen combination teaches the invention as per claim 1. It does not explicitly teach that the non-standard CFA includes a repetition of a 4x4 micro-cell in which a color filter order is BBRR-RBBR-RRBB-BRRB. **Myhrvold** in the same art of imaging teaches various filter arrangements such as RGBE, CYYM & RGBW and such as needed to reduce or compensate diffraction effects. Also see figs. 3a-h). Thus it would have been obvious to one of ordinary skill in the art at the time the invention was made to have modified the Dagher- Koskinen combination with the different possible arrangements of Myhrvold to allow for a cleaner image.

DETAILED ACTION

Any inquiry concerning this communication or earlier communications from the examiner should be directed to EUEL COWAN whose telephone number is (571)270-5093. The examiner can normally be reached on Mon. - Thur: 8am - 5pm est.

If attempts to reach the examiner by telephone are unsuccessful, the examiner's supervisor, Lin Ye can be reached on 571 272 7372. 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 http://pair-direct.uspto.gov. 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.

/EUEL COWAN/
Examiner, Art Unit 2664

/AUNG S. MOE/
Primary Examiner, Art Unit 2664

Notice of References Cited

	Application/Control No. 14/386,823	Applicant(s)/Patent Under Reexamination SHABTAY ET AL.
	Examiner EUEL COWAN	Art Unit 2664 — 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-2011/0064327 A1	03-2011	Dagher; Joseph C.	G06T5/004	382/263
*	B	US-8,179,457 B2	05-2012	Koskinen; Samu T.	H01L27/14621	250/226
*	C	US-8,094,208 B2	01-2012	Myhrvold; Nathan P.	H04N5/2254	348/222.1
	D	US-				
	E	US-				
	F	US-				
	G	US-				
	H	US-				
	I	US-				
	J	US-				
	K	US-				
	L	US-				
	M	US-				

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)
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	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.

Search Notes	Application/Control No.	Applicant(s)/Patent Under Reexamination
	14386823	SHABTAY ET AL.
	Examiner	**Art Unit**
	EUEL COWAN	2664

CPC- SEARCHED

Symbol	Date	Examiner

CPC COMBINATION SETS - SEARCHED

Symbol	Date	Examiner

US CLASSIFICATION SEARCHED

Class	Subclass	Date	Examiner

SEARCH NOTES

Search Notes	Date	Examiner
text limited search in the following US class/subclass: 348/240.99-240.3,237,267,273-280,350,376.	5/10/2016	Euel Cowan
text limited search in the following CPC group: G08B13/19689| G08B13/1963| G06T2207/20221| B60R2300/304	5/10/2016	Euel Cowan
inventor search	5/10/2016	Euel Cowan

INTERFERENCE SEARCH

US Class/ CPC Symbol	US Subclass / CPC Group	Date	Examiner

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CONFIRMATION NO. 1857

SERIAL NUMBER	FILING or 371(c) DATE	CLASS	GROUP ART UNIT	ATTORNEY DOCKET NO.
14/386,823	09/22/2014 RULE	348	2664	COREPH-0072 US NP

APPLICANTS
Corephotonics Ltd., Tel-Aviv, ISRAEL;

INVENTORS
Gal Shabtay, Tel-Aviv, ISRAEL;
Noy Cohen, Tel-Aviv, ISRAEL;
Oded Gigushinski, Herzlia, ISRAEL;
Ephraim Goldenberg, Ashdod, ISRAEL;

** **CONTINUING DATA** *************************
This application is a 371 of PCT/IB2013/060356 11/23/2013
which claims benefit of 61/730,570 11/28/2012

** **FOREIGN APPLICATIONS** *************************

** **IF REQUIRED, FOREIGN FILING LICENSE GRANTED** ** ** SMALL ENTITY **
12/15/2014

Foreign Priority claimed / 35 USC 119(a-d) conditions met / Verified and Acknowledged	Met after Allowance	STATE OR COUNTRY	SHEETS DRAWINGS	TOTAL CLAIMS	INDEPENDENT CLAIMS
Foreign Priority claimed ☑ Yes ☐ No 35 USC 119(a-d) conditions met ☑ Yes ☐ No Verified and Acknowledged /EUEL K COWAN/ Examiner's Signature	☐ Met after Allowance Initials	ISRAEL	7	16	3

ADDRESS

Nathan & Associates Patent Agents Ltd
P.O.Box 10178
Tel Aviv, 6110101
ISRAEL

TITLE

HIGH RESOLUTION THIN MULTI-APERTURE IMAGING SYSTEMS

FILING FEE RECEIVED		
850	FEES: Authority has been given in Paper No.____________ to charge/credit DEPOSIT ACCOUNT No.____________ for following:	☐ All Fees ☐ 1.16 Fees (Filing) ☐ 1.17 Fees (Processing Ext. of time) ☐ 1.18 Fees (Issue) ☐ Other ________________ ☐ Credit

BIB (Rev. 05/07).

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

INFORMATION DISCLOSURE STATEMENT BY APPLICANT (Not for submission under 37 CFR 1.99)		
	Application Number	14386823
	Filing Date	2014-09-22
	First Named Inventor	Gal Shabtay
	Art Unit	
	Examiner Name	
	Attorney Docket Number	COREPH-0072 US NP

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
/E.K.C/	1	8660420		2014-02-25	Chang	
/E.K.C/	2	8553106		2013-08-10	Scarff	
/E.K.C/	3	8542287		2013-09-24	Griffith et al.	
/E.K.C/	4	8439265		2013-05-14	Ferren et al.	
/E.K.C/	5	8149327		2012-04-03	Lin et al.	
/E.K.C/	6	7676146		2010-03-09	Border et al.	
/E.K.C/	7	7561191		2009-07-14	May et al.	
/E.K.C/	8	7305180		2007-12-04	Labaziewicz et al.	

INFORMATION DISCLOSURE STATEMENT BY APPLICANT (**Not for submission under 37 CFR 1.99)**		
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/E.K.C/	9	8134115		2012-03-13	KOSKINEN et al.	
/E.K.C/	10	8094208		2012-01-10	MYHRVOLD	
/E.K.C/	11	8179457		2012-05-15	KOSKINEN et al.	

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U.S.PATENT APPLICATION PUBLICATIONS Remove

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
/E.K.C/	1	20110064327		2011-03-17	Dagher et al.	
/E.K.C/	2	20100277619		2010-04-11	Scarff	
/E.K.C/	3	20080030592		2008-02-07	Border et al.	
/E.K.C/	4	20110285730		2011-11-24	Lai et al.	
/E.K.C/	5	20110121421		2011-05-26	CHARBON et al.	
/E.K.C/	6	20110292258		2011-12-01	ADLER et al.	

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INFORMATION DISCLOSURE STATEMENT BY APPLICANT (Not for submission under 37 CFR 1.99)	Application Number	14386823
	Filing Date	2014-09-22
	First Named Inventor	Gal Shabtay
	Art Unit	
	Examiner Name	
	Attorney Docket Number	COREPH-0072 US NP

FOREIGN PATENT DOCUMENTS Remove

Examiner Initial*	Cite No	Foreign Document Number3	Country Code2 i	Kind Code4	Publication Date	Name of Patentee or Applicant of cited Document	Pages,Columns,Lines where Relevant Passages or Relevant Figures Appear	T5
/E.K.C/	1	2009097552	WO		2009-08-06	Dagher et al.		☐

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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.	T5
/E.K.C/	1	International Search Report and Written Opinion issued in related PCT patent application PCT/IB2013/060356, dated April 17, 2014, 15 pages.	☐

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EXAMINER SIGNATURE

Examiner Signature	/EUEL K COWAN/	Date Considered	05/10/2016

*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)		
	Application Number	14386823
	Filing Date	2014-09-22
	First Named Inventor	Gal Shabtay
	Art Unit	
	Examiner Name	
	Attorney Docket Number	COREPH-0072 US NP

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	/Menachem Nathan/	Date (YYYY-MM-DD)	2014-10-10
Name/Print	MENACHEM NATHAN	Registration Number	65392

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EAST Search History

EAST Search History (Prior Art)

Ref #	Hits	Search Query	DBs	Default Operator	Plurals	Time Stamp
S1	1	14/386823	US-PGPUB; USPAT; USOCR	ADJ	ON	2016/04/11 09:52
S2	17	("20080030592" | "20100277619" | "20110064327" | "20110121421" | "20110285730" | "20110292258" | "7305180" | "7561191" | "7676146" | "8094208" | "8134115" | "8149327" | "8179457" | "8439265" | "8542287" | "8553106" | "8660420").PN.	US-PGPUB; USPAT; USOCR	ADJ	ON	2016/04/17 21:36
S3	0	(HO4N9/735 OR HO4N5/2258 OR HO4N5/23232 OR HO4N5/23296 OR HO4N9/045 OR HO4N9/097 OR HO4N2209/045).CPC.	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	ADJ	ON	2016/04/17 22:31
S4	0	(HO4N9/735 OR HO4N5/2258 OR HO4N5/23232 OR HO4N5/23296 OR HO4N9/045 OR HO4N9/097).CPC.	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	ADJ	ON	2016/05/03 11:01
S5	6686	348/240.99-240.3,237,267,273-280,350,376.ccls.	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	ADJ	ON	2016/05/03 11:06
S6	1	14/386823 & bbrr	US-PGPUB; USPAT; USOCR	ADJ	ON	2016/05/05 14:21
S7	17	("20080030592" | "20100277619" | "20110064327" | "20110121421" | "20110285730" | "20110292258" | "7305180" | "7561191" | "7676146" | "8094208" | "8134115" | "8149327" | "8179457" | "8439265" | "8542287" | "8553106" | "8660420").PN.	US-PGPUB; USPAT; USOCR	ADJ	ON	2016/05/06 08:37
S9	0	S7 & (request$3 or chang$3 or $2creas$3) near3 zoom same (first or second) camera	US-PGPUB; USPAT; USOCR	ADJ	ON	2016/05/06 08:39
S10	1	14/283957	US-PGPUB; USPAT; USOCR	ADJ	ON	2016/05/06 15:24
S11	17	("20080030592" | "20100277619" | "20110064327" | "20110121421" | "20110285730" | "20110292258" |	US-PGPUB; USPAT; USOCR	ADJ	ON	2016/05/06 16:44

		"7305180" | "7561191" | "7676146" | "8094208" | "8134115" | "8149327" | "8179457" | "8439265" | "8542287" | "8553106" | "8660420").PN.				
S12	6	S11 & (request$3 or chang$3 or $2creas$3) near3 zoom	US-PGPUB; USPAT; USOCR	ADJ	ON	2016/05/06 16:44
S13	17	("20080030592" | "20100277619" | "20110064327" | "20110121421" | "20110285730" | "20110292258" | "7305180" | "7561191" | "7676146" | "8094208" | "8134115" | "8149327" | "8179457" | "8439265" | "8542287" | "8553106" | "8660420").PN.	US-PGPUB; USPAT; USOCR	ADJ	ON	2016/05/07 15:43
S14	10	S13 & (request$3 or chang$3 or $2creas$3 or select$3) near5 (focal length or zoom)	US-PGPUB; USPAT; USOCR	ADJ	ON	2016/05/07 15:43
S15	17	("20080030592" | "20100277619" | "20110064327" | "20110121421" | "20110285730" | "20110292258" | "7305180" | "7561191" | "7676146" | "8094208" | "8134115" | "8149327" | "8179457" | "8439265" | "8542287" | "8553106" | "8660420").PN.	US-PGPUB; USPAT; USOCR	ADJ	ON	2016/05/07 20:14
S16	3	S15 & (register$3 or registration) near5 pixel	US-PGPUB; USPAT; USOCR	ADJ	ON	2016/05/07 20:14
S17	2	"20060165398"	US-PGPUB; USPAT; USOCR	ADJ	ON	2016/05/09 10:08
S21	1	14/386823	US-PGPUB; USPAT; USOCR	ADJ	ON	2016/05/09 21:32
S22	0	S21 and luma with luminance	US-PGPUB; USPAT; USOCR	ADJ	ON	2016/05/09 21:32
S23	1	S21 and luma	US-PGPUB; USPAT; USOCR	ADJ	ON	2016/05/09 21:32
S25	2216	(G08B13/19689| G08B13/1963| G06T2207/20221| B60R2300/304).cpc.	US-PGPUB; USPAT; USOCR	ADJ	ON	2016/05/10 14:29
S26	12	zoom$3 same (combin$3 or merg$3) with wide with tele with (image or frame)	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	ADJ	ON	2016/05/10 14:33
S27	0	(focal length or zoom$3) and (combin$3 or merg$3) with wide with tele with (image or frame) same (blend$3 or replac$3) near4 pixel	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	ADJ	ON	2016/05/10 14:36
S28	42	(focal length or zoom$3) and (combin$3 or merg$3 or blend$3 or replac$3) with wide with tele with (image or frame or	US-PGPUB; USPAT; USOCR;	ADJ	ON	2016/05/10 14:37

		pixel)	FPRS; EPO; JPO; DERWENT; IBM_TDB			
S29	6687	348/240.99-240.3,237,267,273-280,350,376.ccls.	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	ADJ	ON	2016/05/10 14:38
S30	8889	(S25 or S29)	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	ADJ	ON	2016/05/10 14:38
S31	60	(("SHABTAY") near3 ("Gal")).INV.	US-PGPUB; USPAT; USOCR	ADJ	ON	2016/05/10 14:50
S32	37	(("COHEN") near3 ("Noy")).INV.	US-PGPUB; USPAT; USOCR	ADJ	ON	2016/05/10 14:50
S33	9	(("GIGUSHINSKI") near3 ("Oded")).INV.	US-PGPUB; USPAT; USOCR	ADJ	ON	2016/05/10 14:50
S34	46	(("GOLDENBERG") near3 ("Ephraim")).INV.	US-PGPUB; USPAT; USOCR	ADJ	ON	2016/05/10 14:50
S35	7	(S31 or S32 or S33 or S34) and (combin$3 or merg$3 or blend$3 or replac$3) near4 (image or frame or pixel) and (select$3 or choos$3 or vary$3) near4 (zoom or focal length)	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	ADJ	ON	2016/05/10 14:53
S36	7	(S31 or S32 or S33 or S34) and (combin$3 or merg$3 or blend$3 or replac$3) near4 (image or frame or pixel) and (composit$3 or select$3 or choos$3 or vary$3) near4 (zoom or focal length)	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	ADJ	ON	2016/05/10 14:55

EAST Search History (Interference)

<This search history is empty>

5/10/2016 4:38:09 PM
C:\Users\ecowan\Documents\EAST\Workspaces\14386823.wsp

Index of Claims	Application/Control No. 14386823	Applicant(s)/Patent Under Reexamination SHABTAY ET AL.
	Examiner EUEL COWAN	Art Unit 2664

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

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

CLAIM		DATE							
Final	Original	05/10/2016							
	1	✓							
	2	-							
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Index of Claims	**Application/Control No.** 14386823	**Applicant(s)/Patent Under Reexamination** SHABTAY ET AL.
	Examiner EUEL COWAN	**Art Unit** 2664

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

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

CLAIM		DATE								
Final	Original	05/10/2016								
	37	-								
	38	-								
	39	-								
	40	-								
	41	-								
	42	-								
	43	-								
	44	✓								
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	61	✓								

IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

In re Applicant: § Confirmation No: 1857
§
Gal Shabtay §
§
Serial No.: 14/386823

Title: **HIGH RESOLUTION THIN MULTI-APERTURE IMAGING SYSTEMS**

Filed: 09/22/2014 §
§ Attorney Docket: Coreph-0072 US NP

Commissioner for Patents
Alexandria, VA 22313-1450

PRELIMINARY AMENDMENT

Sir/Madam

Before substantive examination, Applicant respectfully requests that claims 32-43 presently outstanding in the application be cancelled and replaced with new claims 44-61. A small entity fee of $ 290 for one independent claim in excess of three and two claims in excess of 20 is paid herewith.

IN THE CLAIMS:

Please cancel presently outstanding claims 32-43 and replace them with new claims 44-61.

1. (Original) A multi-aperture imaging system comprising:

a) a first camera subset that provides a first image, the first camera subset having a first sensor with a first plurality of sensor pixels covered at least in part with a non-standard color filter array (CFA), the non-standard CFA used to increase a specific color sampling rate relative to a same color sampling rate in a standard CFA;

b) a second camera subset that provides a second image, the second camera subset having a second sensor with a second plurality of sensor pixels, the second plurality of sensor pixels being either Clear or covered with a standard CFA; and

c) a processor configured to process the first and second images into a combined output image.

2. (Previously Cancelled)

3. (Previously Cancelled)

4. (Original) The imaging system of claim 1, wherein the non-standard CFA includes a repetition of a 4x4 micro-cell in which a color filter order is BBRR-RBBR-RRBB-BRRB.

5-9. (Previously Cancelled)

10. (Previously Presented) The imaging system of claim 1, wherein the processor is further configured to register respective first and second Luma images obtained from the first and second images during the processing of the first and second images into a combined output image, the registered first and second Luma images used together with color information to form the combined output image.

11. (Previously Cancelled)

12. (Previously Cancelled)

13. (Previously presented) The imaging system of claim 1, wherein the first camera subset has a first field of view (FOV), wherein the second camera subset has a second, smaller FOV than the first FOV, and wherein the non-standard CFA covers substantially only an overlap area on the first sensor that captures the second FOV, thereby providing both optical zoom and increased color resolution.

14-31. (Previously Cancelled)

32-43. (Cancelled)

44. (New) A multi-aperture imaging system comprising:

a) a first camera subset that provides a first image, the first camera subset having a first field of view (FOV_1) and a first sensor with a first plurality of sensor pixels covered at least in part with a standard color filter array (CFA);

b) a second camera subset that provides a second image, the second camera subset having a second field of view (FOV_2) such that $FOV_2 < FOV_1$ and a second sensor with a second plurality of sensor pixels, the second plurality of sensor pixels being either Clear or covered with a standard CFA; and

c) a processor configured to provide an output image from a point of view of either the first or the second camera subset based on a zoom factor (ZF) input that defines a respective field of view (FOV_{ZF}).

45. (New) The imaging system of claim 44, wherein if $FOV_2 < FOV_{ZF} \leq FOV_1$, then the point of view of the output image is that of the first camera and if $FOV_2 \geq FOV_{ZF}$, then the point of view of the output image is that of the second camera.

46. (New) The imaging system of claim 45, wherein the processor is further configured to form the output image by processing the first and second images into a combined output image.

47. (New) The imaging system of claim 46, wherein the processing of the first and second images into a combined output image includes a registration process for registering respective pixels from the first and second images to form the combined output image.

48. (New) The imaging system of claim 47, wherein if $FOV_2 < FOV_{ZF} \leq FOV_1$ then the registration process includes finding in an overlap area a corresponding pixel in the second image for each pixel in the first image, wherein the processor is further configured to form the combined output image by modifying values of the first image pixels according to values of the corresponding pixels in the second image, thereby providing a point of view of the output image of the first camera, and if $FOV_2 \geq FOV_{ZF}$ then the registration includes finding a corresponding pixel in the first image for each pixel in the second image, wherein the processor is further configured to form a combined output image by modifying values of the second image pixels according to values of the corresponding pixels in the first image, thereby providing a point of view of the output image of the second camera.

49. (New) The imaging system of claim 48, wherein the modified values are Luma pixel values in the first or second image modified according to corresponding Luma pixel values in, respectively, the second or first image.

50. (New) The imaging system of claim 47, wherein if $FOV_2 < FOV_{ZF} \leq FOV_1$ then a registration process includes finding in an overlap area a corresponding pixel in the second image for each pixel in the first image, wherein the processor is further configured to form the combined output image by modifying values of the first image pixels according to values of the corresponding pixels in the second image, thereby providing a point of view of the output image of the first camera, and if $FOV_2 \geq FOV_{ZF}$ then the processor is further configured to form a combined output image using only pixel values from the second image, thereby providing a point of view of the output image of the second camera.

51. (New) The imaging system of claim 50, wherein the modified values are first image Luma pixel values modified according to corresponding second image Luma pixel values.

52. (New) A multi-aperture imaging system comprising:

a) a first camera subset that provides a first image, the first camera subset having a first field of view (FOV1) and a first sensor with a first plurality of sensor pixels covered at least in part with a standard color filter array (CFA);

b) a second camera subset that provides a second image, the second camera subset having a second field of view (FOV2) such that FOV2 < FOV1 and a second sensor with a second plurality of sensor pixels, the second plurality of sensor pixels being either Clear or covered with a standard CFA; and

c) a processor configured to form an output image by processing the first and second images into a combined output image;

wherein the processing includes registering the first and second images and finding respective pixels in the first and second images and wherein the registering includes applying low pass filtering to the second image, thereby improving registration performance.

53. (New) A method of acquiring images by a multi-aperture imaging system, the method comprising:

d) providing a first image generated by a first camera subset of the imaging system, the first camera subset having a first field of view (FOV_1) and a first sensor with a first plurality of sensor pixels covered at least in part with a standard color filter array (CFA);

e) providing a second image generated by a second camera subset of the imaging system, the second camera subset having a second field of view (FOV_2) such that $FOV_2 < FOV_1$ and a second sensor with a second plurality of sensor pixels, the second plurality of sensor pixels being either Clear or covered with a standard CFA; and

f) using a processor for generating an output image from a point of view of either the first or the second camera subset based on a zoom factor (ZF) input that defines a respective field of view (FOV_{ZF}).

54. (New) The method of claim 53, further comprising: if $FOV_2 < FOV_{ZF} \leq FOV_1$, generating an output image from a point of view of the first camera; and if $FOV_2 \geq FOV_{ZF}$, generating an output image from a point of view of the second camera.

55. (New) The method of claim 54, further comprising generating the output image by processing the first and second images into a combined output image.

56. (New) The method of claim 55, wherein the processing of the first and second images into a combined output image includes executing a registration process for registering respective pixels from the first and second images to form the combined output image.

57. (New) The method of claim 56, wherein the registration process comprises:

if $FOV_2 < FOV_{ZF} \leq FOV_1$, finding in an overlap area a corresponding pixel in the second image for each pixel in the first image and generating the combined output image by modifying values of the first image pixels according to corresponding pixel values in the second image, thereby providing a point of view of the output image of the first camera, and if $FOV_2 \geq FOV_{ZF}$, finding a corresponding pixel in the first image for each pixel in the second image and generating a combined output image by modifying values of the second image pixels according to corresponding pixel values in the first image, thereby providing a point of view of the output image of the second camera.

58. (New) The method of claim 57, wherein the modified values in the first or second image are Luma pixel values modified according to corresponding Luma pixel values in, respectively, the second or first image.

59. (New) The method of claim 56, wherein the registration process comprises:

if $FOV_2 < FOV_{ZF} \leq FOV_1$, finding in an overlap area a corresponding pixel in the second image for each pixel in the first image and generating the combined output image by modifying values of the first image pixels according to corresponding pixel values in the second image, thereby providing a point of view of the output image of the first camera; and if $FOV_2 \geq FOV_{ZF}$, generating a combined output image using only pixel values from the second image, thereby providing a point of view of the output image of the second camera.

60. (New) The method of claim 59, wherein the modified values are first image Luma pixel values modified according to corresponding second image Luma pixel values.

61. (New) A method of acquiring images by a multi-aperture imaging system, the method comprising:

g) providing a first image generated by a first camera subset of the imaging system, the first camera subset having a first field of view (FOV_1) and a first sensor with a first plurality of sensor pixels covered at least in part with a standard color filter array (CFA);

h) providing a second image generated by a second camera subset of the imaging system, the second camera subset having a second field of view (FOV_2) such that $FOV_2 < FOV_1$ and a second sensor with a second plurality of sensor pixels, the second plurality of sensor pixels being either Clear or covered with a standard CFA; and

i) using a processor for generating an output image by processing the first and second images into a combined output image, wherein the processing includes registering the first and second images and finding respective pixels in the first and second images, and wherein the registering includes applying low pass filtering to the second image, thereby improving registration performance.

REMARKS

This preliminary amendment cancels presently outstanding claims 1, 4, 10, 13 and 32-43 and adds new claims 44-61, of which claims 44, 53, 53 and 61 are independent. No new matter is introduced. Support for the new claims may be found with reference to the published PCT application WO 2014/083489 A1, as follows:

Claims 44, 52, 53 and 61: p. 4, lines 3-10 and 23-25, p. 7, line 3-p. 8, line 2, p. 12, lines 15-20
Claims 45 and 54: p. 12, lines 15-20
Claims 46 and 55: p. 13, lines 2-3, p. 4, lines 9-10
Claims 47 and 56: p. 4, lines 23 to p. 5, line 3
Claims 48-51 and 57-60: p. 12, line 1 to p. 13, line 15

In view of the above amendments and remarks it is respectfully submitted that claims 1, 4, 10, 13 and 44-61 are in condition for allowance. Prompt notice of allowance is respectfully and earnestly solicited.

Respectfully submitted,

/Menachem Nathan/

Menachem Nathan
Agent for Applicant
Registration No. 65392

Date: September 15, 2015

Electronic Patent Application Fee Transmittal

Application Number:	14386823
Filing Date:	22-Sep-2014
Title of Invention:	HIGH RESOLUTION THIN MULTI-APERTURE IMAGING SYSTEMS
First Named Inventor/Applicant Name:	Gal Shabtay
Filer:	Menachem Nathan
Attorney Docket Number:	COREPH-0072 US NP

Filed as Small Entity

Filing Fees for **U.S. National Stage under 35 USC 371**

Description	Fee Code	Quantity	Amount	Sub-Total in USD($)
Basic Filing:				
Pages:				
Claims:				
Claims in excess of 20	2615	2	40	80
Independent claims in excess of 3	2614	1	210	210
Miscellaneous-Filing:				
Petition:				
Patent-Appeals-and-Interference:				

Description	Fee Code	Quantity	Amount	Sub-Total in USD($)
Post-Allowance-and-Post-Issuance:				
Extension-of-Time:				
Miscellaneous:				
		Total in USD ($)		**290**

Electronic Acknowledgement Receipt

EFS ID:	23511047
Application Number:	14386823
International Application Number:	
Confirmation Number:	1857
Title of Invention:	HIGH RESOLUTION THIN MULTI-APERTURE IMAGING SYSTEMS
First Named Inventor/Applicant Name:	Gal Shabtay
Customer Number:	92342
Filer:	Menachem Nathan
Filer Authorized By:	
Attorney Docket Number:	COREPH-0072 US NP
Receipt Date:	16-SEP-2015
Filing Date:	22-SEP-2014
Time Stamp:	15:10:20
Application Type:	U.S. National Stage under 35 USC 371

Payment information:

Submitted with Payment	yes
Payment Type	Credit Card
Payment was successfully received in RAM	$290
RAM confirmation Number	1495
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	Preliminary Amendment	Preliminary_amendment.pdf	62119 2ac1bd179fd1c50a318a7fee22da282f34a3ce7a	no	8
Warnings:					
Information:					
2	Fee Worksheet (SB06)	fee-info.pdf	31820 99f33fc5fc39dc12d45c38ec0467357ebbee71d0	no	2
Warnings:					
Information:					
		Total Files Size (in bytes):	93939		

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.

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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.

PTO/SB/06 (09-11)
Approved for use through 1/31/2014. OMB 0651-0032
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PATENT APPLICATION FEE DETERMINATION RECORD Substitute for Form PTO-875	Application or Docket Number 14/386,823	Filing Date 09/22/2014	☐ To be Mailed

ENTITY: ☐ LARGE ☒ SMALL ☐ MICRO

APPLICATION AS FILED – PART I

FOR	NUMBER FILED (Column 1)	NUMBER EXTRA (Column 2)	RATE ($)	FEE ($)
☐ BASIC FEE (37 CFR 1.16(a), (b), or (c))	N/A	N/A	N/A	
☐ SEARCH FEE (37 CFR 1.16(k), (i), or (m))	N/A	N/A	N/A	
☐ EXAMINATION FEE (37 CFR 1.16(o), (p), or (q))	N/A	N/A	N/A	
TOTAL CLAIMS (37 CFR 1.16(i))	minus 20 =	*	X $ =	
INDEPENDENT CLAIMS (37 CFR 1.16(h))	minus 3 =	*	X $ =	
☐ APPLICATION SIZE FEE (37 CFR 1.16(s))	If the specification and drawings exceed 100 sheets of paper, the application size fee due is $310 ($155 for small entity) for each additional 50 sheets or fraction thereof. See 35 U.S.C. 41(a)(1)(G) and 37 CFR 1.16(s).			
☐ MULTIPLE DEPENDENT CLAIM PRESENT (37 CFR 1.16(j))				
* If the difference in column 1 is less than zero, enter "0" in column 2.			TOTAL	

APPLICATION AS AMENDED – PART II

AMENDMENT	09/16/2015	CLAIMS REMAINING AFTER AMENDMENT (Column 1)		HIGHEST NUMBER PREVIOUSLY PAID FOR (Column 2)	PRESENT EXTRA (Column 3)	RATE ($)	ADDITIONAL FEE ($)
	Total (37 CFR 1.16(i))	* 22	Minus	** 20	= 2	x $40 =	80
	Independent (37 CFR 1.16(h))	* 5	Minus	***3	= 2	x $210 =	420
	☐ Application Size Fee (37 CFR 1.16(s))						
	☐ FIRST PRESENTATION OF MULTIPLE DEPENDENT CLAIM (37 CFR 1.16(j))						
						TOTAL ADD'L FEE	**500**

AMENDMENT		CLAIMS REMAINING AFTER AMENDMENT (Column 1)		HIGHEST NUMBER PREVIOUSLY PAID FOR (Column 2)	PRESENT EXTRA (Column 3)	RATE ($)	ADDITIONAL FEE ($)
	Total (37 CFR 1.16(i))	*	Minus	**	=	X $ =	
	Independent (37 CFR 1.16(h))	*	Minus	***	=	X $ =	
	☐ Application Size Fee (37 CFR 1.16(s))						
	☐ FIRST PRESENTATION OF MULTIPLE DEPENDENT CLAIM (37 CFR 1.16(j))						
						TOTAL ADD'L FEE	

* If the entry in column 1 is less than the entry in column 2, write "0" in column 3.
** If the "Highest Number Previously Paid For" IN THIS SPACE is less than 20, enter "20".
*** If the "Highest Number Previously Paid For" IN THIS SPACE is less than 3, enter "3".
The "Highest Number Previously Paid For" (Total or Independent) is the highest number found in the appropriate box in column 1.

LIE
/VINCENT BUTLER/

This collection of information is required by 37 CFR 1.16. 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 12 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, 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.**

If you need assistance in completing the form, call 1-800-PTO-9199 and select option 2.

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APPLICATION NUMBER	FILING OR 371(C) DATE	FIRST NAMED APPLICANT	ATTY. DOCKET NO./TITLE
14/386,823	09/22/2014	Gal Shabtay	COREPH-0072 US NP

CONFIRMATION NO. 1857

PUBLICATION NOTICE

OC000000074240735

92342
Nathan & Associates Patent Agents Ltd
P.O.Box 10178
Tel Aviv, 6110101
ISRAEL

Title:HIGH RESOLUTION THIN MULTI-APERTURE IMAGING SYSTEMS

Publication No.US-2015-0085174-A1
Publication Date:03/26/2015

NOTICE OF PUBLICATION OF APPLICATION

The above-identified application will be electronically published as a patent application publication pursuant to 37 CFR 1.211, et seq. The patent application publication number and publication date are set forth above.

The publication may be accessed through the USPTO's publically available Searchable Databases via the Internet at www.uspto.gov. The direct link to access the publication is currently http://www.uspto.gov/patft/.

The publication process established by the Office does not provide for mailing a copy of the publication to applicant. A copy of the publication may be obtained from the Office upon payment of the appropriate fee set forth in 37 CFR 1.19(a)(1). Orders for copies of patent application publications are handled by the USPTO's Office of Public Records. The Office of Public Records can be reached by telephone at (703) 308-9726 or (800) 972-6382, by facsimile at (703) 305-8759, by mail addressed to the United States Patent and Trademark Office, Office of Public Records, Alexandria, VA 22313-1450 or via the Internet.

In addition, information on the status of the application, including the mailing date of Office actions and the dates of receipt of correspondence filed in the Office, may also be accessed via the Internet through the Patent Electronic Business Center at www.uspto.gov using the public side of the Patent Application Information and Retrieval (PAIR) system. The direct link to access this status information is currently http://pair.uspto.gov/. Prior to publication, such status information is confidential and may only be obtained by applicant using the private side of PAIR.

Further assistance in electronically accessing the publication, or about PAIR, is available by calling the Patent Electronic Business Center at 1-866-217-9197.

Office of Data Managment, Application Assistance Unit (571) 272-4000, or (571) 272-4200, or 1-888-786-0101

UNITED STATES PATENT AND TRADEMARK OFFICE

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U.S. APPLICATION NUMBER NO.	FIRST NAMED INVENTOR	ATTY. DOCKET NO.
14/386,823	Gal Shabtay	COREPH-0072 US NP

92342
Nathan & Associates Patent Agents Ltd
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ISRAEL

INTERNATIONAL APPLICATION NO.	
PCT/IB2013/060356	
I.A. FILING DATE	PRIORITY DATE
11/23/2013	11/28/2012

CONFIRMATION NO. 1857
371 ACCEPTANCE LETTER

OC000000072407537

Date Mailed: 12/18/2014

NOTICE OF ACCEPTANCE OF APPLICATION UNDER 35 U.S.C 371 AND 37 CFR 1.495

The applicant is hereby advised that the United States Patent and Trademark Office, in its capacity as a Designated / Elected Office (37 CFR 1.495), has ACCEPTED the above identified international application for national patentability examination in the United States Patent and Trademark Office.

The United States Application Number assigned to the application is shown above. A Filing Receipt will be issued for the present application in due course. **THE DATE APPEARING ON THE FILING RECEIPT AS THE "FILING DATE or 371(c) DATE" IS THE DATE ON WHICH THE LAST OF THE 35 U.S.C. 371 (c)(1) and (c)(2) REQUIREMENTS HAS BEEN RECEIVED IN THE OFFICE. THIS DATE IS SHOWN BELOW.** The filing date of the above identified application is the international filing date of the international application (Article 11(3) and 35 U.S.C. 363)

09/22/2014
DATE OF RECEIPT OF 35 U.S.C.
371(c)(1) and (c)(2) REQUIREMENTS

The following items have been received:

- Indication of Small Entity Status
- Copy of the International Application filed on 09/22/2014
- Copy of the International Search Report filed on 09/22/2014
- Preliminary Amendments filed on 09/22/2014
- Information Disclosure Statements filed on 09/22/2014
- Inventor's Oath or Declaration filed on 09/22/2014
- Request for Immediate Examination filed on 09/22/2014
- U.S. Basic National Fees filed on 09/22/2014
- Assignment filed on 09/22/2014
- Priority Documents filed on 09/22/2014
- Power of Attorney filed on 09/22/2014
- Application Data Sheet (37 CFR 1.76) filed on 09/22/2014

FORM PCT/DO/EO/903 (371 Acceptance Notice)

Applicant is reminded that any communications to the United States Patent and Trademark Office must be mailed to the address given in the heading and include the U.S. application no. shown above (37 CFR 1.5)

JUELETHIA A PALMER

Telephone: (571) 272-9050

PATENT APPLICATION FEE DETERMINATION RECORD Substitute for Form PTO-875	Application or Docket Number 14/386,823

APPLICATION AS FILED - PART I

	(Column 1)	(Column 2)	SMALL ENTITY		OR	OTHER THAN SMALL ENTITY	
FOR	NUMBER FILED	NUMBER EXTRA	RATE($)	FEE($)		RATE($)	FEE($)
BASIC FEE (37 CFR 1.16(a), (b), or (c))	N/A	N/A	N/A	140		N/A	
SEARCH FEE (37 CFR 1.16(k), (i), or (m))	N/A	N/A	N/A	240		N/A	
EXAMINATION FEE (37 CFR 1.16(o), (p), or (q))	N/A	N/A	N/A	360		N/A	
TOTAL CLAIMS (37 CFR 1.16(i))	16 minus 20 =	*	x 40 =	0.00	OR		
INDEPENDENT CLAIMS (37 CFR 1.16(h))	3 minus 3 =	*	x 210 =	0.00			
APPLICATION SIZE FEE (37 CFR 1.16(s))	If the specification and drawings exceed 100 sheets of paper, the application size fee due is $310 ($155 for small entity) for each additional 50 sheets or fraction thereof. See 35 U.S.C. 41(a)(1)(G) and 37 CFR 1.16(s).			0.00			
MULTIPLE DEPENDENT CLAIM PRESENT (37 CFR 1.16(j))				0.00			
* If the difference in column 1 is less than zero, enter "0" in column 2.			TOTAL	740		TOTAL	

APPLICATION AS AMENDED - PART II

AMENDMENT A

	(Column 1) CLAIMS REMAINING AFTER AMENDMENT		(Column 2) HIGHEST NUMBER PREVIOUSLY PAID FOR	(Column 3) PRESENT EXTRA	SMALL ENTITY RATE($)	ADDITIONAL FEE($)	OR	OTHER THAN SMALL ENTITY RATE($)	ADDITIONAL FEE($)
Total (37 CFR 1.16(i))	*	Minus	**	=	x =		OR	x =	
Independent (37 CFR 1.16(h))	*	Minus	***	=	x =		OR	x =	
Application Size Fee (37 CFR 1.16(s))									
FIRST PRESENTATION OF MULTIPLE DEPENDENT CLAIM (37 CFR 1.16(j))							OR		
					TOTAL ADD'L FEE		OR	TOTAL ADD'L FEE	

AMENDMENT B

	(Column 1) CLAIMS REMAINING AFTER AMENDMENT		(Column 2) HIGHEST NUMBER PREVIOUSLY PAID FOR	(Column 3) PRESENT EXTRA	RATE($)	ADDITIONAL FEE($)		RATE($)	ADDITIONAL FEE($)
Total (37 CFR 1.16(i))	*	Minus	**	=	x =		OR	x =	
Independent (37 CFR 1.16(h))	*	Minus	***	=	x =		OR	x =	
Application Size Fee (37 CFR 1.16(s))									
FIRST PRESENTATION OF MULTIPLE DEPENDENT CLAIM (37 CFR 1.16(j))							OR		
					TOTAL ADD'L FEE		OR	TOTAL ADD'L FEE	

* If the entry in column 1 is less than the entry in column 2, write "0" in column 3.
** If the "Highest Number Previously Paid For" IN THIS SPACE is less than 20, enter "20".
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APPLICATION NUMBER	FILING or 371(c) DATE	GRP ART UNIT	FIL FEE REC'D	ATTY.DOCKET.NO	TOT CLAIMS	IND CLAIMS
14/386,823	09/22/2014		560	COREPH-0072 US NP	16	3

CONFIRMATION NO. 1857

92342
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ISRAEL

FILING RECEIPT

OC000000072407536

Date Mailed: 12/18/2014

Receipt is acknowledged of this non-provisional patent application. The application will be taken up for examination in due course. Applicant will be notified as to the results of the examination. Any correspondence concerning the application must include the following identification information: the U.S. APPLICATION NUMBER, FILING DATE, NAME OF APPLICANT, and TITLE OF INVENTION. Fees transmitted by check or draft are subject to collection. Please verify the accuracy of the data presented on this receipt. **If an error is noted on this Filing Receipt, please submit a written request for a Filing Receipt Correction. Please provide a copy of this Filing Receipt with the changes noted thereon. If you received a "Notice to File Missing Parts" for this application, please submit any corrections to this Filing Receipt with your reply to the Notice. When the USPTO processes the reply to the Notice, the USPTO will generate another Filing Receipt incorporating the requested corrections**

Inventor(s)

Gal Shabtay, Tel-Aviv, ISRAEL;
Noy Cohen, Tel-Aviv, ISRAEL;
Oded Gigushinski, Herzlia, ISRAEL;
Ephraim Goldenberg, Ashdod, ISRAEL;

Applicant(s)

Corephotonics Ltd., Tel-Aviv, ISRAEL

Assignment For Published Patent Application

Corephotonics Ltd., Tel-Aviv, ISRAEL

Power of Attorney: The patent practitioners associated with Customer Number 92342

Domestic Priority data as claimed by applicant

This application is a 371 of PCT/IB2013/060356 11/23/2013
which claims benefit of 61/730,570 11/28/2012

Foreign Applications for which priority is claimed (You may be eligible to benefit from the **Patent Prosecution Highway** program at the USPTO. Please see http://www.uspto.gov for more information.) - None.
Foreign application information must be provided in an Application Data Sheet in order to constitute a claim to foreign priority. See 37 CFR 1.55 and 1.76.

If Required, Foreign Filing License Granted: 12/15/2014
The country code and number of your priority application, to be used for filing abroad under the Paris Convention, is **US 14/386,823**
Projected Publication Date: 03/26/2015
Non-Publication Request: No

Early Publication Request: No
**** SMALL ENTITY ****
Title

HIGH RESOLUTION THIN MULTI-APERTURE IMAGING SYSTEMS

Preliminary Class

Statement under 37 CFR 1.55 or 1.78 for AIA (First Inventor to File) Transition Applications: No

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Since the rights granted by a U.S. patent extend only throughout the territory of the United States and have no effect in a foreign country, an inventor who wishes patent protection in another country must apply for a patent in a specific country or in regional patent offices. Applicants may wish to consider the filing of an international application under the Patent Cooperation Treaty (PCT). An international (PCT) application generally has the same effect as a regular national patent application in each PCT-member country. The PCT process **simplifies** the filing of patent applications on the same invention in member countries, but **does not result** in a grant of "an international patent" and does not eliminate the need of applicants to file additional documents and fees in countries where patent protection is desired.

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Applicants may wish to consult the USPTO booklet, "General Information Concerning Patents" (specifically, the section entitled "Treaties and Foreign Patents") for more information on timeframes and deadlines for filing foreign patent applications. The guide is available either by contacting the USPTO Contact Center at 800-786-9199, or it can be viewed on the USPTO website at http://www.uspto.gov/web/offices/pac/doc/general/index.html.

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Title 37, Code of Federal Regulations, 5.11 & 5.15

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NOT GRANTED

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INFORMATION DISCLOSURE STATEMENT BY APPLICANT (**Not for submission under 37 CFR 1.99)**		
	Application Number	14386823
	Filing Date	2014-09-22
	First Named Inventor	Gal Shabtay
	Art Unit	
	Examiner Name	
	Attorney Docket Number	COREPH-0072 US NP

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	8660420		2014-02-25	Chang	
	2	8553106		2013-08-10	Scarff	
	3	8542287		2013-09-24	Griffith et al.	
	4	8439265		2013-05-14	Ferren et al.	
	5	8149327		2012-04-03	Lin et al.	
	6	7676146		2010-03-09	Border et al.	
	7	7561191		2009-07-14	May et al.	
	8	7305180		2007-12-04	Labaziewicz et al.	

INFORMATION DISCLOSURE STATEMENT BY APPLICANT
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Attorney Docket Number	COREPH-0072 US NP

	9	8134115		2012-03-13	KOSKINEN et al.	
	10	8094208		2012-01-10	MYHRVOLD	
	11	8179457		2012-05-15	KOSKINEN et al.	

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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	20110064327		2011-03-17	Dagher et al.	
	2	20100277619		2010-04-11	Scarff	
	3	20080030592		2008-02-07	Border et al.	
	4	20110285730		2011-11-24	Lai et al.	
	5	20110121421		2011-05-26	CHARBON et al.	
	6	20110292258		2011-12-01	ADLER et al.	

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INFORMATION DISCLOSURE STATEMENT BY APPLICANT (**Not for submission under 37 CFR 1.99)**		
	Application Number	14386823
	Filing Date	2014-09-22
	First Named Inventor	Gal Shabtay
	Art Unit	
	Examiner Name	
	Attorney Docket Number	COREPH-0072 US NP

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	1	2009097552	WO		2009-08-06	Dagher et al.		☐

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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	International Search Report and Written Opinion issued in related PCT patent application PCT/IB2013/060356, dated April 17, 2014, 15 pages.	☐

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*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)		
	Application Number	14386823
	Filing Date	2014-09-22
	First Named Inventor	Gal Shabtay
	Art Unit	
	Examiner Name	
	Attorney Docket Number	COREPH-0072 US NP

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	/Menachem Nathan/	Date (YYYY-MM-DD)	2014-10-10
Name/Print	MENACHEM NATHAN	Registration Number	65392

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

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PATENT COOPERATION TREATY

From the
INTERNATIONAL SEARCHING AUTHORITY

To: GAL SHABTAY
NATHAN & ASSOCIATES PATENT AGENTS LTD.
P.O. BOX 10178
6110101 TEL AVIV
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PCT

WRITTEN OPINION OF THE INTERNATIONAL SEARCHING AUTHORITY

(PCT Rule 43*bis*.1)

Date of mailing *(day/month/year)*	17 APR 2014
Applicant's or agent's file reference: COREPH-72	**FOR FURTHER ACTION** See paragraph 2 below

International application No.	International filing date *(day/month/year)*	Priority date *(day/month/year)*
PCT/IB2013/060356	23 November 2013	28 November 2012

International Patent Classification (IPC) or both national classification and IPC
IPC(8) - H04N9/09 (2014.01)
USPC - 348/277

Applicant COREPHOTONICS LTD.

1. This opinion contains indications relating to the following items:

- [x] Box No. I Basis of the opinion
- [ ] Box No. II Priority
- [ ] Box No. III Non-establishment of opinion with regard to novelty, inventive step and industrial applicability
- [ ] Box No. IV Lack of unity of invention
- [x] Box No. V Reasoned statement under Rule 43*bis*.1(a)(i) with regard to novelty, inventive step or industrial applicability; citations and explanations supporting such statement
- [ ] Box No. VI Certain documents cited
- [ ] Box No. VII Certain defects in the international application
- [ ] Box No. VIII Certain observations on the international application

2. **FURTHER ACTION**

If a demand for international preliminary examination is made, this opinion will be considered to be a written opinion of the International Preliminary Examining Authority ("IPEA") except that this does not apply where the applicant chooses an Authority other than this one to be the IPEA and the chosen IPEA has notified the International Bureau under Rule 66.1*bis*(b) that written opinions of this International Searching Authority will not be so considered.

If this opinion is, as provided above, considered to be a written opinion of the IPEA, the applicant is invited to submit to the IPEA a written reply together, where appropriate, with amendments, before the expiration of 3 months from the date of mailing of Form PCT/ISA/220 or before the expiration of 22 months from the priority date, whichever expires later.

For further options, see Form PCT/ISA/220.

Name and mailing address of the ISA/US	Date of completion of this opinion	Authorized officer:
Mail Stop PCT, Attn: ISA/US Commissioner for Patents P.O. Box 1450, Alexandria, Virginia 22313-1450 Facsimile No. 571-273-3201	27 March 2014	Blaine R. Copenheaver PCT Helpdesk: 571-272-4300 PCT OSP: 571-272-7774

Form PCT/ISA/237 (cover sheet) (July 2011)

Box No. I Basis of this opinion

1. With regard to the **language**, this opinion has been established on the basis of:
   - [X] the international application in the language in which it was filed.
   - [ ] a translation of the international application into ____________ which is the language of a translation furnished for the purposes of international search (Rules 12.3(a) and 23.1(b)).

2. [ ] This opinion has been established taking into account the **rectification of an obvious mistake** authorized by or notified to this Authority under Rule 91 (Rule 43*bis*.1(a))

3. With regard to any **nucleotide and/or amino acid sequence** disclosed in the international application, this opinion has been established on the basis of a sequence listing filed or furnished:

   a. (means)
   - [ ] on paper
   - [ ] in electronic form

   b. (time)
   - [ ] in the international application as filed
   - [ ] together with the international application in electronic form
   - [ ] subsequently to this Authority for the purposes of search

4. [ ] In addition, in the case that more than one version or copy of a sequence listing has been filed or furnished, the required statements that the information in the subsequent or additional copies is identical to that in the application as filed or does not go beyond the application as filed, as appropriate, were furnished.

5. Additional comments:

WRITTEN OPINION OF THE INTERNATIONAL SEARCHING AUTHORITY	International application No. PCT/IB2013/060356

Box No. V Reasoned statement under Rule 43*bis*.1(a)(i) with regard to novelty, inventive step or industrial applicability; citations and explanations supporting such statement

1. Statement

Novelty (N)	Claims	1-20,30,31	YES
	Claims	21-29,32	NO
Inventive step (IS)	Claims	None	YES
	Claims	1-32	NO
Industrial applicability (IA)	Claims	1-32	YES
	Claims	None	NO

2. Citations and explanations:

Claims 21-29, 32 lack lack novelty under PCT Article 33(2) as being anticipated by Dagher et al. (US 2011/0064327 A1), hereinafter Dagher.

Regarding claim 21, Dagher teaches a multi-aperture imaging system (... multi-aperture camera systems with the imaging characteristics [0041]-[0042], Fig.1; multi-aperture camera Fig.3) comprising:
a) a first camera subset that provides a first image, the first camera subset having a first sensor with a first plurality of sensor pixels (... A scene (5) is imaged by two cameras (10) and (12) that image fields of view (20) and (22)... cameras (10) and (12) may be... sub-cameras of a single multi-aperture camera [0046], Fig.1, Fig.2; ... It is contemplated that sensors of sub-cameras of a single multi-aperture camera may be shared in any manner... blocks of pixels adjacent one another in a single sensor chip... not limited to having identical shapes or sizes [0049], Fig.2; ... multi-aperture camera (100), each of first and second optical sub-systems (110) and (120) is shown imaging onto its own sensor (i.e., sensors (130) and (140), respectively) [0067], Fig.2) covered at least in part with a standard CFA (... Image sensors often utilize a Red-Green-Blue ("RGB") color filter array ("CFA"), such as a Bayer pattern... in FIG. 8, both the tele and the wide images are converted from RGB to YUV [0063], Fig.8; ... a CFA such as a Bayer filter, or be formed of individual color sensor elements (e.g., RGB or Cyan-Magenta-Yellow ("CMY")) [0067]);
b) a second camera subset that provides a second image, the second camera subset having a second sensor with a second plurality of sensor pixels (... A scene (5) is imaged by two cameras (10) and (12) that image fields of view (20) and (22)... cameras (10) and (12) may be... sub-cameras of a single multi-aperture camera [0046], Fig.1, Fig.2; ... It is contemplated that sensors of sub-cameras of a single multi-aperture camera may be shared in any manner... blocks of pixels adjacent one another in a single sensor chip... not limited to having identical shapes or sizes [0049], Fig.2; ... multi-aperture camera (100), each of first and second optical sub-systems (110) and (120) is shown imaging onto its own sensor (i.e., sensors (130) and (140), respectively) [0067], Fig.2), the second plurality of sensor pixels being either Clear or covered with a standard CFA (... Image sensors often utilize a Red-Green-Blue ("RGB") color filter array ("CFA"), such as a Bayer pattern... in FIG. 8, both the tele and the wide images are converted from RGB to YUV... the tele sub-camera may utilize an image sensor that does not have a color filter array... to utilize its entire sensor area [0063], Fig.8); and
c) a processor (... Multi aperture camera (100) provides first and second sets of image data (301) and (302) to a processor (166) which may, for example, be configured for combining or "fusing" the image data sets... to an image output device (167) [0053], Fig.3) configured to register first and second Luma images obtained respectively from the first and second images and to process the registered first and second Luma images together with color information into a combined output image (... FIG.8, both the tele and wide images are converted from RGB to YUV... one luminance (Y) channel and two chrominance channels (U, V) [0063], Fig.8; ... Process (338)... may be applied to full color images... an image registration procedure (342) is applied [0065], Fig.9; ... fusion of image data... may involve addition of color information from a color sub-camera image to luminance information from a grayscale sub-camera image... a complementary operation may be performed where luminance information from the grayscale sub-camera is added to the color image from the color sub-camera... FIG. 11, which illustrates an exemplary process (365) that utilizes processor (166) (see FIG. 3) for fusion of image data [0073]-[0077], Fig.11; ... a grayscale sub-camera generally produces only a luminance signal (e.g., Y information [0067]).
[The term "Luma" is synonymous with "luminance".]

Regarding claim 22, Dagher teaches the imaging system of claim 21 (... multi-aperture camera systems with the imaging characteristics [0041]-[0042], Fig.1; multi-aperture camera Fig.3), wherein the first and the second camera subsets (... cameras (10) and (12) may be... sub-cameras of a single multi-aperture camera [0046], Fig.1, Fig.2; ... It is contemplated that sensors of sub-cameras of a single multi-aperture camera may be shared in any manner... blocks of pixels adjacent one another in a single sensor chip... not limited to having identical shapes or sizes [0049]) have respectively identical fields of view (In a particular aspect, configuring the first sub-camera may include establishing a first focal length... configuring the second camera may include establishing a second focal length... The second focal length may be different than the first focal length such that the second camera exhibits a different field of view as compared to the first camera [0013]; ... each optical sub-system may have a different focal length resulting in different fields of view [0048], Fig.2).
[The first and second sub-cameras may have identical focal lengths and therefore identical fields of view.]

Supplemental Box

In case **the space in any of the preceding boxes is not sufficient.**
Continuation of:

Regarding claim 23, Dagher teaches the imaging system of claim 22 (... multi-aperture camera systems with the imaging characteristics [0041]-[0042], Fig.1; multi-aperture camera Fig.3), wherein the registration includes finding a corresponding pixel in the second Luma image for each pixel in the first Luma image (... Process (338)... may be applied to full color images... an image registration procedure (342) is applied [0065], Fig.9; ... FIG. 11, which illustrates an exemplary process (365) that utilizes processor (166) (see FIG. 3) for fusion of image data [0073]-[0077], Fig.11; ... image may be divided into overlapping or non-overlapping blocks of size Kx x Ky (i.e., Kx pixels in an x-direction and Ky pixels in a y-direction) [0083], Fig.12; ... knowledge of the sub-camera geometry for a multi-aperture camera (e.g., first and second sub-cameras (150) and (160) of FIG. 2B) and its sensor(s)... it is possible to estimate a parallax shift between the two or more sub-cameras [0084]; ... image registration step (369) (see FIG. 11) implemented with a block-wise sliding window transform [0090], Fig.13; ... image fusion step (373) (see FIG. 11)... registration information computed in image registration step (369)... may be 'merged' [0098], Fig.15) and wherein the processor is further configured to form the output image by transferring information from the second image to the first image (... Process (338)... may be applied to full color images... an image registration procedure (342) is applied [0065], Fig.9; ... fusion of image data... may involve addition of color information from a color sub-camera image to luminance information from a grayscale sub-camera image... a complementary operation may be performed where luminance information from the grayscale sub-camera is added to the color image from the color sub-camera... FIG. 11, which illustrates an exemplary process (365) that utilizes processor (166) (see FIG. 3) for fusion of image data [0073]-[0077], Fig.11).

Regarding claim 24, Dagher teaches the imaging system of claim 22 (... multi-aperture camera systems with the imaging characteristics [0041]-[0042], Fig.1; multi-aperture camera Fig.3), wherein the registration includes finding a corresponding pixel in the first Luma image for each pixel in the second Luma image (... Process (338)... may be applied to full color images... an image registration procedure (342) is applied [0065], Fig.9; ... FIG. 11, which illustrates an exemplary process (365) that utilizes processor (166) (see FIG. 3) for fusion of image data [0073]-[0077], Fig.11; ... image may be divided into overlapping or non-overlapping blocks of size Kx x Ky (i.e., Kx pixels in an x-direction and Ky pixels in a y-direction) [0083], Fig.12; ... knowledge of the sub-camera geometry for a multi-aperture camera (e.g., first and second sub-cameras (150) and (160) of FIG. 2B) and its sensor(s)... it is possible to estimate a parallax shift between the two or more sub-cameras [0084]; ... image registration step (369) (see FIG. 11) implemented with a block-wise sliding window transform [0090], Fig.13; ... image fusion step (373) (see FIG. 11)... registration information computed in image registration step (369)... may be 'merged' [0098], Fig.15) and wherein the processor is further configured to form the output image by transferring information from the first image to the second image (... Process (338)... may be applied to full color images... an image registration procedure (342) is applied [0065], Fig.9; ... fusion of image data... may involve addition of color information from a color sub-camera image to luminance information from a grayscale sub-camera image... a complementary operation may be performed where luminance information from the grayscale sub-camera is added to the color image from the color sub-camera... FIG. 11, which illustrates an exemplary process (365) that utilizes processor (166) (see FIG. 3) for fusion of image data [0073]-[0077], Fig.11).

Regarding claim 25, Dagher teaches the imaging system of claim 21 (... multi-aperture camera systems with the imaging characteristics [0041]-[0042], Fig.1; multi-aperture camera Fig.3), wherein the first camera subset has a first field of view (FOV), wherein the second camera subset has a second, smaller FOV than the first FOV (... two cameras (10) and (12) that image fields of view (20) and (22)... cameras (10) and (12) may be... sub-cameras of a single multi-aperture camera [0046], Fig.1, Fig.2; ... It is contemplated that sensors of sub-cameras of a single multi-aperture camera may be shared in any manner... blocks of pixels adjacent one another in a single sensor chip... not limited to having identical shapes or sizes [0049], Fig.2; In a particular aspect, configuring the first sub-camera may include establishing a first focal length... configuring the second camera may include establishing a second focal length... The second focal length may be different than the first focal length such that the second camera exhibits a different field of view as compared to the first camera [0013]; ... each optical sub-system may have a different focal length resulting in different fields of view [0048], Fig.2), and wherein the processor (... Multi aperture camera (100) provides first and second sets of image data (301) and (302) to a processor (166) which may, for example, be configured for combining or "fusing" the image data sets... to an image output device (167) [0053], Fig.3) is further configured to register the first and second Luma images (... FIG.8, both the tele and wide images are converted from RGB to YUV... one luminance (Y) channel and two chrominance channels (U, V) [0063], Fig.8; ... Process (338)... may be applied to full color images... an image registration procedure (342) is applied [0065], Fig.9; ... fusion of image data... may involve addition of color information from a color sub-camera image to luminance information from a grayscale sub-camera image... a complementary operation may be performed where luminance information from the grayscale sub-camera is added to the color image from the color sub-camera... FIG. 11, which illustrates an exemplary process (365) that utilizes processor (166) (see FIG. 3) for fusion of image data [0073]-[0077], Fig.11) based on a zoom factor (ZF) input (... "zoom" may be understood as a capability to provide different magnifications... by changing the focal length of an optical system [0004]; ... allows the user to choose any level of zoom and to utilize the multi-aperture camera as a continuous zoom camera [0062]).
[The first and second sub-cameras have variable focal lengths and therefore variable fields of view.]

Supplemental Box

In case **the space in any of the preceding boxes is not sufficient.**
Continuation of:

Regarding claim 26, Dagher teaches the imaging system of claim 25 (… multi-aperture camera systems with the imaging characteristics [0041]-[0042], Fig.1; multi-aperture camera Fig.3), wherein the registration includes, for a ZF input (… "zoom" may be understood as a capability to provide different magnifications… by changing the focal length of an optical system [0004]; … allows the user to choose any level of zoom and to utilize the multi-aperture camera as a continuous zoom camera [0062]) that defines an FOV greater than the second FOV (… two cameras (10) and (12) that image fields of view (20) and (22)… cameras (10) and (12) may be… sub-cameras of a single multi-aperture camera [0046], Fig.1, Fig.2; … It is contemplated that sensors of sub-cameras of a single multi-aperture camera may be shared in any manner… blocks of pixels adjacent one another in a single sensor chip… not limited to having identical shapes or sizes [0049], Fig.2; In a particular aspect, configuring the first sub-camera may include establishing a first focal length… configuring the second camera may include establishing a second focal length… The second focal length may be different than the first focal length such that the second camera exhibits a different field of view as compared to the first camera [0013]; … each optical sub-system may have a different focal length resulting in different fields of view [0048], Fig.2), finding a corresponding pixel in the second Luma image for each pixel in the first Luma image (… Process (338)… may be applied to full color images… an image registration procedure (342) is applied [0065], Fig.9; … FIG. 11, which illustrates an exemplary process (365) that utilizes processor (166) (see FIG. 3) for fusion of image data [0073]-[0077], Fig.11; … image may be divided into overlapping or non-overlapping blocks of size Kx x Ky (i.e., Kx pixels in an x-direction and Ky pixels in a y-direction) [0083], Fig.12; … knowledge of the sub-camera geometry for a multi-aperture camera (e.g., first and second sub-cameras (150) and (160) of FIG. 2B) and its sensor(s)… it is possible to estimate a parallax shift between the two or more sub-cameras [0084]; … image registration step (369) (see FIG. 11) implemented with a block-wise sliding window transform [0090], Fig.13; … image fusion step (373) (see FIG. 11)… registration information computed in image registration step (369)… may be 'merged' [0098], Fig.15) and wherein the processor is further configured to form the output image by transferring information from the second image to the first image (… Process (338)… may be applied to full color images… an image registration procedure (342) is applied [0065], Fig.9; … fusion of image data… may involve addition of color information from a color sub-camera image to luminance information from a grayscale sub-camera image… a complementary operation may be performed where luminance information from the grayscale sub-camera is added to the color image from the color sub-camera… FIG. 11, which illustrates an exemplary process (365) that utilizes processor (166) (see FIG. 3) for fusion of image data [0073]-[0077], Fig.11).

Regarding claim 27, Dagher teaches the imaging system of claim 25 (… multi-aperture camera systems with the imaging characteristics [0041]-[0042], Fig.1; multi-aperture camera Fig.3), wherein the registration includes, for a ZF input (… "zoom" may be understood as a capability to provide different magnifications… by changing the focal length of an optical system [0004]; … allows the user to choose any level of zoom and to utilize the multi-aperture camera as a continuous zoom camera [0062]) that defines an FOV smaller than, or equal to the second FOV (… two cameras (10) and (12) that image fields of view (20) and (22)… cameras (10) and (12) may be… sub-cameras of a single multi-aperture camera [0046], Fig.1, Fig.2; … It is contemplated that sensors of sub-cameras of a single multi-aperture camera may be shared in any manner… blocks of pixels adjacent one another in a single sensor chip… not limited to having identical shapes or sizes [0049], Fig.2; In a particular aspect, configuring the first sub-camera may include establishing a first focal length… configuring the second camera may include establishing a second focal length… The second focal length may be different than the first focal length such that the second camera exhibits a different field of view as compared to the first camera [0013]; … each optical sub-system may have a different focal length resulting in different fields of view [0048], Fig.2), finding a corresponding pixel in the first Luma image for each pixel in the second Luma image (… Process (338)… may be applied to full color images… an image registration procedure (342) is applied [0065], Fig.9; … FIG. 11, which illustrates an exemplary process (365) that utilizes processor (166) (see FIG. 3) for fusion of image data [0073]-[0077], Fig.11; … image may be divided into overlapping or non-overlapping blocks of size Kx x Ky (i.e., Kx pixels in an x-direction and Ky pixels in a y-direction) [0083], Fig.12; … knowledge of the sub-camera geometry for a multi-aperture camera (e.g., first and second sub-cameras (150) and (160) of FIG. 2B) and its sensor(s)… it is possible to estimate a parallax shift between the two or more sub-cameras [0084]; … image registration step (369) (see FIG. 11) implemented with a block-wise sliding window transform [0090], Fig.13; … image fusion step (373) (see FIG. 11)… registration information computed in image registration step (369)… may be 'merged' [0098], Fig.15) and wherein the processor is further configured to form the output image by transferring information from the first image to the second image (… Process (338)… may be applied to full color images… an image registration procedure (342) is applied [0065], Fig.9; … fusion of image data… may involve addition of color information from a color sub-camera image to luminance information from a grayscale sub-camera image… a complementary operation may be performed where luminance information from the grayscale sub-camera is added to the color image from the color sub-camera… FIG. 11, which illustrates an exemplary process (365) that utilizes processor (166) (see FIG. 3) for fusion of image data [0073]-[0077], Fig.11).

Supplemental Box

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Regarding claim 28, Dagher teaches the imaging system of claim 25, wherein the second sensor (... cameras (10) and (12) may be... sub-cameras of a single multi-aperture camera [0046], Fig.1, Fig.2; ... It is contemplated that sensors of sub-cameras of a single multi-aperture camera may be shared in any manner... blocks of pixels adjacent one another in a single sensor chip... not limited to having identical shapes or sizes [0049], Fig.2; ... first and second optical sub-systems (110) and (120) is shown imaging onto its own sensor (i.e., sensors (130) and (140), respectively) [0067], Fig.2) includes a standard CFA (... Image sensors often utilize a Red-Green-Blue ("RGB") color filter array ("CFA"), such as a Bayer pattern... in FIG. 8, both the tele and the wide images are converted from RGB to YUV [0063], Fig.8; ... a CFA such as a Bayer filter, or be formed of individual color sensor elements (e.g., RGB or Cyan-Magenta-Yellow ("CMY")) [0067]) and wherein, for a ZF input (... "zoom" may be understood as a capability to provide different magnifications... by changing the focal length of an optical system [0004]; ... allows the user to choose any level of zoom and to utilize the multi-aperture camera as a continuous zoom camera [0062]) that defines an FOV equal to or smaller than the second FOV (... two cameras (10) and (12) that image fields of view (20) and (22)... cameras (10) and (12) may be... sub-cameras of a single multi-aperture camera [0046], Fig.1, Fig.2; ... It is contemplated that sensors of sub-cameras of a single multi-aperture camera may be shared in any manner... blocks of pixels adjacent one another in a single sensor chip... not limited to having identical shapes or sizes [0049], Fig.2; In a particular aspect, configuring the first sub-camera may include establishing a first focal length... configuring the second camera may include establishing a second focal length... The second focal length may be different than the first focal length such that the second camera exhibits a different field of view as compared to the first camera [0013]; ... each optical sub-system may have a different focal length resulting in different fields of view [0048], Fig.2), the processor is further configured to form the output image based on the second image (... Process (338)... may be applied to full color images... an image registration procedure (342) is applied [0065], Fig.9; ... fusion of image data... may involve addition of color information from a color sub-camera image to luminance information from a grayscale sub-camera image... a complementary operation may be performed where luminance information from the grayscale sub-camera is added to the color image from the color sub-camera... FIG. 11, which illustrates an exemplary process (365) that utilizes processor (166) (see FIG. 3) for fusion of image data [0073]-[0077], Fig.11).

Regarding claim 29, Dagher teaches the imaging system of claim 21 (... multi-aperture camera systems with the imaging characteristics [0041]-[0042], Fig.1; multi-aperture camera Fig.3), wherein the standard CFA includes a Bayer filter (... Image sensors often utilize a Red-Green-Blue ("RGB") color filter array ("CFA"), such as a Bayer pattern... in FIG. 8, both the tele and the wide images are converted from RGB to YUV [0063], Fig.8; ... a CFA such as a Bayer filter, or be formed of individual color sensor elements (e.g., RGB or Cyan-Magenta-Yellow ("CMY")) [0067]).

Regarding claim 32, Dagher teaches a multi-aperture imaging system (... multi-aperture camera systems with the imaging characteristics [0041]-[0042], Fig.1; multi-aperture camera Fig.3) comprising:
a) a first camera subset that provides a first image, the first camera subset having a first field of view (FOV) (... two cameras (10) and (12) that image fields of view (20) and (22)... cameras (10) and (12) may be... sub-cameras of a single multi-aperture camera [0046], Fig.1, Fig.2; ... It is contemplated that sensors of sub-cameras of a single multi-aperture camera may be shared in any manner... blocks of pixels adjacent one another in a single sensor chip... not limited to having identical shapes or sizes [0049], Fig.2; In a particular aspect, configuring the first sub-camera may include establishing a first focal length... configuring the second camera may include establishing a second focal length... The second focal length may be different than the first focal length such that the second camera exhibits a different field of view as compared to the first camera [0013]; ... each optical sub-system may have a different focal length resulting in different fields of view [0048], Fig.2) and first sensor with a first plurality of sensor pixels (... multi-aperture camera (100), each of first and second optical sub-systems (110) and (120) is shown imaging onto its own sensor (i.e., sensors (130) and (140), respectively) [0067], Fig.2) covered at least in part with a standard CFA (... Image sensors often utilize a Red-Green-Blue ("RGB") color filter array ("CFA"), such as a Bayer pattern... in FIG. 8, both the tele and the wide images are converted from RGB to YUV [0063], Fig.8; ... a CFA such as a Bayer filter, or be formed of individual color sensor elements (e.g., RGB or Cyan-Magenta-Yellow ("CMY")) [0067]);
b) a second camera subset that provides a second image, the second camera subset having a second, smaller FOV than the first FOV (... two cameras (10) and (12) that image fields of view (20) and (22)... cameras (10) and (12) may be... sub-cameras of a single multi-aperture camera [0046], Fig.1, Fig.2; ... It is contemplated that sensors of sub-cameras of a single multi-aperture camera may be shared in any manner... blocks of pixels adjacent one another in a single sensor chip... not limited to having identical shapes or sizes [0049], Fig.2; In a particular aspect, configuring the first sub-camera may include establishing a first focal length... configuring the second camera may include establishing a second focal length... The second focal length may be different than the first focal length such that the second camera exhibits a different field of view as compared to the first camera [0013]; ... each optical sub-system may have a different focal length resulting in different fields of view [0048], Fig.2) and a second sensor with a second plurality of sensor pixels (... multi-aperture camera (100), each of first and second optical sub-systems (110) and (120) is shown imaging onto its own sensor (i.e., sensors (130) and (140), respectively) [0067], Fig.2) covered with a standard CFA (... Image sensors often utilize a Red-Green-Blue ("RGB") color filter array ("CFA"), such as a Bayer pattern... in FIG. 8, both the tele and the wide images are converted from RGB to YUV [0063], Fig.8; ... a CFA such as a Bayer filter, or be formed of individual color sensor elements (e.g., RGB or Cyan-Magenta-Yellow ("CMY")) [0067]); and
c) a processor (... Multi aperture camera (100) provides first and second sets of image data (301) and (302) to a processor (166) which may, for example, be configured for combining or "fusing" the image data sets... to an image output device (167) [0053], Fig.3) configured to, for a zoom factor input (... "zoom" may be understood as a capability to provide different magnifications... by changing the focal length of an optical system [0004]; ... allows the user to choose any level of zoom and to utilize the multi-aperture camera as a continuous zoom camera [0062]) that defines an FOV equal to or smaller than the second FOV (... two cameras (10) and (12) that image fields of view (20) and (22)... cameras (10) and (12) may be... sub-cameras of a single multi-aperture camera [0046], Fig.1, Fig.2; ... It is contemplated that sensors of sub-cameras of a single multi-aperture camera may be shared in any manner... blocks of pixels adjacent one another in a single sensor chip... not limited to having identical shapes or sizes [0049], Fig.2; In a particular aspect, configuring the first sub-camera may include establishing a first focal length... configuring the second camera may include establishing a second focal length... The second focal length may be different than the first focal length such that the second camera exhibits a different field of view as compared to the first camera [0013]; ... each optical sub-system may have a different focal length resulting in different fields of view [0048], Fig.2), form an output image based on the second image (... Process (338)... may be applied to full color images... an image registration procedure (342) is applied [0065], Fig.9; ... fusion of image data... may involve addition of color information from a color sub-camera image to luminance information from a grayscale sub-camera image... a complementary operation may be performed where luminance information from the grayscale sub-camera is added to the color image from the color sub-camera... FIG. 11, which illustrates an exemplary process (365) that utilizes processor (166) (see FIG. 3) for fusion of image data [0073]-[0077], Fig.11).

Supplemental Box

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Claims 1, 6-20, 30-31 lack an inventive step under PCT Article 33(3) as being obvious over Dagher et al. (US 2011/0064327 A1), hereinafter Dagher in view of Koskinen et al. (US 8,134,115 B2), hereinafter Koskinen.

Regarding claim 1, Dagher teaches a multi-aperture imaging system (... multi-aperture camera systems with the imaging characteristics [0041]-[0042], Fig.1; multi-aperture camera Fig.3) comprising:
a) a first camera subset that provides a first image, the first camera subset having a first sensor with a first plurality of sensor pixels (... A scene (5) is imaged by two cameras (10) and (12) that image fields of view (20) and (22)... cameras (10) and (12) may be... sub-cameras of a single multi-aperture camera [0046], Fig.1, Fig.2; ... It is contemplated that sensors of sub-cameras of a single multi-aperture camera may be shared in any manner... blocks of pixels adjacent one another in a single sensor chip... not limited to having identical shapes or sizes [0049], Fig.2; ... multi-aperture camera (100), each of first and second optical sub-systems (110) and (120) is shown imaging onto its own sensor (i.e., sensors (130) and (140), respectively) [0067], Fig.2) covered at least in part with a color filter array (CFA) (... Image sensors often utilize a Red-Green-Blue ("RGB") color filter array ("CFA"), such as a Bayer pattern... in FIG. 8, both the tele and the wide images are converted from RGB to YUV [0063], Fig.8; ... a CFA such as a Bayer filter, or be formed of individual color sensor elements (e.g., RGB or Cyan-Magenta-Yellow ("CMY")) [0067]), the CFA used to increase a specific color sampling rate relative to a same color sampling rate in a standard CFA (... upsampling and interpolation of the first and second sets of image data... increasing the sampling frequency... higher level of image quality... higher resolution [0054], Fig.4, Fig.5, Fig.6);
b) a second camera subset that provides a second image, the second camera subset having a second sensor with a second plurality of sensor pixels (... A scene (5) is imaged by two cameras (10) and (12) that image fields of view (20) and (22)... cameras (10) and (12) may be... sub-cameras of a single multi-aperture camera [0046], Fig.1, Fig.2; ... It is contemplated that sensors of sub-cameras of a single multi-aperture camera may be shared in any manner... blocks of pixels adjacent one another in a single sensor chip... not limited to having identical shapes or sizes [0049], Fig.2; ... multi-aperture camera (100), each of first and second optical sub-systems (110) and (120) is shown imaging onto its own sensor (i.e., sensors (130) and (140), respectively) [0067], Fig.2), the second plurality of sensor pixels being either Clear or covered with a standard CFA (... Image sensors often utilize a Red-Green-Blue ("RGB") color filter array ("CFA"), such as a Bayer pattern... in FIG. 8, both the tele and the wide images are converted from RGB to YUV... the tele sub-camera may utilize an image sensor that does not have a color filter array... to utilize its entire sensor area [0063], Fig.8); and
c) a processor configured to process the first and second images into a combined output image (... Multi aperture camera (100) provides first and second sets of image data (301) and (302) to a processor (166) which may, for example, be configured for combining or "fusing" the image data sets... to an image output device (167) [0053], Fig.3), but lacks the explicit teaching of a non-standard color filter array (CFA).
However, Koskinen is analogous to Dagher and has a non-standard color filter array (CFA) (Typical technologies for generating color images rely on the Bayer sensor and its variations... FIG. 1 shows a typical Bayer-type pattern... Other filter types include, by example, CYGM filters... and RGBE filters Col.1 ln.46-56, Fig.1; The exemplary embodiments of this invention use... sub-diffraction limit receptors in combination with a color filter array. The color filter array may be designed much more freely than conventional color filter arrays Col.3 ln.41-48, Fig.3; Contrasting FIG. 3 with FIG. 1, the optical filters... enable a plurality of different filter types to be used in any desired combinations Col.3 ln.59-63 Fig.3; It should be noted that the color filters do not have to be separate for each receptor (2)... each of three different filter types is shown overlaying a plurality of the receptors Col.7 ln.51-55, Fig.7, Fig.9).
It would have been obvious to one of ordinary skill in the art at the time of the invention to combine a non-standard color filter array (CFA) as taught by Koskinen with the invention of Dagher.
The motivation would have been an obvious design choice and allows the designer much more freedom than conventional or standard color filter arrays and enable a plurality of different filter types to be used in any desired combination (Koskinen, Col.3 ln.41-48, Col.3 ln.59-63, Fig.3).

Regarding claim 6, Dagher teaches the imaging system of claim 1 (... multi-aperture camera systems with the imaging characteristics [0041]-[0042], Fig.1; multi-aperture camera Fig.3), wherein the standard CFA includes a Bayer filter (... Image sensors often utilize a Red-Green-Blue ("RGB") color filter array ("CFA"), such as a Bayer pattern... in FIG. 8, both the tele and the wide images are converted from RGB to YUV [0063], Fig.8; ... a CFA such as a Bayer filter, or be formed of individual color sensor elements (e.g., RGB or Cyan-Magenta-Yellow ("CMY")) [0067]).

Regarding claim 7, Dagher teaches the imaging system of claim 1 (... multi-aperture camera systems with the imaging characteristics [0041]-[0042], Fig.1; multi-aperture camera Fig.3), wherein the standard CFA includes a Bayer filter (... Image sensors often utilize a Red-Green-Blue ("RGB") color filter array ("CFA"), such as a Bayer pattern... in FIG. 8, both the tele and the wide images are converted from RGB to YUV [0063], Fig.8; ... a CFA such as a Bayer filter, or be formed of individual color sensor elements (e.g., RGB or Cyan-Magenta-Yellow ("CMY")) [0067]), but lacks the explicit teaching of a non-Bayer filter.
However, Koskinen is analogous to Dagher and has a non-Bayer filter (Typical technologies for generating color images rely on the Bayer sensor and its variations... FIG. 1 shows a typical Bayer-type pattern... Other filter types include, by example, CYGM filters... and RGBE filters Col.1 ln.46-56, Fig.1).
It would have been obvious to one of ordinary skill in the art at the time of the invention to combine a non-Bayer filter as taught by Koskinen with the invention of Dagher.
The motivation would have been an obvious design choice and allows the designer much more freedom than a standard Bayer color filter array (Koskinen, Col.1 ln.46-56, Col.3 ln.41-48, Col.3 ln.59-63, Fig.1, Fig.3).

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Regarding claim 8, Dagher teaches the imaging system of claim 7 (... multi-aperture camera systems with the imaging characteristics [0041]-[0042], Fig.1; multi-aperture camera Fig.3; ... Image sensors often utilize a Red-Green-Blue ("RGB") color filter array ("CFA"), such as a Bayer pattern... in FIG. 8, both the tele and the wide images are converted from RGB to YUV [0063], Fig.8; ... a CFA such as a Bayer filter, or be formed of individual color sensor elements (e.g., RGB or Cyan-Magenta-Yellow ("CMY")) [0067]), but lacks the explicit teaching of wherein the non-Bayer filter is selected from the group consisting of a RGBE, a CYYM, a CYGM, a RGBW#1, a RGBW#2 and a RGBW#3 filter.
However, Koskinen is analogous to Dagher and has wherein the non-Bayer filter is selected from the group consisting of a RGBE, a CYYM, a CYGM, a RGBW#1, a RGBW#2 and a RGBW#3 filter (Typical technologies for generating color images rely on the Bayer sensor and its variations... FIG. 1 shows a typical Bayer-type pattern... Other filter types include, by example, CYGM filters... and RGBE filters Col.1 ln.46-56, Fig.1).
It would have been obvious to one of ordinary skill in the art at the time of the invention to combine wherein the non-Bayer filter is selected from the group consisting of a RGBE, a CYYM, a CYGM, a RGBW#1, a RGBW#2 and a RGBW#3 filter as taught by Koskinen with the invention of Dagher.
The motivation would have been an obvious design choice and allows the designer much more freedom than a standard Bayer color filter array (Koskinen, Col.1 ln.46-56, Col.3 ln.41-48, Col.3 ln.59-63, Fig.1, Fig.3).

Regarding claim 9, Dagher teaches the imaging system of claim 1 (... multi-aperture camera systems with the imaging characteristics [0041]-[0042], Fig.1; multi-aperture camera Fig.3), wherein the first and the second camera subsets (... cameras (10) and (12) may be... sub-cameras of a single multi-aperture camera [0046], Fig.1, Fig.2; ... It is contemplated that sensors of sub-cameras of a single multi-aperture camera may be shared in any manner... blocks of pixels adjacent one another in a single sensor chip... not limited to having identical shapes or sizes [0049]) have identical fields of view (In a particular aspect, configuring the first sub-camera may include establishing a first focal length... configuring the second camera may include establishing a second focal length... The second focal length may be different than the first focal length such that the second camera exhibits a different field of view as compared to the first camera [0013]; ... each optical sub-system may have a different focal length resulting in different fields of view [0048], Fig.2), but lacks the explicit teaching of and wherein the non-standard CFA covers an overlap area that includes all the pixels of the first sensor, thereby providing increased color resolution.
However, Koskinen is analogous to Dagher and has and wherein the non-standard CFA (The exemplary embodiments of this invention use... sub-diffraction limit receptors in combination with a color filter array. The color filter array may be designed much more freely than conventional color filter arrays Col.3 ln.41-48, Fig.3; Contrasting FIG. 3 with FIG. 1, the optical filters... enable a plurality of different filter types to be used in any desired combinations Col.3 ln.59-63, Fig.3) covers an overlap area that includes all the pixels of the first sensor (It should be noted that the color filters do not have to be separate for each receptor (2)... each of three different filter types is shown overlaying a plurality of the receptors Col.7 ln.51-55, Fig.7, Fig.9), thereby providing increased color resolution (This enables the use of the multiple filters... resolution is not degraded... A dynamic optimization between resolution and color fidelity and sensitivity may be achieved Col.3 ln.52-58; In certain cases it may be beneficial to vary the spectral characteristics of the filter array (6)... the center area of the filter array (6) may have higher resolution Col.7 ln.41-44, Fig.7, Fig.9).
It would have been obvious to one of ordinary skill in the art at the time of the invention to combine and wherein the non-standard CFA covers an overlap area that includes all the pixels of the first sensor, thereby providing increased color resolution as taught by Koskinen with the invention of Dagher.
The motivation would have been an obvious design choice and allows the designer much more freedom than conventional or standard color filter arrays and enable a plurality of different filter types to be used in any desired combination (Koskinen, Col.3 ln.41-48, Col.3 ln.59-63, Fig.3). In addition, a dynamic optimization between resolution and color fidelity may be achieved and designation of higher resolution in certain areas of the filter array (Koskinen, Col.3 ln.52-58, Col.7 ln.41-44).

Regarding claim 10, Dagher teaches the imaging system of claim 9 (... multi-aperture camera systems with the imaging characteristics [0041]-[0042], Fig.1; multi-aperture camera Fig.3), wherein the processor (... Multi aperture camera (100) provides first and second sets of image data (301) and (302) to a processor (166) which may, for example, be configured for combining or "fusing" the image data sets... to an image output device (167) [0053], Fig.3) is further configured to register respective first and second Luma images obtained from the first and second images during the processing of the first and second images into a combined output image, the registered first and second Luma images used together with color information to form the combined output image (... FIG.8, both the tele and wide images are converted from RGB to YUV... one luminance (Y) channel and two chrominance channels (U, V) [0063], Fig.8; ... Process (338)... may be applied to full color images... an image registration procedure (342) is applied [0065], Fig.9; ... fusion of image data... may involve addition of color information from a color sub-camera image to luminance information from a grayscale sub-camera image... a complementary operation may be performed where luminance information from the grayscale sub-camera is added to the color image from the color sub-camera... FIG. 11, which illustrates an exemplary process (365) that utilizes processor (166) (see FIG. 3) for fusion of image data [0073]-[0077], Fig.11; ... a grayscale sub-camera generally produces only a luminance signal (e.g., Y information [0067]).

Regarding claim 11, Dagher teaches the imaging system of claim 10, wherein the registration includes finding a corresponding pixel in the second Luma image for each pixel in the first Luma image (... Process (338)... may be applied to full color images... an image registration procedure (342) is applied [0065], Fig.9; ... FIG. 11, which illustrates an exemplary process (365) that utilizes processor (166) (see FIG. 3) for fusion of image data [0073]-[0077], Fig.11; ... image may be divided into overlapping or non-overlapping blocks of size Kx x Ky (i.e., Kx pixels in an x-direction and Ky pixels in a y-direction) [0083], Fig.12; ... knowledge of the sub-camera geometry for a multi-aperture camera (e.g., first and second sub-cameras (150) and (160) of FIG. 2B) and its sensor(s)... it is possible to estimate a parallax shift between the two or more sub-cameras [0084]; ... image registration step (369) (see FIG. 11) implemented with a block-wise sliding window transform [0090], Fig.13; ... image fusion step (373) (see FIG. 11)... registration information computed in image registration step (369)... may be 'merged' [0098], Fig.15) and wherein the processor is further configured to form the output image by transferring information from the second image to the first image (... Process (338)... may be applied to full color images... an image registration procedure (342) is applied [0065], Fig.9; ... fusion of image data... may involve addition of color information from a color sub-camera image to luminance information from a grayscale sub-camera image... a complementary operation may be performed where luminance information from the grayscale sub-camera is added to the color image from the color sub-camera... FIG. 11, which illustrates an exemplary process (365) that utilizes processor (166) (see FIG. 3) for fusion of image data [0073]-[0077], Fig.11).

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Regarding claim 12, Dagher teaches the imaging system of claim 10, wherein the registration includes finding a corresponding pixel in the first Luma image for each pixel in the second Luma image (... Process (338)... may be applied to full color images... an image registration procedure (342) is applied [0065], Fig.9; ... FIG. 11, which illustrates an exemplary process (365) that utilizes processor (166) (see FIG. 3) for fusion of image data [0073]-[0077], Fig.11; ... image may be divided into overlapping or non-overlapping blocks of size Kx x Ky (i.e., Kx pixels in an x-direction and Ky pixels in a y-direction) [0083], Fig.12; ... knowledge of the sub-camera geometry for a multi-aperture camera (e.g., first and second sub-cameras (150) and (160) of FIG. 2B) and its sensor(s)... it is possible to estimate a parallax shift between the two or more sub-cameras [0084]; ... image registration step (369) (see FIG. 11) implemented with a block-wise sliding window transform [0090], Fig.13; ... image fusion step (373) (see FIG. 11)... registration information computed in image registration step (369)... may be 'merged' [0098], Fig.15) and wherein the processor is further configured to form the output image by transferring information from the first image to the second image (... Process (338)... may be applied to full color images... an image registration procedure (342) is applied [0065], Fig.9; ... fusion of image data... may involve addition of color information from a color sub-camera image to luminance information from a grayscale sub-camera image... a complementary operation may be performed where luminance information from the grayscale sub-camera is added to the color image from the color sub-camera... FIG. 11, which illustrates an exemplary process (365) that utilizes processor (166) (see FIG. 3) for fusion of image data [0073]-[0077], Fig.11).

Regarding claim 13, Dagher teaches the imaging system of claim 1 (... multi-aperture camera systems with the imaging characteristics [0041]-[0042], Fig.1; multi-aperture camera Fig.3), wherein the first camera subset has a first field of view (FOV) (... two cameras (10) and (12) that image fields of view (20) and (22)... cameras (10) and (12) may be... sub-cameras of a single multi-aperture camera [0046], Fig.1, Fig.2; ... It is contemplated that sensors of sub-cameras of a single multi-aperture camera may be shared in any manner... blocks of pixels adjacent one another in a single sensor chip... not limited to having identical shapes or sizes [0049], Fig.2; In a particular aspect, configuring the first sub-camera may include establishing a first focal length... configuring the second camera may include establishing a second focal length... The second focal length may be different than the first focal length such that the second camera exhibits a different field of view as compared to the first camera [0013]; ... each optical sub-system may have a different focal length resulting in different fields of view [0048], Fig.2), wherein the second camera subset has a second, smaller FOV than the first FOV (... two cameras (10) and (12) that image fields of view (20) and (22)... cameras (10) and (12) may be... sub-cameras of a single multi-aperture camera [0046], Fig.1, Fig.2; ... It is contemplated that sensors of sub-cameras of a single multi-aperture camera may be shared in any manner... blocks of pixels adjacent one another in a single sensor chip... not limited to having identical shapes or sizes [0049], Fig.2; In a particular aspect, configuring the first sub-camera may include establishing a first focal length... configuring the second camera may include establishing a second focal length... The second focal length may be different than the first focal length such that the second camera exhibits a different field of view as compared to the first camera [0013]; ... each optical sub-system may have a different focal length resulting in different fields of view [0048], Fig.2; ... first sub-camera (150) has a wider field of view as compared to second sub-camera (160)... (160) may serve as a "tele" sub-camera having a higher level of zoom as compared to first sub-camera (150) [0051]), thereby providing both optical zoom and increased color resolution (... (160) may serve as a "tele" sub-camera having a higher level of zoom as compared to first sub-camera (150) [0051]; ... it is possible to combine... two or more images... to create a single, foveated high resolution image... images will have regions of higher resolution [0054]; ... the tele sub-camera... resulting in even higher image resolution in the overlap region [0063]; ... in order to ensure good color fidelity [0106]), but lacks the explicit teaching of and wherein the non-standard CFA covers an overlap area on the first sensor that captures the second FOV.

However, Koskinen is analogous to Dagher and has and wherein the non-standard CFA (The exemplary embodiments of this invention use... sub-diffraction limit receptors in combination with a color filter array. The color filter array may be designed much more freely than conventional color filter arrays Col.3 ln.41-48, Fig.3; Contrasting FIG. 3 with FIG. 1, the optical filters... enable a plurality of different filter types to be used in any desired combinations Col.3 ln.59-63, Fig.3) covers an overlap area on the first sensor that captures the second FOV (It should be noted that the color filters do not have to be separate for each receptor (2)... each of three different filter types is shown overlaying a plurality of the receptors Col.7 ln.51-55, Fig.7, Fig.9; The direction at which the light arrives is assumed to be within a field of view (FOV) of the sensor (1) Col.4 ln.46-47).

It would have been obvious to one of ordinary skill in the art at the time of the invention to combine and wherein the non-standard CFA covers an overlap area on the first sensor that captures the second FOV as taught by Koskinen with the invention of Dagher.

The motivation would have been an obvious design choice and allows the designer much more freedom than conventional or standard color filter arrays and enable a plurality of different filter types to be used in any desired combination (Koskinen, Col.3 ln.41-48, Col.3 ln.59-63, Fig.3). In addition, a dynamic optimization between resolution and color fidelity may be achieved and designation of higher resolution in certain areas of the filter array (Koskinen, Col.3 ln.52-58, Col.7 ln.41-44, Fig.7, Fig.9).

Regarding claim 14, Dagher teaches the imaging system of claim 13, wherein the processor is further configured to, during the processing of the first and second images into a combined output image (... Multi aperture camera (100) provides first and second sets of image data (301) and (302) to a processor (166) which may, for example, be configured for combining or "fusing" the image data sets... to an image output device (167) [0053], Fig.3) and based on a zoom factor (ZF) input (... "zoom" may be understood as a capability to provide different magnifications... by changing the focal length of an optical system [0004]; ... allows the user to choose any level of zoom and to utilize the multi-aperture camera as a continuous zoom camera [0062]), register respective first and second Luma images obtained from the first and second images, the registered first and second Luma images used together with color information to form the combined output image (... FIG.8, both the tele and wide images are converted from RGB to YUV... one luminance (Y) channel and two chrominance channels (U, V) [0063], Fig.8; ... Process (338)... may be applied to full color images... an image registration procedure (342) is applied [0065], Fig.9; ... fusion of image data... may involve addition of color information from a color sub-camera image to luminance information from a grayscale sub-camera image... a complementary operation may be performed where luminance information from the grayscale sub-camera is added to the color image from the color sub-camera... FIG. 11, which illustrates an exemplary process (365) that utilizes processor (166) (see FIG. 3) for fusion of image data [0073]-[0077], Fig.11; ... a grayscale sub-camera generally produces only a luminance signal (e.g., Y information [0067]).

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Regarding claim 15, Dagher teaches the imaging system of claim 14, wherein the registration includes, for a ZF input (... "zoom" may be understood as a capability to provide different magnifications... by changing the focal length of an optical system [0004]; ... allows the user to choose any level of zoom and to utilize the multi-aperture camera as a continuous zoom camera [0062]) that defines an FOV greater than the second FOV (... two cameras (10) and (12) that image fields of view (20) and (22)... cameras (10) and (12) may be... sub-cameras of a single multi-aperture camera [0046], Fig.1, Fig.2; ... It is contemplated that sensors of sub-cameras of a single multi-aperture camera may be shared in any manner... blocks of pixels adjacent one another in a single sensor chip... not limited to having identical shapes or sizes [0049], Fig.2; In a particular aspect, configuring the first sub-camera may include establishing a first focal length... configuring the second camera may include establishing a second focal length... The second focal length may be different than the first focal length such that the second camera exhibits a different field of view as compared to the first camera [0013]; ... each optical sub-system may have a different focal length resulting in different fields of view [0048], Fig.2), finding a corresponding pixel in the second Luma image for each pixel in the first Luma image (... Process (338)... may be applied to full color images... an image registration procedure (342) is applied [0065], Fig.9; ... FIG. 11, which illustrates an exemplary process (365) that utilizes processor (166) (see FIG. 3) for fusion of image data [0073]-[0077], Fig.11; ... image may be divided into overlapping or non-overlapping blocks of size Kx x Ky (i.e., Kx pixels in an x-direction and Ky pixels in a y-direction) [0083], Fig.12; ... knowledge of the sub-camera geometry for a multi-aperture camera (e.g., first and second sub-cameras (150) and (160) of FIG. 2B) and its sensor(s)... it is possible to estimate a parallax shift between the two or more sub-cameras [0084]; ... image registration step (369) (see FIG. 11) implemented with a block-wise sliding window transform [0090], Fig.13; ... image fusion step (373) (see FIG. 11)... registration information computed in image registration step (369)... may be 'merged' [0098], Fig.15) and wherein the processor is further configured to form the output image by transferring information from the second image to the first image (... Process (338)... may be applied to full color images... an image registration procedure (342) is applied [0065], Fig.9; ... fusion of image data... may involve addition of color information from a color sub-camera image to luminance information from a grayscale sub-camera image... a complementary operation may be performed where luminance information from the grayscale sub-camera is added to the color image from the color sub-camera... FIG. 11, which illustrates an exemplary process (365) that utilizes processor (166) (see FIG. 3) for fusion of image data [0073]-[0077], Fig.11).

Regarding claim 16, Dagher teaches the imaging system of claim 14, wherein the registration includes, for a ZF input (... "zoom" may be understood as a capability to provide different magnifications... by changing the focal length of an optical system [0004]; ... allows the user to choose any level of zoom and to utilize the multi-aperture camera as a continuous zoom camera [0062]) that defines an FOV smaller than, or equal to the second FOV (... two cameras (10) and (12) that image fields of view (20) and (22)... cameras (10) and (12) may be... sub-cameras of a single multi-aperture camera [0046], Fig.1, Fig.2; ... It is contemplated that sensors of sub-cameras of a single multi-aperture camera may be shared in any manner... blocks of pixels adjacent one another in a single sensor chip... not limited to having identical shapes or sizes [0049], Fig.2; In a particular aspect, configuring the first sub-camera may include establishing a first focal length... configuring the second camera may include establishing a second focal length... The second focal length may be different than the first focal length such that the second camera exhibits a different field of view as compared to the first camera [0013]; ... each optical sub-system may have a different focal length resulting in different fields of view [0048], Fig.2), finding a corresponding pixel in the first Luma image for each pixel in the second Luma image (... Process (338)... may be applied to full color images... an image registration procedure (342) is applied [0065], Fig.9; ... FIG. 11, which illustrates an exemplary process (365) that utilizes processor (166) (see FIG. 3) for fusion of image data [0073]-[0077], Fig.11; ... image may be divided into overlapping or non-overlapping blocks of size Kx x Ky (i.e., Kx pixels in an x-direction and Ky pixels in a y-direction) [0083], Fig.12; ... knowledge of the sub-camera geometry for a multi-aperture camera (e.g., first and second sub-cameras (150) and (160) of FIG. 2B) and its sensor(s)... it is possible to estimate a parallax shift between the two or more sub-cameras [0084]; ... image registration step (369) (see FIG. 11) implemented with a block-wise sliding window transform [0090], Fig.13; ... image fusion step (373) (see FIG. 11)... registration information computed in image registration step (369)... may be 'merged' [0098], Fig.15) and wherein the processor is further configured to form the output image by transferring information from the first image to the second image (... Process (338)... may be applied to full color images... an image registration procedure (342) is applied [0065], Fig.9; ... fusion of image data... may involve addition of color information from a color sub-camera image to luminance information from a grayscale sub-camera image... a complementary operation may be performed where luminance information from the grayscale sub-camera is added to the color image from the color sub-camera... FIG. 11, which illustrates an exemplary process (365) that utilizes processor (166) (see FIG. 3) for fusion of image data [0073]-[0077], Fig.11).

Regarding claim 17, Dagher teaches the imaging system of claim 13, wherein the second sensor (... cameras (10) and (12) may be... sub-cameras of a single multi-aperture camera [0046], Fig.1, Fig.2; ... It is contemplated that sensors of sub-cameras of a single multi-aperture camera may be shared in any manner... blocks of pixels adjacent one another in a single sensor chip... not limited to having identical shapes or sizes [0049], Fig.2; ... first and second optical sub-systems (110) and (120) is shown imaging onto its own sensor (i.e., sensors (130) and (140), respectively) [0067], Fig.2) includes a standard CFA (... Image sensors often utilize a Red-Green-Blue ("RGB") color filter array ("CFA"), such as a Bayer pattern... in FIG. 8, both the tele and the wide images are converted from RGB to YUV [0063], Fig.8; ... a CFA such as a Bayer filter, or be formed of individual color sensor elements (e.g., RGB or Cyan-Magenta-Yellow ("CMY")) [0067]) and wherein the processing includes, for a ZF input (... "zoom" may be understood as a capability to provide different magnifications... by changing the focal length of an optical system [0004]; ... allows the user to choose any level of zoom and to utilize the multi-aperture camera as a continuous zoom camera [0062]) that defines an FOV equal to or smaller than the second FOV (... two cameras (10) and (12) that image fields of view (20) and (22)... cameras (10) and (12) may be... sub-cameras of a single multi-aperture camera [0046], Fig.1, Fig.2; ... It is contemplated that sensors of sub-cameras of a single multi-aperture camera may be shared in any manner... blocks of pixels adjacent one another in a single sensor chip... not limited to having identical shapes or sizes [0049], Fig.2; In a particular aspect, configuring the first sub-camera may include establishing a first focal length... configuring the second camera may include establishing a second focal length... The second focal length may be different than the first focal length such that the second camera exhibits a different field of view as compared to the first camera [0013]; ... each optical sub-system may have a different focal length resulting in different fields of view [0048], Fig.2), forming the output image based on the second image (... Process (338)... may be applied to full color images... an image registration procedure (342) is applied [0065], Fig.9; ... fusion of image data... may involve addition of color information from a color sub-camera image to luminance information from a grayscale sub-camera image... a complementary operation may be performed where luminance information from the grayscale sub-camera is added to the color image from the color sub-camera... FIG. 11, which illustrates an exemplary process (365) that utilizes processor (166) (see FIG. 3) for fusion of image data [0073]-[0077], Fig.11).

Supplemental Box

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Regarding claim 18, Dagher teaches the imaging system of claim 13 (... Multi aperture camera (100) provides first and second sets of image data (301) and (302) to a processor (166) which may, for example, be configured for combining or "fusing" the image data sets... to an image output device (167) [0053], Fig.3; In a particular aspect, configuring the first sub-camera may include establishing a first focal length... configuring the second camera may include establishing a second focal length... The second focal length may be different than the first focal length such that the second camera exhibits a different field of view as compared to the first camera [0013]; ... each optical sub-system may have a different focal length resulting in different fields of view [0048], Fig.2), wherein the standard CFA includes a Bayer filter (... Image sensors often utilize a Red-Green-Blue ("RGB") color filter array ("CFA"), such as a Bayer pattern... in FIG. 8, both the tele and the wide images are converted from RGB to YUV [0063], Fig.8; ... a CFA such as a Bayer filter, or be formed of individual color sensor elements (e.g., RGB or Cyan-Magenta-Yellow ("CMY")) [0067]).

Regarding claim 19, Dagher teaches the imaging system of claim 13 (... Multi aperture camera (100) provides first and second sets of image data (301) and (302) to a processor (166) which may, for example, be configured for combining or "fusing" the image data sets... to an image output device (167) [0053], Fig.3; In a particular aspect, configuring the first sub-camera may include establishing a first focal length... configuring the second camera may include establishing a second focal length... The second focal length may be different than the first focal length such that the second camera exhibits a different field of view as compared to the first camera [0013]; ... each optical sub-system may have a different focal length resulting in different fields of view [0048], Fig.2), wherein the standard CFA includes a Bayer filter (... Image sensors often utilize a Red-Green-Blue ("RGB") color filter array ("CFA"), such as a Bayer pattern... in FIG. 8, both the tele and the wide images are converted from RGB to YUV [0063], Fig.8; ... a CFA such as a Bayer filter, or be formed of individual color sensor elements (e.g., RGB or Cyan-Magenta-Yellow ("CMY")) [0067]), but lacks the explicit teaching of a non-Bayer filter.
However, Koskinen is analogous to Dagher and has a non-Bayer filter (Typical technologies for generating color images rely on the Bayer sensor and its variations... FIG. 1 shows a typical Bayer-type pattern... Other filter types include, by example, CYGM filters... and RGBE filters Col.1 ln.46-56, Fig.1).
It would have been obvious to one of ordinary skill in the art at the time of the invention to combine a non-Bayer filter as taught by Koskinen with the invention of Dagher.
The motivation would have been an obvious design choice and allows the designer much more freedom than a standard Bayer color filter array (Koskinen, Col.1 ln.46-56, Col.3 ln.41-48, Col.3 ln.59-63, Fig.1, Fig.3).

Regarding claim 20, Dagher teaches the imaging system of claim 19 (... multi-aperture camera systems with the imaging characteristics [0041]-[0042], Fig.1; multi-aperture camera Fig.3; ... Image sensors often utilize a Red-Green-Blue ("RGB") color filter array ("CFA"), such as a Bayer pattern... in FIG. 8, both the tele and the wide images are converted from RGB to YUV [0063], Fig.8; ... a CFA such as a Bayer filter, or be formed of individual color sensor elements (e.g., RGB or Cyan-Magenta-Yellow ("CMY")) [0067]), but lacks the explicit teaching of wherein the non-Bayer filter is selected from the group consisting of a RGBE, a CYYM, a CYGM, a RGBW#1, a RGBW#2 and a RGBW#3 filter.
However, Koskinen is analogous to Dagher and has wherein the non-Bayer filter is selected from the group consisting of a RGBE, a CYYM, a CYGM, a RGBW#1, a RGBW#2 and a RGBW#3 filter (Typical technologies for generating color images rely on the Bayer sensor and its variations... FIG. 1 shows a typical Bayer-type pattern... Other filter types include, by example, CYGM filters... and RGBE filters Col.1 ln.46-56, Fig.1).
It would have been obvious to one of ordinary skill in the art at the time of the invention to combine wherein the non-Bayer filter is selected from the group consisting of a RGBE, a CYYM, a CYGM, a RGBW#1, a RGBW#2 and a RGBW#3 filter as taught by Koskinen with the invention of Dagher.
The motivation would have been an obvious design choice and allows the designer much more freedom than a standard Bayer color filter array (Koskinen, Col.1 ln.46-56, Col.3 ln.41-48, Col.3 ln.59-63, Fig.1, Fig.3).

Regarding claim 30, Dagher teaches the imaging system of claim 21 (... multi-aperture camera systems with the imaging characteristics [0041]-[0042], Fig.1; multi-aperture camera Fig.3), wherein the standard CFA includes a Bayer filter (... Image sensors often utilize a Red-Green-Blue ("RGB") color filter array ("CFA"), such as a Bayer pattern... in FIG. 8, both the tele and the wide images are converted from RGB to YUV [0063], Fig.8; ... a CFA such as a Bayer filter, or be formed of individual color sensor elements (e.g., RGB or Cyan-Magenta-Yellow ("CMY")) [0067]), but lacks the explicit teaching of a non-Bayer filter.
However, Koskinen is analogous to Dagher and has a non-Bayer filter (Typical technologies for generating color images rely on the Bayer sensor and its variations... FIG. 1 shows a typical Bayer-type pattern... Other filter types include, by example, CYGM filters... and RGBE filters Col.1 ln.46-56, Fig.1).
It would have been obvious to one of ordinary skill in the art at the time of the invention to combine a non-Bayer filter as taught by Koskinen with the invention of Dagher.
The motivation would have been an obvious design choice and allows the designer much more freedom than a standard Bayer color filter array (Koskinen, Col.1 ln.46-56, Col.3 ln.41-48, Col.3 ln.59-63, Fig.1, Fig.3).

Regarding claim 31, Dagher teaches the imaging system of claim 30 (... multi-aperture camera systems with the imaging characteristics [0041]-[0042], Fig.1; multi-aperture camera Fig.3; ... Image sensors often utilize a Red-Green-Blue ("RGB") color filter array ("CFA"), such as a Bayer pattern... in FIG. 8, both the tele and the wide images are converted from RGB to YUV [0063], Fig.8; ... a CFA such as a Bayer filter, or be formed of individual color sensor elements (e.g., RGB or Cyan-Magenta-Yellow ("CMY")) [0067]), but lacks the explicit teaching of wherein the non-Bayer filter is selected from the group consisting of a RGBE, a CYYM, a CYGM, a RGBW#1, a RGBW#2 and a RGBW#3 filter.
However, Koskinen is analogous to Dagher and has wherein the non-Bayer filter is selected from the group consisting of a RGBE, a CYYM, a CYGM, a RGBW#1, a RGBW#2 and a RGBW#3 filter (Typical technologies for generating color images rely on the Bayer sensor and its variations... FIG. 1 shows a typical Bayer-type pattern... Other filter types include, by example, CYGM filters... and RGBE filters Col.1 ln.46-56, Fig.1).
It would have been obvious to one of ordinary skill in the art at the time of the invention to combine wherein the non-Bayer filter is selected from the group consisting of a RGBE, a CYYM, a CYGM, a RGBW#1, a RGBW#2 and a RGBW#3 filter as taught by Koskinen with the invention of Dagher.
The motivation would have been an obvious design choice and allows the designer much more freedom than a standard Bayer color filter array (Koskinen, Col.1 ln.46-56, Col.3 ln.41-48, Col.3 ln.59-63, Fig.1, Fig.3).

Supplemental Box

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Claims 2-5 lack an inventive step under PCT Article 33(3) as being obvious over Dagher et al. (US 2011/0064327 A1), hereinafter Dagher in view of Koskinen et al. (US 8,134,115 B2), hereinafter Koskinen and further in view of Myhrvold (US 8,094,208 B2), hereinafter Myhrvold.

Regarding claim 2, Dagher teaches the imaging system of claim 1 (... multi-aperture camera systems with the imaging characteristics [0041]-[0042], Fig.1; multi-aperture camera Fig.3; ... cameras (10) and (12) may be... sub-cameras of a single multi-aperture camera [0046], Fig.1, Fig.2; ... It is contemplated that sensors of sub-cameras of a single multi-aperture camera may be shared in any manner... blocks of pixels adjacent one another in a single sensor chip... not limited to having identical shapes or sizes [0049]), but lacks the explicit teaching of wherein the non-standard CFA includes a repetition of a 2x2 micro-cell in which a color filter order is either BR-RB or YC-CY.
However, Koskinen is analogous to Dagher and has wherein the non-standard CFA (Typical technologies for generating color images rely on the Bayer sensor and its variations... FIG. 1 shows a typical Bayer-type pattern... Other filter types include, by example, CYGM filters... and RGBE filters Col.1 ln.46-56, Fig.1; The exemplary embodiments of this invention use... sub-diffraction limit receptors in combination with a color filter array. The color filter array may be designed much more freely than conventional color filter arrays Col.3 ln.41-48, Fig.3; Contrasting FIG. 3 with FIG. 1, the optical filters... enable a plurality of different filter types to be used in any desired combinations Col.3 ln.59-63 Fig.3; It should be noted that the color filters do not have to be separate for each receptor (2)... each of three different filter types is shown overlaying a plurality of the receptors Col.7 ln.51-55, Fig.7, Fig.9).
It would have been obvious to one of ordinary skill in the art at the time of the invention to combine wherein the non-standard CFA as taught by Koskinen with the invention of Dagher.
The motivation would have been an obvious design choice and allows the designer much more freedom than conventional or standard color filter arrays and enable a plurality of different filter types to be used in any desired combination (Koskinen, Col.3 ln.41-48, Col.3 ln.59-63 Fig.3).
Dagher as modified lacks includes a repetition of a 2x2 micro-cell in which a color filter order is either BR-RB or YC-CY.
Myhrvold is analogous to Dagher and has includes a repetition of a 2x2 micro-cell (Color mosaics or filter arrays (CFAs) and demosaicing techniques for digital imaging are disclosed herein... CFAs and demosaicing techniques described herein are not restricted to any particular color sensor Col.5 ln.44-53; FIG. 2 shows an exemplary RGB pattern (200) for a color filter array... may be used for CFAs based on other color combinations (e.g., RGBE, CYYM, CYGM, RGBW, etc.) Col.6 ln.56-Col.7 ln.1, Fig.2; Exemplary CFA patterns may include NxN repeat units... corresponding to a 2x2 array... a 3x3 array... a 4x4 array... a 5x5 array Col.7 ln.20-30, Col.8 ln.14-22, Fig.3; 2x2 array Fig.3A; 3x3 array Fig.3B, Fig.3C; 4x4 array Fig.2, Fig.3D, Fig.3E; 6x6 array Fig.1), but lacks the explicit teaching of in which a color filter order is either BR-RB or YC-CY.
However, it would have been obvious to one of ordinary skill in the art at the time of the invention was made to combine includes a repetition of a 2x2 micro-cell in which a color filter order is either BR-RB or YC-CY as taught by Myhrvold with the invention of Dagher, since rearranging parts of an invention involves only routine skill in the art.
The motivation for doing so would be to allow a designer CFAs based on other color combinations for NxN repeat units and not be restricted to any particular color sensor (Myhrvold Col.5 ln.44-53, Col.6 ln.56-Col.7 ln.1, Col.7 ln.20-30, Figs.1-3).

Regarding claim 3, Dagher teaches the imaging system of claim 1 (... multi-aperture camera systems with the imaging characteristics [0041]-[0042], Fig.1; multi-aperture camera Fig.3; ... cameras (10) and (12) may be... sub-cameras of a single multi-aperture camera [0046], Fig.1, Fig.2; ... It is contemplated that sensors of sub-cameras of a single multi-aperture camera may be shared in any manner... blocks of pixels adjacent one another in a single sensor chip... not limited to having identical shapes or sizes [0049]), but lacks the explicit teaching of wherein the non-standard CFA includes a repetition of a 3x3 micro-cell in which a color filter order is GBR-RGB-BRG.
However, Koskinen is analogous to Dagher and has wherein the non-standard CFA (Typical technologies for generating color images rely on the Bayer sensor and its variations... FIG. 1 shows a typical Bayer-type pattern... Other filter types include, by example, CYGM filters... and RGBE filters Col.1 ln.46-56, Fig.1; The exemplary embodiments of this invention use... sub-diffraction limit receptors in combination with a color filter array. The color filter array may be designed much more freely than conventional color filter arrays Col.3 ln.41-48, Fig.3; Contrasting FIG. 3 with FIG. 1, the optical filters... enable a plurality of different filter types to be used in any desired combinations Col.3 ln.59-63 Fig.3; It should be noted that the color filters do not have to be separate for each receptor (2)... each of three different filter types is shown overlaying a plurality of the receptors Col.7 ln.51-55, Fig.7, Fig.9).
It would have been obvious to one of ordinary skill in the art at the time of the invention to combine wherein the non-standard CFA as taught by Koskinen with the invention of Dagher.
The motivation would have been an obvious design choice and allows the designer much more freedom than conventional or standard color filter arrays and enable a plurality of different filter types to be used in any desired combination (Koskinen, Col.3 ln.41-48, Col.3 ln.59-63 Fig.3).
Dagher as modified lacks includes a repetition of a 3x3 micro-cell in which a color filter order is GBR-RGB-BRG.
Myhrvold is analogous to Dagher and has includes a repetition of a 3x3 micro-cell (Color mosaics or filter arrays (CFAs) and demosaicing techniques for digital imaging are disclosed herein... CFAs and demosaicing techniques described herein are not restricted to any particular color sensor Col.5 ln.44-53; FIG. 2 shows an exemplary RGB pattern (200) for a color filter array... may be used for CFAs based on other color combinations (e.g., RGBE, CYYM, CYGM, RGBW, etc.) Col.6 ln.56-Col.7 ln.1, Fig.2; Exemplary CFA patterns may include NxN repeat units... corresponding to a 2x2 array... a 3x3 array... a 4x4 array... a 5x5 array Col.7 ln.20-30, Col.8 ln.14-22, Fig.3; 2x2 array Fig.3A; 3x3 array Fig.3B, Fig.3C; 4x4 array Fig.2, Fig.3D, Fig.3E; 6x6 array Fig.1), but lacks the explicit teaching of in which a color filter order is GBR-RGB-BRG.
However, it would have been obvious to one of ordinary skill in the art at the time of the invention was made to combine includes a repetition of a 3x3 micro-cell in which a color filter order is GBR-RGB-BRG as taught by Myhrvold with the invention of Dagher, since rearranging parts of an invention involves only routine skill in the art.
The motivation for doing so would be to allow a designer CFAs based on other color combinations for NxN repeat units and not be restricted to any particular color sensor (Myhrvold Col.5 ln.44-53, Col.6 ln.56-Col.7 ln.1, Col.7 ln.20-30, Figs.1-3).

WRITTEN OPINION OF THE INTERNATIONAL SEARCHING AUTHORITY

International application No. PCT/IB2013/060356

Supplemental Box

In case **the space in any of the preceding boxes is not sufficient.**
Continuation of:

Regarding claim 4, Dagher teaches the imaging system of claim 1 (... multi-aperture camera systems with the imaging characteristics [0041]-[0042], Fig.1; multi-aperture camera Fig.3; ... cameras (10) and (12) may be... sub-cameras of a single multi-aperture camera [0046], Fig.1, Fig.2; ... It is contemplated that sensors of sub-cameras of a single multi-aperture camera may be shared in any manner... blocks of pixels adjacent one another in a single sensor chip... not limited to having identical shapes or sizes [0049]), but lacks the explicit teaching of wherein the non-standard CFA includes a repetition of a 4x4 micro-cell in which a color filter order is BBRR-RBBR-RRBB-BRRB.

However, Koskinen is analogous to Dagher and has wherein the non-standard CFA (Typical technologies for generating color images rely on the Bayer sensor and its variations... FIG. 1 shows a typical Bayer-type pattern... Other filter types include, by example, CYGM filters... and RGBE filters Col.1 ln.46-56, Fig.1; The exemplary embodiments of this invention use... sub-diffraction limit receptors in combination with a color filter array. The color filter array may be designed much more freely than conventional color filter arrays Col.3 ln.41-48, Fig.3; Contrasting FIG. 3 with FIG. 1, the optical filters... enable a plurality of different filter types to be used in any desired combinations Col.3 ln.59-63 Fig.3; It should be noted that the color filters do not have to be separate for each receptor (2)... each of three different filter types is shown overlaying a plurality of the receptors Col.7 ln.51-55, Fig.7, Fig.9).

It would have been obvious to one of ordinary skill in the art at the time of the invention to combine wherein the non-standard CFA as taught by Koskinen with the invention of Dagher.

The motivation would have been an obvious design choice and allows the designer much more freedom than conventional or standard color filter arrays and enable a plurality of different filter types to be used in any desired combination (Koskinen, Col.3 ln.41-48, Col.3 ln.59-63 Fig.3).

Dagher as modified lacks includes a repetition of a 4x4 micro-cell in which a color filter order is BBRR-RBBR-RRBB-BRRB.

Myhrvold is analogous to Dagher and has includes a repetition of a 4x4 micro-cell (Color mosaics or filter arrays (CFAs) and demosaicing techniques for digital imaging are disclosed herein... CFAs and demosaicing techniques described herein are not restricted to any particular color sensor Col.5 ln.44-53; FIG. 2 shows an exemplary RGB pattern (200) for a color filter array... may be used for CFAs based on other color combinations (e.g., RGBE, CYYM, CYGM, RGBW, etc.) Col.6 ln.56-Col.7 ln.1, Fig.2; Exemplary CFA patterns may include NxN repeat units... corresponding to a 2x2 array... a 3x3 array... a 4x4 array... a 5x5 array Col.7 ln.20-30, Col.8 ln.14-22, Fig.3; 2x2 array Fig.3A; 3x3 array Fig.3B, Fig.3C; 4x4 array Fig.2, Fig.3D, Fig.3E; 6x6 array Fig.1), but lacks the explicit teaching of in which a color filter order is BBRR-RBBR-RRBB-BRRB.

However, it would have been obvious to one of ordinary skill in the art at the time of the invention was made to combine includes a repetition of a 4x4 micro-cell in which a color filter order is BBRR-RBBR-RRBB-BRRB as taught by Myhrvold with the invention of Dagher, since rearranging parts of an invention involves only routine skill in the art.

The motivation for doing so would be to allow a designer CFAs based on other color combinations for NxN repeat units and not be restricted to any particular color sensor (Myhrvold Col.5 ln.44-53, Col.6 ln.56-Col.7 ln.1, Col.7 ln.20-30, Figs.1-3).

Supplemental Box

In case the space in any of the preceding boxes is not sufficient.
Continuation of:

Regarding claim 5, Dagher teaches the imaging system of claim 1 (... multi-aperture camera systems with the imaging characteristics [0041]-[0042], Fig.1; multi-aperture camera Fig.3; ... cameras (10) and (12) may be... sub-cameras of a single multi-aperture camera [0046], Fig.1, Fig.2; ... It is contemplated that sensors of sub-cameras of a single multi-aperture camera may be shared in any manner... blocks of pixels adjacent one another in a single sensor chip... not limited to having identical shapes or sizes [0049]), but lacks the explicit teaching of wherein the non-standard CFA includes a repetition of a 6x6 micro-cell in which a color filter order is selected from the group consisting of RBBRRB-RWRBWB-BBRBRR-RRBRBB-BWBRWR-BRRBBR, BBGRRG-RGRBGBGBRGRB-RRGBBG-BGBRGR-GRBGBR, RBBRRB-RGRBGB-BBRBRR-RRBRBBBGBRGR-BRRBBR and RBRBRB-BGBRGR-RBRBRB-BRBRBR-RGRBGB-BRBRBR.
However, Koskinen is analogous to Dagher and has wherein the non-standard CFA (Typical technologies for generating color images rely on the Bayer sensor and its variations... FIG. 1 shows a typical Bayer-type pattern... Other filter types include, by example, CYGM filters... and RGBE filters Col.1 ln.46-56, Fig.1; The exemplary embodiments of this invention use... sub-diffraction limit receptors in combination with a color filter array. The color filter array may be designed much more freely than conventional color filter arrays Col.3 ln.41-48, Fig.3; Contrasting FIG. 3 with FIG. 1, the optical filters... enable a plurality of different filter types to be used in any desired combinations Col.3 ln.59-63 Fig.3; It should be noted that the color filters do not have to be separate for each receptor (2)... each of three different filter types is shown overlaying a plurality of the receptors Col.7 ln.51-55, Fig.7, Fig.9).
It would have been obvious to one of ordinary skill in the art at the time of the invention to combine wherein the non-standard CFA as taught by Koskinen with the invention of Dagher.
The motivation would have been an obvious design choice and allows the designer much more freedom than conventional or standard color filter arrays and enable a plurality of different filter types to be used in any desired combination (Koskinen, Col.3 ln.41-48, Col.3 ln.59-63 Fig.3).
Dagher as modified lacks includes a repetition of a 6x6 micro-cell in which a color filter order is selected from the group consisting of RBBRRB-RWRBWB-BBRBRR-RRBRBB-BWBRWR-BRRBBR, BBGRRG-RGRBGBGBRGRB-RRGBBG-BGBRGR-GRBGBR, RBBRRB-RGRBGB-BBRBRR-RRBRBBBGBRGR-BRRBBR and RBRBRB-BGBRGR-RBRBRB-BRBRBR-RGRBGB-BRBRBR.
Myhrvold is analogous to Dagher and has includes a repetition of a 6x6 micro-cell (Color mosaics or filter arrays (CFAs) and demosaicing techniques for digital imaging are disclosed herein... CFAs and demosaicing techniques described herein are not restricted to any particular color sensor Col.5 ln.44-53; FIG. 2 shows an exemplary RGB pattern (200) for a color filter array... may be used for CFAs based on other color combinations (e.g., RGBE, CYYM, CYGM, RGBW, etc.) Col.6 ln.56-Col.7 ln.1, Fig.2; Exemplary CFA patterns may include NxN repeat units... corresponding to a 2x2 array... a 3x3 array... a 4x4 array... a 5x5 array Col.7 ln.20-30, Col.8 ln.14-22, Fig.3; 2x2 array Fig.3A; 3x3 array Fig.3B, Fig.3C; 4x4 array Fig.2, Fig.3D, Fig.3E; 6x6 array Fig.1), but lacks the explicit teaching of in which a color filter order is selected from the group consisting of RBBRRB-RWRBWB-BBRBRR-RRBRBB-BWBRWR-BRRBBR, BBGRRG-RGRBGBGBRGRB-RRGBBG-BGBRGR-GRBGBR, RBBRRB-RGRBGB-BBRBRR-RRBRBBBGBRGR-BRRBBR and RBRBRB-BGBRGR-RBRBRB-BRBRBR-RGRBGB-BRBRBR.
However, it would have been obvious to one of ordinary skill in the art at the time of the invention was made to combine includes a repetition of a 6x6 micro-cell in which a color filter order is selected from the group consisting of RBBRRB-RWRBWB-BBRBRR-RRBRBB-BWBRWR-BRRBBR, BBGRRG-RGRBGBGBRGRB-RRGBBG-BGBRGR-GRBGBR, RBBRRB-RGRBGB-BBRBRR-RRBRBBBGBRGR-BRRBBR and RBRBRB-BGBRGR-RBRBRB-BRBRBR-RGRBGB-BRBRBR as taught by Myhrvold with the invention of Dagher, since rearranging parts of an invention involves only routine skill in the art.
The motivation for doing so would be to allow a designer CFAs based on other color combinations for NxN repeat units and not be restricted to any particular color sensor (Myhrvold Col.5 ln.44-53, Col.6 ln.56-Col.7 ln.1, Col.7 ln.20-30, Figs.1-3).

Claims 1-32 meet the criteria set out in PCT Article 33(4), and thus have industrial applicability because the subject matter claimed can be made or used in industry.

INTERNATIONAL SEARCH REPORT

International application No.
PCT/IB2013/060356

A. CLASSIFICATION OF SUBJECT MATTER
IPC(8) - H04N 9/09 (2014.01)
USPC - 348/277
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(8) - G06T 5/00; H01L 27/146; H04N 9/04, H04N 9/09, H04N 9/097 (2014.01)
USPC - 348/273, 348/274, 348/277, 348/279, 348/281, 348/283, 348/302

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched
CPC - G06T 2207/10148, G06T 2207/20221; G06T 3/4015; G06T 5/50; H01L 27/14621; H04N 9/04 (2013.01)

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)
PatBase, TotalPatent, Google Patents, Google Scholar

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 2011/0064327 A1 (DAGHER et al) 17 March 2011 (17.03.2011) entire document	21-29,32 ----- 1-20,30,31
Y	US 8,134,115 B2 (KOSKINEN et al) 13 March 2012 (13.03.2012) entire document	1-20,30,31
Y	US 8,094,208 B2 (MYHRVOLD) 10 January 2012 (10.01.2012) entire document	2-5
A	WO 2009/097552 A1 (DAGHER et al) 06 August 2009 (06.08.2009) entire document	1-32
A	US 8,179,457 B2 (KOSKINEN et al) 15 May 2012 (15.05.2012) entire document	1-32
A	US 2011/0285730 A1 (LAI et al) 24 November 2011 (24.11.2011) entire document	1-32
A	US 2011/0121421 A1 (CHARBON et al) 26 May 2011 (26.05.2011) entire document	1-32
A	US 2011/0292258 A1 (ADLER et al) 01 December 2011 (01.12.2011) entire document	1-32

☐ 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
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- "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
27 March 2014	17 APR 2014
Name and mailing address of the ISA/US Mail Stop PCT, Attn: ISA/US, Commissioner for Patents P.O. Box 1450, Alexandria, Virginia 22313-1450 Facsimile No. 571-273-3201	Authorized officer: Blaine R. Copenheaver PCT Helpdesk: 571-272-4300 PCT OSP: 571-272-7774

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(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, 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, 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.

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[Continued on next page]

(54) Title: IMAGE DATA FUSION SYSTEMS AND METHODS

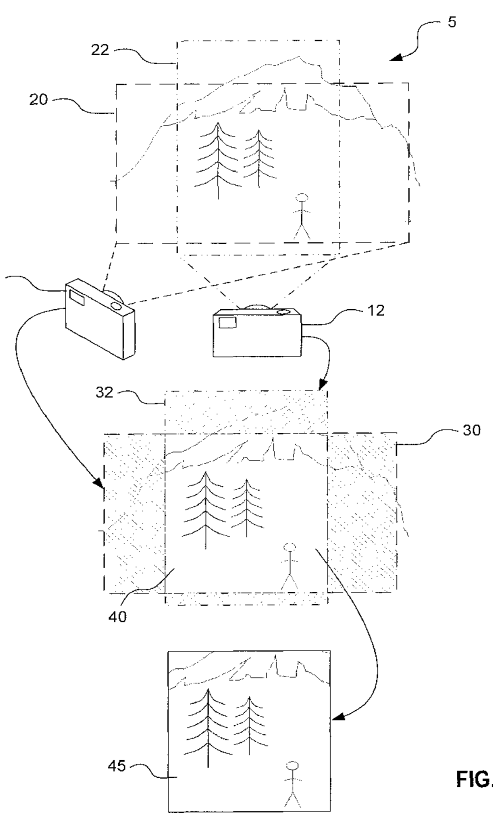

FIG. 1

(57) Abstract: Systems and methods for image data fusion include providing first and second sets of image data corresponding to an imaged first and second scene respectively. The scenes at least partially overlap in an overlap region, defining a first collection of overlap image data as part of the first set of image data, and a second collection of overlap image data as part of the second set of image data. The second collection of overlap image data is represented as a plurality of image data subsets such that each of the subsets is based on at least one characteristic of the second collection, and each subset spans the overlap region. A fused set of image data is produced by an image processor, by modifying the first collection of overlap image data based on at least a selected one of, but less than all of, the image data subsets.

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GM, KE, LS, MW, MZ, NA, SD, SL, SZ, TZ, UG, ZM, ZW), Eurasian (AM, AZ, BY, KG, KZ, MD, RU, TJ, 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, MT, NL, NO, PL, PT, RO, SE, SI, SK, TR), OAPI (BF, BJ, CF, CG, CI, CM, GA, GN, GQ, GW, ML, MR, NE, SN, TD, TG).

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IMAGE DATA FUSION SYSTEMS AND METHODS

CROSS-REFERENCE TO RELATED APPLICATIONS

[0001] This application claims priority to U.S. Provisional Patent application No. 61/025,533, filed on 1 February 2008 and entitled MULTI-FOCAL LENGTH IMAGE FUSION, U.S. Provisional Patent application No. 61/051,338, filed 7 May 2008 and entitled TRANSFORM DOMAIN REGISTRATION FOR IMAGE FUSION, and U.S. Provisional Patent application No. 61/059,319, filed 6 June 2008 and entitled TRANSFORM DOMAIN REGISTRATION FOR IMAGE FUSION. All of the above-identified applications are incorporated herein by reference in their entireties.

BACKGROUND

[0002] Small, digital cameras integrated into mobile electronics such as mobile phones, personal digital assistants ("PDAs") and music players are becoming ubiquitous. Each year, mobile phone manufacturers add more imaging features to their handsets, causing these mobile imaging devices to converge towards feature sets that consumers expect from stand-alone digital still cameras. At the same time, the size of these handsets is shrinking, making it necessary to accordingly reduce the total size of the camera modules while still adding imaging features. Optical zoom is a primary feature that many digital still cameras have that many mobile phones may not have, primarily due to the severe size constraints in mobile imaging devices.

[0003] Cameras (including digital cameras) may be arranged to receive electromagnetic radiation (such as visible light) through an aperture that can be defined by the camera based on a number of well known techniques. For example, an optical sub-system, including one or more lenses and/or other optical elements, may define the aperture such that the received radiation is imaged by the optical sub-system and a resulting image is directed towards a sensor region such as a sensor array that includes a plurality of detectors defining a sensing surface. The sensor region may be configured to receive the image and to generate a set of image data based on the image. In some common applications, such as when using conventional digital cameras to capture images, the camera may be aligned to receive electromagnetic radiation associated with scenery having a given set of one or more objects. In these applications the set of image data is, for example, represented as digital image data using an electrical signal conveyed by electrical conductors or stored using memory or other digital storage techniques. In addition, the set of image data can be processed using a number of known image processing techniques.

[0004] In the context of the present disclosure, "zoom" may be understood as a capability to provide different magnifications of the same scene and/or object by changing the focal length of an optical system, with a higher "level of zoom" being associated herein with greater magnification and a lower level of zoom being associated with lower magnification. In typical film-based cameras, as well as in conventional digital cameras, optical zoom can be accomplished with multiple lens groups that are moved along an optical axis of an imaging system for defining a range of different lens configurations. For any given configuration, the position of the lens groups determines a focal length specific to that configuration. Based on well known techniques, camera users can adjustably control the positioning of the lens groups for selecting a specific level of zoom. At any specific level of zoom associated with a selected focal length of a camera's optical sub-assembly, an image represents a portion of a given scene based in part on the field of view defined by the lens system. For example, an image plane can be defined by the camera's sensor region (such as a sensor array), and the resulting image represents a field of view consistent with (i) a shape and transverse extent of the sensor region's sensing surface, and (ii) the selected focal length. For a given camera, there is a tradeoff between zoom and field of view such that camera settings exhibiting longer focal lengths generally tend to result in a greater level of zoom in conjunction with correspondingly narrower field of view. Conversely, camera settings exhibiting comparatively shorter focal lengths tend to result in a lower level of zoom in conjunction with a wider field of view.

[0005] Certain film-based cameras and digital cameras utilize a fixed focus imaging system, and these cameras generally do not feature adjustable optical zoom. Fixed focus imaging systems are especially common in PDAs. The high complexity, cost and decreased durability typically associated with moveable lenses (e.g., in cameras having optical zoom) limit their use in inexpensive camera modules such as mobile phone camera modules and other low cost modules. Film based cameras with fixed focus imaging systems generally offer no means for the user to adjust the degree of magnification while preparing to take a picture. On the other hand, digital cameras having fixed optical focus can incorporate digital zoom to allow the user to control the level of zoom before and/or after capturing the image by generating a corresponding set of image data. For example, digital zoom can utilize computer-processed cropping followed by signal upsampling and data interpolation of the cropped image to convert the cropped image to the original display size. As a result, however, the resolution of the cropped, final image is decreased and the image quality suffers.

SUMMARY

[0006] The following embodiments and aspects thereof are described and illustrated in conjunction with systems, tools and methods, which are meant to be exemplary and illustrative, not limiting in scope. In various embodiments, one or more problems and/or limitations associated with the above-described systems and methods have been addressed, while other embodiments are directed to other improvements.

[0007] In an embodiment, an imaging method utilizes a multi-aperture imaging system for producing a fused set of image data. This method may include providing a multi-aperture camera having first and second sub-cameras including a first sub-camera, having imaging optics defining a first aperture, with the first camera configured for imaging a first scene through the first aperture and for generating a first set of image data corresponding to the imaged first scene. A second camera may be provided, having imaging optics defining a second aperture, and the second sub-camera may be configured for imaging a second scene through the second aperture and for generating a second set of image data corresponding to the imaged second scene. The second sub-camera can be aligned such that the second scene at least partially overlaps the first scene in an overlap region that defines (i) a first collection of overlap image data as part of the first set of image data for the imaged first scene and (ii) an at least generally corresponding, second collection of overlap image data as part of the second set of image data for the imaged second scene. The second collection of overlap image data of the second scene may be represented as a plurality

of image data subsets based on at least one associated characteristic of the second collection of overlap image data, such that each subset is superimposed across the overlap region. A fused set of image data can be produced from the first set of image data by changing the first collection of overlap image data in the overlap region of the first scene based on at least a selected one of, but less than all of the image data subsets.

[0008] In one aspect, representing the second collection of overlap image data may include configuring the plurality of image data subsets such that each subset is based on a different characteristic as compared to the characteristic associated with any one of the other subsets.

[0009] In another aspect, the first collection of overlap image data may include a first collection of luminance data, and the selected one of the image data subsets may be a luminance channel (of luminance data) based on luminance as the characteristic of the second collection of overlap image data, and changing of the first collection of overlap image data may include combining the first and second collections of luminance data. Arranging of the second sub-camera may include supplying the second sub-camera as a grayscale camera for providing the luminance channel as being composed of grayscale scaled image data.

[0010] In yet another aspect, representing the second collection of overlap image data may include filtering the second collection of overlap image data such that the selected image data subset is composed of filtered data, and filtering the second collection of overlap image data may include applying convolution filtering to the second collection of overlap image data such that the selected image data subset is influenced by the convolution filtering. Furthermore, representing the second collection of overlap image data may include scaling the second collection of overlap image data such that the selected image data subset is composed of scaled data.

[0011] In an additional aspect, the second collection of overlap image data may include intensity information, and scaling the second collection of overlap image data may include changing at least some of the intensity information. In this case scaling the second collection of overlap image data includes applying a gain for causing the changing of the intensity information.

[0012] In another aspect, representing the second collection of overlap image data may include transforming at least some of the second collection of overlap image data such that the characteristic of the second collection of overlap image data is represented in a transform domain, and the selected image data subset is composed of transformed data.

[0013] In a particular aspect, configuring the first sub-camera may include establishing a first focal length for the first sub-camera, and configuring the second camera may include establishing a second focal length for the second camera. The second focal length may be different than the first focal length such that the second camera exhibits a different field of view as compared to the first camera. Configuring the first camera may include providing a first sensing surface that has a first shape, with the first shape being characterized by a first transverse width. The first sensing surface may be oriented for receiving the imaged first scene to cause the generating of the first set of image data. In this particular aspect, configuring the second camera may include providing a second sensing surface that has a second shape that matches the first shape and has a transverse width that matches the first transverse width, and the second sensing surface may be oriented for receiving the imaged second scene to cause the generating of the first set of image data. Establishing the first focal length may cause the first set of image data to exhibit a first level of zoom with respect to the first scene, and establishing the second focal length may cause the second set of data to exhibit a second level of zoom with respect to the second scene, and the first level of zoom may be greater than the first level of zoom. In some instances, imaging of the first scene may causes the first set of image data to have a first angular frequency based at least in part on the first focal length, and the imaging of the second scene may cause the second collection of overlap data to have a second angular frequency based at least in part on the second focal length, such that the second angular frequency is higher than the first angular frequency. In this particular aspect, generating the first set of image data may include initially producing an initial set of image data and then producing the first set of image data from the initial set of image data by upsampling the initial set of image data for increasing the angular frequency of the first set of image data, as compared to the initial image data, to a target angular frequency such that the first set of image data is upsampled image data. The initial set of image data may include a group of initial data points, and the upsampling may cause the first set of image data to include (i) the group of initial data points and (ii) an additional number of data points. The upsampling of the initial set of image data may further include interpolating between the initial data points for assigning values for each of the additional of data points. Furthermore, the upsampling can include matching the increased angular frequency to the second angular frequency such that the target angular frequency of the first set of image data is at least approximately equal to the second angular frequency.

[0014] In one embodiment, the first sub-camera may be configured with a first sensor region having a first sensing surface, and the first sensor region may be aligned such that the imaging of the first scene includes projecting an image of the first scene through the first aperture and onto the first sensing surface such that the first sensor region causes the generating of the first set of image data. In this example, the second sub-camera may be furnished with a second sensor region having a second sensing surface, and the second sensor region may be aligned such that the imaging of the second scene includes projecting an image of the second scene through the second aperture and onto the second sensing surface such that the second sensor region causes the generating of the second set of image data. In one aspect of this embodiment, the first sensing surface may have a first shape defined by a first surface area and the second sensing surface may have a second shape that at least generally matches the first shape, and the second surface may have a second surface area that is at least approximately equal to the first surface area. It is noted that the first sensor region and the second sensor region may each be a part of a single image sensor.

[0015] In another aspect of this embodiment, the first collection of overlap image data may initially be represented based on first, second and third data channels, and changing the first collection of overlap image data may include converting the first collection of overlap image data, as represented by the first second and third data channels, to represent the first collection of overlap image data based on a different set of three data channels. For example, the first, second, and third channels may be R, G and B channels, respectively, and the different set of data channels may be Y, U and V channels.

[0016] In yet another aspect of this embodiment, the second collection of overlap image data may be initially based on first, second, and third channels, and representing the fused set of overlap image data may further include converting the second collection of overlap image data (as represented by the first, second, and third channels) to represent the second collection of overlap data based on a different set of three channels. Each of the different channels may serve as one of the plurality of image data subsets. For example, the three data channels may be R, G, and B channels, and the different set of data channels may be Y, U and V channels, and the Y channel may serve as the selected subset of overlap image data.

[0017] In an aspect, generating the first set of image data may include initially producing a set of initial image data and then producing the first set of image data from the initial image data by applying a first forward transformation to at least a portion of the initial image data such that the first set of image data may be transformed data in a transform domain such that the first set of image data least generally represents, in the transform domain, at least some of the portion of the initial image data, and representing the second collection of overlap image data may include applying a second forward transformation to at least some of the second set of image data such that the characteristic of the second collection of image data is represented in the transform domain, and at least the selected image data subset is composed of transformed data. Changing the first collection of overlap image data may include merging the selected one of the image data subsets with the first collection of overlap image data in the transform domain to generate a merged data set in the transform domain, and producing the fused set of image data may include converting the merged data set from the transform domain by applying thereto at least one of (i) a reverse transformation and (ii) an inverse transformation.

[0018] In an additional aspect, producing the fused set of image data further may include identifying at least one spatial feature that is present at a feature position within the first collection of overlap image data of the first set of image data, searching for a related representation of at least one identified spatial feature (in the selected image data subset) such that each related representation at least approximately corresponds to one of the identified features, and (for at least a selected one of the related representations that is located in the selected image data subset based on the searching) registering the selected related representation as being associated with the feature position of the corresponding identified feature. In this additional aspect, changing the first collection of overlap image data may include modifying each identified spatial feature based on the corresponding related representation of that feature. It is noted that the related representation may have a related feature position within the selected image data subset, and searching for the related representation can include finding a spatial shift between the related feature position and the feature position. It is further noted that finding the spatial shift may include determining that the spatial shift is non-zero and is caused by parallax between the first and second sub-cameras.

[0019] The additional aspect may include (i) defining a reference block overlying the feature position and having a shape that overlies a reference portion of the first collection of overlap image data such that the reference portion of image data at least represents the spatial feature, (ii) defining a search region within the selected image data subset, and (iii) designating a plurality of candidate blocks within the search region, each of which candidate blocks overlies an associated portion of the selected image data subset at a candidate position therein. In some instances the searching may include determining a degree of correspondence between (i) the reference portion of data overlaid by the reference block and (ii) the portion of data associated with each of the plurality of candidate blocks, and in this instance one candidate block may be selected based on the degree of correspondence, such that the selected candidate block exhibits the highest degree of correspondence as compared to the other candidate blocks. Registering the selected related representation may include associating the candidate position of the selected candidate block with the feature position, and modifying of the spatial feature may include include changing the reference portion of data based on at least some of the portion of data associated with the selected candidate block. Designating the plurality of candidate blocks may include defining a first candidate block as a specific one of the plurality of candidate blocks, and a second candidate block as a different one of the plurality of candidate blocks, such that the first and second candidate blocks partially overlap one another.

[0020] In addition to the exemplary aspects and embodiments described above, further aspects and embodiments will become apparent by reference to the drawings and by study of the following descriptions. In addition to the exemplary aspects and embodiments described above, further aspects and embodiments will become apparent by reference to the drawings and by study of the following descriptions.

BRIEF DESCRIPTION OF THE DRAWINGS

[0021] Exemplary embodiments are illustrated in referenced figures of the drawings. It is intended that the embodiments and figures disclosed herein are to be illustrative rather than limiting.

[0022] FIG. 1 is a schematic view illustrating fusion of image data from two sources.

[0023] FIG. 2A is a diagrammatic view of one embodiment of an optical design for a multi-aperture camera.

[0024] FIG. 2B is a diagrammatic view of another embodiment of an optical design for a multi-aperture camera.

[0025] FIG. 3 is a block diagram illustrating a multi-aperture imaging system.

[0026] FIG. 4 is a block diagram illustrating one embodiment of a process for creating full-size images from a multi-aperture camera that shares a single sensor.

[0027] FIG. 5 is an exemplary plot illustrating the differences in angular frequency information contained in the images produced from optical sub-systems having different focal lengths, but the same f-number.

[0028] FIG. 6 is a series of exemplary plots, shown here to illustrate how differences in angular frequency information from images produced from sub-cameras having different focal lengths can be exploited in fusing the images.

[0029] FIG. 7 is a combination block diagram and flow chart illustrating optional embodiments of the methods for processing and fusing images from a multi-aperture camera.

[0030] FIG. 8 is a combination block diagram and flow chart illustrating other embodiments of methods for processing and fusing images from a multi-aperture camera.

[0031] FIG. 9 is a combination block diagram and flow chart illustrating another embodiment for processing and fusing images from a multi-aperture camera.

[0032] FIG. 10 is a diagramatic view of a two-dimensional sensor array for use in one embodiment of a multi-aperture camera.

[0033] FIG. 11 illustrates one embodiment of a process for registering and fusing image data produced by grayscale and color sub-cameras in a multi-aperture camera.

[0034] FIG. 12 illustrates one embodiment of a process for registering image data produced by grayscale and color sub-cameras in a multi-aperture camera, in an embodiment.

[0035] FIG. 13 illustrates one embodiment of a process for fusing registered image data produced by grayscale and color sub-cameras in a multi-aperture camera, in another embodiment.

[0036] FIG. 14 is a contour plot illustrating the amount of parallax present between objects imaged by grayscale and color sub-cameras in one embodiment of a multi-aperture camera.

[0037] FIG. 15 is a plot comparing cross-sectional intensity changes for grayscale and color sub-cameras in one embodiment of a multi-aperture camera.

[0038] FIG. 16 is a plot comparing cross-sectional contrast changes for grayscale and color sub-cameras in one embodiment of a multi-aperture camera, in an embodiment.

[0039] FIG. 17 shows line plots of a cross-section through a dark to bright transition region, in a luminance channel of a color image produced by a color sub-camera before image fusion.

DETAILED DESCRIPTION OF THE DRAWINGS

[0040] The following description is presented to enable one of ordinary skill in the art to make and use the embodiments herein, and is provided in the context of a patent application and its requirements. Various modifications to the described embodiments will be readily apparent to those skilled in the art and the principles herein may be applied to other embodiments. Thus, the present disclosure is not intended to be limited to the embodiments shown but is to be accorded the widest scope consistent with the principles and features described herein.

[0041] Certain embodiments described in this disclosure address issues that affect currently available systems by providing multi-aperture camera systems with the imaging characteristics approaching those of optical zoom and a size profile similar to fixed focus systems. In addition to combinations of optical and electronic components, this disclosure provides methods for fusing images having different optical characteristics.

[0042] The use of multi-aperture digital camera systems provides advantages over certain optical zoom systems (e.g., smaller module height, lower cost, elimination of moving parts) and over strictly digital zoom systems (e.g., better image quality, as quantified by, for example, image resolution).

[0043] A first digital camera, for example, operated by a first photographer, exhibits a specific fixed focal length, and the focal length influences an overall field of view that is consistent with a given level of zoom of the first digital camera. For example, the first digital camera is hand-held by the first photographer and hand-aligned in a direction suitable for imaging a set of objects that is centered on a tree (as a first object) and includes a person (as a second object) sitting at a picnic table (as a third object) The field of view of the first digital camera can be of sufficient transverse extent such that the imaged scene includes all three objects, each in their entirety, in a way that is consistent at least with (i) the directional orientation of the camera, (ii) a given spacing from the camera to the tree, and (iii) the level of zoom of the camera. The first photographer can select a fixed focal length camera having a sufficiently "wide" angle lens (i.e., corresponding to a low degree of zoom) such that all three objects can be simultaneously imaged. Alternatively, the first photographer can intentionally place herself at a selected distance from the objects in order to achieve the desired result of having all three objects within the field of view of the camera. As described immediately above, the level of zoom of the camera is determined in part by the focal length of the camera, with the resulting field of view being determined by other factors such as a physical size of a sensor array (such as a charge-coupled device, or "CCD" array) utilized by and associated with the camera.

In this example, the first digital camera produces a first set of image data corresponding to the imaged scene.

[0044] Continuing with the above example, a second photographer can stand next to the first photographer, and hold a fixed focal length compact digital camera that is aligned in approximately the same direction as the first photographer's camera. The second photographer in this example might be particularly interested in the tree, and may therefore elect to utilize a digital zoom feature to digitally adjust the level of zoom such that only the tree (the first object in the scene) is captured, while the rest of the scene is cropped. In this example, the compact digital camera produces a second set of image data corresponding to the tree. While the second set of image data (captured by the second photographer) corresponds to the same tree that is imaged in a corresponding portion of the first set of image data, and therefore can be considered as representing a part of the same scene imaged by the first set of image data, for purposes of this disclosure, the second set of image data is regarded as representing a second scene that overlaps the first scene.

[0045] Throughout this disclosure, the terms "image" and "digital signal" are used interchangeably when referring to signal processing. For example, those skilled in the art will recognize that the term "image processing" is often used interchangeably with "digital signal processing" or, more simply, "signal processing".

[0046] Turning now to the figures, wherein like reference numbers are used hereinafter to refer to like components whenever possible throughout the various figures, FIG. 1 is a schematic view illustrating fusion of image data from two sources. A scene 5 is imaged by two cameras 10 and 12 that image fields of view 20 and 22, respectively, producing first and second sets of image data 30 and 32, respectively. In embodiments herein, cameras 10 and 12 may be physically separate devices, as shown in FIG. 1, or may be sub-cameras of a single multi-aperture camera, as discussed below in connection with FIG. 2A and 2B. First and second sets of image data 30 and 32 overlap in an overlap region 40. In an embodiment, data from first and second sets of image data 30 and 32 are utilized to generate a fused set of image data 45. Fused set of imaged data 45 may span overlap region 40, as shown in FIG. 1, or may extend beyond overlap region 40 to the extent of either first and second sets of image data 30 and 32, as will be discussed below.

[0047] FIG. 2A illustrates a simplified diagrammatic representation of an exemplary multi-aperture zoom camera 95 that includes two sub-cameras. Each sub-camera includes an optical sub-system (represented by boxes 110 and 120 in FIG. 2A) in optical communication with a detector, or sensor region, 100 or a portion of image sensor region 100 along a respective optical axis (102, 103). The optical sub-systems may include one or more optical elements such as lenses, but also may include spacers and elements without optical power.

[0048] In the embodiment of a multi-aperture camera illustrated in FIG. 2A, each of optical sub-systems 110 and 120 may have a different focal length, but the same f-number, and each optical sub-system may image a scene and project an image onto a portion (such as approximately one half) of sensor region **100** for generating a corresponding set of image data corresponding to each scene. Sensor region **100** in this exemplary embodiment may be provided, for instance, as a complementary metal oxide semiconductor ("CMOS") sensor, a CCD array or any other analog or digital array of sensors or sensor media capable of receiving image information from two or more optical sub-systems. While sensor region 100 is illustrated in FIG. 2A as one continuous part or component, there is no requirement for this to be the case, as will be described below. In the exemplified illustration in FIG. 2, each optical sub-system may have a different focal length resulting in different fields of view; there is a "wide" sub-camera 120 having aperture 107 and a "tele" or "zoom" sub-camera 110 having aperture 105.

[0049] In the embodiment of FIG. 2A, it is convenient for illustrative purposes to consider an image sensor that is a two-dimensional array of individual sensing pixels, with a total of about 3 megapixels in the entire array. In a two-aperture system such as the one shown in FIG. 2, each half of the image sensor used by each of the optical sub-systems might include about 1.5 megapixels. It is contemplated that sensors of sub-cameras of a single multi-aperture camera may be shared in any manner; that is, pixels thereof may be (1) in separate sensor chips with images focused thereon by a single optical system or by separate optical subsystems, (2) blocks of pixels adjacent one another in a single sensor chip, or (3) interleaved in any manner within a single sensor chip. Similarly, sensors (and/or pixels thereof) of separate cameras that provide image data for embodiments herein are not limited to having identical shapes or sizes.

[0050] Attention is now turned to FIG. 2B with continuing reference to FIG. 2A. FIG. 2B illustrates another embodiment of multi-aperture camera 95, having a sensor region configured as two separate sensors 130 and 140 respectively. In FIG. 2B first sub-camera 150 is indicated with a coarse dashed line and second sub-camera 160 is indicated with a fine dashed line. First sub-camera 150 includes optical sub-system 110 configured to image a first scene through first aperture 105 and first sensor 130 may receive the resulting image for generating therefrom a first set of image data (represented by an arrow 301) corresponding to the imaged first scene. Second sub-camera 160 includes second optical sub-system 120 configured to image a second scene through second aperture 107 and second sensor 140 may receive the resulting second image for generating therefrom a second set of image data (represented by an arrow 302) corresponding to the imaged second scene. First and second sub-cameras 150 and 160 are therefore disclosed as a way to generate image data from two sub-cameras. Certain embodiments herein may require that one or the other of sub-cameras 150 and 160 have certain relative focal lengths (e.g., tele or wide) or imaging capabilities (e.g,. grayscale or color image data); it is not intended that such requirements remain fixed to one sub-camera or the other throughout the present disclosure. Also, it is recognized herein that the first and second optical sub-systems each may include one or more optical elements such as, but not limited to, refractive elements, diffractive elements, apertures, phase modifying elements and spacers, and that the first and second optical sub-systems may be identical to each other, may have different optical or physical characteristics, and may or may not be physically adjacent to one another as shown in FIGS. 2A and 2B.

[0051] Aperture 105 and optical sub-system 110 may be configured, for example, such that first sub-camera 150 has a wider field of view as compared to second sub-camera 160. In other words, first sub-camera 150 serves as a wide sub-camera having a field of view that is wider as compared to that of second sub-camera 160. Furthermore, second sub-camera 160 may serve as a "tele" sub-camera having a higher level of zoom as compared to first sub-camera 150.

[0052] As described above, the first and second sub-cameras in the present example may be oriented in a direction that is approximately the same for both the first and second cameras, as indicated by optical axes 102 and 103, respectively. As a result, the first and second scenes may overlap one another such that overlapping portions of the two scenes may simultaneously represent a similar image, albeit from two slightly different views. This causes the first and second image data sets to include subsets of data that are to be considered as overlapping one another, as will be discussed in greater detail below.

[0053] Attention is now turned to FIG. 3 with ongoing reference to FIG. 2B. FIG. 3 illustrates an embodiment of a multi-aperture imaging system 164. Multi aperture camera 100 provides first and second sets of image data 301 and 302 to a processor 166 which may, for example, be configured for combining or "fusing" the image data sets as will be described hereinafter, and fused image data 350 may then be provided to an image output device 167. It is noted that one or both of processor 166 and output device 167 may be arranged integrally with the multi-aperture camera, in a manner that is analogous to conventional digital cameras having integral processors and displays. In another example, one or both of processor 166 and output device 167 may be arranged externally to the given multi-aperture camera. In either arrangement, processor 167 is configured for receiving image data from multi-aperture camera 100, and image output device 167 is configured for receiving processed image data from processor 166. As described above, and based on well known techniques, image data may be represented and/or conveyed using one or both of (i) electrical signals (wirelessly or by electrical conductors) and (ii) memory or other digital storage techniques.

[0054] FIG. 4 schematically illustrates operation of a system 170 for processing first and second sets of image data generated by first and second sub-cameras of a multi-aperture camera (e.g., sub-cameras 150 and 160 of FIG. 2A and FIG. 2B). First and second sensor regions 171 and 172 respectively, associated with first and second sub-cameras 150 and 160 respectively, each have N/2 pixels such that the multi-aperture camera has a total of N pixels. In some instances, a user of the multi-aperture camera may desire that a final image size have a total of N pixels. For example, a multi-aperture camera may include first and second sensor regions, associated with the first and second sub-cameras, that each have 1.5 megapixels, such that the overall sensor region of the multi-aperture camera is 3 megapixels. In another example, a user of the multi-aperture camera may desire that a final image size (tele or wide) correspond to the original 3 megapixel sensor size. FIG. 4 represents one way to accomplish this by applying 2-dimensional upsampling and interpolation to the first and second sets of image data (for example digital signals) associated with the first and second sub-cameras. Upsampling is a process of increasing the sampling frequency of a digital signal and creates new data points in the signal. Interpolation calculates the values for the created data points. A first set of image data 173, having N/2 pixels, is upsampled and interpolated to provide a first upsampled and interpolated set 174, and a second set of image data 175 having N/2 pixels, is upsampled and interpolated to provide a second upsampled and interpolated set 176. Importantly, the newly created data points did not exist in the original digital signal and as a consequence, upsampling and interpolation generally results in some level of degradation in image quality. Methods of upsampling and interpolation include, but are not limited to, linear interpolation, polynomial interpolation, spline interpolation, bilinear interpolation, bicubic interpolation, and wavelet interpolation. In cases where a higher level of image quality is desired by the multi-aperture camera user, it is possible to combine, or fuse, the data contained in two or more of the images recorded in the multi-aperture camera to create a single, foveated high resolution image. These fused images will have regions of higher resolution and may be combined with other upsampling and interpolation techniques to create a high quality image.

[0055] FIG. 5 shows a plot 180 that illustrates differences in angular frequency information present in images having different fields of views, but identical image sensor sizes. For simplicity, the plot applies with respect to image data values lying along one-dimension only of a given image sensor and/or sensing region. Those skilled in the art will recognize that this discussion may be adapted to apply to the two-dimensional sensor systems described herein.

[0056] Well known principles of sampling theory dictate that for a detector with ‘n’ pixels, the sampling frequency (fs) of the detector is

$$fs = n/FOV\ ,$$

where FOV is the field of view, in degrees. This yields a Nyquist sampling frequency of:

$$\text{Nyquist} = fs/2$$

in cycles/degree. Optical systems generally cannot distinguish frequencies above the Nyquist limit. As depicted in FIGS. 2A and 2B, the wide and tele optical sub-systems may be configured such that the image captured by the tele system corresponds to, or overlaps with, some portion of the image captured by the wide optical sub-system. This will be referred to as the "overlap region". For the multi-aperture cameras illustrated in FIGS. 2A and 2B, the "wide" optical sub-system may have, for example, a field of view of 60 degrees. As an example, given a 1024 pixel sampling (in one dimension), the "wide" Nyquist frequency is 8.5 cycles/degree. The "tele" optical sub-system in FIGS. 2A and 2B uses the same number of pixels as the wide optical sub-system, but has a field of view, for example, of 30 degrees, yielding a "tele" Nyquist frequency of 17 cycles/degree. In the embodiments in FIG. 2A and 1B, the tele optical sub-system may create an image with a field of view that substantially overlaps the central portion of the wide image, defining an overlap region over which the second scene (imaged by the second sub-camera) substantially overlaps the first scene (imaged by the first sub-camera). With regard to this overlap region, a corresponding collection of the first set of image data is considered as a first collection of overlap image data, and a corresponding collection of the second set of image data is to be considered herein as a second collection of overlap image data. In other words, the first collection of overlap image data (from the first sub-camera) overlaps the second collection of overlap image data (from the second sub-camera). In a particular example depicted graphically by FIG. 5 the wide signal only includes frequency data below 8.5 cycles/degree (a region 200 in FIG. 4) and the tele image contains frequency data from 0 to 17 cycles/degree for the overlap region. That is, the tele image contains high frequency data that was not captured by the wide sub-camera (e.g., between 8.5 and 17 cycles/degree). A shaded region 210 represents the high frequency data captured by the tele optical sub-system.

[0057] FIG. 6 shows a series of three plots 192, 194 and 196, vertically aligned with one another and generally indicated by reference number 190, that illustrate certain principles underlying one embodiment of a method of image fusion.

As illustrated in FIG. 6, a first set of image data (for example a digital signal) generated by a wide optical sub-system (e.g., a "wide image") may be upsampled (for example as described with reference to FIG. 4) to match an angular sampling frequency of a tele digital signal obtained from a tele optical sub-system (e.g., a "tele image") such that each of the images has the same, or nearly the same, effective Nyquist frequency. The upsampled first set of image data 191 is represented in first plot 192, and the second set of image data 193 is represented in second plot 194. It is noted that second set of image data 193 has been high-pass filtered, as will be described in greater detail below. Upsampling the first set of image data to create first set of image data 191 effectively doubles a number of points in the wide image without changing its field of view, but it also leaves a "gap" in the frequency domain between a detected Nyquist frequency and an upsampled Nyquist frequency of the image data (in this example, from 8.5 to 17 cycles per degree). This gap can be filled by calculated data (e.g., interpolation, as previously described with reference to FIG. 3), but if the region of overlap between the fields of view of the tele and wide images is known, or can be determined by image registration techniques, high-frequency information captured by the tele image may be added back into the upsampled wide image at that overlap region. In other words, the high frequency tele data may be used to fill the 'gap' created by upsampling the wide image, at the overlap region. This results in a fused, foveated image of high resolution, represented in FIG. 6 by fused data set 195, shown in third plot 196 that includes both first set of image data 191 and second set of image data 193. In the event that the upsampling of the first set of image data results in an angular frequency that does not exactly match the angular frequency of the tele signal, additional blending steps may be utilized as part of, or in addition to, the fusion of tele image data with wide image data, to improve image quality of fused data set 195.

[0058] FIG. 7 illustrates details of one embodiment of the process of FIG. 6. In FIG. 7, a first set of image data 300 (e.g., a wide image) is upsampled and interpolated to form a target image 310. A second set of image data 320 (e.g., a tele image) is centered and blended into target image 310. As described previously with reference to FIGS. 2A and 2B, the first and second sub-cameras in the present example may be oriented in a direction that is approximately the same for both the first and second cameras, as indicated by axes 102 and 103, respectively. As a result, the first and second scenes, imaged by the first and second cameras and represented by the first and second sets of image data, may overlap with one another such that overlapping portions of the two scenes may simultaneously represent a similar physical source of scenery, albeit from two slightly different views. As described previously, this may cause the first and second image data sets to include collections of data that are to be considered as overlapping one another, as will be discussed in greater detail immediately hereinafter.

[0059] FIG. 7 illustrates a particular example wherein a multi-aperture camera is configured such that the second sub-camera (e.g., sub-camera 160, FIG. 2A) having a higher level of zoom as compared to the first sub-camera) is aligned with the first sub-camera (e.g., sub-camera 150) in an orientation that causes the second scene (imaged by the second camera) to be at least approximately centered within the first scene (imaged by the first camera). One result of this arrangement is that a second set of image data overlaps a first collection of overlap data that is centered within the first set of image data. In this particular arrangement, as depicted in FIG. 7, the second set of image data is entirely overlapped by the first set of image data, and the entire second set of image data serves as the second set of overlap image data.

[0060] In one embodiment (Option A – indicated in FIG. 7 by a circled letter "A"), a blend procedure may include changing a first set of overlap image data by directly replacing data from an upsampled wide image with low and high frequency data from a tele image. Alternatively, the low frequency data from the tele and wide images may be averaged as part of the center and blend step, and the high frequency data (obtained after interpolation of the wide image) is replaced with data from the tele image. In another embodiment, indicated by Option B (indicated in FIG. 7 by a circled letter "B"), a high-pass filter 315 is optionally applied to the signal from the tele image prior to the steps of centering and blending, to remove low frequency data. High-pass filters, suitable for use as high-pass filter 315 in the process illustrated in FIG. 6, may include convolution filters such as finite impulse response (FIR) filters and infinite impulse response (IIR) filters, among others. Removing low frequency data already present in an overlap region 312 of the wide image, from the tele image, allows faster, less computationally intense fusion of the two images.

[0061] As mentioned previously, a tele image may not correspond to the exact image center of a wide image, or that the tele image may only partially overlap with the wide image. For example, mechanical alignment between axes of a first camera and a second camera (e.g., axes 102 and 103, FIG. 2B) may be of limited precision, and the mechanical alignment may result in a spatial shift between the first and second scenes such that the second scene is not perfectly centered within the first scene. Therefore, it may be necessary to compensate for the spatial shift using signal processing techniques to register the two images prior to fusion. Image registration techniques, to be described in detail at appropriate points hereinafter include, but are not limited to: identification and alignment of center pixels for the two images to be registered; mapping features (e.g., lines, curves, boundaries, points, line intersections, and others) in one image to features in a second image; image similarity methods; search-based methods; spatial-domain methods (using control points); and frequency domain methods (e.g., phase correlation).

[0062] In certain of the image fusion processes presented herein, a resulting image is either a full-size wide image or a full-size tele image, produced using upsampling/interpolation of the original tele image. The term "full-size," in the case where sub-cameras in a multi-aperture camera share a single sensor, means that a resulting image size corresponds to an image that would be produced using substantially all of the pixels available on the sensor, were it not shared. This does not preclude a user from choosing an intermediate level of zoom between wide and tele fields of view. Further cropping and re-sampling of target image 310, for example, allows the user to choose any level of zoom and to utilize the multi-aperture camera as a continuous zoom camera.

[0063] FIG. 8 illustrates an embodiment of a process 332 for fusing tele and wide images. It relies on the principles described above with reference to FIG. 7, but also takes advantage of the human eye's increased sensitivity to luminance over chrominance with respect to blending of overlap regions of wide and tele images represented by first and second sets of image data, respectively. Using only luminance data allows for a decrease in computational demands for signal processing and fusion algorithms, and may reduce susceptibility to color effects (e.g., color aliasing) at edges. Image sensors often utilize a Red-Green-Blue ("RGB") color filter array ("CFA"), such as a Bayer pattern CFA, for representing a given set of image data as a group using three data subsets corresponding to red, green and blue. There are a number of other available techniques for representing image data as a plurality of image data subsets, and it is often possible to apply well established techniques to convert image data from one representation to another. As one example, in the embodiment exemplified in FIG. 8, both the tele and the wide images are converted from RGB to YUV in a conversion procedure 334. The YUV model defines a set of image data in terms of one luminance (Y) channel and two chrominance channels (U, V), and these channels may each be regarded as subsets of a given set of image data. Then, as in previous examples, the wide image data is upsampled and interpolated in an upsampling procedure 336. The step of upsampling/interpolating data from the wide image may occur before or after conversion of RGB to YUV. Data from the Y channel (luminance) of a tele sub-camera may be optionally high-pass filtered (i.e., option B, as indicated by filtering procedure 315, FIG. 8), as described previously. The resulting high frequency luminance data from the tele image is fused with the low frequency luminance data from the wide image, also as described previously. Optionally, as part of signal processing of the second set of image data, a gain procedure 340 may also be applied to the high frequency data extracted from the tele image prior to fusion with the low frequency data from the wide image. This process is a form of an unsharp mask process. Finally, chrominance data from the wide image may be returned to form a final, blended image. Alternatively, because chrominance data has been discarded from the tele sub-camera in this embodiment, the tele sub-camera may utilize an image sensor that does not have a color filter array. This allows the tele optical sub-system to utilize its entire sensor area to collect luminance data, resulting in even higher image resolution in the overlap region of the fused image. In the example presented above, and as indicated in FIG. 8, chrominance data from the U and V channels (chrominance data), as part of a second set of image data (e.g., the tele image) are discarded as redundant to the U and V data obtained from the wide image. In another embodiment, however, data from the tele U and V channels may be averaged with the U and V data from the wide image to reduce noise.

[0064] It is noted that high and/or low pass filtering of a given set of image is considered herein as one way of at least approximately representing the given set of image data based on one or more image data subsets, since applying filtering procedures to the given data set may be regarded as a procedure for dividing the data into different subsets of image data. For example, applying a high pass filter to the given set of image data produces filtered data that may be considered as a subset of the image data, since the filtered data corresponds to the given set of image data and represents only a filtered subset thereof. Also, for a given overlap region represented by at least two sets of overlap image data, the tele image captures both high and low frequency information for that region while the wide image captures only low frequency information. As will be described immediately hereinafter, the unsharp mask process described above can be accomplished using much less computational power by treating the wide image data as a low-pass subset of the tele image data.

[0065] FIG. 9 schematically illustrates yet another embodiment of a method 338 for image fusion. In method 338, high pass filtering is provided by subtraction of the original wide image signal (discarding interpolated high frequency data) from a tele image signal, after registration at a region of overlap. It is noted that method 338 may be performed in a way that produces results that are substantially the same as those or method 332, FIG. 7 (e.g., applying a high-pass filter to the tele image signal). However, method 338 may be performed without using a computational filtering operation. Method 338 includes what is referred to herein as an "optical-digital high-pass filter." Again, a step of applying a gain 340 to a filtered signal is optional. Based on known digital processing techniques, this subtraction operation may be used in conjunction with the gain operation to optionally replace the high-pass filtering step described above and as illustrated in FIG. 8 when, for example, access to computational power is limited. For example, a subtraction operation requires far less computational power, pixel for pixel, than, for example, applying a 7 × 7 convolution filter that requires 49 multiplications and 48 additions for each pixel in the overlap region. Process 338 may be thought of as an optical-digital high-pass filter that may be applied either to full color images, or as in the example shown in FIG. 7, to a signal from a luminance channel only. It is noted that an image registration procedure

342 is applied prior to subtraction procedure 344. As described above in reference to FIG. 7, FIG. 2A and FIG. 2B, mechanical alignment between axis 102 of the first camera and axis 103 of the second camera may be of limited precision, and the mechanical alignment may result in a spatial shift between first and second scenes such that the second scene is not perfectly centered within the first scene. It may thus be desirable to compensate for the spatial shift using signal processing techniques to register the two images prior to fusion. Image registration techniques are described in greater detail immediately hereinafter.

[0066] While the embodiments herein disclose fusion of tele and wide images produced by a multi-aperture camera, it will be appreciated by those skilled in the art that the processes described and claimed herein can be applied to the fusion of any two images that have image overlap regions but differ in field of view and/or native resolution. It is also contemplated that simply changing the order of certain steps in the processes and methods described herein may result in substantially the same fused images. Such re-ordering of steps thus falls within the scope of the disclosed methods.

[0067] Having described systems and methods relating to multi-aperture cameras and image fusion, a number of further details are described below. Attention is again returned to FIG. 2B. As discussed previously above, in multi-aperture camera 100, each of first and second optical sub-systems 110 and 120 is shown imaging onto its own sensor (i.e., sensors 130 and 140, respectively), and additional examples of a multi-aperture camera may include one or more optical subsystems sharing the same or different regions of a single sensor. Similarly, it may be desirable for each sub-camera, or a group of sub-cameras, to use sensors positioned on different planes. Image sensors suitable for use with multi-aperture camera 100 may include, for example, a CMOS sensor, a CCD array or any other analog or digital array of sensors or sensor media capable of receiving image information from one or more optical sub-systems. Image sensors 130 and 140 may be identical, or may be configured to have different physical, optical or electronic properties. For example, first sensor 130 may be a grayscale sensor for capturing and generating first image data 301 including luminance information corresponding to an object or a scene, while second sensor 140 may be a color sensor for providing second image data 302, including color information about the object or scene. Second sensor 140 may include, for instance, a CFA such as a Bayer filter, or be formed of individual color sensor elements (e.g., RGB or Cyan-Magenta-Yellow ("CMY")). It is noted that a grayscale sub-camera generally produces only a luminance signal (e.g., Y information without U, V chrominance information). Conversely, a color sub-camera produces a color image (e.g., RGB or CMY) that contains both chrominance and luminance information.

[0068] Attention is now directed to FIG. 10 with continued reference to FIG. 2B. A top view of sensors 130 and 140 of FIG. 2B is shown in FIG. 10. In this example, first sensor 130 of FIG. 2B is an array of grayscale pixels, and second sensor 140 of FIG. 2B is an array of color-sensitive pixels. While FIG. 10 is not drawn to scale, and only depicts a limited number of pixels, it illustrates that a position of a given pixel 360 can be described in terms of its position along a row (*i*) and a column (*j*) such that each given pixel 360 is associated with a position indicated by a coordinate (*i, j*). While FIG. 10 depicts grayscale, first sensor 130 and color, second sensor 140 aligned along sensor rows, it is noted that the sensors (or portions of a single sensor shared by multiple optical sub-systems) may be aligned along the columns or offset in some other manner.

[0069] Two characteristics of a multi-aperture camera, such as multi-aperture camera 100 of FIG. 2B, may include parallax and a differential sensitivity between a grayscale and a color sub-camera. These characteristics are discussed briefly below.

[0070] Due to a separation between first and second sub-cameras 150 and 160 of FIG. 2B, multi-aperture camera 100 may have parallax between a grayscale, luminance image produced by first sub-camera 150 and a color image produced by second sub-camera 160. In other words, because each sub-camera images a given object or feature from a slightly different position, the position of the given object or feature as projected on each sub-camera's sensor may vary. It is noted that parallax is a function of a camera-to-object depth (e.g., distance from the multi-aperture camera 95, FIG. 2B) and therefore, for a three-dimensional object parallax changes across the imaged object. That is, for objects or features at different camera-to-object distances, an image of the object or feature in the first sub-camera may fall on different pixels as compared to an image of the same object or feature in the second sub-camera. When the images are combined, it is desirable in most applications to at least reduce the effects of parallax during image fusion.

[0071] Additionally, because substantially all of the light available to a grayscale sub-camera may fall on pixels of its grayscale sensor, the grayscale sub-camera may exhibit higher light sensitivity than a color sub-camera that utilizes a CFA for extracting color information. Moreover, spatial resolution of image data obtained from the grayscale sensor (i.e., image data including luminance information only) may also be higher than spatial resolution of image data in a luminance (Y) channel of the CFA. The higher light sensitivity and higher spatial resolution of the grayscale sub-camera may be exploited by combining the set of image data generated by the grayscale sub-camera with the set of color image data to form a final color image with higher overall image quality, as compared to the set of image data obtained from the color sub-camera alone. Consequently, multi-aperture imaging system **100** may provide advantages such as, but not limited to: 1) improved low-light performance in terms of lower noise levels; 2) higher contrast as a result of the better light-sensitivity of the grayscale sensor; and 3) knowledge of object depth derived from the fusion algorithm and known camera geometries.

[0072] While the exemplary embodiment of the multi-aperture camera of FIG. 2B is shown to include two sub-cameras, other numbers and configurations of sub-cameras are possible. For example, three sub-cameras may be arranged in linear or triangular configurations. Four or more sub-cameras may be arranged in a linear manner, or in two or more rows (i.e., horizontal) or columns (i.e., vertical).

IMAGE REGISTRATION AND FUSION ALGORITHM

[0073] In an embodiment, fusion of image data from a multi-aperture camera may involve addition of color information from a color sub-camera image to luminance information from a grayscale sub-camera image. In another embodiment, a complementary operation may be performed where luminance information from the grayscale sub-camera is added to the color image from the color sub-camera. Due to parallax, one main difference between these two embodiments is that certain objects are spatially shifted in the resulting fused images.

[0074] Attention is now turned to FIG. 11, which illustrates an exemplary process 365 that utilizes processor 166 (see FIG. 3) for fusion of image data 301 and 302 produced, for example, by grayscale and color sub-cameras in a multi-aperture camera system. (It is appreciated that although process 365 and other processes herein are described as operating on image data from a multi-aperture camera system, other embodiments apply such processes to appropriate image data from imaging systems of other types.) In a step 367, a second set of image data 302 from second sub-camera 160 is converted to luminance-chrominance (i.e., YUV channels). Conversion step 367 is necessary due to the fact that, in the present example, image data 301 from first sub-camera 150 is already in the luminance domain; consequently, the color channels (e.g., RGB or CMY) from second sensor 140 are advantageously converted to include a first channel of luminance data (Y) and additional channels of chrominance data (UV) as a part of the image fusion process. We denote the luminance channels of the grayscale and color images as Y_G and Y_C, respectively; (U_G, V_G) and (U_C, V_C) denote their corresponding color channels. Note that, in the exemplary embodiment, the (U_G, V_G) channels are effectively zero initially because the grayscale sub-camera collects no chrominance data. Consistent with terminology established above and used throughout this disclosure, each one of the (Y_G, Y_C, U_C, V_C) channels is to be regarded as a subset of its associated set of image data.

[0075] Luminance channel Y_C from step 367 is directed to a step 369, where both grayscale and color luminance channels Y_G and Y_C are registered so as to generate registration information 371 (indicated by an arrow). This registration step may utilize a set of basis functions applied to a digital signal in the sampled domain to decompose that signal into image data subsets, including at least two frequency sub-bands in the transform domain, while maintaining localized information about the frequency content. The application of such a function to data in the sampled domain is referred to herein as a localized sampled domain frequency transform ("LSDFT"). One example of a LSDFT is the use of successive convolution filters to apply a series of high pass and low pass filters to decompose an image, initially into high and low frequency sub-bands, then into High/Low ("HL"), High/High ("HH"), Low/Low

("LL") and Low/High ("LH") bands. Another example of a LSDFT is the use of short time Fourier transforms ("STFT") to obtain information about bands of frequencies for a given spatial interval. Another exemplary basis function is the wavelet transform. Consistent with terminology established above, particularly in reference to filtering of image data, any given frequency sub-band, including but not limited to HH, LL, and LH bands, may be regarded as a subset of its associated set of image data, and STFT may be utilized to decompose a given set of image data into subsets of image data.

[0076] In one exemplary embodiment, registration step 369 utilizes LSDFT processing in order to determine any disparity between the grayscale and color luminance channels Y_G and Y_C caused by parallax effects. For instance, registration step 369 may determine which group of pixels in image Y_C corresponds to a given group of pixels in image Y_G.

[0077] Still referring to FIG. 11, registration information 371 generated in registration step 369 is directed to a step 373 where registration information 371 is combined with chrominance information (U_C, V_C) from color image data 302 to form fused set of color image data 375 with (Y_F, U_F, V_F). That is, image fusion step 373 calls corresponding color information from the (U_C, V_C) channels and adds it to the appropriate (U_G, V_G) channels.

[0078] In certain applications, it may be desirable to perform some processing of the images prior to or following image fusion step 373 in order to, for instance, improve the fidelity of the fusion and/or reduce artifacts that result from any potential registration errors. For instance, prior to image registration step 369, the (Y_C, U_C, V_C) channels may be scaled prior to processing in order to account for any intensity difference between the two sensors. For example, the data may be scaled by applying gain to a given set of image data. Such intensity matching may be necessary for proper registration of the grayscale and color images in image registration step 369. The matching of the Y channel intensity levels may be performed using a method such as, but not limited to, scaling and gamma correction. Additionally, post processing after image fusion step 373 may be performed, for instance, to ensure that relative color gain stays the same after the image fusion operation. Such additional processing steps are optional.

[0079] One advantage of the process illustrated in FIG. 11 resides in enabling estimation of the (U_G, V_G) channels from the (Y_G, Y_C, U_C, V_C) channels while utilizing any known information about any inherent dependence between them. In other words, (Y_G, Y_C, U_C, V_C) channels may be used to estimate the (previously zero) (U_G, V_G) channels, first by utilizing known (or calculated) registration between them, then applying the known color information from the (U_C, V_C) channels, as discussed below.

IMAGE REGISTRATION

[0080] Image registration may require at least some overlap region between two collections of overlap image data that are to be registered with one another. When this occurs, some feature may be identified in a first collection of overlap image data, and a second collection of overlap image data may be registered with the first collection of overlap image data. In particular, an example of image registration step 369 is discussed in detail immediately hereinafter.

[0081] Image registration may be performed utilizing any LSDFT applicable to a given sampled domain. For example, image registration may be performed in the wavelet domain. As another example, image registration may be applied in a transform domain such that at least one of the collections of overlap image data is represented in that transform domain. The wavelet transform includes an inherent property of allowing simultaneous access to localized spatial information and localized frequency content without certain artifacts (e.g., ringing, intensity mismatch, and edge discontinuity) commonly encountered in other block transform methods. As an example, the wavelet transform may be applied in a sliding-window fashion, which may be particularly useful when working in memory-constrained processing environments. The exemplary wavelet transform described herein utilizes Daubechies' 4×4 wavelets [See, I. Daubechies, *Ten Lectures on Wavelets*, SIAM: Society for Industrial and Applied Mathematics; First edition (June 1, 1992)]. Alternatives using higher level wavelets, other families of wavelets (e.g., biorthogonal, Haar, Meyer, and Gabor), or other types of LSFTs are contemplated and are considered as within the scope of embodiments disclosed herein.

[0082] Attention is now turned to FIG. 12 with ongoing reference to FIG. 2B, FIG. 10 and FIG. 11. FIG. 12 illustrates an exemplary embodiment 369(1) of image registration step 369 (see FIG. 11) implemented with a block-wise sliding window transform. First, forward transforms 380 and 385, respectively, are applied to grayscale and color luminance channels Y_G and Y_C. The results of forward transforms 380 and 385 are two groups of dyadic frequency sub-bands denoted 400 $\left(Y_G{}^{LL}, Y_G{}^{HL}, Y_G{}^{LH}, Y_G{}^{HH}\right)$ and 410 $\left(Y_C{}^{LL}, Y_C{}^{HL}, Y_C{}^{LH}, Y_C{}^{HH}\right)$ for the Y_G and Y_C channels, respectively. The schematic illustrations of of the two groups of sub-bands are not drawn to scale. Each one of the $\left(Y_G{}^{LL}, Y_G{}^{HL}, Y_G{}^{LH}, Y_G{}^{HH}\right)$ sub-bands includes a subset of image data represented in the transform domain and corresponding to the entire block that is illustrated in FIG. 12 and denoted as Y_G. Similarly, each one of the $\left(Y_C{}^{LL}, Y_C{}^{HL}, Y_C{}^{LH}, Y_C{}^{HH}\right)$ sub-bands includes a subset of image data corresponding to the entire block that is illustrated in FIG. 12 and denoted as Y_C. For example, the $Y_G{}^{LL}$ sub block entirely overlaps and corresponds to the Y_G channel.

[0083] Next, the $Y_G{}^{LL}$ sub-band image may be divided into overlapping or non-overlapping blocks of size $K_X \times K_Y$ (i.e., K_x pixels in an x-direction and K_Y pixels in a y-direction). Note that this division of the sub-band image may not be necessary in practice. However, it is contemplated that a "sliding" transform may be used, that is, the transform may operate on one block at a time and the data needed to generate subsequent blocks may be buffered. A full-frame version is described herein for clarity. A given kth block in the LL sub-band from the Y_G image is denoted in FIG. 12 as $\left(Y_G^{LL}\right)_k$, and the corresponding blocks in the HL, LH and HH frequency sub-bands are denoted in FIG. 12 as $\left(Y_G^{HL}\right)_k$, $\left(Y_G^{LH}\right)_k$, and $\left(Y_G^{HH}\right)_k$ respectively.

[0084] For each "target" block $\left(Y_G^{LL}\right)_k$, a block in the LL sub-band from the Y_C image corresponding to the same spatial region in object space that is occupied by the target block is identified. This identified block from the Y_C image may be chosen from all sets of possible (overlapping) $K_X \times K_Y$ blocks in Y_C^{LL}. With prior knowledge of a spatial relationship between sub-cameras in a multi-aperture camera system (or between other imaging systems that supply the Y_C and Y_G channels) the search region may be greatly reduced. For example, using knowledge of the sub-camera geometry for a multi-aperture camera (e.g., first and second sub-cameras 150 and 160 of FIG. 2B) and its sensor(s) (e.g., first and second sensors 130 and 140 of FIG. 2B), it is possible to estimate a parallax shift between the two or more sub-cameras. For example, an inspection of FIG. 10, which illustrates the sensor orientation for the exemplary arrangement of grayscale and color sensors from FIG. 2B, reveals that any parallax that occurs in this particular multi-aperture camera, occurs in one direction (e.g., along a row of pixels and spanning several columns of the sensors). Because of the position of the grayscale sensor with respect to the color sensor in the exemplary configuration shown in FIG. 10, any parallax for each pixel position (i, j) in Y_G^{LL}, if present, would occur at positions (i, j') in Y_C^{LL}, where $j' \leq j$. Also, given prior knowledge of the imaging geometry for a given multi-aperture system, it is possible to determine a maximum expected parallax shift from a closest object distance of interest. For example, the maximum expected parallax for closest objects in image space may be P pixels in the wavelet domain. Thus, a search region Z (denoted as the Z region in FIG. 12) may be defined as a block of pixels in Y_C^{LL} whose row indices and maximum column index are the same as those pixels in $\left(Y_G^{LL}\right)_k$ but whose minimum column index is P pixels less than the smallest column index in $\left(Y_G^{LL}\right)_k$.

[0085] In addition to utilizing prior knowledge of the spatial relationship between sub-cameras (or separate imaging systems), it may be desirable to refine a determination of parallax by identifying at least one spatial feature having a feature position within the first collection of overlap image data, and then searching within the second collection of image data for a related representation of the spatial feature such that the related feature at least approximately corresponds to the identified feature. It is then possible to register the related representation as being associated with the first feature position. This makes it possible to compensate for parallax by changing the first collection of overlap image data by modifying each identified spatial feature based on the related representation thereof. For example, changing the feature may include shifting the associated feature position in order to spatially align it with the related representation. Certain embodiments described below provide examplary techniques for performing such registration.

[0086] Still referring to FIG. 12, search region Z may be divided into overlapping $K_X \times K_Y$ blocks. An overlap between these blocks may be chosen as, for example, one pixel. Any such candidate j[th] block may be denoted as $\left(Y_C^{LL}\right)_j$ for the LL frequency sub-band of the color channel. The corresponding blocks in the HL, LH and HH color channel frequency sub-bands may be similarly denoted as $\left(Y_C^{HL}\right)_j$, $\left(Y_C^{LH}\right)_j$, and $\left(Y_C^{HH}\right)_j$, respectively. In order to determine which of candidate blocks $\left(Y_C^{LL}\right)_j$ correspond to target block $\left(Y_G^{LL}\right)_k$ the following sequence of steps may be performed:

(i) Merge (i.e., project) the high frequency blocks corresponding to low frequency block $\left(Y_C^{LL}\right)_j$ onto the high frequency blocks corresponding to low frequency block $\left(Y_G^{LL}\right)_k$. This operation may be performed, for instance, by swapping the blocks $\left\{\left(Y_G^{HL}\right)_k, \left(Y_G^{LH}\right)_k, \left(Y_G^{HH}\right)_k\right\}$ with the blocks $\left\{\left(Y_C^{HL}\right)_j, \left(Y_C^{LH}\right)_j, \left(Y_C^{HH}\right)_j\right\}$ and performing an inverse transform. Denote the spatial domain block that results from this operation as ε.

(ii) Compute an error between ε and $\left(Y_C\right)_j$, where $\left(Y_C\right)_j$ is the j[th] block in the sampled domain that corresponds to the j[th] blocks in the transform domain that are used to compute ε in step (i). For example, the comparison may utilize a mean squared error ("MSE") operation scaled by the overall block intensity. Other error metrics, such as L1 norm, may be used.

(iii) Steps (i) and (ii) may be repeated for all j values. The block index j* that generates the lowest error may be selected as the block associated with $\left(Y_G^{LL}\right)_k$.

[0087] Attention is now directed to FIG. 13 in conjunction with FIG. 12. FIG. 13 illustrates an embodiment 369(2) of image registration step 369 (see FIG. 11) implemented with a block-wise sliding window transform.. The initial processing in this alterative embodiment is substantially the same as illustrated in FIG. 12 and described above and may be performed in the wavelet domain using Daubechies' 4×4 wavelets. For example, the steps of performing a forward transform (e.g., an LSDFT such as a discrete wavelet transform) on both color and grayscale Y channels, defining a "target" block $\left(Y_G^{LL}\right)_k$, and defining a search region Z are similar to the embodiment illustrated in FIG. 12. Further processing as shown in FIG. 13 may include the following:

(i) Merge (e.g., project) the high frequency blocks corresponding to low frequency block $\left(Y_C^{LL}\right)_j$ onto the high frequency blocks corresponding to low frequency block $\left(Y_G^{LL}\right)_k$. Like the process shown in FIG. 12, this operation may be performed, for instance, by swapping the blocks $\left\{\left(Y_G^{HL}\right)_k, \left(Y_G^{LH}\right)_k, \left(Y_G^{HH}\right)_k\right\}$ with the blocks $\left\{\left(Y_C^{HL}\right)_j, \left(Y_C^{LH}\right)_j, \left(Y_C^{HH}\right)_j\right\}$ and performing an inverse transform, with an additional step of performing a forward transform. Denote the block that results in the LL sub-band at the same location as $\left(Y_G^{LL}\right)_k$ as ε'.

(ii) Compute an error between ε' and $\left(Y_C^{LL}\right)_j$. Again, the error computation may utilize an MSE operation scaled by overall block intensity, or other suitable error metrics, such as L1 norm, may be used.

(iii) Steps (i) and (ii) may be repeated for all j values. The block index j* that generates the lowest error may be selected as the block associated with $\left(Y_G^{LL}\right)_k$.

[0088] As in the embodiment described by FIG. 12, steps (i) and (ii) may be repeated for all j values. The block index j* that generates the lowest error may be selected as the block associated with $\left(Y_G^{LL}\right)_k$.

[0089] Index and error information obtained using either of methods 369(1) and 369(2) described above may be represented, for example, as a "parallax map" and/or an "error map." The error map is a two-dimensional array of error values calculated in step (iii) above for the block selected in step (iv) for each target block processed. The parallax map is a two-dimensional array indicating which index (i, j^*) from Y_C^{LL} corresponds to each index (i, j) in Y_G^{LL} and may be represented as pixel offset as a function of image coordinate.

[0090] Turning now to FIG. 14, an example of such a parallax map is illustrated as a contour plot 500. In this example, two planar objects were imaged with a multi-aperture camera, such as multi-aperture camera 95 of FIG. 2B. One object (at a center of the imaged scene) was placed at an object distance of 60 cm from the multi-aperture camera and the other was placed at an object distance of 1 m (background). Contour plot 500 in FIG. 14 reflects this object composition, showing 22 to 28 pixels of parallax in the center (e.g., associated with the object at 60 cm in the present example) and 2 to 6 pixels of parallax associated with the object at 1 m. With prior knowledge of the geometry for a particular multi-aperture camera, creation of such a parallax map may be used to obtain "ranging" information for objects in an image created using the multi-aperture camera.

[0091] In another example, image registration step 369 (FIG. 11) may include a simplified version of the process outlined above. For example, steps (i)-(iii) as described above in connection with step 369(1) (FIG. 12) may be replaced by a simpler process where, instead of computing ε, only blocks $\left(Y_C^{LL}\right)_j$ and $\left(Y_G^{LL}\right)_k$ are directly compared. In most instances, results of this simplified comparison operation are similar to the results of performing step 369(1). However, with certain objects having high-frequency content, step 369(1) may yield more accurate registration results. This is expected because inspection of only low-frequency sub-bands would "miss" certain registration error that may be present only in the higher spatial frequencies.

IMAGE FUSION

[0092] Attention is now turned to FIG. 15 in conjunction with FIG. 11. In certain embodiments, image fusion step 373 (see FIG. 11) is integrated within or performed concurrently with registration step 369. However, FIG. 15 illustrates the operation of image fusion component 373 as a stand-alone step. Using registration information computed in image registration step 369, color channels (U_C, V_C) may be 'merged' onto grayscale channels (U_G, V_G). This image fusion step may be accomplished utilizing a variety of digital signal processing methods and using some or all of the frequency components of the digital signals. In one embodiment, only low passed color information is used from the color channels. This offers two main benefits: 1) using only low-frequency information may eliminate high-frequency noise components that are inherently more significant in the color image, and thus reduce the total noise in the fused set of image data; and 2) a low-pass smoothing operation may reduce any artifacts that result from registration errors. In the embodiment illustrated in FIG. 15, a wavelet transform may be applied to grayscale and color chrominance channels (U_C, V_C) and (U_G, V_G). Subsequently, resulting LL frequency sub-band blocks from (U_C, V_C) may be assigned (e.g., based on registration information obtained in image registration step 369) onto the LL sub-band of (U_G, V_G) according to a parallax map generated as described above. In the present example, high-frequency sub-bands may be ignored for the color channels. After the LL frequency sub-band blocks from (U_C, V_C) are assigned onto the LL sub-band of (U_G, V_G), an inverse wavelet transform may be applied to the merged Y, U, and V channels to obtain a fused (Y_F, U_F, V_F) image as a fused set of image data, wherein $Y_F = Y_G$ and U_F, V_F are subsets of image data that represent the U and V channels from the original color image, registered and assigned onto the LL sub-band of (U_G, V_G), as discussed above.

[0093] A resulting fused set of image data, obtained as described above, may offer improved image quality, for example, in low-light conditions, as compared to a color image captured by a conventional, single aperture imaging system. For example, application of the above-described algorithms to the images produced by a multi-aperture camera may result in a variety of advantages such as, but not limited to: 1) improved low-light performance in terms of lower noise levels; 2) higher-contrast as a result of the better light-sensitivity of the grayscale sensor; and 3) object depth information as a by-product of the aforedescribed image fusion process.

[0094] Attention is now turned to FIG. 16. FIG. 16 shows two line plots of luminance (i.e., Y channel) intensity as a function of pixel position for a cross-section (after correction for parallax) for a fused color image and a color sub-camera image. First line plot 610 corresponds to Y_F of fused set of image data 350 (see FIG. 3), and second line plot 620 corresponds to Y_C of color image data 302. A first signal mean 630 (corresponding to fused set of image data 350) is indicated as a solid horizontal line, and a second signal mean 640 (corresponding to color image data 302) is indicated as a dashed horizontal line. In each line plot, variations of the image data around the corresponding mean intensity can be attributed to noise sources in the imaging system. It may thus be seen that first line plot 610 is higher in intensity than second line plot 620, and, based on first and second line plots 610 and 620, that noise is less severe in the luminance channel of the fused set of image data as compared to the luminance channel of the original color image. Signal-to-noise ratio ("SNR") may be used in the example shown in FIG. 16 to quantify the noise reduction for the luminance channel of the fused set of image data from the exemplary multi-aperture camera over the luminance channel of the un-fused, original color image. In the present context, SNR is understood to be the ratio of the signal mean to the signal standard deviation (e.g., due to noise). In the example shown in FIG. 16, the SNR of the luminance channel of the fused set of image data may be calculated to be 100 while the SNR of the luminance channel of the original color image obtained from the color sub-camera is 73.6. These values demonstrate an improvement of over 25% in SNR of the fused set of image data, which amounts to a 2.7dB improvement.

[0095] Turning now to FIG. 17, in addition to the noise reduction, the fused set of image data 350 from the exemplary multi-aperture camera also yields a higher contrast compared to the color image produced by the color sub-camera alone. FIG. 17 shows first and second line plots 710 and 720 of a cross-section through a dark to bright transition region from the luminance channel Y_F of the fused color image, and the luminance channel Y_C of the color image produced by the color sub-camera before image fusion, respectively. First and second line plots 710 and 720 provide the necessary data to compute a contrast measure for each of these images. In the context of the present disclosure, the contrast measure M may be defined as:

$$\mathbf{M} = \frac{\max(I) - \min(I)}{\max(I) + \min(I)}$$

where I is intensity of the luminance channel. Based on first and second line plots 710 and 720, the contrast measure for the fused image from the exemplary multi-aperture camera is M = 0.22, while that for the un-fused, color image from the color sub-camera is M = 0.20, thereby demonstrating an improvement of 10% in the fused image over the un-fused color image.

PRE- AND POST-PROCESSING ALGORITHMS

[0096] Referring briefly again to FIG. 11, a number of additional image processing algorithms may be applied to the digital signals produced by the sub-cameras of a multi-aperture camera. These additional algorithms may be applied prior to, during, or after application of the image registration and fusion steps of FIG. 11, and may result in a higher quality fused set of image data 375. Image processing algorithms that are applied to digital signals prior to image registration step 369 are referred to herein as "pre-processing algorithms". Algorithms that are applied after image fusion step 373 are referred to herein as "post-processing algorithms".

[0097] One example of a pre-processing algorithm is edge enhancement. While enhancing edges (i.e., areas of high spatial frequency) may result in a higher MSE for registration errors than an MSE calculated without edge enhancement, the effect may be desirable in certain applications. One method of edge enhancement involves increasing contrast of the images. Suitable methods include, for instance, high pass boost and application of an unsharp mask. Methods for increasing contrast include, but are not limited to, application of a gamma curve to the intensity levels in the Y channels, and/or application of histogram stretch. In certain applications, if contrast is increased in pre-processing, it may be necessary to reverse this operation prior to an image fusion step.

[0098] One example of an image processing algorithm that may be applied between the image registration and image fusion steps is a filtering operation to correct for localized errors in the parallax map created during image registration step 369. Such localized errors may be caused by noise and can be removed, or reduced, using a filtering operation applied to the parallax map prior to image fusion step 373. For example, a filter may be selected to remove isolated sparse registration errors. One such filtering operation may be achieved, for instance, using median filtering. Other filtering operations suitable for removal of noise in the parallax map include the application of band-pass filters.

[0099] Additionally, examination of the error map generated at image registration step 369 may yield information about the fidelity of the registration operation. By comparing the errors to some predetermined or adaptively computed threshold, an additional algorithm may be utilized to decide whether or not to "color" a certain wavelet block. This additional algorithm may be particularly useful in the presence of occluded regions, where there are objects visible in the grayscale image data that are not visible in the color image data due to parallax effects, which results in that object having no corresponding color information. In such regions, the calculated MSE may be higher than other, non-occluded areas and, consequently, the additional algorithm may be configured such that application of the algorithm does not add color in occluded regions.

[0100] Also, it should be noted that the scaling of the chrominance (i.e., U and V) channels of the color image from the color sub-camera system to the chrominance channels of the grayscale image in step 367 should be performed with care. For example, since color saturation is a function of the corresponding intensity level, adaptive scaling of the chrominance channels may be desirable during fusion in order to ensure good color fidelity.

[0101] While the examples described in this disclosure relate to the fusion of images produced by a multi-aperture camera having color and grayscale sub-cameras, it will be appreciated by those skilled in the art that the processes described and claimed herein may be applied to the fusion of any two or more images that have image overlap regions, whether produced by a multi-aperture camera system or by other imaging means. In addition, the examples described herein are applications of a localized transform to a digital signal in which the sampled domain is the spatial domain. It is recognized herein that such localized transforms may be applied to digital signals having other sampled domains such as, but not limited to, the temporal domain. Application of the methods described herein to such images may thus be considered to fall within the scope of the disclosed embodiments. It should thus be noted that the matter contained in the above description or shown in the accompanying drawings should be interpreted as illustrative and not a limiting sense.

CLAIMS

What is claimed is:

1. A method for image data fusion, comprising:

providing a first set of image data corresponding to an imaged first scene;

providing a second set of image data corresponding to an imaged second scene that at least partially overlaps said first scene in an overlap region, the overlap region defining

a first collection of overlap image data as part of the first set of image data and

a second collection of overlap image data as part of the second set of image data;

representing said second collection of overlap image data as a plurality of image data subsets such that each of the subsets is based on at least one characteristic of the second collection of overlap image data, and each subset spans the overlap region; and

producing a fused set of image data by modifying the first collection of overlap image data based on at least a selected one of, but less than all of, said image data subsets,

wherein the representing and producing steps are performed by an image processor.

2. The method of Claim 1 wherein

providing the first set of image data includes providing luminance data as part of the first set of image data, such that said first collection of overlap image data includes first luminance data;

providing the second set of image data includes providing luminance data as part of the second set of image data, such that said selected one of said image data subsets is a luminance channel including second luminance data;

representing the second collection of overlap image data includes utilizing luminance as the characteristic of the second collection of overlap image data, and modifying the first collection of overlap image data includes combining the first and second luminance data.

3. The method of Claim 2 wherein providing the second set of image data includes providing grayscale image data as said second luminance data.

4. The method of Claim 1 wherein representing said second collection of overlap image data includes filtering the second collection of overlap image data to form the selected image data subset.

5. The method of Claim 4 wherein filtering the second collection of overlap image data includes high-pass filtering the second collection of overlap image data such that high-pass filtered data forms the selected image data subset.

6. The method of Claim 4 wherein filtering the second collection of overlap image data includes convolution filtering the second collection of overlap image data.

7. The method of Claim 1 wherein representing said second collection of overlap image data includes scaling said second collection of overlap image data.

8. The method of Claim 7 wherein

providing the second set of image data includes providing intensity information as part of the second set of image data, such that said second collection of overlap image data includes said intensity information, and

scaling said second collection of overlap image data includes changing at least some of said intensity information.

9. The method of Claim 8 wherein scaling said second collection of overlap image data includes applying a gain to said intensity information.

10. The method of Claim 1 wherein representing said second collection of overlap image data includes transforming at least some of the second collection of overlap image data such that the characteristic of the second collection of overlap

image data is represented in a transform domain and at least the selected image data subset includes transformed data.

11. The method of Claim 1 wherein

providing said first set of image data includes establishing a first level of zoom with respect to said first scene, and

providing said second set of image data includes establishing a second level of zoom with respect to said second scene that is greater than said first level of zoom.

12. The method of Claim 11 wherein establishing the first and second levels of zoom causes said first set of image data to have first angular frequency information based at least in part on said first level of zoom, and causes said second collection of overlap image data to have second angular frequency information based at least in part on said second level of zoom, and said second angular frequency information represents a higher angular frequency than said first angular frequency information.

13. The method of Claim 12 wherein generating the first set of image data includes

producing an initial set of image data and

producing said first set of image data from the initial set of image data by upsampling said initial set of image data to increase the angular frequency represented in said first set of image data to a target angular frequency.

14. The method of Claim 13 wherein

producing said initial set of image data generates a group of initial data points, and

upsampling causes the first set of image data to include (i) said group of initial data points and (ii) an additional number of data points produced by interpolating between the initial data points for assigning values for each of the additional of data points.

15. The method of Claim 13 wherein said upsampling includes matching said increased angular frequency to said second angular frequency such that the target angular frequency of the first set of image data is at least approximately equal to said second angular frequency.

16. The method of Claim 15 wherein modifying the first collection of overlap image data includes blending said second collection of overlap image data with said first set of image data such that at least a majority of said fused image data exhibits a resulting angular frequency that is at least approximately equal to said second angular frequency.

17. The method of Claim 1 wherein providing the first set of image data includes providing said first collection of overlap image data as first, second and third data channels, and modifying said first collection of overlap image data includes converting the first, second and third data channels to a different set of three data channels.

18. The method of claim 17 wherein providing said first collection of overlap image data includes providing said first, second and third channels as R, G and B channels, respectively, and converting the first, second and third data channels includes converting the R, G and B channels to Y, U and V channels.

19. The method of Claim 1 wherein providing the second set of image data includes providing said second collection of overlap image data as first, second and third channels, and representing said second collection of overlap image data includes converting the second collection of overlap image data to a different set of three channels, each of which different channels forms one of said plurality of image data subsets.

20. The method of Claim 19 wherein providing said second collection of overlap image data includes providing said first, second and third channels as R, G, and B channels, and converting the second collection of overlap image data includes converting the R, G and B channels to a different set of three channels including Y, U and V channels.

21. The method of Claim 20 including selecting said Y channel as the selected subset of overlap image data.

22. The method of Claim 1 including modifying said second collection of overlap image data by subtracting therefrom said first set of overlap image data.

23. The method of Claim 1 wherein
providing the first set of image data includes
producing an initial set of initial image data and
producing said first set of image data from the set of initial image data by
applying a first forward transformation to at least a portion of said initial image data such that said first set of image data is transformed data in a transform domain and represents, in said transform domain, at least some of said portion of the initial image data; and
representing the second collection of overlap image data includes applying a second forward transformation to at least some of said second set of image data such that the characteristic of the second collection of overlap image data is represented in said transform domain, and the selected image data subset is a transformed data subset.

24. The method of Claim 23 wherein modifying said first collection of overlap image data includes merging the selected one of the image data subsets with the first collection of overlap image data in the transform domain to generate a merged data set in the transform domain.

25. The method of Claim 24 wherein producing the fused set of image data includes converting the merged data set from the transform domain by applying thereto at least one of (i) a forward transformation and (ii) an inverse transformation.

26. The method of Claim 1 wherein producing the fused set of image data further includes
identifying at least one spatial feature that is present at a feature position within the first collection of overlap image data, as an identified spatial feature;

identifying a related representation of each such identified spatial feature, in the selected image data subset, such that each related representation at least approximately corresponds to one of the identified spatial features;

registering a selected related representation as corresponding with a feature position of the corresponding identified spatial feature; and

wherein changing the first collection of overlap image data includes modifying at least one identified spatial feature based on the corresponding related representation of that feature.

27. The method of Claim 26 wherein the related representation has a related feature position within the selected image data subset, and identifying the related representation includes identifying a non-zero spatial shift between said related feature position and said feature position.

28. The method of Claim 26 wherein identifying said spatial shift includes determining that the spatial shift is caused by parallax between first and second sub-cameras that provide the first and second sets of image data, respectively.

29. The method of Claim 26 further including

defining a reference block overlying said feature position and having a shape that overlies a reference portion of said first collection of overlap image data such that the reference portion of image data represents said spatial feature, and

defining a search region within the selected image data subset,

designating a plurality of candidate blocks within the search region, each of which overlies an associated portion of the selected image data subset at a candidate position therein,

wherein said identifying includes

determining a degree of correspondence between (i) the reference portion of image data overlaid by the reference block and (ii) the portion of the selected image data associated with each of the plurality of candidate blocks, and selecting one of the candidate blocks, based on the degree of correspondence, that exhibits the highest degree of correspondence among the candidate blocks.

30. The method of Claim 29 wherein designating the plurality of candidate blocks includes defining a first candidate block and a second candidate block that partially overlap one another.

31. The method of Claim 29 wherein registering the selected related representation includes associating the candidate position of the selected candidate block with the feature position, and modifying the at least one identified spatial feature includes changing the reference portion of data based on at least some of the portion of data associated with the selected candidate block.

32. The method of Claim 31 wherein generating the first set of image data includes

producing a set of initial image data and

producing said first set of image data from the initial image data by applying a first forward transformation to at least a portion of said initial image data, such that said first set of image data is transformed data in a transform domain, and

wherein said representing the second collection of overlap image data includes applying a second forward transformation to at least some of said second set of image data such that the characteristic of the second collection of overlap image data is represented in said transform domain, and the selected image data subset is a transformed data subset.

33. The method of Claim 32 wherein modifying said first collection of overlap image data includes

merging the selected one of the image data subsets with the first collection of overlap image data in the transform domain, to generate a merged data set in the transform domain, and converting the merged data set from the transform domain by applying thereto at least one of (i) a forward transformation and (ii) an inverse transformation.

34. The method of Claim 1, further comprising

configuring a first sub-camera to provide the first set of image data corresponding to a first field of view;

configuring a second sub-camera to provide the second set of image data corresponding to a second field of view; and

arranging an overlap of the first and second fields of view, to generate the overlap region.

35. The method of Claim 34, wherein configuring the second sub-camera includes supplying the second sub-camera as a grayscale camera that provides at least a luminance channel.

36. The method of Claim 34 wherein

configuring the first sub-camera includes providing a first sensing surface characterized by a first transverse width, and orienting said first sensing surface for receiving the imaged first scene to generate the first set of image data, and

configuring the second sub-camera includes providing a second sensing surface characterized by a second transverse width, and orienting said second sensing surface for receiving the imaged second scene to generate the second set of image data.

37. The method of Claim 34 wherein

configuring the first sub-camera includes establishing a first focal length for the first sub-camera, and

configuring the second sub-camera includes establishing a second focal length for the second sub-camera, the first and second focal lengths being different from one another.

38. The method of Claim 37 wherein establishing the first focal length causes the first set of image data to exhibit a first level of zoom with respect to said first scene, and establishing the second focal length causes the second set of data to exhibit a second level of zoom with respect to said second scene that is greater than said first level of zoom.

39. The method of Claim 37 wherein providing the first set of image data includes generating said first set of image data with a first angular frequency based at least in part on said first focal length, and said providing the second set of image data includes generating said second set of image data with a second angular frequency based at least in part on said second focal length, and said second angular frequency is higher than said first angular frequency.

40. The method of Claim 34 wherein

configuring the first sub-camera includes furnishing said first sub-camera with a first sensor region having a first sensing surface, and aligning the first sensor region such that said imaging of said first scene includes projecting an image of said first scene onto said first sensing surface such that said first sensor region generates said first set of image data, and

configuring the second sub-camera includes furnishing said second sub-camera with a second sensor region having a second sensing surface, and aligning the second sensor region such that said imaging of said second scene includes projecting an image of said second scene onto said second sensing surface such that said second sensor region generates said second set of image data.

41. The method of Claim 40 wherein

furnishing said first sub-camera with said first sensor region having said first sensing surface, and furnishing said second sub-camera with said second sensor region having said second sensing surface includes supplying the first and second sensing surfaces with sensing surface shapes and surface areas that substantially correspond with one another.

42. The method of Claim 40 wherein furnishing said first sub-camera with said first sensor region having said first sensing surface, and furnishing said second sub-camera with said second sensor region having said second sensing surface, include supplying the first and second sensing surfaces as portions of a single image sensor chip.

43. The method of Claim 34 wherein

providing the first set of image data includes

producing an initial set of initial image data and

producing said first set of image data from the set of initial image data by applying a first forward transformation to at least a portion of said initial image data such that said first set of image data is transformed data in a transform domain and represents, in said transform domain, at least some of said portion of the initial image data, and

representing the second collection of overlap image data includes applying a second forward transformation to at least some of said second set of image data such that the characteristic of the second collection of overlap image data is represented in said transform domain, and the selected image data subset is a transformed data subset.

44. The method of Claim 43 wherein modifying said first collection of overlap image data includes merging the selected one of the image data subsets with the first collection of overlap image data in the transform domain to generate a merged data set in the transform domain.

45. The method of Claim 44 wherein producing the fused set of image data includes converting the merged data set from the transform domain by applying thereto at least one of (i) a forward transformation and (ii) an inverse transformation.

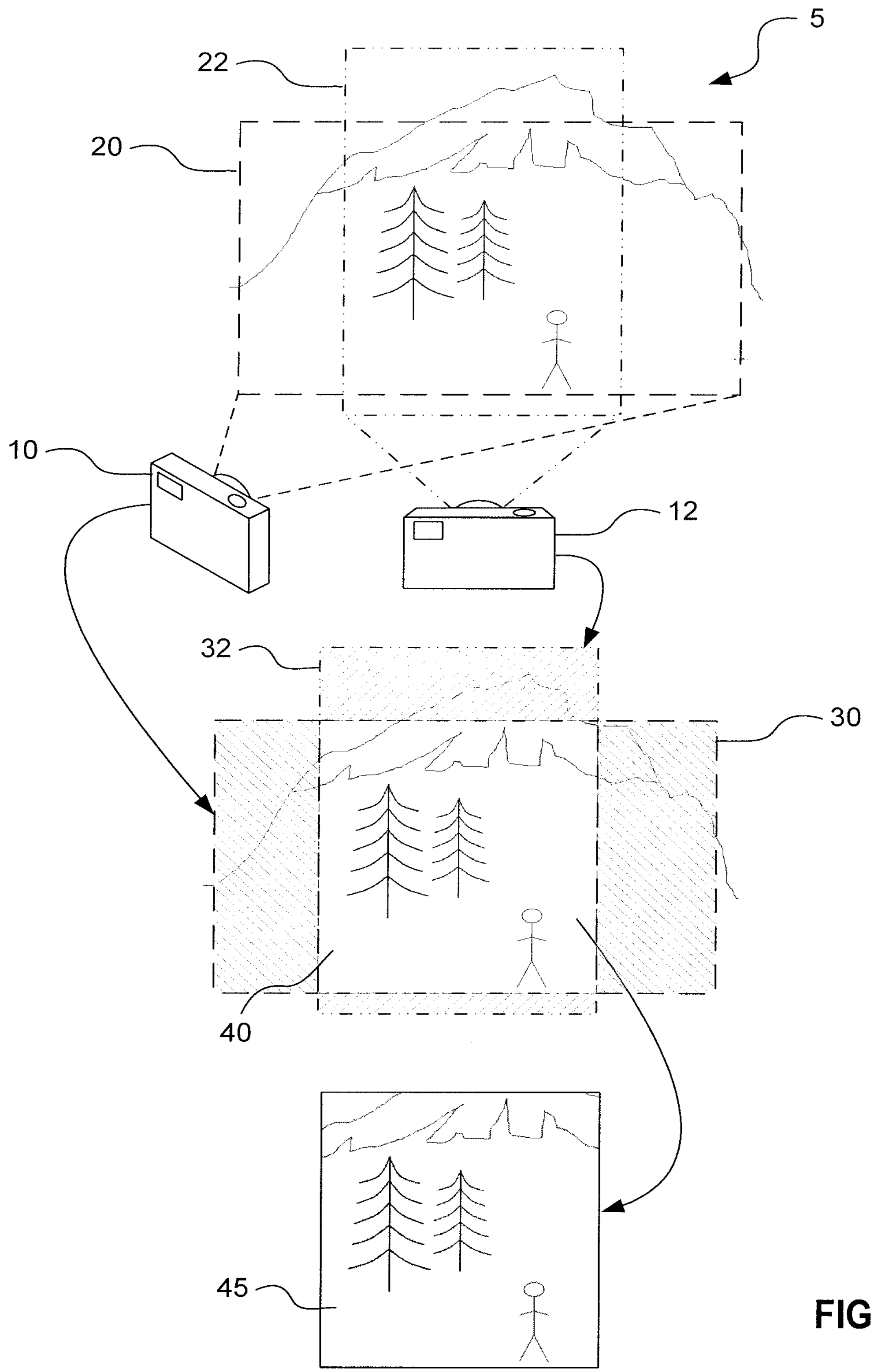


FIG. 1

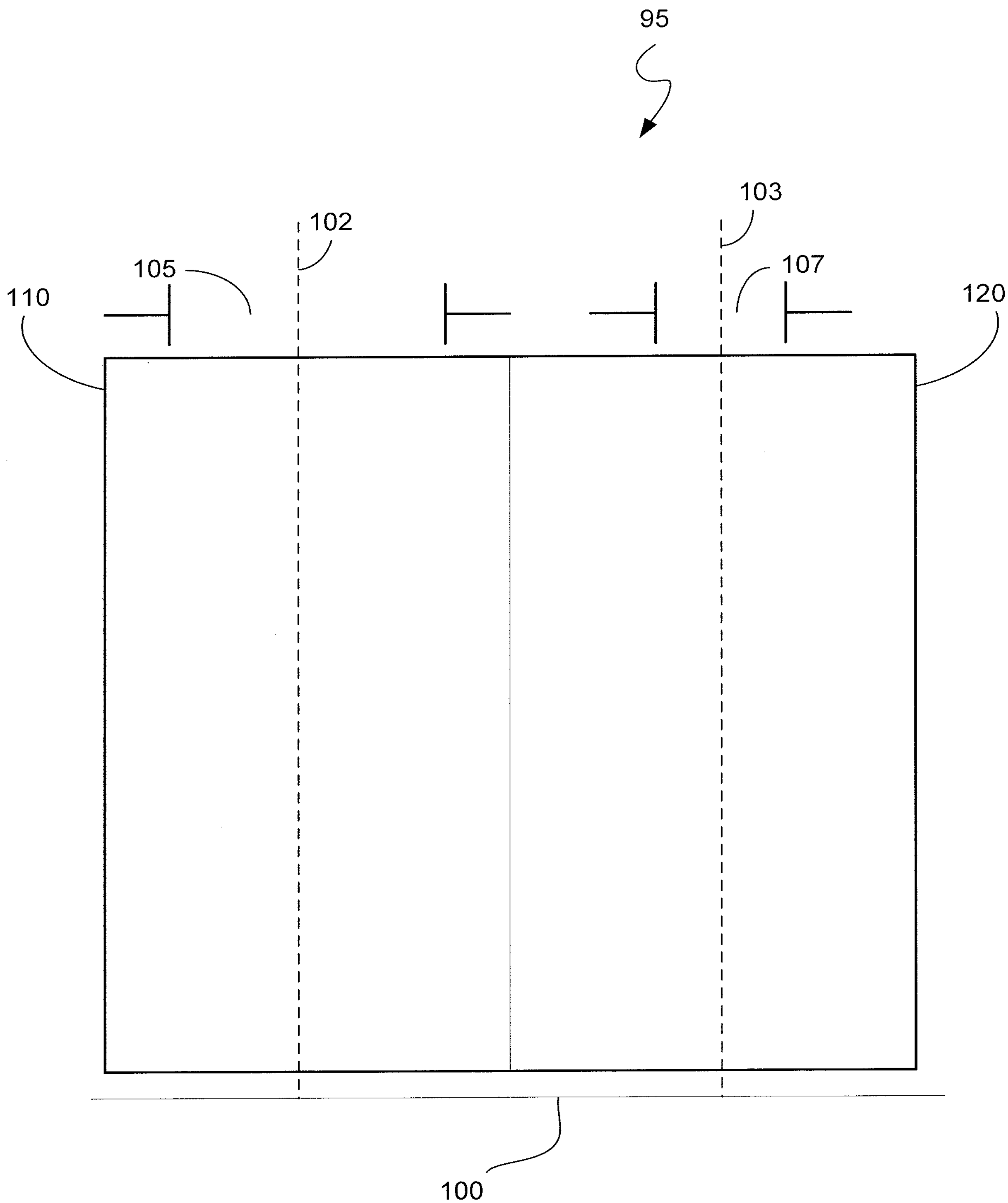


FIG. 2A

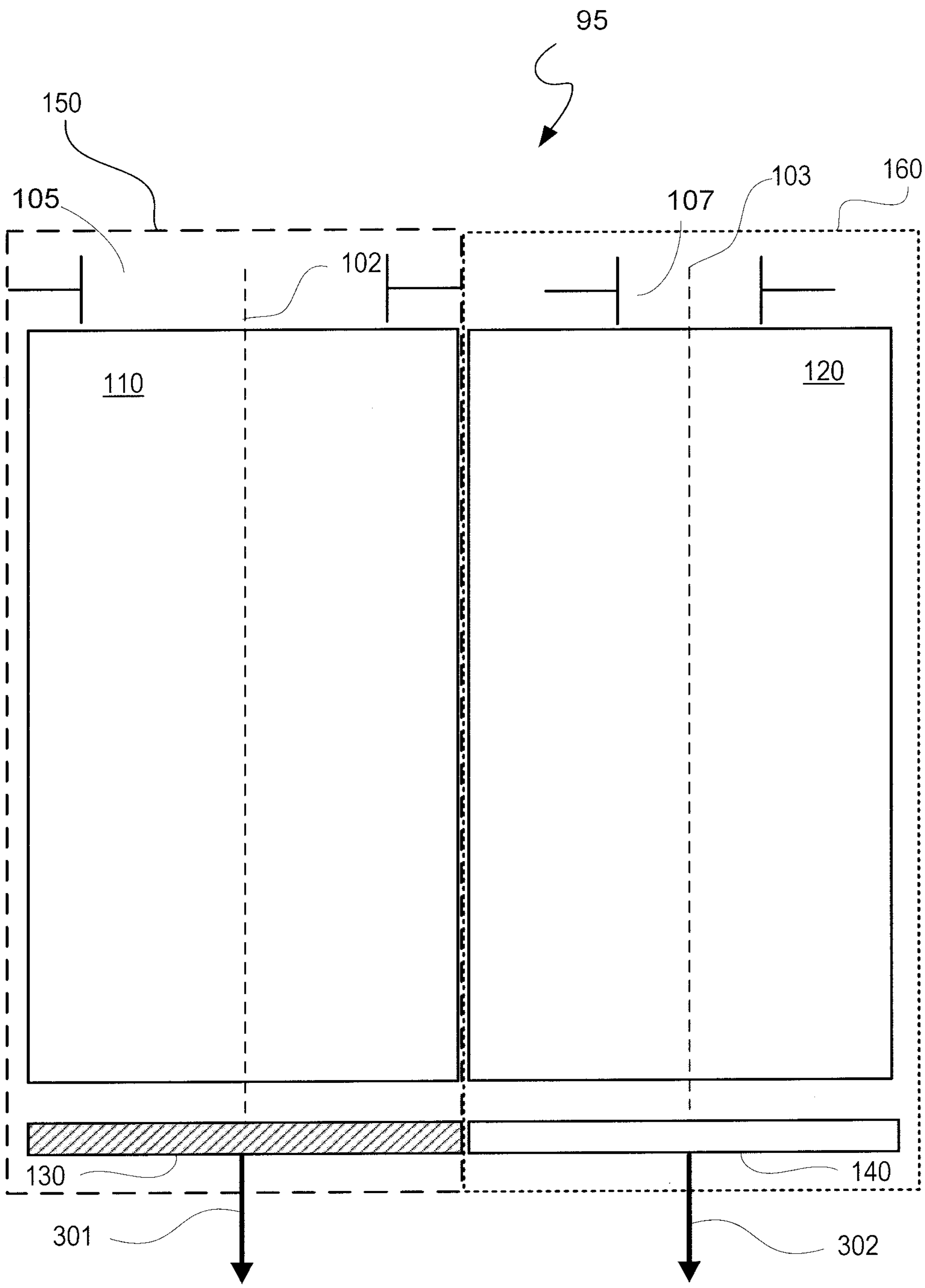


FIG. 2B

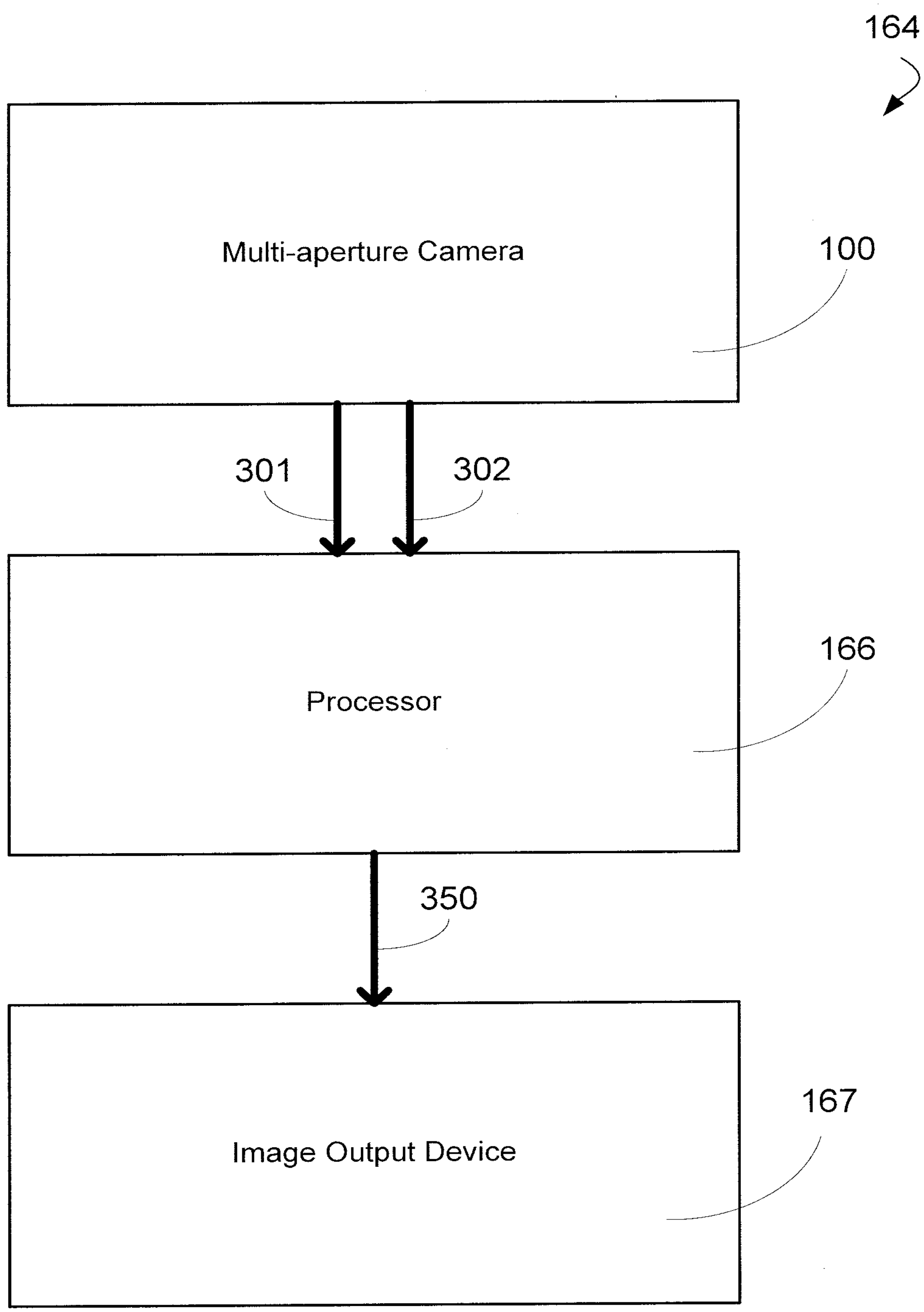

164
Multi-aperture Camera
100
301
302
Processor
166
350
Image Output Device
167

FIG. 3

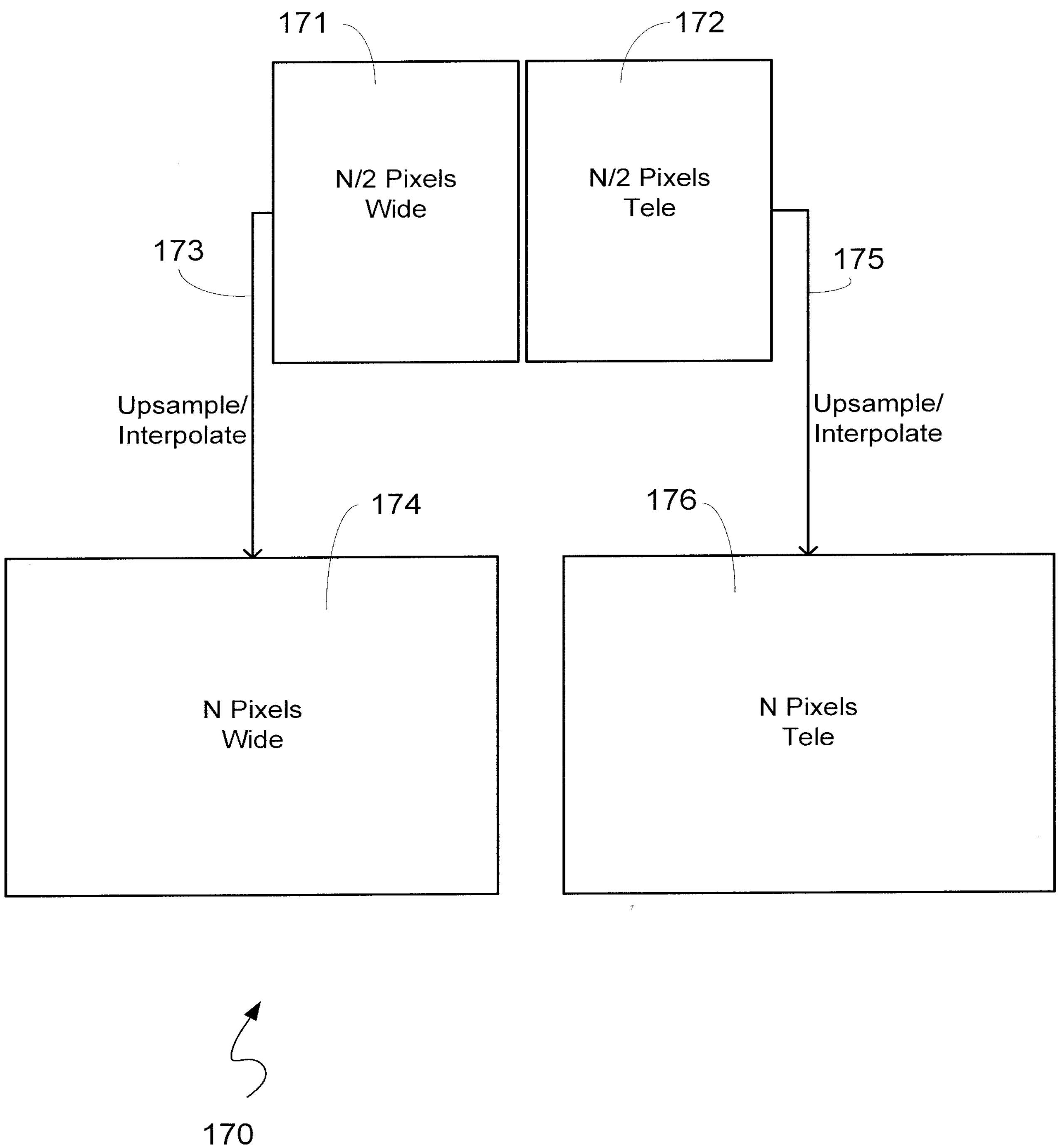

171
172
N/2 Pixels
Wide
N/2 Pixels
Tele
173
175
Upsample/
Interpolate
Upsample/
Interpolate
174
176
N Pixels
Wide
N Pixels
Tele
170

FIG. 4

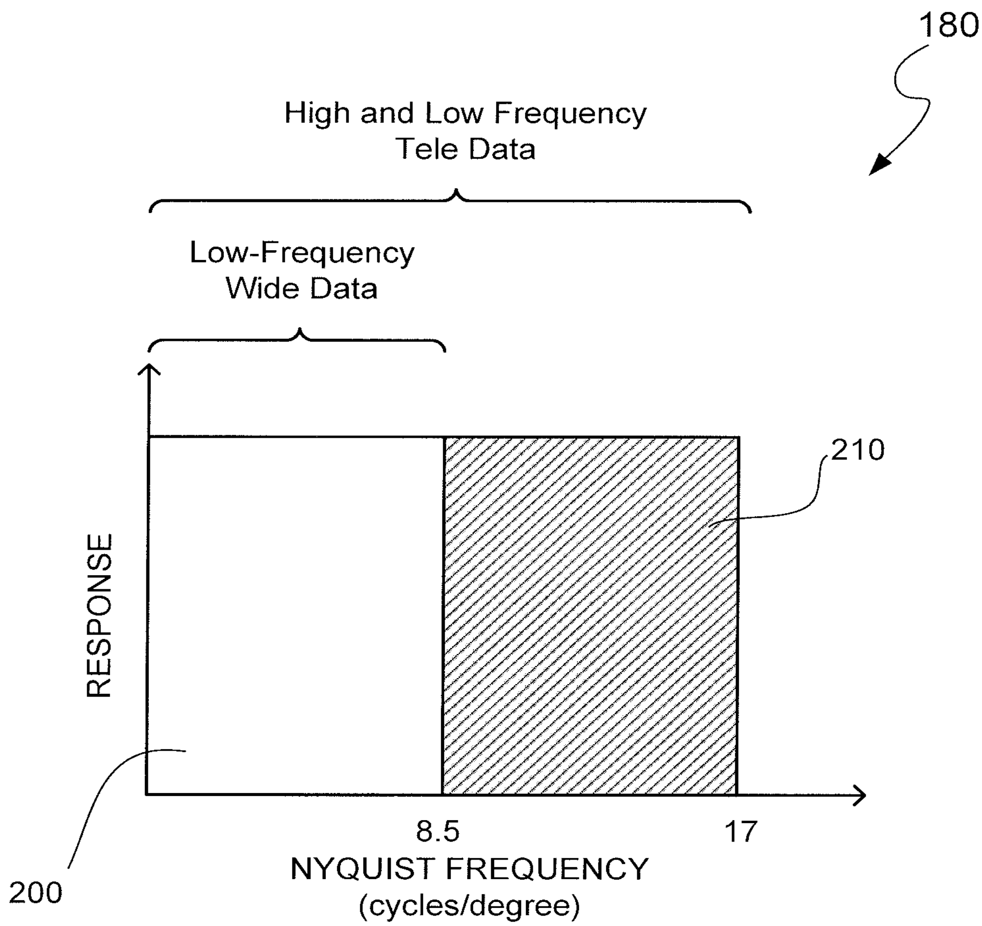

180
High and Low Frequency
Tele Data
Low-Frequency
Wide Data
210
RESPONSE
200
8.5
17
NYQUIST FREQUENCY
(cycles/degree)

FIG. 5

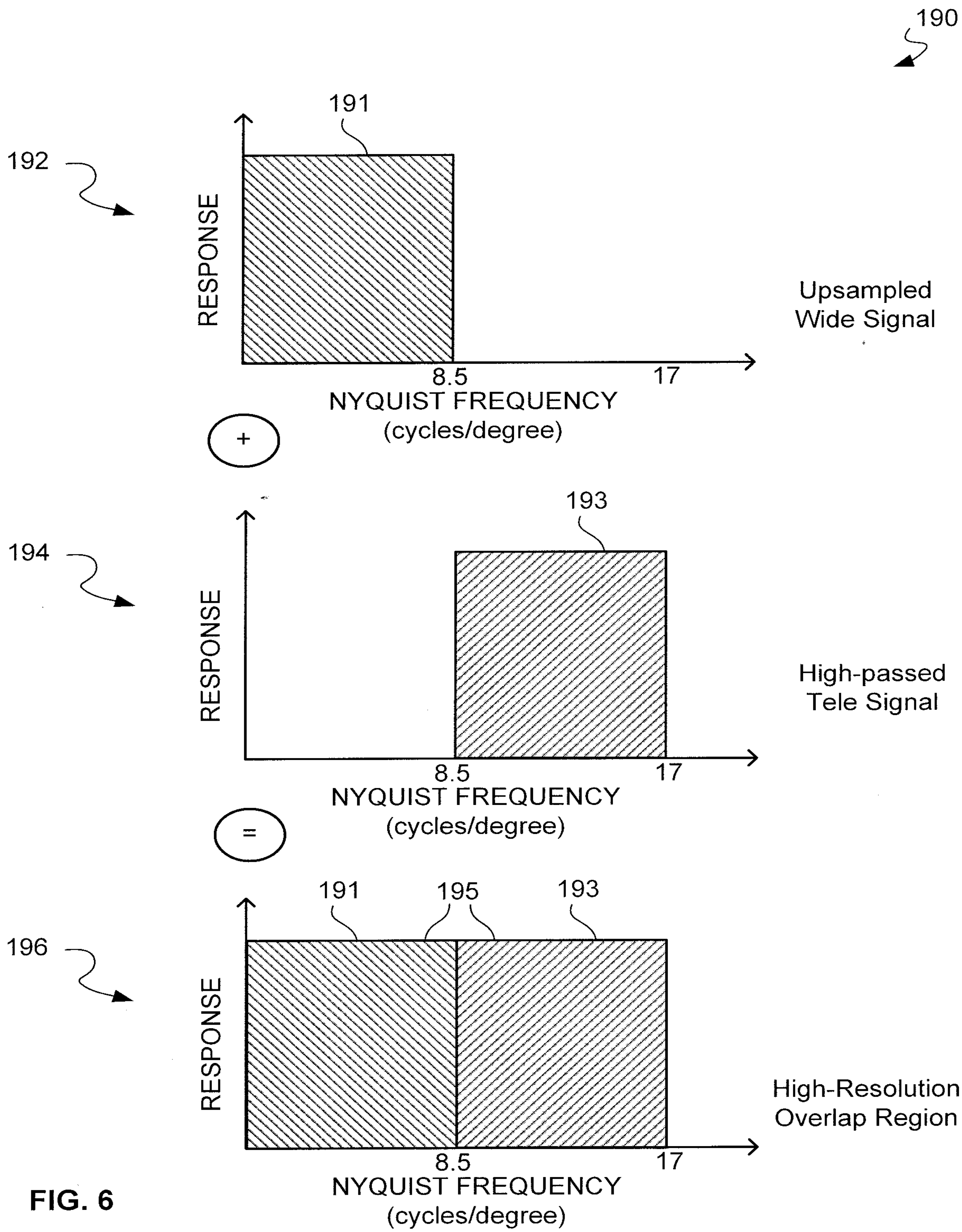

190
191
192
RESPONSE
Upsampled
Wide Signal
8.5
17
NYQUIST FREQUENCY
(cycles/degree)
+
193
194
RESPONSE
High-passed
Tele Signal
8.5
17
NYQUIST FREQUENCY
(cycles/degree)
=
191
195
193
196
RESPONSE
High-Resolution
Overlap Region
8.5
17
NYQUIST FREQUENCY
(cycles/degree)

FIG. 6

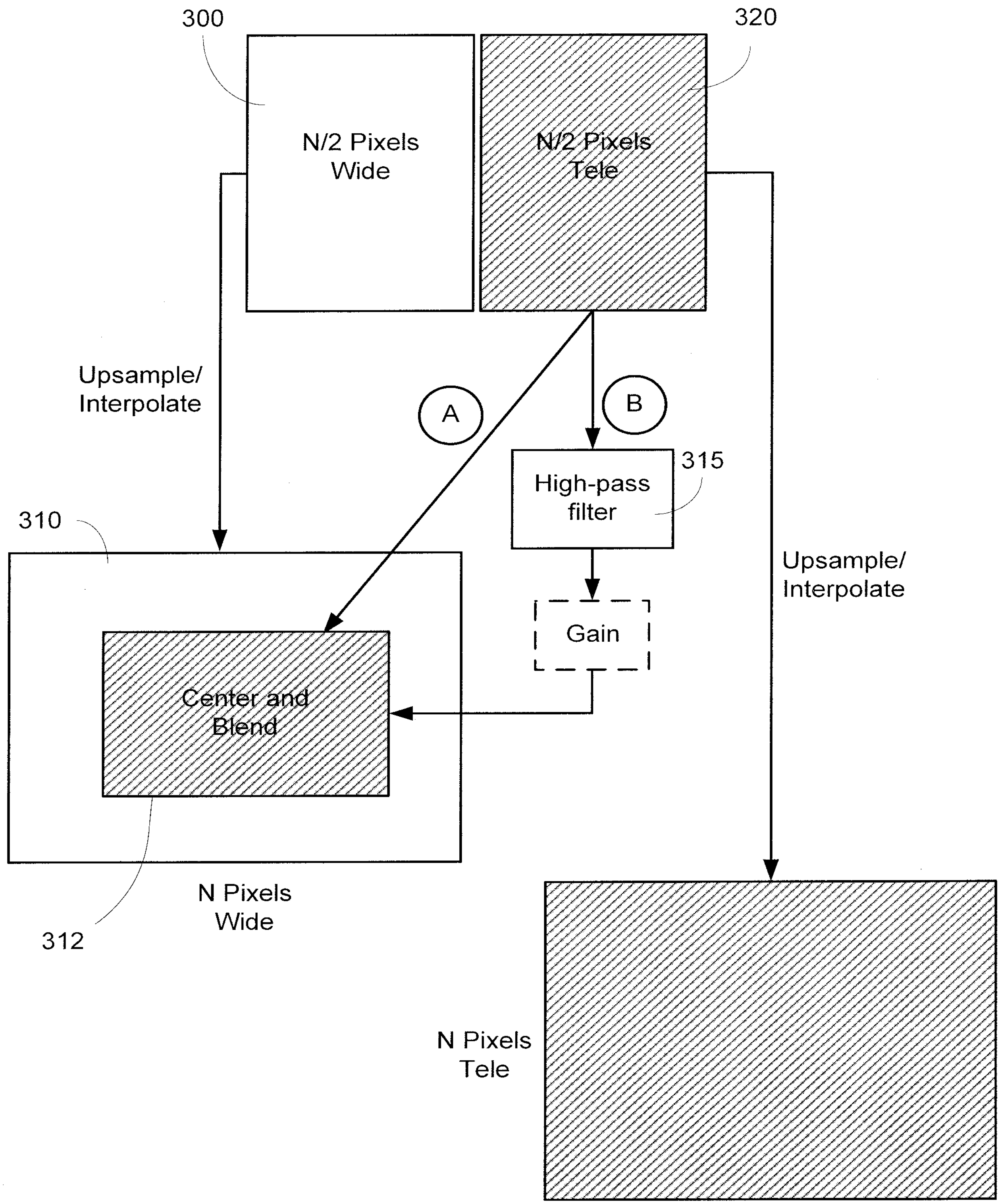

300
320
N/2 Pixels
Wide
N/2 Pixels
Tele
Upsample/
Interpolate
A
B
315
High-pass
filter
310
Upsample/
Interpolate
Gain
Center and
Blend
N Pixels
Wide
312
N Pixels
Tele

FIG. 7

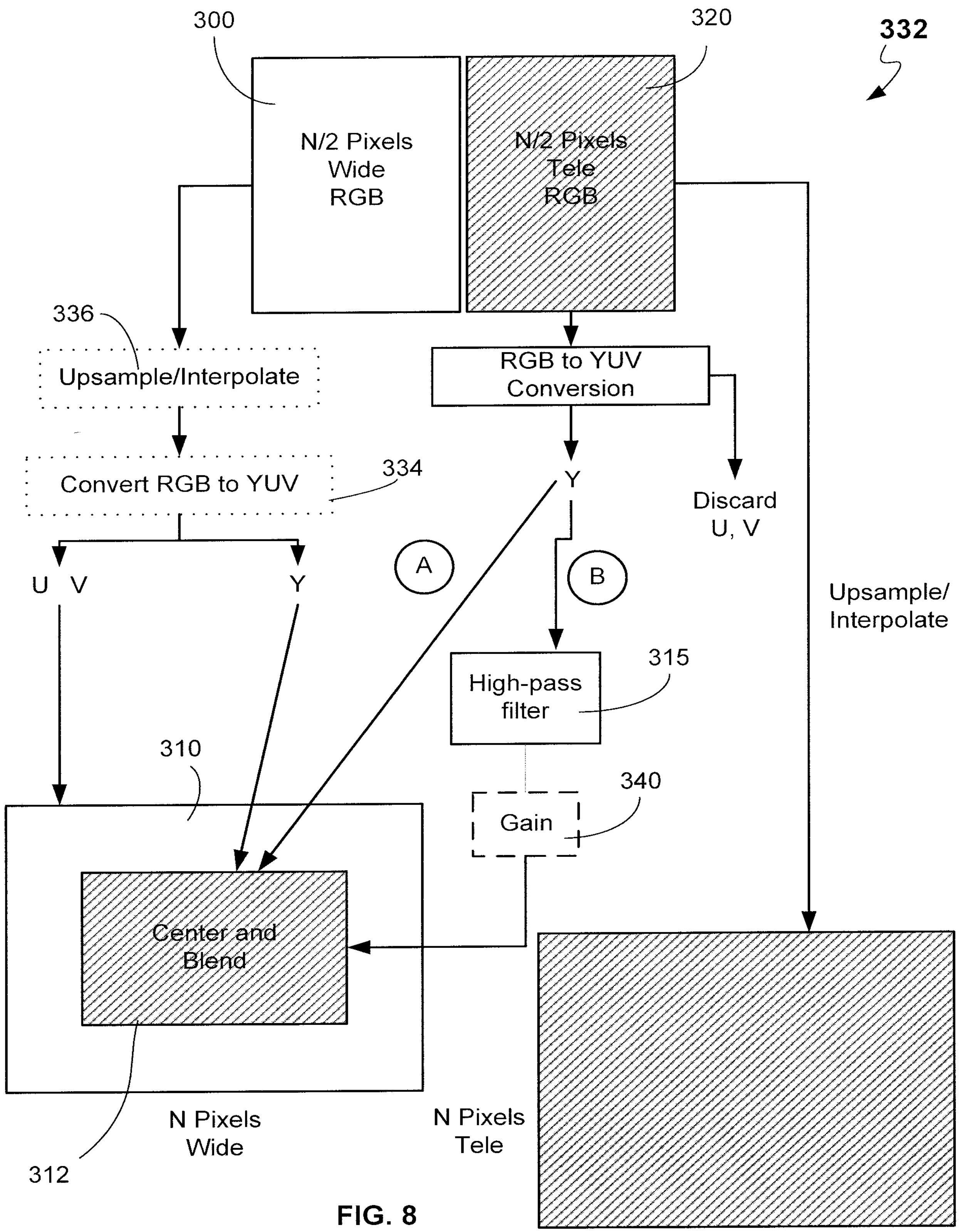

300
320
332
N/2 Pixels
Wide
RGB
N/2 Pixels
Tele
RGB
336
Upsample/Interpolate
RGB to YUV
Conversion
Convert RGB to YUV
334
Y
Discard
U, V
U V
Y
A
B
Upsample/
Interpolate
High-pass
filter
315
310
340
Gain
Center and
Blend
N Pixels
Wide
N Pixels
Tele
312

FIG. 8

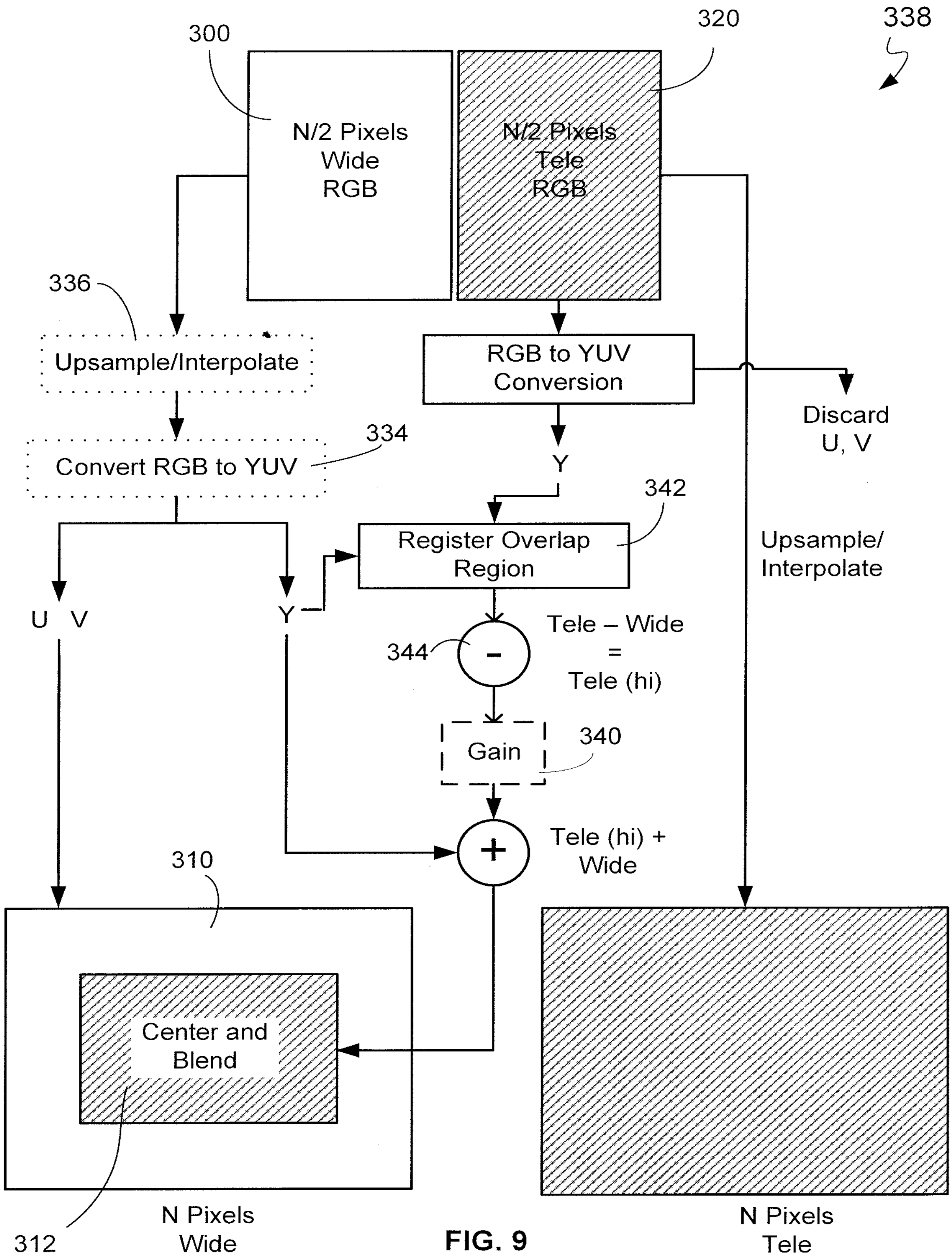

300
320
338
N/2 Pixels
Wide
RGB
N/2 Pixels
Tele
RGB
336
Upsample/Interpolate
RGB to YUV
Conversion
Discard
U, V
334
Convert RGB to YUV
Y
342
Register Overlap
Region
Upsample/
Interpolate
U V
Y
Tele – Wide
=
Tele (hi)
344
-
Gain
340
+
Tele (hi) +
Wide
310
Center and
Blend
312
N Pixels
Wide
N Pixels
Tele

FIG. 9

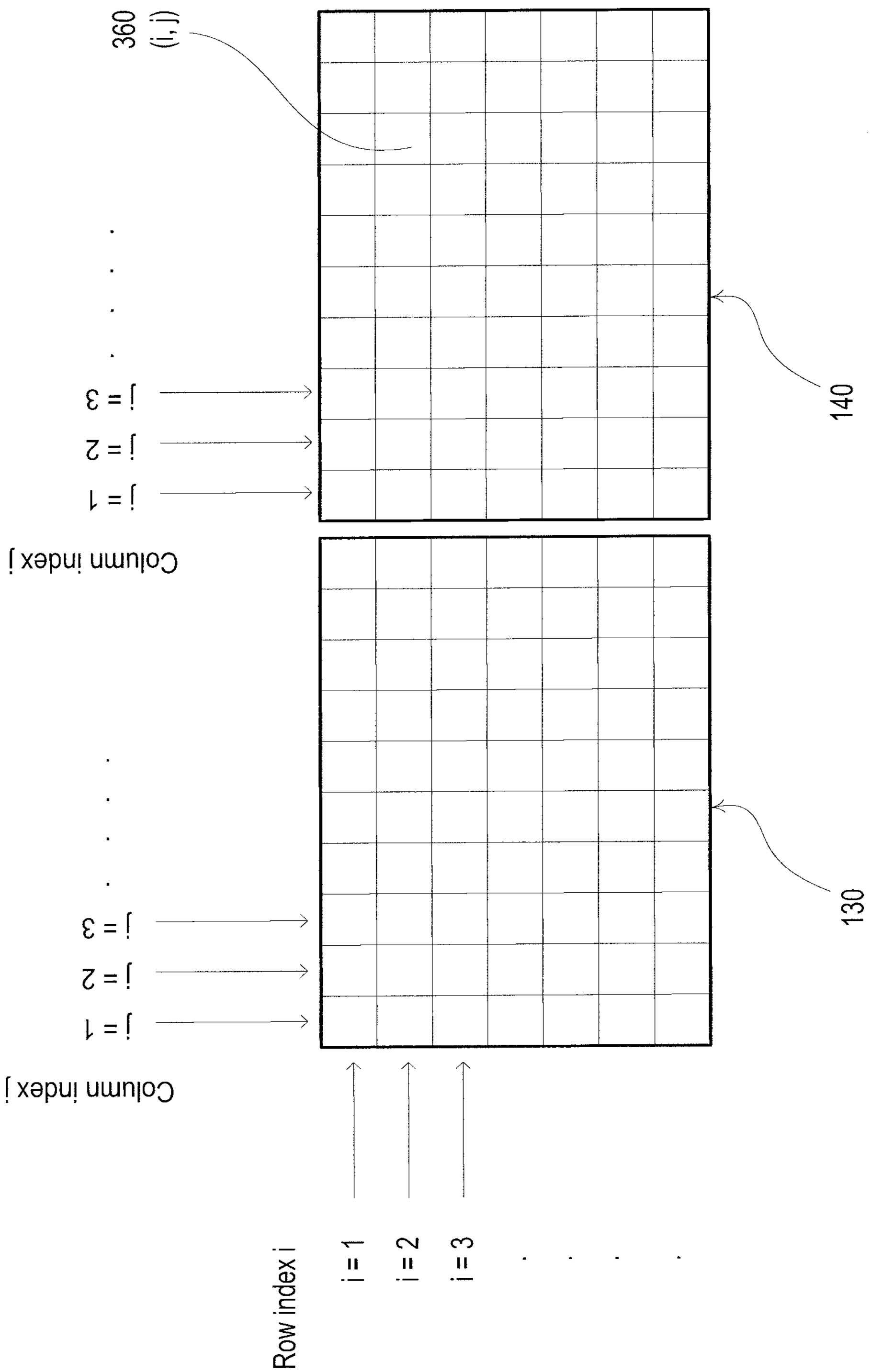

360
(i, j)
Column index j
j = 1
j = 2
j = 3
140
Column index j
j = 1
j = 2
j = 3
130
Row index i
i = 1
i = 2
i = 3

FIG. 10

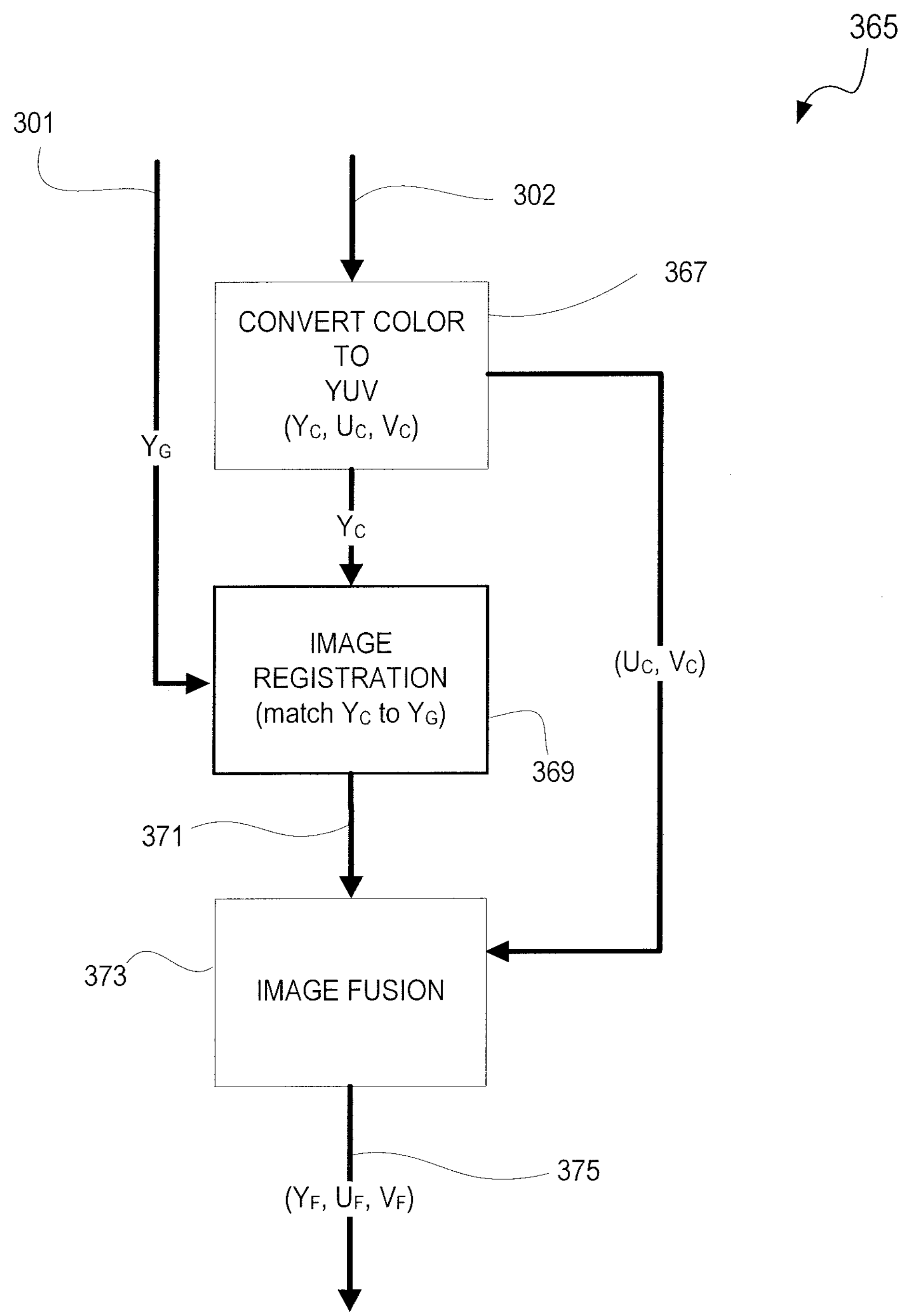

365
301
302
367
CONVERT COLOR TO YUV (Y_C, U_C, V_C)
Y_G
Y_C
IMAGE REGISTRATION (match Y_C to Y_G)
(U_C, V_C)
369
371
373
IMAGE FUSION
375
(Y_F, U_F, V_F)

FIG. 11

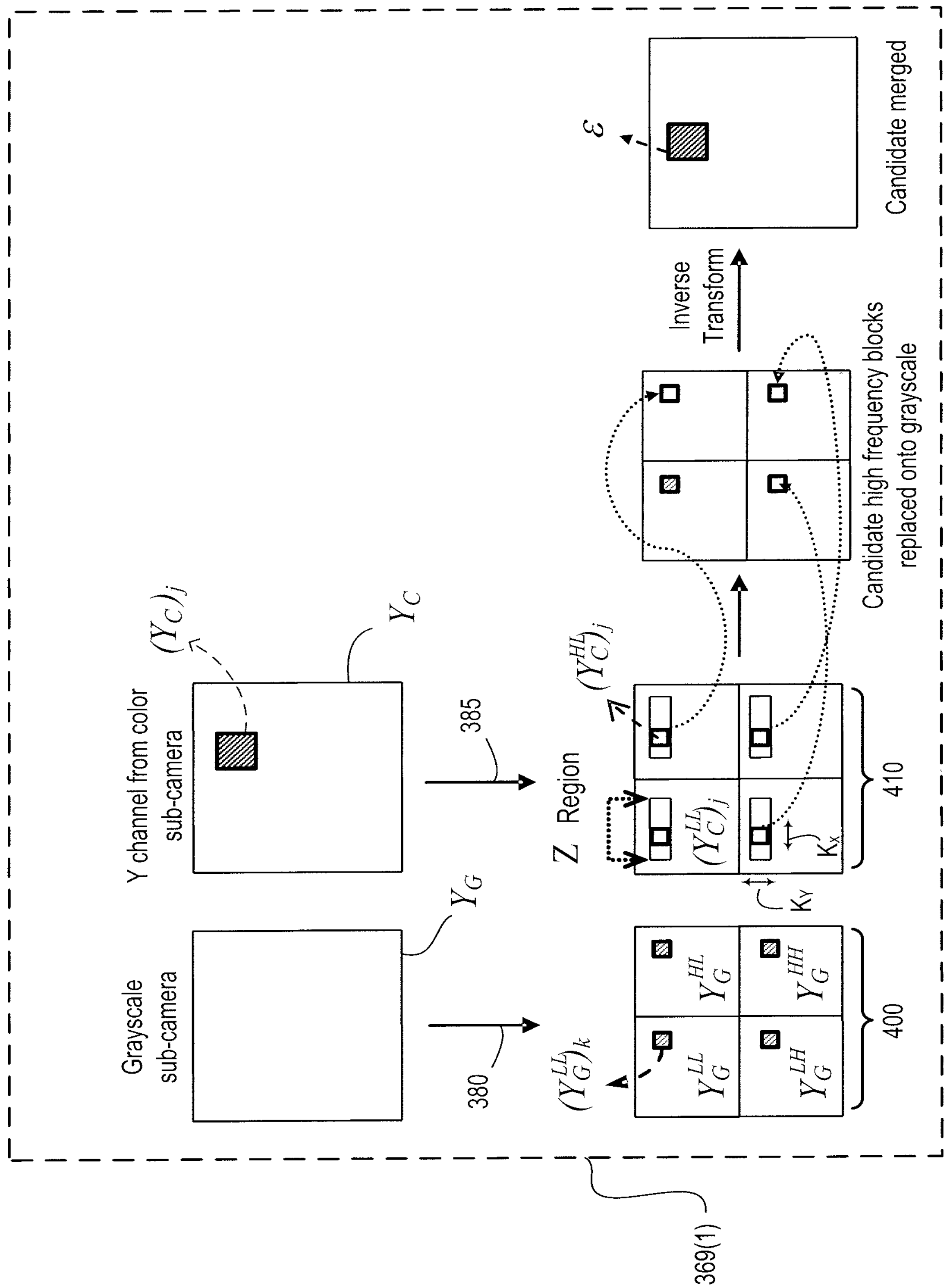

Grayscale sub-camera
Y channel from color sub-camera
Y_G
Y_C
$(Y_C)_j$
380
385
Z Region
$(Y_G^{LL})_k$
Y_G^{LL}
Y_G^{HL}
Y_G^{LH}
Y_G^{HH}
$(Y_C^{LL})_j$
$(Y_C^{HL})_j$
K_Y
K_X
400
410
Candidate high frequency blocks replaced onto grayscale
Inverse Transform
ε
Candidate merged
369(1)

FIG. 12

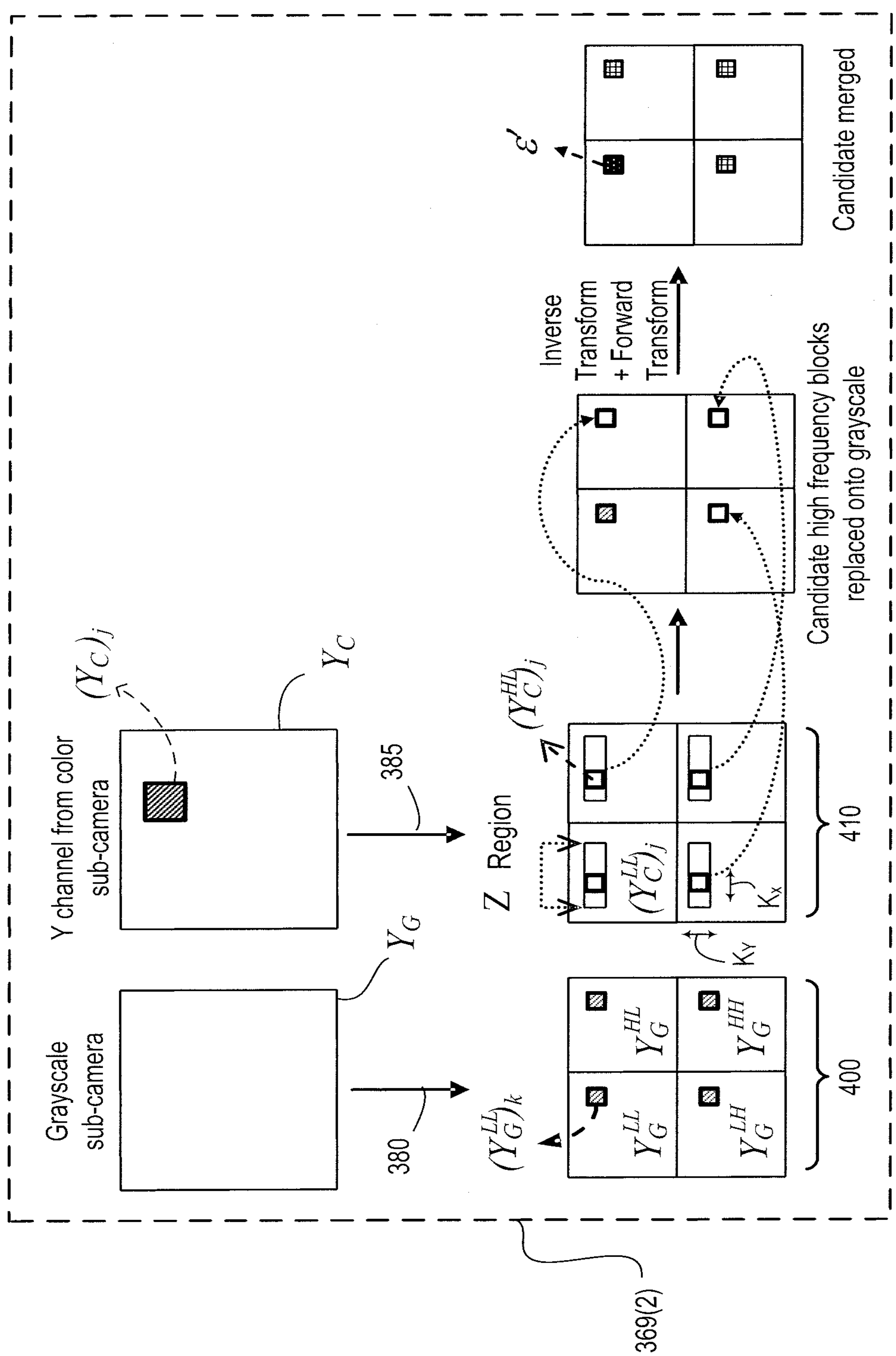

Grayscale sub-camera
Y channel from color sub-camera
Y_G
Y_C
$(Y_C)_j$
380
385
Z Region
$(Y_G^{LL})_k$
Y_G^{LL}
Y_G^{HL}
Y_G^{LH}
Y_G^{HH}
$(Y_C^{LL})_j$
$(Y_C^{HL})_j$
K_Y
K_x
400
410
Candidate high frequency blocks replaced onto grayscale
Inverse Transform + Forward Transform
ε'
Candidate merged
369(2)

FIG. 13

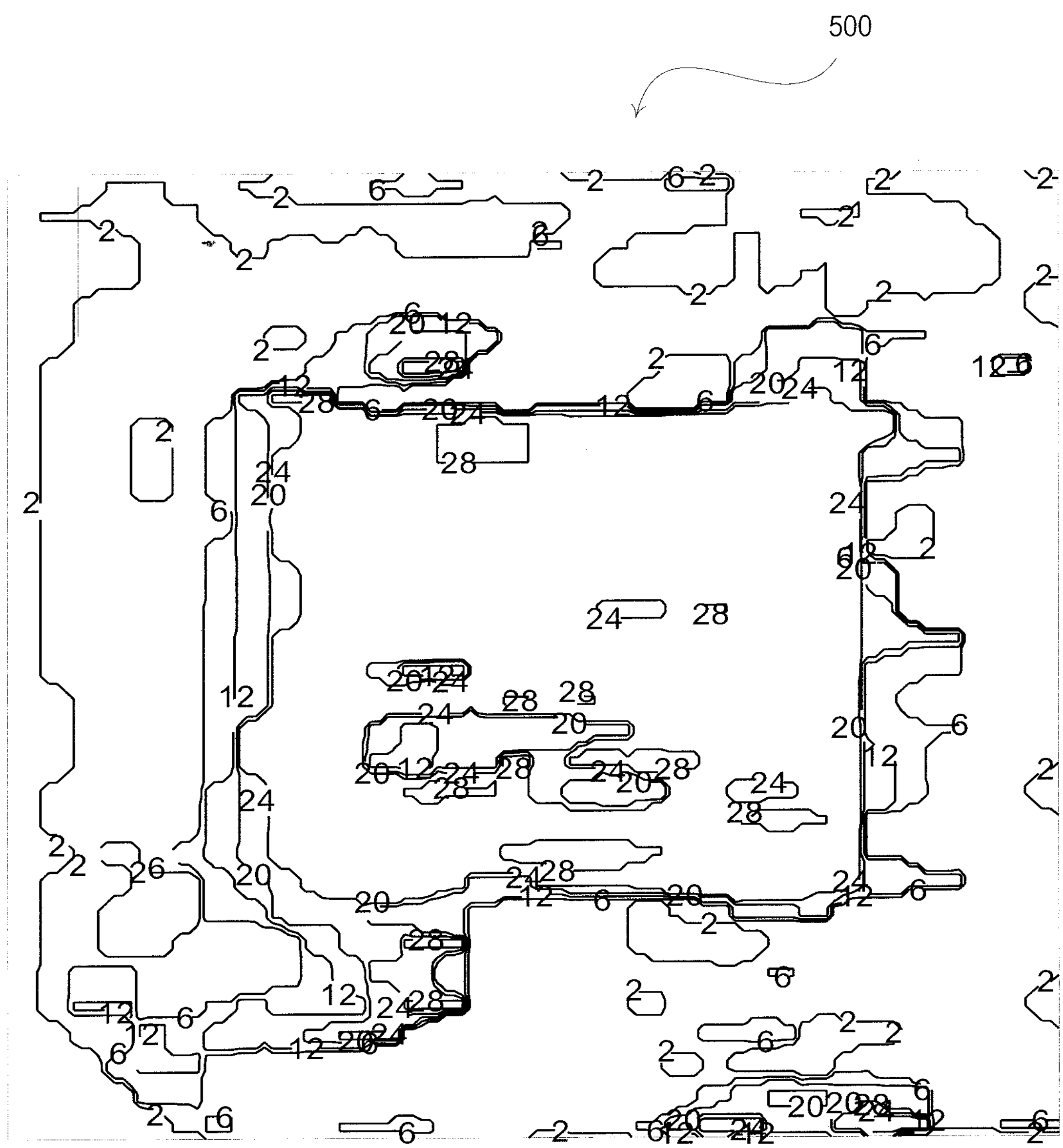


FIG. 14

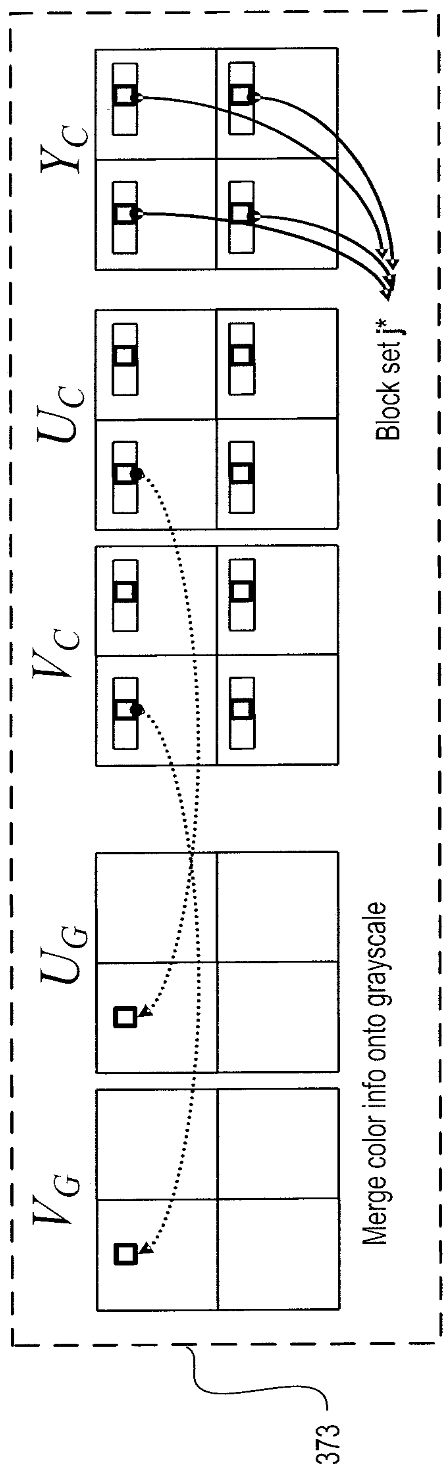
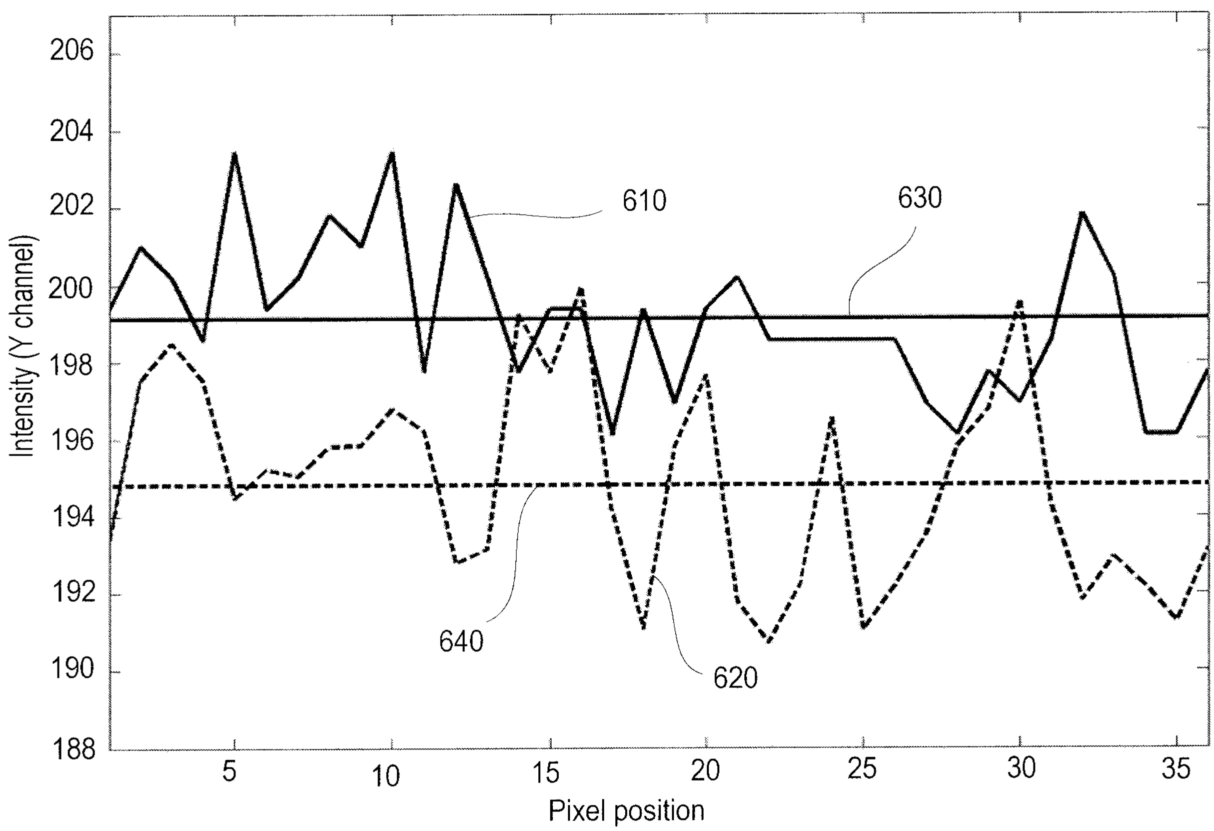


FIG. 15



206
204
202
200
198
196
194
192
190
188
Intensity (Y channel)
5
10
15
20
25
30
35
Pixel position
610
630
640
620

FIG. 16

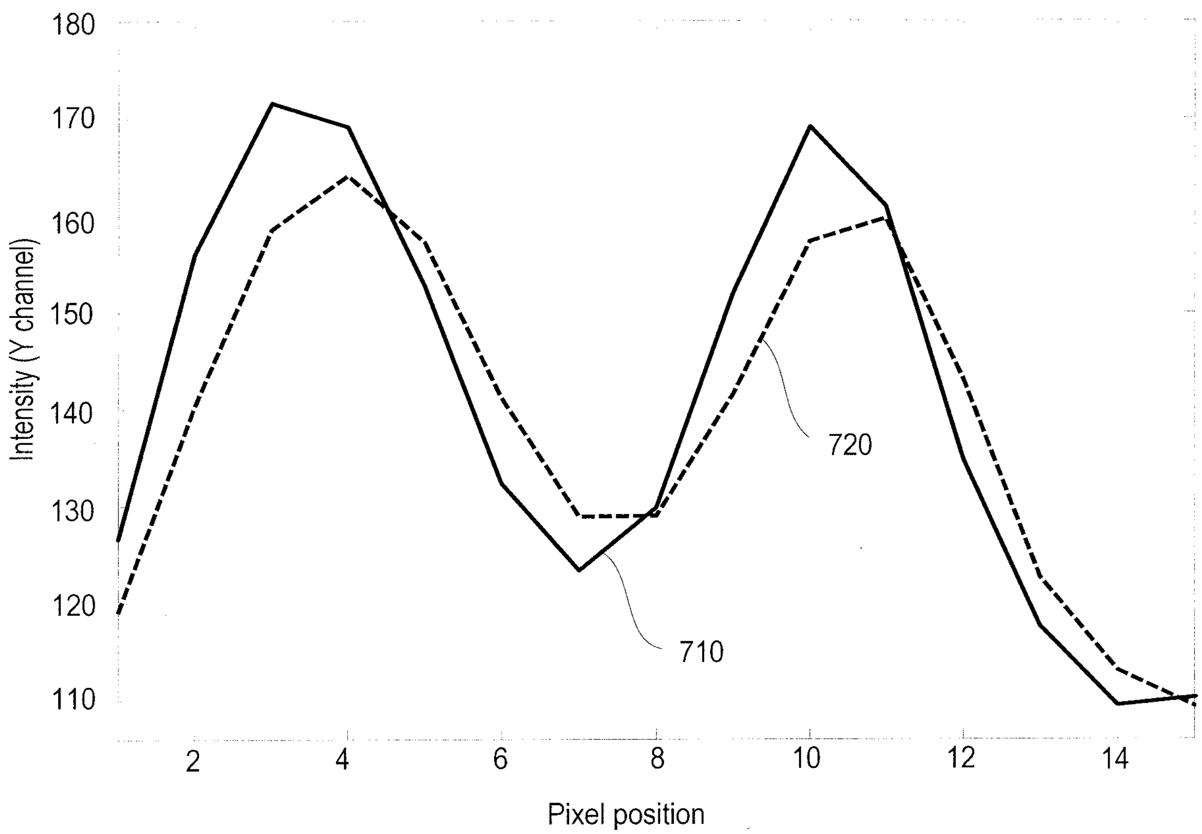

180
170
160
150
140
130
120
110
Intensity (Y channel)
2
4
6
8
10
12
14
Pixel position
720
710

FIG. 17

INTERNATIONAL SEARCH REPORT

International application No
PCT/US2009/032683

A. CLASSIFICATION OF SUBJECT MATTER
INV. G06T5/00 H04N5/232 H04N5/262

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)
H04N

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)

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 2006/061678 A1 (YAMAZAKI HITOSHI [JP]) 23 March 2006 (2006-03-23) abstract; figures 1-14 -----	1-3,11
A	US 5 282 045 A (MIMURA ITARU [JP] ET AL) 25 January 1994 (1994-01-25) -----	
A	US 6 856 708 B1 (AOKI SHIN [JP]) 15 February 2005 (2005-02-15) -----	
A	US 5 172 236 A (TAKEMOTO HIROSHI [JP] ET AL) 15 December 1992 (1992-12-15) -----	
A	US 2004/080661 A1 (AFSENIUS SVEN-AKE [SE] ET AL) 29 April 2004 (2004-04-29) -----	
A	US 6 201 899 B1 (BERGEN JAMES R [US]) 13 March 2001 (2001-03-13) -----	
	-/--	

[X] Further documents are listed in the continuation of Box C.

[X] 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 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
24 March 2009	31/03/2009

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, Fax: (+31-70) 340-3016	Kassow, Harald

Form PCT/ISA/210 (second sheet) (April 2005)

INTERNATIONAL SEARCH REPORT

International application No
PCT/US2009/032683

C(Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	US 2002/140823 A1 (SAKURAI MIKIO [JP] ET AL) 3 October 2002 (2002-10-03) -----	
A	US 2001/045982 A1 (OKISU NORIYUKI [JP] ET AL) 29 November 2001 (2001-11-29) -----	
A	KIYOHARU AIZAWA ET AL: "Producing Object-Based Special Effects by Fusing Multiple Differently Focused Images" IEEE TRANSACTIONS ON CIRCUITS AND SYSTEMS FOR VIDEO TECHNOLOGY, IEEE SERVICE CENTER, PISCATAWAY, NJ, US, vol. 10, no. 2, 1 March 2000 (2000-03-01), XP011014023 ISSN: 1051-8215 -----	
A	KAZUYA KODAMA ET AL: "All-in-Focus Image Generation by Merging Multiple Differently Focused Images in Three-Dimensional Frequency Domain" ADVANCES IN MULITMEDIA INFORMATION PROCESSING - PCM 2005 LECTURE NOTES IN COMPUTER SCIENCE;;LNCS, SPRINGER, BERLIN, DE, vol. 3767, 1 January 2005 (2005-01-01), pages 303-314, XP019023969 ISBN: 978-3-540-30027-4 -----	

Form PCT/ISA/210 (continuation of second sheet) (April 2005)

INTERNATIONAL SEARCH REPORT

International application No
PCT/US2009/032683

Patent document cited in search report		Publication date	Patent family member(s)			Publication date
US 2006061678	A1	23-03-2006	JP	2006086952	A	30-03-2006
US 5282045	A	25-01-1994	JP	3429755	B2	22-07-2003
			JP	4010777	A	14-01-1992
US 6856708	B1	15-02-2005	JP	3803950	B2	02-08-2006
			JP	2000251060	A	14-09-2000
US 5172236	A	15-12-1992	JP	3080676	A	05-04-1991
US 2004080661	A1	29-04-2004	AT	401588	T	15-08-2008
			EP	1348148	A1	01-10-2003
			SE	518050	C2	20-08-2002
			SE	0004836	A	23-06-2002
			WO	02059692	A1	01-08-2002
US 6201899	B1	13-03-2001	AU	6421999	A	01-05-2000
			WO	0022566	A1	20-04-2000
US 2002140823	A1	03-10-2002	JP	2002300373	A	11-10-2002
US 2001045982	A1	29-11-2001	NONE			

Form PCT/ISA/210 (patent family annex) (April 2005)

Electronic Patent Application Fee Transmittal

Application Number:	14386823
Filing Date:	
Title of Invention:	HIGH RESOLUTION THIN MULTI-APERTURE IMAGING SYSTEMS
First Named Inventor/Applicant Name:	Gal Shabtay
Filer:	Menachem Nathan
Attorney Docket Number:	COREPH-0072 US NP

Filed as Small Entity

U.S. National Stage under 35 USC 371 Filing Fees

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:				
Extension-of-Time:				

Description	Fee Code	Quantity	Amount	Sub-Total in USD($)
Miscellaneous:				
Submission- Information Disclosure Stmt	2806	1	90	90
		Total in USD ($)		**90**

Electronic Acknowledgement Receipt

EFS ID:	20393475
Application Number:	14386823
International Application Number:	
Confirmation Number:	1857
Title of Invention:	HIGH RESOLUTION THIN MULTI-APERTURE IMAGING SYSTEMS
First Named Inventor/Applicant Name:	Gal Shabtay
Customer Number:	92342
Filer:	Menachem Nathan
Filer Authorized By:	
Attorney Docket Number:	COREPH-0072 US NP
Receipt Date:	12-OCT-2014
Filing Date:	
Time Stamp:	13:55:58
Application Type:	U.S. National Stage under 35 USC 371

Payment information:

Submitted with Payment	yes
Payment Type	Credit Card
Payment was successfully received in RAM	$90
RAM confirmation Number	6387
Deposit Account	
Authorized User	

File Listing:

Document Number	Document Description	File Name	File Size(Bytes)/ Message Digest	Multi Part /.zip	Pages (if appl.)

1	Transmittal Letter	TF_72.pdf	276735 dfae1163610c4a23d64896a55cdeb947ac00dd49	no	2
Warnings:					
Information:					
2	Information Disclosure Statement (IDS) Form (SB08)	IDS_72.pdf	613171 c6231e1f410e023cf63bb8031279b5bf256245ba	no	5
Warnings:					
Information:					
3	Other Reference-Patent/App/Search documents	COREPH_0072_PCT_WO.pdf	1856235 098dacce97ef2ca9fc819f9f3043e6d0cb283186	no	14
Warnings:					
Information:					
4	Other Reference-Patent/App/Search documents	COREPH_0072_PCT_ISR.pdf	234630 db5ef400af07cc94d0df61224859d1735a0ae6d5	no	1
Warnings:					
Information:					
5	Foreign Reference	WO2009097552.pdf	3320417 2c9f4045ce5c349c28aecf113b39ad49f9c57d2d	no	71
Warnings:					
Information:					
6	Fee Worksheet (SB06)	fee-info.pdf	29996 21480aacd888c24c3481fc20cbec144fe488b592	no	2
Warnings:					
Information:					
		Total Files Size (in bytes):	6331184		

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.

UTILITY PATENT APPLICATION TRANSMITTAL

(Only for new nonprovisional applications under 37 CFR 1.53(b))

Attorney Docket No.	COREPH-0072 US NP
First Named Inventor	Gal Shabtay
Title	HIGH RESOLUTION THIN MULTI-APERTURE IMAGING SYSTEMS
Express Mail Label No.	

APPLICATION ELEMENTS

See MPEP chapter 600 concerning utility patent application contents.

ADDRESS TO: **Commissioner for Patents, P.O. Box 1450, Alexandria, VA 22313-1450**

1. ☐ **Fee Transmittal Form** (PTO/SB/17 or equivalent)
2. ☐ **Applicant asserts small entity status.** See 37 CFR 1.27
3. ☐ **Applicant certifies micro entity status.** See 37 CFR 1.29. Applicant must attach form PTO/SB/15A or B or equivalent.
4. ☐ **Specification** [*Total Pages* ____________]
   Both the claims and abstract must start on a new page.
   (See MPEP § 608.01(a) for information on the preferred arrangement)
5. ☐ **Drawing(s)** (35 U.S.C. 113) [*Total Sheets* ____________]
6. **Inventor's Oath or Declaration** [*Total Pages* ____________]
   (including substitute statements under 37 CFR 1.64 and assignments serving as an oath or declaration under 37 CFR 1.63(e))
   a. ☐ Newly executed (original or copy)
   b. ☐ A copy from a prior application (37 CFR 1.63(d))
7. ☐ **Application Data Sheet** ** See note below.*
   See 37 CFR 1.76 (PTO/AIA/14 or equivalent)
8. **CD-ROM or CD-R**
   in duplicate, large table, or Computer Program (*Appendix*)
   ☐ Landscape Table on CD
9. **Nucleotide and/or Amino Acid Sequence Submission**
   (*if applicable, items a. – c. are required*)
   a. ☐ Computer Readable Form (CRF)
   b. ☐ Specification Sequence Listing on:
      i. ☐ CD-ROM or CD-R (2 copies); or
      ii. ☐ Paper
   c. ☐ Statements verifying identity of above copies

ACCOMPANYING APPLICATION PAPERS

10. ☐ **Assignment Papers**
    (cover sheet & document(s))
    Name of Assignee ____________________
11. ☐ **37 CFR 3.73(c) Statement** (*when there is an assignee*) ☐ **Power of Attorney**
12. ☐ **English Translation Document** (*if applicable*)
13. ☑ **Information Disclosure Statement**
    (PTO/SB/08 or PTO-1449)
    ☑ Copies of citations attached
14. ☐ **Preliminary Amendment**
15. ☐ **Return Receipt Postcard**
    (*MPEP § 503*) (*Should be specifically itemized*)
16. ☐ **Certified Copy of Priority Document(s)**
    (*if foreign priority is claimed*)
17. ☐ **Nonpublication Request**
    Under 35 U.S.C. 122(b)(2)(B)(i). Applicant must attach form PTO/SB/35 or equivalent.
18. ☑ **Other:** Foreign references; International Search Report

    Remarks - This is an IDS. Citation or identification of any reference in this IDS shall not be construed as an admission that such reference is available as prior art.

***Note**: (1) Benefit claims under 37 CFR 1.78 and foreign priority claims under 1.55 **must** be included in an Application Data Sheet (ADS).
(2) For applications filed under 35 U.S.C. 111, the application must contain an ADS specifying the applicant if the applicant is an assignee, person to whom the inventor is under an obligation to assign, or person who otherwise shows sufficient proprietary interest in the matter. See 37 CFR 1.46(b).

19. CORRESPONDENCE ADDRESS

☑ The address associated with Customer Number: 92342 **OR** ☐ Correspondence address below

Name					
Address					
City		State		Zip Code	
Country		Telephone		Email	

Signature	/Menachem Nathan/	Date	10-10-2014
Name (Print/Type)	MENACHEM NATHAN	Registration No. (Attorney/Agent)	65,392

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.

POWER OF ATTORNEY TO PROSECUTE APPLICATIONS BEFORE THE USPTO

I hereby revoke all previous powers of attorney given in the application identified in the attached statement under 37 CFR 3.73(c).

I hereby appoint:

■ Practitioners associated with Customer Number: 92342

OR

☐ Practitioner(s) named below (if more than ten patent practitioners are to be named, then a customer number must be used):

Name	Registration Number	Name	Registration Number

As attorney(s) or agent(s) to represent the undersigned before the United States Patent and Trademark Office (USPTO) in connection with any and all patent applications assigned only to the undersigned according to the USPTO assignment records or assignments documents attached to this form in accordance with 37 CFR 3.73(c).

Please change the correspondence address for the application identified in the attached statement under 37 CFR 3.73(c) to:

■ The address associated with Customer Number: 92342

OR

☐

Firm or Individual Name			
Address			
City		State	Zip
Country			
Telephone		Email	

Assignee Name and Address: Corephotonics Ltd.
25 Habarzel St. 3rd Floor
Ramat Hachayal, 6971035
Israel

A copy of this form, together with a statement under 37 CFR 3.73(c) (Form PTO/AIA/96 or equivalent) is required to be Filed in each application in which this form is used. The statement under 37 CFR 3.73(c) may be completed by one of The practitioners appointed in this form, and must identify the application in which this Power of Attorney is to be filed.

SIGNATURE of Assignee of Record

The individual whose signature and title is supplied below is authorized to act on behalf of the assignee

Signature	/GAL SHABTAY/	Date	09-20-2014
Name	GAL SHABTAY	Telephone	
Title	VP-R&D		

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.

PTO/AIA/96 (08-12)
Approved for use through 01/31/2013. OMB 0651-0031
U.S. Patent and Trademark Office;U.S. DEPARTMENT OF COMMERCE
Under the Paperwork Reduction Act of1995, no persons arerequired to respond to a collection of information unless it displays a valid OMB control number.

STATEMENT UNDER 37 CFR 3.73(c)

Applicant/Patent Owner: Corephotonics Ltd.

Application No./Patent No.: ______________________ Filed/Issue Date: ______________________

Titled: HIGH RESOLUTION THIN MULTI-APERTURE IMAGING SYSTEMS

Corephotonics Ltd. , a COMPANY

(Name of Assignee) (Type of Assignee, e.g., corporation, partnership, university, government agency, etc.)

states that, for the patent application/patent identified above, it is (choose **one** of options 1, 2, 3 or 4 below):

1. ☑ The assignee of the entire right, title, and interest.

2. ☐ An assignee of less than the entire right, title, and interest (check applicable box):

☐ The extent (by percentage) of its ownership interest is ____________%. Additional Statement(s) by the owners holding the balance of the interest must be submitted to account for 100% of the ownership interest.

☐ There are unspecified percentages of ownership. The other parties, including inventors, who together own the entire right, title and interest are:

Additional Statement(s) by the owner(s) holding the balance of the interest must be submitted to account for the entire right, title, and interest.

3. ☐ The assignee of an undivided interest in the entirety (a complete assignment from one of the joint inventors was made). The other parties, including inventors, who together own the entire right, title, and interest are:

Additional Statement(s) by the owner(s) holding the balance of the interest must be submitted to account for the entire right, title, and interest.

4. ☐ The recipient, via a court proceeding or the like (*e.g.*, bankruptcy, probate), of an undivided interest in the entirety (a complete transfer of ownership interest was made). The certified document(s) showing the transfer is attached.

The interest identified in option 1, 2 or 3 above (not option 4) is evidenced by either (choose **one** of options A or B below):

A. ☑ An assignment from the inventor(s) of the patent application/patent identified above. The assignment was recorded in the United States Patent and Trademark Office at Reel ____________, Frame ____________, or for which a copy thereof is attached.

B. ☐ A chain of title from the inventor(s), of the patent application/patent identified above, to the current assignee as follows:

1. From: ______________________ To: ______________________

The document was recorded in the United States Patent and Trademark Office at

Reel ____________, Frame ____________, or for which a copy thereof is attached.

2. From: ______________________ To: ______________________

The document was recorded in the United States Patent and Trademark Office at

Reel ____________, Frame ____________, or for which a copy thereof is attached.

STATEMENT UNDER 37 CFR 3.73(c)

3. From: ____ To: ____

The document was recorded in the United States Patent and Trademark Office at

Reel ____________, Frame ____________, or for which a copy thereof is attached.

4. From: ____ To: ____

The document was recorded in the United States Patent and Trademark Office at

Reel ____________, Frame ____________, or for which a copy thereof is attached.

5. From: ____ To: ____

The document was recorded in the United States Patent and Trademark Office at

Reel ____________, Frame ____________, or for which a copy thereof is attached.

6. From: ____ To: ____

The document was recorded in the United States Patent and Trademark Office at

Reel ____________, Frame ____________, or for which a copy thereof is attached.

☐ Additional documents in the chain of title are listed on a supplemental sheet(s).

☐ As required by 37 CFR 3.73(c)(1)(i), the documentary evidence of the chain of title from the original owner to the assignee was, or concurrently is being, submitted for recordation pursuant to 37 CFR 3.11.

[NOTE: A separate copy (i.e., a true copy of the original assignment document(s)) must be submitted to Assignment Division in accordance with 37 CFR Part 3, to record the assignment in the records of the USPTO. See MPEP 302.08]

The undersigned (whose title is supplied below) is authorized to act on behalf of the assignee.

/GAL SHABTAY/	09-20-2014
Signature	Date
GAL SHABTAY	VP-R&D
Printed or Typed Name	Title or Registration Number

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

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IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

In re Applicant: §
§
Gal Shabtay §
§
Serial No.:14/XXX,XXX

Title: **HIGH RESOLUTION THIN MULTI-APERTURE IMAGING SYSTEMS**

§
Filed: Concurrently §
§ Attorney Docket: Coreph-0072 US NP

Commissioner of Patents and Trademarks
Alexandria, VA 22313-1450

PRELIMINARY AMENDMENT

This Preliminary Amendment is filed concurrently with the National Phase application of PCT/IB2013/060356. Before substantive examination, please amend the application as follows:

IN THE CLAIMS:

Please amend the claims as follows:

1. (Original) A multi-aperture imaging system comprising:

a) a first camera subset that provides a first image, the first camera subset having a first sensor with a first plurality of sensor pixels covered at least in part with a non-standard color filter array (CFA), the non-standard CFA used to increase a specific color sampling rate relative to a same color sampling rate in a standard CFA;

b) a second camera subset that provides a second image, the second camera subset having a second sensor with a second plurality of sensor pixels, the second plurality of sensor pixels being either Clear or covered with a standard CFA; and

c) a processor configured to process the first and second images into a combined output image.

2. (Cancelled)

3. (Cancelled)

4. (Original) The imaging system of claim 1, wherein the non-standard CFA includes a repetition of a 4x4 micro-cell in which a color filter order is BBRR-RBBR-RRBB-BRRB.

5-9. (Cancelled)

10. (Currently amended) The imaging system of claim ~~9~~ 1, wherein the processor is further configured to register respective first and second Luma images obtained from the first and second images during the processing of the first and second images into a combined output image, the registered first and second Luma images used together with color information to form the combined output image.

11. (Cancelled)

12. (Cancelled)

13. (Currently amended) The imaging system of claim 1, wherein the first camera

subset has a first field of view (FOV), wherein the second camera subset has a second, smaller FOV than the first FOV, and wherein the non-standard CFA covers substantially only an overlap area on the first sensor that captures the second FOV, thereby providing both optical zoom and increased color resolution.

14-31. (Cancelled)

32. (Original) A multi-aperture imaging system comprising:

a) a first camera subset that provides a first image, the first camera subset having a first field of view (FOV) and first sensor with a first plurality of sensor pixels covered at least in part with a standard CFA;

b) a second camera subset that provides a second image, the second camera subset having a second, smaller FOV than the first FOV and a second sensor with a second plurality of sensor pixels covered with a standard CFA; and

c) a processor configured to, for a zoom factor input that defines an FOV equal to or smaller than the second FOV, form an output image based on the second image.

33. (New) A multi-aperture imaging system comprising:

a) a first camera subset that provides a first image, the first camera subset having a first field of view (FOV_1) and a first sensor with a first plurality of sensor pixels covered at least in part with a standard color filter array (CFA);

b) a second camera subset that provides a second image, the second camera subset having a second field of view (FOV_2) such that $FOV_2 < FOV_1$ and a second sensor with a second plurality of sensor pixels, the second plurality of sensor pixels being either Clear or covered with a standard CFA; and

c) a processor configured to provide an output image from a point of view of either the first or the second camera subset based on a zoom factor (ZF) input that defines a respective field of view (FOV_{ZF}).

34. (New) The imaging system of claim 33, wherein the processor is further configured to form the output image by processing the first and second images into a combined output image.

35. (New) The imaging system of claim 34, wherein if $FOV_2 < FOV_{ZF} \leq FOV_1$, then the point of view of the output image is that of the first camera and if $FOV_2 \geq FOV_{ZF}$, then the point of view of the output image is that of the second camera.

36. (New) The imaging system of claim 34, wherein the processor is further configured to, during the processing of the first and second images into a combined output image and based on the ZF input, register respective first and second Luma images obtained from the first and second images, the registered first and second Luma images used together with color information to form the combined output image.

37. (New) The imaging system of claim 36, wherein if $FOV_2 < FOV_{ZF} \leq FOV_1$ then the registration includes finding a corresponding pixel in the second Luma image for each pixel in the first Luma image and the processor is further configured to form the combined output image by transferring information from the second image to the first image, and if $FOV_2 \geq FOV_{ZF}$ then the registration includes finding a corresponding pixel in the first Luma image for each pixel in the second Luma image and the processor is further configured to form the combined output image by transferring information from the first image to the second image.

38. (New) The imaging system of claim 33, wherein the first plurality of sensor pixels is covered at least in part with a non-standard CFA, the non-standard CFA used to increase a specific color sampling rate relative to a same color sampling rate in a standard CFA.

39. (New) The imaging system of claim 38, wherein if $FOV_2 < FOV_{ZF} \leq FOV_1$, then the point of view of the output image is that of the first camera and if $FOV_2 \geq FOV_{ZF}$, then the point of view of the output image is that of the second camera.

40. (New) The imaging system of claim 38, wherein the processor is further configured to form the output image by processing the first and second images into a combined output image.

41. (New) The imaging system of claim 40, wherein the processor is further

configured to, during the processing of the first and second images into a combined output image and based on the ZF input, register respective first and second Luma images obtained from the first and second images, the registered first and second Luma images used together with color information to form the combined output image.

42. (New) The imaging system of claim 41, wherein if $FOV_2 < FOV_{ZF} \leq FOV_1$ then the registration includes finding a corresponding pixel in the second Luma image for each pixel in the first Luma image and the processor is further configured to form the combined output image by transferring information from the second image to the first image, and if $FOV_2 \geq FOV_{ZF}$ then the registration includes finding a corresponding pixel in the first Luma image for each pixel in the second Luma image and the processor is further configured to form the combined output image by transferring information from the first image to the second image.

43. (New) The imaging system of claim 38, wherein the non-standard CFA covers substantially only an overlap area on the first sensor that captures the second FOV, thereby providing both optical zoom and increased color resolution.

REMARKS

This preliminary amendment cancels claims 2, 3. 5-9, 11, 12 and 14-31 of related PCT application PCT/IB2013/060356 and adds new claims 33-43, thereby reducing the number of claims to a total of 16. No new matter is introduced. Support for the amended and new claims may be found as follows:

Claim 13: at least in description of Figure 1A from page 7, line 15 to line 29, Figures 2-9;
Claim 33: at least in description of Figure 1A from page 7, line 15 to page 8, line 2;
Claims 34 and 40: from page 3, line 34 to page 4, line 2;
Claims 35 and 39: original claim 1, from page 3, line 32 to page 4, line 2;
Claims 36-37 and 41-42: original claims 14-16, page 11, line 11 to page 13, line 15;
Claims 38 and 43: original claim 1, at least in description of Figure 1A from page 7, line 15 to page 8, line 2, Figures 2-9.

In view of the above amendments and remarks it is respectfully submitted that claims 1, 4, 10, 13 and 32-43 are in condition for allowance. Prompt notice of allowance is respectfully and earnestly solicited.

Respectfully submitted,

/Menachem Nathan/
Menachem Nathan
Agent for Applicant
Registration No. 65392

Date: September 19, 2014

Electronic Patent Application Fee Transmittal

Application Number:	
Filing Date:	
Title of Invention:	HIGH RESOLUTION THIN MULTI-APERTURE IMAGING SYSTEMS
First Named Inventor/Applicant Name:	Gal Shabtay
Filer:	Menachem Nathan
Attorney Docket Number:	COREPH-0072 US NP

Filed as Small Entity

U.S. National Stage under 35 USC 371 Filing Fees

Description	Fee Code	Quantity	Amount	Sub-Total in USD($)
Basic Filing:				
Basic National Stage Fee	2631	1	140	140
Natl Stage Search Fee - U.S. was the ISA	2641	1	60	60
Natl Stage Exam Fee - all other cases	2633	1	360	360
Pages:				
Claims:				
Miscellaneous-Filing:				
Petition:				
Patent-Appeals-and-Interference:				

Description	Fee Code	Quantity	Amount	Sub-Total in USD($)
Post-Allowance-and-Post-Issuance:				
Extension-of-Time:				
Miscellaneous:				
		Total in USD ($)		**560**

Electronic Acknowledgement Receipt

EFS ID:	20198551
Application Number:	14386823
International Application Number:	PCT/IB2013/060356
Confirmation Number:	1857
Title of Invention:	HIGH RESOLUTION THIN MULTI-APERTURE IMAGING SYSTEMS
First Named Inventor/Applicant Name:	Gal Shabtay
Customer Number:	92342
Filer:	Menachem Nathan
Filer Authorized By:	
Attorney Docket Number:	COREPH-0072 US NP
Receipt Date:	22-SEP-2014
Filing Date:	
Time Stamp:	07:23:14
Application Type:	U.S. National Stage under 35 USC 371

Payment information:

Submitted with Payment	yes
Payment Type	Credit Card
Payment was successfully received in RAM	$560
RAM confirmation Number	7608
Deposit Account	
Authorized User	

File Listing:

Document Number	Document Description	File Name	File Size(Bytes)/ Message Digest	Multi Part /.zip	Pages (if appl.)

1	Application Data Sheet	ADS.pdf	1503894 796de7b77d37bdd4f67bbc87bdc8213889 47c2ab	no	7
Warnings:					
Information:					
2	Assignee showing of ownership per 37 CFR 3.73.	ASSIGNMENT.pdf	16628 2e642f354b3e47fe8da85a4c0c759c90e8c2 9606	no	1
Warnings:					
Information:					
3	Oath or Declaration filed	Declaration1.pdf	942907 cce8ad17a94b72434bd3a660a68a962ce3b 242f3	no	2
Warnings:					
Information:					
4	Oath or Declaration filed	Declaration2.pdf	941099 6ed4de394290738883155c26cf45efed5e00 41c2	no	2
Warnings:					
Information:					
5	Oath or Declaration filed	Declaration3.pdf	946070 ef0584e9d155eddaf91c687e085c34b17a30 cb3c	no	2
Warnings:					
Information:					
6	Oath or Declaration filed	Declaration4.pdf	947771 523285ef5b2f442d342e79f7d547039c9d60 5091	no	2
Warnings:					
Information:					
7		Full_application_plus_Figs.pdf	2262326 e84ae8ee1a4ef04329daba9ef160715b7bb 8b9c2	yes	30

Multipart Description/PDF files in .zip description

Document Description	Start	End
Specification	1	17
Claims	18	22
Abstract	23	23
Drawings-only black and white line drawings	24	30

Warnings:

Information:					
8	Transmittal Letter	NP_TF.pdf	215306 47c9d3a172078ba17448930843da04809a4d9153	no	4
Warnings:					
Information:					
9	Other Reference-Patent/App/Search documents	PCT_ISR.pdf	1665535 fc1f534c054f99269729887a4b3a50d661a6d804	no	31
Warnings:					
Information:					
10	Other Reference-Patent/App/Search documents	WO.pdf	1856235 02e6e961405c24ea2b9d4d8eb5c6fbaad3f84a95	no	14
Warnings:					
Information:					
11	Power of Attorney	POA.pdf	80487 c1da9f4611c4ed05fc48a1fddac8036cdc3b4a0e	no	2
Warnings:					
Information:					
12	Assignee showing of ownership per 37 CFR 3.73.	STATEMENT.pdf	117553 bb40a61e51352e3b27f69d51ccc64bea2f8c180c	no	3
Warnings:					
Information:					
13	Preliminary Amendment	Preliminary_amendment.pdf	58555 72df37be82f0d3f95b97be85355334458e9e11a8	no	6
Warnings:					
Information:					
14	Fee Worksheet (SB06)	fee-info.pdf	32825 76f3bd36f4e99438837e650d219e20874187a5e1	no	2
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		Total Files Size (in bytes):	11587191		

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New Applications Under 35 U.S.C. 111
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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.

Application Data Sheet 37 CFR 1.76	Attorney Docket Number	COREPH-0072 US NP
	Application Number	

Title of Invention	HIGH RESOLUTION THIN MULTI-APERTURE IMAGING SYSTEMS

The application data sheet is part of the provisional or nonprovisional application for which it is being submitted. The following form contains the bibliographic data arranged in a format specified by the United States Patent and Trademark Office as outlined in 37 CFR 1.76.
This document may be completed electronically and submitted to the Office in electronic format using the Electronic Filing System (EFS) or the document may be printed and included in a paper filed application.

Secrecy Order 37 CFR 5.2

☐ Portions or all of the application associated with this Application Data Sheet may fall under a Secrecy Order pursuant to 37 CFR 5.2 (Paper filers only. Applications that fall under Secrecy Order may not be filed electronically.)

Inventor Information:

Inventor 1 Remove
Legal Name

Prefix	Given Name	Middle Name	Family Name	Suffix
	Gal		Shabtay	

Residence Information (Select One) ○ US Residency ◉ Non US Residency ○ Active US Military Service

City	Tel-Aviv	Country of Residence i	IL

Mailing Address of Inventor:

Address 1	4 Shmuel Shnitzer St.		
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Inventor 2 Remove
Legal Name

Prefix	Given Name	Middle Name	Family Name	Suffix
	Noy		Cohen	

Residence Information (Select One) ○ US Residency ◉ Non US Residency ○ Active US Military Service

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Mailing Address of Inventor:

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Address 2			
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Postal Code	6912529	**Country** i	IL

Inventor 3 Remove
Legal Name

Application Data Sheet 37 CFR 1.76	Attorney Docket Number	COREPH-0072 US NP
	Application Number	

Title of Invention	HIGH RESOLUTION THIN MULTI-APERTURE IMAGING SYSTEMS

Prefix	Given Name	Middle Name	Family Name	Suffix
	Oded		Gigushinski	

Residence Information (Select One) ◯ US Residency ◉ Non US Residency ◯ Active US Military Service

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Mailing Address of Inventor:

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Address 2			
City	Herzlia	**State/Province**	
Postal Code	4670223	**Country** i	IL

Inventor 4 Remove
Legal Name

Prefix	Given Name	Middle Name	Family Name	Suffix
	Ephraim		Goldenberg	

Residence Information (Select One) ◯ US Residency ◉ Non US Residency ◯ Active US Military Service

City	Ashdod	Country of Residence i	IL

Mailing Address of Inventor:

Address 1	32 Tel Chai St.		
Address 2			
City	Ashdod	**State/Province**	
Postal Code	7751025	**Country** i	IL

All Inventors Must Be Listed - Additional Inventor Information blocks may be generated within this form by selecting the **Add** button. Add

Correspondence Information:

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For further information see 37 CFR 1.33(a).

☐ **An Address is being provided for the correspondence Information of this application.**

Customer Number	92342	
Email Address		Add Email Remove Email

Application Data Sheet 37 CFR 1.76	Attorney Docket Number	COREPH-0072 US NP
	Application Number	
Title of Invention	HIGH RESOLUTION THIN MULTI-APERTURE IMAGING SYSTEMS	

Application Information:

Title of the Invention	HIGH RESOLUTION THIN MULTI-APERTURE IMAGING SYSTEMS		
Attorney Docket Number	COREPH-0072 US NP	Small Entity Status Claimed	☒
Application Type	Nonprovisional		
Subject Matter	Utility		
Total Number of Drawing Sheets (if any)	7	Suggested Figure for Publication (if any)	1

Publication Information:

☐ Request Early Publication (Fee required at time of Request 37 CFR 1.219)

☐ **Request Not to Publish.** I hereby request that the attached application not be published under 35 U.S.C. 122(b) and certify that the invention disclosed in the attached application **has not and will not** be the subject of an application filed in another country, or under a multilateral international agreement, that requires publication at eighteen months after filing.

Representative Information:

Representative information should be provided for all practitioners having a power of attorney in the application. Providing this information in the Application Data Sheet does not constitute a power of attorney in the application (see 37 CFR 1.32).
Either enter Customer Number or complete the Representative Name section below. If both sections are completed the customer Number will be used for the Representative Information during processing.

Please Select One:	◉ Customer Number	○ US Patent Practitioner	○ Limited Recognition (37 CFR 11.9)
Customer Number	92342		

Domestic Benefit/National Stage Information:

This section allows for the applicant to either claim benefit under 35 U.S.C. 119(e), 120, 121, or 365(c) or indicate National Stage entry from a PCT application. Providing this information in the application data sheet constitutes the specific reference required by 35 U.S.C. 119(e) or 120, and 37 CFR 1.78.

Prior Application Status	Expired		Remove
Application Number	Continuity Type	Prior Application Number	Filing Date (YYYY-MM-DD)
	non provisional of	61730570	2012-11-28
Prior Application Status	Pending		Remove
Application Number	Continuity Type	Prior Application Number	Filing Date (YYYY-MM-DD)
	a 371 of international	PCT/IB2013/060356	2013-11-23

Additional Domestic Benefit/National Stage Data may be generated within this form by selecting the **Add** button. Add

Foreign Priority Information:

Application Data Sheet 37 CFR 1.76	Attorney Docket Number	COREPH-0072 US NP
	Application Number	
Title of Invention	HIGH RESOLUTION THIN MULTI-APERTURE IMAGING SYSTEMS	

This section allows for the applicant to claim priority to a foreign application. Providing this information in the application data sheet constitutes the claim for priority as required by 35 U.S.C. 119(b) and 37 CFR 1.55(d). When priority is claimed to a foreign application that is eligible for retrieval under the priority document exchange program (PDX) i the information will be used by the Office to automatically attempt retrieval pursuant to 37 CFR 1.55(h)(1) and (2). Under the PDX program, applicant bears the ultimate responsibility for ensuring that a copy of the foreign application is received by the Office from the participating foreign intellectual property office, or a certified copy of the foreign priority application is filed, within the time period specified in 37 CFR 1.55(g)(1).

Remove

Application Number	Country i	Filing Date (YYYY-MM-DD)	Access Code i (if applicable)

Additional Foreign Priority Data may be generated within this form by selecting the **Add** button.

Add

Statement under 37 CFR 1.55 or 1.78 for AIA (First Inventor to File) Transition Applications

☐ This application (1) claims priority to or the benefit of an application filed before March 16, 2013 and (2) also contains, or contained at any time, a claim to a claimed invention that has an effective filing date on or after March 16, 2013.

Authorization to Permit Access:

☒ Authorization to Permit Access to the Instant Application by the Participating Offices

If checked, the undersigned hereby grants the USPTO authority to provide the European Patent Office (EPO), the Japan Patent Office (JPO), the Korean Intellectual Property Office (KIPO), the World Intellectual Property Office (WIPO), and any other intellectual property offices in which a foreign application claiming priority to the instant patent application is filed access to the instant patent application. See 37 CFR 1.14(c) and (h). This box should not be checked if the applicant does not wish the EPO, JPO, KIPO, WIPO, or other intellectual property office in which a foreign application claiming priority to the instant patent application is filed to have access to the instant patent application.

In accordance with 37 CFR 1.14(h)(3), access will be provided to a copy of the instant patent application with respect to: 1) the instant patent application-as-filed; 2) any foreign application to which the instant patent application claims priority under 35 U.S.C. 119(a)-(d) if a copy of the foreign application that satisfies the certified copy requirement of 37 CFR 1.55 has been filed in the instant patent application; and 3) any U.S. application-as-filed from which benefit is sought in the instant patent application.

In accordance with 37 CFR 1.14(c), access may be provided to information concerning the date of filing this Authorization.

Application Data Sheet 37 CFR 1.76	Attorney Docket Number	COREPH-0072 US NP
	Application Number	

Title of Invention	HIGH RESOLUTION THIN MULTI-APERTURE IMAGING SYSTEMS

Applicant Information:

Providing assignment information in this section does not substitute for compliance with any requirement of part 3 of Title 37 of CFR to have an assignment recorded by the Office.

Applicant 1 Remove

If the applicant is the inventor (or the remaining joint inventor or inventors under 37 CFR 1.45), this section should not be completed. The information to be provided in this section is the name and address of the legal representative who is the applicant under 37 CFR 1.43; or the name and address of the assignee, person to whom the inventor is under an obligation to assign the invention, or person who otherwise shows sufficient proprietary interest in the matter who is the applicant under 37 CFR 1.46. If the applicant is an applicant under 37 CFR 1.46 (assignee, person to whom the inventor is obligated to assign, or person who otherwise shows sufficient proprietary interest) together with one or more joint inventors, then the joint inventor or inventors who are also the applicant should be identified in this section. Clear

- (●) Assignee
- ( ) Legal Representative under 35 U.S.C. 117
- ( ) Joint Inventor
- ( ) Person to whom the inventor is obligated to assign.
- ( ) Person who shows sufficient proprietary interest

If applicant is the legal representative, indicate the authority to file the patent application, the inventor is:

Name of the Deceased or Legally Incapacitated Inventor :

If the Applicant is an Organization check here. [X]

Organization Name	Corephotonics Ltd.		
Mailing Address Information:			
Address 1	25 Habarzel St. 3rd Floor		
Address 2	Ramat Hachayal		
City	Tel-Aviv	**State/Province**	
Country i	IL	Postal Code	6971035
Phone Number		Fax Number	
Email Address			

Additional Applicant Data may be generated within this form by selecting the Add button. Add

Non-Applicant Assignee Information:

Providing assignment information in this section does not subsitute for compliance with any requirement of part 3 of Title 37 of CFR to have an assignment recorded by the Office.

Application Data Sheet 37 CFR 1.76	Attorney Docket Number	COREPH-0072 US NP
	Application Number	

Title of Invention	HIGH RESOLUTION THIN MULTI-APERTURE IMAGING SYSTEMS

Assignee 1

Complete this section only if non-applicant assignee information is desired to be included on the patent application publication in accordance with 37 CFR 1.215(b). Do not include in this section an applicant under 37 CFR 1.46 (assignee, person to whom the inventor is obligated to assign, or person who otherwise shows sufficient proprietary interest), as the patent application publication will include the name of the applicant(s).

Remove

If the Assignee is an Organization check here. ☐

Prefix	**Given Name**	Middle Name	**Family Name**	Suffix

Mailing Address Information:

Address 1			
Address 2			
City		**State/Province**	
Country i		Postal Code	
Phone Number		Fax Number	
Email Address			

Additional Assignee Data may be generated within this form by selecting the Add button. Add

Signature:

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

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First Name	MENACHEM	Last Name	NATHAN	Registration Number	65392

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This collection of information is required by 37 CFR 1.76. 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 23 minutes to complete, including gathering, preparing, and submitting the completed application data sheet 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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ASSIGNMENT

For good and valuable consideration, the receipt and sufficiency of which is hereby acknowledged, the undersigned:

GAL SHABTAY NOY COHEN

ODED GIGUSHINSKI EPHRAIM GOLDENBERG

(hereinafter called the "assignor(s)"), hereby assign(s) and transfer(s) to:

Corephotonics Ltd.
25 Habarzel St. 3rd Floor
Ramat Hachayal, 6971035
Israel

(hereinafter called the "assignee(s)"), its/his successors, assignees, nominees, or other legal representatives, the assignor's entire right, title and interest in and to the invention entitled:

HIGH RESOLUTION THIN MULTI-APERTURE IMAGING SYSTEMS

Described and claimed in the following US National Phase Patent Application identified as Attorney docket No. COREPH-0072 US NP and filed herewith; and in and to said Patent Applications, and all original and reissued Patents granted therefor, and all divisions and continuations thereof, including the right to apply and obtain Patents in all other countries, the priority rights under International Conventions, and the Letters Patent which may be granted thereon.

Signed and sealed this 20 day of September, 2014

GAL SHABTAY	/ GAL SHABTAY /
NOY COHEN	/ NOY COHEN /
ODED GIGUSHINSKI	/ ODED GIGUSHINSKI /
EPHRAIM GOLDENBERG	/ EPHRAIM GOLDENBERG /

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DECLARATION (37 CFR 1.63) FOR UTILITY OR DESIGN APPLICATION USING AN APPLICATION DATA SHEET (37 CFR 1.76)

Title of Invention	HIGH RESOLUTION THIN MULTI-APERTURE IMAGING SYSTEMS

As the below named inventor, I hereby declare that:

This declaration is directed to:

- [x] The attached application, or
- [ ] United States application or PCT international application number ______________________ filed on ______________________.

The above-identified application was made or authorized to be made by me.

I believe that I am the original inventor or an original joint inventor of a claimed invention in the application.

I hereby acknowledge that any willful false statement made in this declaration is punishable under 18 U.S.C. 1001 by fine or imprisonment of not more than five (5) years, or both.

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LEGAL NAME OF INVENTOR

Inventor: Gal Shabtay Date (Optional) : 09-20-2014

Signature: /Gal Shabtay/

Note: An application data sheet (PTO/SB/14 or equivalent), including naming the entire inventive entity, must accompany this form or must have been previously filed. Use an additional PTO/AIA/01 form for each additional inventor.

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Title of Invention HIGH RESOLUTION THIN MULTI-APERTURE IMAGING SYSTEMS

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This declaration is directed to:

- [x] The attached application, or
- [ ] United States application or PCT international application number ______________________

filed on ______________________________.

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LEGAL NAME OF INVENTOR

Inventor: Noy Cohen Date (Optional) : 09-20-2014

Signature: /Noy Cohen/

Note: An application data sheet (PTO/SB/14 or equivalent), including naming the entire inventive entity, must accompany this form or must have been previously filed. Use an additional PTO/AIA/01 form for each additional inventor.

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LEGAL NAME OF INVENTOR

Inventor: Oded Gigushinski   Date (Optional) : 09-20-2014

Signature: /Oded Gigushinski/

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LEGAL NAME OF INVENTOR

Inventor: Ephraim Goldenberg Date (Optional) : 09-20-2014

Signature: /Ephraim Goldenberg/

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HIGH RESOLUTION THIN MULTI-APERTURE IMAGING SYSTEMS

CROSS REFERENCE TO RELATED APPLICATIONS

This application is a National Phase application from PCT patent application PCT/IB2013/060356 which claims priority from US Provisional Patent Application No. 61/730,570 having the same title and filed November 28, 2013, which is incorporated herein by reference in its entirety.

FIELD

Embodiments disclosed herein relate in general to multi-aperture imaging ("MAI") systems (where “multi” refers to two or more apertures) and more specifically to thin MAI systems with high color resolution and/or optical zoom.

BACKGROUND

Small digital cameras integrated into mobile (cell) phones, personal digital assistants and music players are becoming ubiquitous. Each year, mobile phone manufacturers add more imaging features to their handsets, causing these mobile imaging devices to converge towards feature sets and image quality that customers expect from stand-alone digital still cameras. Concurrently, the size of these handsets is shrinking, making it necessary to reduce the total size of the camera accordingly while adding more imaging features. Optical Zoom is a primary feature of many digital still cameras but one that mobile phone cameras usually lack, mainly due to camera height constraints in mobile imaging devices, cost and mechanical reliability.

Mechanical zoom solutions are common in digital still cameras but are typically too thick for most camera phones. Furthermore, the F/# (“F number) in such systems typically increases with the zoom factor (ZF) resulting in poor light sensitivity and higher noise (especially in low-light scenarios). In mobile cameras, this also results in resolution compromise, due to the small pixel size of their image sensors and the diffraction limit optics associated with the F/#.

One way of implementing zoom in mobile cameras is by over-sampling the image and cropping and interpolating it in accordance with the desired ZF. While this method is mechanically reliable, it results in thick optics and in an expensive image sensor due to the large number of pixels associated therewith. As an example, if one is interested in implementing a 12 Megapixel camera with X3 ZF, one needs a sensor of 108 Megapixels.

Another way of implementing zoom, as well as increasing the output resolution, is by using a dual-aperture imaging ("DAI") system. In its basic form, a DAI system includes two optical apertures which may be formed by one or two optical modules, and one or two image sensors (e.g., CMOS or CCD) that grab the optical image or images and convert the data into the electronic domain, where the image can be processed and stored.

The design of a thin MAI system with improved resolution requires a careful choice of parameters coupled with advanced signal processing algorithms to support the output of a high quality image. Known MAI systems, in particular ones with short optical paths, often trade-off functionalities and properties, for example zoom and color resolution, or image resolution and quality for camera module height. Therefore, there is a need for, and it would be advantageous to have thin MAI systems that produce an image with high resolution (and specifically high color resolution) together with zoom functionality.

Moreover, known signal processing algorithms used together with existing MAI systems often further degrade the output image quality by introducing artifacts when combining information from different apertures. A primary source of these artifacts is the image registration process, which has to find correspondences between the different images that are often captured by different sensors with different color filter arrays (CFAs). There is therefore a need for, and it would be advantageous to have an image registration algorithm that is more robust to the type of CFA used by the cameras and which can produce better correspondence between images captured by a multi-aperture system.

SUMMARY

Embodiments disclosed herein teach the use of multi-aperture imaging systems to implement thin cameras (with short optical paths of less than about 9 mm) and/or to realize optical zoom systems in such thin cameras. Embodiments disclosed herein further teach new color filter arrays that optimize the color information which may be achieved in a multi-aperture imaging system with or without zoom. In various embodiments, a MAI system disclosed herein includes at least two sensors or a single sensor divided into at least two areas. Hereinafter, the description refers to “two sensors”, with the understanding that they may represent sections of a single physical sensor (imager chip). Exemplarily, in a dual-aperture imaging system, a left sensor (or left side of a single sensor) captures an image coming from a

first aperture while a right sensor (or right side of a single sensor) captures an image coming from a second aperture. In various embodiments disclosed herein, one sensor is a “Wide” sensor while another sensor is a “Tele” sensor, see e.g. FIG. 1A. The Wide sensor includes either a single standard CFA or two different CFAs: a non-standard CFA with higher color sampling rate positioned in an “overlap area” of the sensor (see below description of FIG. 1B) and a standard CFA with a lower color sampling rate surrounding the overlap area. When including a single standard CFA, the CFA may cover the entire Wide sensor area. A "standard CFA" may include a RGB (Bayer) pattern or a non-Bayer pattern such as RGBE, CYYM, CYGM, RGBW#1, RGBW#2 or RGBW#3. Thus, reference may be made to "standard Bayer" or "standard non-Bayer" patterns or filters. As used herein, “non-standard CFA” refers to a CFA that is different in its pattern that CFAs listed above as “standard”. Exemplary non-standard CFA patterns may include repetitions of a 2x2 micro-cell in which the color filter order is RR-BB, RB-BR or YC-CY where Y=Yellow = Green + Red, C = Cyan = Green + Blue; repetitions of a 3x3 micro-cell in which the color filter order is GBR-RGB-BRG; and repetitions of a 6x6 micro-cell in which the color filter order is
RBBRRB-RWRBWB-BBRBRR-RRBRBB-BWBRWR-BRRBBR, or
BBGRRG-RGRBGB-GBRGRB-RRGBBG-BGBRGR-GRBGBR, or
RBBRRB-RGRBGB-BBRBRR-RRBRBB-BGBRGR-BRRBBR, or,
RBRBRB-BGBRGR-RBRBRB-BRBRBR-RGRBGB-BRBRBR.

The Tele sensor may be a Clear sensor (i.e. a sensor without color filters) or a standard CFA sensor. This arrangement of the two (or more than two) sensors and of two (or more than two) Wide and Tele “subset cameras” (or simply “subsets”) related to the two Wide and Tele subsets. Each sensor provides a separate image (referred to respectively as a Wide image and a Tele image), except for the case of a single sensor, where two images are captured (grabbed) by the single sensor (example above). In some embodiments, zoom is achieved by fusing the two images, resulting in higher color resolution that approaches that of a high quality dual-aperture zoom camera. Some thin MAI systems disclosed herein therefore provide zoom, super-resolution, high dynamic range and enhanced user experience.

In some embodiments, in order to reach optical zoom capabilities, a different magnification image of the same scene is grabbed by each subset, resulting in field of view (FOV) overlap between the two subsets. In some embodiments, the two subsets have the same zoom (i.e. same FOV). In some embodiments, the Tele subset is the higher zoom subset and the Wide subset is the lower zoom subset. Post processing is applied on the two images grabbed by the MAI system to fuse and output one fused (combined) output zoom image processed according to a user ZF input request. In some embodiments, the resolution of the fused image may be higher than the resolution of the Wide/Tele sensors. As part of the fusion procedure, up-sampling may be applied on the Wide image to scale it to the Tele image.

In an embodiment there is provided a multi-aperture imaging system comprising a first camera subset that provides a first image, the first camera subset having a first sensor with a first plurality of sensor pixels covered at least in part with a non-standard CFA, the non-standard CFA used to increase a specific color sampling rate relative to a same color sampling rate in a standard CFA; a second camera subset that provides a second image, the second camera subset having a second sensor with a second plurality of sensor pixels either Clear or covered with a standard CFA; and a processor configured to process the first and second images into a combined output image.

In some embodiments, the first and the second camera subsets have identical FOVs and the non-standard CFA may cover an overlap area that includes all the pixels of first sensor, thereby providing increased color resolution. In some such embodiments, the processor is further configured to, during the processing of the first and second images into a combined output image, register respective first and second Luma images obtained from the first and second images, the registered first and second Luma images used together with color information to form the combined output image. In an embodiment, the registration includes finding a corresponding pixel in the second Luma image for each pixel in the first Luma image, whereby the output image is formed by transferring information from the second image to the first image. In another embodiment, the registration includes finding a corresponding pixel in the first Luma image for each pixel in the second Luma image, whereby the output image is formed by transferring information from the first image to the second image.

In some embodiments, the first camera subset has a first FOV, the second camera subset has a second, smaller FOV than the first FOV, and the non-standard CFA covers an overlap area on the first sensor that captures the second FOV, thereby providing both optical zoom and increased color resolution. In some such embodiments, the processor is further configured to, during the processing of the first and second images into a combined output image and based on a ZF input, register respective first and second Luma images obtained from the first and second images, the registered first and second Luma images used together with color information to form the combined output image. For a ZF input that defines an FOV greater than the second FOV, the registration includes finding a corresponding pixel in the second Luma image for each pixel in the first Luma image and the processing includes forming the output image by transferring information from the second image to the first image. For a

ZF input that defines an FOV smaller than or equal to the second FOV, the registration includes finding a corresponding pixel in the first Luma image for each pixel in the second Luma image, and the processing includes forming the output image by transferring information from the first image to the second image.

In an embodiment there is provided a multi-aperture imaging system comprising a first camera subset that provides a first image, the first camera subset having a first sensor with a first plurality of sensor pixels covered at least in part with a standard CFA; a second camera subset that provides a second image, the second camera subset having a second sensor with a second plurality of sensor pixels either Clear or covered with a standard CFA; and a processor configured to register first and second Luma images obtained respectively from the first and second images and to process the registered first and second Luma images together with color information into a combined output image.

In some embodiments, the first and the second camera subsets have identical first and second FOVs. In some such embodiments, the registration includes finding a corresponding pixel in the second Luma image for each pixel in the first Luma image and the processing includes forming the output image by transferring information from the second image to the first image. In other such embodiments, the registration includes finding a corresponding pixel in the first Luma image for each pixel in the second Luma image and the processing includes forming the output image by transferring information from the first image to the second image.

In some embodiments, the first camera subset has a first FOV, the second camera subset has a second, smaller FOV than the first FOV, and the processor is further configured to register the first and second Luma images based on a ZF input. For a ZF input that defines an FOV greater than the second FOV, the registration includes finding a corresponding pixel in the second Luma image for each pixel in the first Luma image and the processing includes forming the output image by transferring information from the second image to the first image. For a ZF input that defines an FOV smaller than or equal to the second FOV, the registration includes finding a corresponding pixel in the first Luma image for each pixel in the second Luma image, and the processing includes forming the output image by transferring information from the first image to the second image.

BRIEF DESCRIPTION OF THE DRAWINGS

Non-limiting examples of embodiments disclosed herein are described below with reference to figures attached hereto that are listed following this paragraph. The drawings and descriptions are meant to illuminate and clarify embodiments disclosed herein, and should not be considered limiting in any way.

FIG. 1A shows schematically a block diagram illustrating a dual-aperture zoom imaging system disclosed herein;

FIG. 1B shows an example of an image captured by the Wide sensor and the Tele sensor while illustrating the overlap area on the Wide sensor;

FIG. 2 shows schematically an embodiment of a Wide sensor that may be implemented in a dual-aperture zoom imaging system disclosed herein;

FIG. 3 shows schematically another embodiment of a Wide camera sensor that may be implemented in a dual-aperture zoom imaging system disclosed herein;

FIG. 4 shows schematically yet another embodiment of a Wide camera sensor that may be implemented in a dual-aperture zoom imaging system disclosed herein;

FIG. 5 shows schematically yet another embodiment of a Wide camera sensor that may be implemented in a dual-aperture zoom imaging system disclosed herein;

FIG. 6 shows schematically yet another embodiment of a Wide camera sensor that may be implemented in a dual-aperture zoom imaging system disclosed herein;

FIG. 7 shows schematically yet another embodiment of a Wide camera sensor that may be implemented in a dual-aperture zoom imaging system disclosed herein;

FIG. 8 shows schematically yet another embodiment of a Wide camera sensor that may be implemented in a dual-aperture zoom imaging system disclosed herein;

FIG. 9 shows schematically yet another embodiment of a Wide camera sensor that may be implemented in a dual-aperture zoom imaging system disclosed herein;

FIG. 10 shows a schematically in a flow chart an embodiment of a method disclosed herein for acquiring and outputting a zoom image;

FIG. 11A shows exemplary images captured by a triple aperture zoom imaging system disclosed herein;

FIG. 11B illustrates schematically the three sensors of the triple aperture imaging system of FIG. 11A.

DETAILED DESCRIPTION

Embodiments disclosed herein relate to multi-aperture imaging systems that include at least one Wide sensor with a single CFA or with two different CFAs and at least one Tele sensor. The description continues with particular reference to dual-aperture imaging systems that include two (Wide and Tele) subsets with respective sensors. A three-aperture imaging system is described later with reference to FIGS. 11A-11B.

The Wide sensor includes an overlap area (see description of FIG. 1B) that captures the Tele FOV. The overlap area may cover the entire Wide sensor or only part of the sensor. The overlap area may include a standard CFA or a non-standard CFA. Since the Tele image is optically magnified compared to the Wide image, the effective sampling rate of the Tele image is higher than that of the Wide image. Thus, the effective color sampling rate in the Wide sensor is much lower than the Clear sampling rate in the Tele sensor. In addition, the Tele and Wide images fusion procedure (see below) requires up-scaling of the color data from the Wide sensor. Up-scaling will not improve color resolution. In some applications, it is therefore advantageous to use a non-standard CFA in the Wide overlap area that increases color resolution for cases in which the Tele sensor includes only Clear pixels. In some embodiments in which the Tele sensor includes a Bayer CFA, the Wide sensor may have a Bayer CFA in the overlap area. In such embodiments, color resolution improvement depends on using color information from the Tele sensor in the fused output image.

FIG. 1A shows schematically a block diagram illustrating a dual-aperture zoom imaging ("DAZI") system **100** disclosed herein. System **100** includes a dual-aperture camera **102** with a Wide subset **104** and a Tele subset **106** (each subset having a respective sensor), and a processor **108** that fuses two images, a Wide image obtained with the Wide subset and a Tele image obtained with the Tele subset, into a single fused output image according to a user-defined "applied" ZF input or request. The ZF is input to processor **108**. The Wide sensor may include a non-standard CFA in an overlap area illustrated by **110** in FIG. 1B. Overlap area **110** is surrounded by a non-overlap area **112** with a standard CFA (for example a Bayer pattern). FIG. 1B also shows an example of an image captured by both Wide and Tele sensors. Note that “overlap” and “non-overlap” areas refer to parts of the Wide image as well as to the CFA arrangements of the Wide sensor. The overlap area may cover different portions of a Wide sensor, for example half the sensor area, a third of the sensor area, a quarter of the sensor area, etc. A number of such Wide sensor CFA arrangements are described in more detail with reference to FIGS. 2-9. The non-standard CFA pattern increases the color resolution of the DAZI system.

The Tele sensor may be Clear (providing a Tele Clear image scaled relative to the Wide image) or may include a standard (Bayer or non-Bayer) CFA. It in the latter case, it is desirable to define primary and auxiliary sensors based on the applied ZF. If the ZF is such that the output FOV is larger than the Tele FOV, the primary sensor is the Wide sensor and the auxiliary sensor is the Tele sensor. If the ZF is such that the output FOV is equal to, or smaller than the Tele FOV, the primary sensor is the Tele sensor and the auxiliary sensor is the Wide sensor. The point of view defined by the output image is that of the primary sensor.

FIG. 2 shows schematically an embodiment of a Wide sensor **200** that may be implemented in a DAZI system such as system **100**. Sensor **200** has a non-overlap area **202** with a Bayer CFA and an overlap area **204** covered by a non-standard CFA with a repetition of a 4x4 micro-cell in which the color filter order is BBRR-RBBR-RRBB-BRRB. In this figure, as well as in FIGS. 3-9, "Width 1" and "Height 1" refer to the full Wide sensor dimension. "Width 2" and "Height 2" refer to the dimensions of the Wide sensor overlap area. Note that in FIG. 2 (as in following figures 3-5 and 7, 8) the empty row and column to the left and top of the overlap area are for clarity purposes only, and that the sensor pixels follow there the pattern of the non-overlap area (as shown in FIG. 6). In overlap area **204**, R and B are sampled at $1/2^{0.5}$ Nyquist frequency in the diagonal (left to right) direction with 2 pixel intervals instead of at 1/2 Nyquist frequency in a standard Bayer pattern.

FIG. 3 shows schematically an embodiment of a Wide sensor **300** that may be implemented in a DAZI system such as system **100.** Sensor **300** has a non-overlap area **302** with a Bayer CFA and an overlap area **304** covered by a non-standard CFA with a repetition of a 2x2 micro-cell in which the color filter order is BR-RB. In the overlap area, R and B are sampled at $1/2^{0.5}$ Nyquist frequency in both diagonal directions.

FIG. 4 shows schematically an embodiment of a Wide sensor **400** that may be implemented in a DAZI system such as system **100.** Sensor **400** has a non-overlap area **402** with a Bayer CFA and an overlap area **404** covered by a non-standard CFA with a repetition of a 2x2 micro-cell in which the color filter order is YC-CY, where Y=Yellow = Green + Red, C = Cyan = Green + Blue. As a result, in the overlap area, R and B are sampled at $1/2^{0.5}$ Nyquist frequency in a diagonal direction. The non-standard CFA includes green information for registration purposes. This allows for example registration between the two images where the object is green, since there is green information in both sensor images.

FIG. 5 shows schematically an embodiment of a Wide sensor **500** that may be implemented in a DAZI system such as system **100**. Sensor **500** has a non-overlap area **502** with a Bayer CFA and an overlap area **504** covered by a non-standard CFA with a repetition of a 6x6 micro-cell in which the color filter order is RBBRRB-RWRBWB-BBRBRR-RRBRBB-BWBRWR-BRRBBR, where "W" represents White or Clear pixels. In the overlap area, R and B are sampled at a higher frequency than in a standard CFA. For example, in a Bayer pixel order, the Red average sampling rate ("R_S") is 0.25 (sampled once for every 4 pixels). In the overlap area pattern, R_S is 0.44.

FIG. 6 shows schematically an embodiment of a Wide sensor **600** that may be implemented in a DAZI system such as system **100**. Sensor **600** has a non-overlap area **602** with a Bayer CFA and an overlap area **604** covered by a non-standard CFA with a repetition of a 6x6 micro-cell in which the color filter order is BBGRRG-RGRBGB-GBRGRB-RRGBBG-BGBRGR-GRBGBR. In the overlap area, R and B are sampled at a higher frequency than in a standard CFA. For example, in the overlap area pattern, R_S is 0. 33 vs. 0.25 in a Bayer pixel order.

FIG. 7 shows schematically an embodiment of a Wide sensor **700** that may be implemented in a DAZI system such as system **100**. Sensor **700** has a non-overlap area **702** with a Bayer CFA and an overlap area **704** covered by a non-standard CFA with a repetition of a 3x3 micro-cell in which the color filter order is GBR-RGB-BRG. In the overlap area, R and B are sampled at a higher frequency than in a standard CFA. For example, in the overlap area pattern, R_S is 0. 33 vs. 0.25 in a Bayer pixel order.

FIG. 8 shows schematically an embodiment of a Wide sensor **800** that may be implemented in a DAZI system such as system **100**. Sensor **800** has a non-overlap area **802** with a Bayer CFA and an overlap area **804** covered by a non-standard CFA with a repetition of a 6x6 micro-cell in which the color filter order is RBBRRB-RGRBGB-BBRBRR-RRBRBB-BGBRGR-BRRBBR. In the overlap area, R and B are sampled at a higher frequency than in a standard CFA. For example, in the overlap area pattern, R_S is 0. 44 vs. 0.25 in a Bayer pixel order.

FIG. 9 shows schematically an embodiment of a Wide sensor **900** that may be implemented in a DAZI system such as system **100**. Sensor **900** has a non-overlap area **902** with a Bayer CFA and an overlap area **904** covered by a non-standard CFA with a repetition of a 6x6 micro-cell in which the color filter order is RBRBRB-BGBRGR-RBRBRB-BRBRBR-RGRBGB-BRBRBR. In the overlap area, R and B are sampled at a higher frequency than in a standard CFA. For example, in the overlap area pattern, R_S is 0. 44 vs. 0.25 in a Bayer pixel order.

Processing flow

In use, an image is acquired with imaging system **100** and is processed according to steps illustrated in a flowchart shown in FIG. 10. In step **1000**, demosaicing is performed on the Wide overlap area pixels (which refer to the Tele image FOV) according to the specific

CFA pattern. If the CFA in the Wide overlap area is a standard CFA, a standard demosaicing process may be applied to it. If the CFA in the Wide overlap area is non-standard CFA, the overlap and non-overlap subsets of pixels may need different demosaicing processes. That is, the Wide overlap area may need a non-standard demosaicing process and the Wide non-overlap area may need a standard demosaicing process. Exemplary and non-limiting non-standard demosaicing interpolations for the overlap area of each of the Wide sensors shown in FIGS. 2-9 are given in detail below. The aim of the demosaicing is to reconstruct missing colors in each pixel. Demosaicing is applied also to the Tele sensor pixels if the Tele sensor is not a Clear only sensor. This will result in a Wide subset color image where the colors (in the overlap area) hold higher resolution than those of a standard CFA pattern. In step **1002**, the Tele image is registered (mapped) into the Wide image. The mapping includes finding correspondences between pixels in the two images. In step **1002**, actual registration is performed on luminance Tele and Wide images (respectively $Luma_{Tele}$ and $Luma_{Wide}$) calculated from the pixel information of the Tele and Wide cameras. These luminance images are estimates for the scene luminance as captured by each camera and do not include any color information. If the Wide or Tele sensors have CFAs, the calculation of the luminance images is performed on the respective demosaiced images. The calculation of the Wide luminance image varies according to the type of non-standard CFA used in the Wide overlap area. If the CFA permits calculation of a full RGB demosaiced image, the luminance image calculation is straightforward. If the CFA is such that it does not permit calculation of a full RGB demosaiced image, the luminance image is estimated from the available color channels. If the Tele sensor is a Clear sensor, the Tele luminance image is just the pixel information. Performing the registration on luminance images has the advantage of enabling registration between images captured by sensors with different CFAs or between images captured by a standard CFA or non-standard CFA sensor and a standard CFA or Clear sensor and avoiding color artifacts that may arise from erroneous registration.

In step **1004**, the data from the Wide and Tele images is processed together with the registration information from step **1002** to form a high quality output zoom image. In cases where the Tele sensor is a Clear only sensor, the high resolution luminance component is taken from the Tele sensor and color resolution is taken from the Wide sensor. In cases where the Tele sensor includes a CFA, both color and luminance data are taken from the Tele subset to form the high quality zoom image. In addition, color and luminance data is taken from the Wide subset.

Exemplary process for fusing a zoom image

1. Special demosaicing

In this step, the Wide image is interpolated to reconstruct the missing pixel values. Standard demosaicing is applied in the non-overlap area. If the overlap area includes a standard CFA, standard demosaicing is applied there as well. If the overlap area includes a non-standard CFA, a special demosaicing algorithm is applied, depending on the CFA pattern used. In addition, in case the Tele sensor has a CFA, standard demosaicing is applied to reconstruct the missing pixel values in each pixel location and to generate a full RGB color image.

2. Registration preparation

- Tele image: a luminance image $Luma_{Tele}$ is calculated from the Tele sensor pixels. If the Tele subset has a Clear sensor, $Luma_{Tele}$ is simply the sensor pixels data. If the Tele subset has a standard CFA, $Luma_{Tele}$ is calculated from the demosaiced Tele image.
- Wide image: as a first step, in case the Wide overlap CFA permits estimating the luminance component of the image, the luminance component is calculated from the demosaiced Wide image, $Luma_{Wide}$. If the CFA is one of those depicted in FIGS. 4-9, a luminance image is calculated first. If the CFA is one of the CFAs depicted in FIG. 2 or FIG. 3, a luminance image is not calculated. Instead, the following registration step is performed between a weighted average of the demosaiced channels of the Wide image and $Luma_{Tele}$. For convenience, this weighted average image is also denoted $Luma_{Wide}$. For example, if the Wide sensor CFA in the overlap region is as shown in FIG. 2, the demosaiced channels R_{Wide} and B_{Wide} are averaged to create $Luma_{Wide}$ according to $Luma_{Wide} = (f1*R_{Wide}+f2*B_{Wide})/(f1+f2)$, where f1 may be f1=1 and f2 may be f2=1.
- Low-pass filtering is applied on the Tele luminance image in order to match its spatial frequency content to that of the $Luma_{Wide}$ image. This improves the registration performance, as after low-pass filtering the luminance images become more similar. The calculation is $Luma_{Tele} \rightarrow$ Low pass filter $\rightarrow Luma_{Tele}^{LP}$, where "LP" denotes an image after low pass filtering.

3. Registration of $Luma_{Wide}$ and $Luma_{Tele}^{LP}$

This step of the algorithm calculates the mapping between the overlap areas in the two luminance images. The registration step does not depend on the type of CFA used (or the lack thereof), as it is applied on luminance images. The same registration step can therefore be applied on Wide and Tele images captured by standard CFA sensors, as well as by any combination of CFAs or Clear sensor pixels disclosed herein. The registration process chooses either the Wide image or the Tele image to be a primary image. The other image is defined as an auxiliary image. The registration process considers the primary image as the baseline image and registers the overlap area in the auxiliary image to it, by finding for each pixel in the overlap area of the primary image its corresponding pixel in the auxiliary image. The output image point of view is determined according to the primary image point of view (camera angle). Various correspondence metrics could be used for this purpose, among which are a sum of absolute differences and correlation.

In an embodiment, the choice of the Wide image or the Tele image as the primary and auxiliary images is based on the ZF chosen for the output image. If the chosen ZF is larger than the ratio between the focal-lengths of the Tele and Wide cameras, the Tele image is set to be the primary image and the Wide image is set to be the auxiliary image. If the chosen ZF is smaller than or equal to the ratio between the focal-lengths of the Tele and Wide cameras, the Wide image is set to be the primary image and the Tele image is set to be the auxiliary image. In another embodiment independent of a zoom factor, the Wide image is always the primary image and the Tele image is always the auxiliary image. The output of the registration stage is a map relating Wide image pixels indices to matching Tele image pixels indices.

4. Combination into a high resolution image

In this final step, the primary and auxiliary images are used to produce a high resolution image. One can distinguish between several cases:

a. If the Wide image is the primary image, and the Tele image was generated from a Clear sensor, $Luma_{Wide}$ is calculated and replaced or averaged with $Luma_{Tele}$ in the overlap area between the two images to create a luminance output image, matching corresponding pixels according to the registration map $Luma_{Out} = c1 * Luma_{Wide} + c2 * Luma_{Tele}$. The values of c1 and c2 may change between different pixels in the image. Then, RGB values of the output are calculated from $Luma_{Out}$ and R_{Wide}, G_{Wide}, and B_{Wide}.

b. If the Wide image is the primary image and the Tele image was generated from a CFA sensor, $Luma_{Tele}$ is calculated and is combined with $Luma_{Wide}$ in the overlap area between the two images, according to the flow described in 4a.

c. If the Tele image is the primary image generated from a Clear sensor, the RGB values of the output are calculated from the $Luma_{Tele}$ image and R_{Wide}, G_{Wide}, and B_{Wide} (matching pixels according to the registration map).

d. If the Tele image is the primary image generated from a CFA sensor, the RGB values of the output (matching pixels according to the registration map) are calculated either by using only the Tele image data, or by also combining data from the Wide image. The choice depends on the zoom factor.

Certain portions of the registered Wide and Tele images are used to generate the output image based on the ZF of the output image. In an embodiment, if the ZF of the output image defines a FOV smaller than the Tele FOV, the fused high resolution image is cropped to the required field of view and digital interpolation is applied to scale up the image to the required output image resolution.

Exemplary and non-limiting pixel interpolations specifications for the overlap area

FIG. 2

B11	B12	R13
R21	B22	B23
R31	R32	B33

In order to reconstruct the missing R22 pixel, we perform R22 = (R31+R13)/2. The same operation is performed for all missing Blue pixels.

FIG. 3

R11	B12	R13
B21	R22	B23
R31	B32	R33

In order to reconstruct the missing B22 pixel, we perform B22 = (B12+B21+B32+B23)/4. The same operation is performed for all missing Red pixels.

FIG. 4

Y11	C12	Y13
C21	Y22	C23
Y31	C32	Y33

In order to reconstruct the missing C22 pixel, we perform C22 = (C12+C21+C32+C23)/4. The same operation is performed for all missing Yellow pixels.

FIG. 5

<u>Case 1</u>: W is center pixel

R11	B12	B13
R21	W22	R23
B31	B32	R33

In order to reconstruct the missing 22 pixels, we perform the following:

B22 = (B12+B32)/2

R22 = (R21+R23)/2

G22= (W22-R22-B22) (assuming that W includes the same amount of R, G and B colors).

<u>Case 2</u>: R22 is center pixel

B11	B12	R13	R14
W21	R22	B23	W24
B31	R32	B33	R34

In order to reconstruct the missing 22 pixels, we perform the following:

B22 = (B11+R33)/2

W22 = (2*W21+W24)/3

G22 = (W22-R22-B22) (assuming that W contains the same amount of R, G and B colors). The same operation is performed for Blue as the center pixel.

FIG. 6

B11	B12	G13	R14
R21	G22	R23	B24
G31	B32	R33	G34
R41	R42	G43	B44

In order to reconstruct the missing 22 pixels, we perform the following:

B22 = (B12+B32)/2

R22 = (R21+R23)/2.

In order to reconstruct the missing 32 pixels, we perform the following:

G32 = (2*G31+2*G22+G43)/5

R32 = (R41+2*R42+2*R33+R23+R21)/7.

FIG. 7

G11	B12	R13	G14
R21	G22	B23	R24
B31	R32	G33	B34
G41	B42	R43	G44

In order to reconstruct the missing 22 pixels, we perform the following:

B22 = (2*B12+2*B23+B31)/5

R22 = (2*R21+2*R32+R13)/5

and similarly for all other missing pixels.

FIG. 8

R11	B12	B13	R14
R21	G22	R23	B24
B31	B32	R33	B34
R41	R42	B43	R44
B51	G52	B53	R54

In order to reconstruct the missing 22 pixels, we perform the following:

B22 = (2*B12+2*B32+B13)/5

R22 = (2*R21+2*R23+R11)/5.

In order to reconstruct the missing 32 pixels, we perform the following:

G32 = (2*G22+G52)/3

R32 = (2*R33+2*R42+R41+R21+R23)/7.

FIG. 9

R11	B12	R13	B14
B21	G22	B23	R24
R31	B32	R33	B34
B41	R42	B43	R44
R51	G52	R53	B54

In order to reconstruct the missing 22 pixels, we perform the following:

B22 = (B12+B32+B23+B21)/4

R22 = (R11+R13+R31+R33)/4.

In order to reconstruct the missing 32 pixels, we perform the following:

G32 = (2*G22+G52)/3

R32 = (R42+R31+R33)/3.

Triple-aperture zoom imaging system with improved color resolution

As mentioned, a multi-aperture zoom or non-zoom imaging system disclosed herein may include more than two apertures. A non-limiting and exemplary embodiment **1100** of a triple-aperture imaging system is shown in FIGS. 11A-11B. System **1100** includes a first Wide subset camera **1102** (with exemplarily X1), a second Wide subset camera (with exemplarily

X1.5, and referred to as a "Wide-Tele" subset) and a Tele subset camera (with exemplarily X2). FIG. 11A shows exemplary images captured by imaging system **1100**, while FIG. 11B illustrates schematically three sensors marked **1102**, **1104** and **1106**, which belong respectively to the Wide, Wide-Tele and Tele subsets. FIG. 11B also shows the CFA arrangements in each sensor: sensors **1102** and **1104** are similar to Wide sensors described above with reference to any of FIGS. 2-9, in the sense that they include an overlap area and a non-overlap area. The overlap area includes a non-standard CFA. In both Wide sensors, the non-overlap area may have a Clear pattern or a standard CFA. Thus, neither Wide subset is solely a Clear channel camera. The Tele sensor may be Clear or have a standard Bayer CFA or a standard non-Bayer CFA. In use, an image is acquired with imaging system **1100** and processed as follows: demosaicing is performed on the overlap area pixels of the Wide and Wide-Tele sensors according to the specific CFA pattern in each overlap area. The overlap and non-overlap subsets of pixels in each of these sensors may need different demosaicing. Exemplary and non-limiting demosaicing specifications for the overlap area for Wide sensors shown in FIGS. 2-9 are given above. The aim is to reconstruct the missing colors in each and every pixel. In cases in which the Tele subset sensor is not Clear only, demosaicing is performed as well. The Wide and Wide-Tele subset color images acquired this way will have colors (in the overlap area) holding higher resolution than that of a standard CFA pattern. Then, the Tele image acquired with the Tele sensor is registered (mapped) into the respective Wide image. The data from the Wide, Wide-Tele and Tele images is then processed to form a high quality zoom image. In cases where the Tele subset is Clear only, high Luma resolution is taken from the Tele sensor and color resolution is taken from the Wide sensor. In cases where the Tele subset includes a CFA, both color and Luma resolution is taken from the Tele subset. In addition, color resolution is taken from the Wide sensor. The resolution of the fused image may be higher than the resolution of both sensors.

While this disclosure has been described in terms of certain embodiments and generally associated methods, alterations and permutations of the embodiments and methods will be apparent to those skilled in the art. For example, multi-aperture imaging systems with more than two Wide or Wide-Tele subsets (and sensors) or with more than one Tele subset (and sensor) may be constructed and used according to principles set forth herein. Similarly, non-zoom multi-aperture imaging systems with more than two sensors, at least one of which has a non-standard CFA, may be constructed and used according to principles set forth herein. The disclosure is to be understood as not limited by the specific embodiments described herein, but only by the scope of the appended claims.

CLAIMS:

1. A multi-aperture imaging system comprising:

a) a first camera subset that provides a first image, the first camera subset having a first sensor with a first plurality of sensor pixels covered at least in part with a non-standard color filter array (CFA), the non-standard CFA used to increase a specific color sampling rate relative to a same color sampling rate in a standard CFA;

b) a second camera subset that provides a second image, the second camera subset having a second sensor with a second plurality of sensor pixels, the second plurality of sensor pixels being either Clear or covered with a standard CFA; and

c) a processor configured to process the first and second images into a combined output image.

2. The imaging system of claim 1, wherein the non-standard CFA includes a repetition of a 2x2 micro-cell in which a color filter order is either BR-RB or YC-CY.

3. The imaging system of claim 1, wherein the non-standard CFA includes a repetition of a 3x3 micro-cell in which a color filter order is GBR-RGB-BRG.

4. The imaging system of claim 1, wherein the non-standard CFA includes a repetition of a 4x4 micro-cell in which a color filter order is BBRR-RBBR-RRBB-BRRB.

5. The imaging system of claim 1, wherein the non-standard CFA includes a repetition of a 6x6 micro-cell in which a color filter order is selected from the group consisting of RBBRRB-RWRBWB-BBRBRR-RRBRBB-BWBRWR-BRRBBR, BBGRRG-RGRBGB-GBRGRB-RRGBBG-BGBRGR-GRBGBR, RBBRRB-RGRBGB-BBRBRR-RRBRBB-BGBRGR-BRRBBR and RBRBRB-BGBRGR-RBRBRB-BRBRBR-RGRBGB-BRBRBR.

6. The imaging system of any of claims 1-5, wherein the standard CFA includes a Bayer filter.

7. The imaging system of any of claims 1-5, wherein the standard CFA includes a non-Bayer filter.

8. The imaging system of claim 7, wherein the non-Bayer filter is selected from the group consisting of a RGBE, a CYYM, a CYGM, a RGBW#1, a RGBW#2 and a RGBW#3 filter.

9. The imaging system of claim 1, wherein the first and the second camera subsets have identical fields of view and wherein the non-standard CFA covers an overlap area that includes all the pixels of the first sensor, thereby providing increased color resolution.

10. The imaging system of claim 9, wherein the processor is further configured to register respective first and second Luma images obtained from the first and second images during the processing of the first and second images into a combined output image, the registered first and second Luma images used together with color information to form the combined output image.

11. The imaging system of claim 10, wherein the registration includes finding a corresponding pixel in the second Luma image for each pixel in the first Luma image and wherein the processor is further configured to form the output image by transferring information from the second image to the first image.

12. The imaging system of claim 10, wherein the registration includes finding a corresponding pixel in the first Luma image for each pixel in the second Luma image and wherein the processor is further configured to form the output image by transferring information from the first image to the second image.

13. The imaging system of claim 1, wherein the first camera subset has a first field of view (FOV), wherein the second camera subset has a second, smaller FOV than the first FOV, and wherein the non-standard CFA covers an overlap area on the first sensor that captures the second FOV, thereby providing both optical zoom and increased color resolution.

14. The imaging system of claim 13, wherein the processor is further configured to, during the processing of the first and second images into a combined output image and based on a zoom factor (ZF) input, register respective first and second Luma images obtained from the first and second images, the registered first and second Luma images used together with color information to form the combined output image.

15. The imaging system of claim 14, wherein the registration includes, for a ZF input that defines an FOV greater than the second FOV, finding a corresponding pixel in the second Luma image for each pixel in the first Luma image and wherein the processor is further configured to form the output image by transferring information from the second image to the first image.

16. The imaging system of claim 14, wherein the registration includes, for a ZF input that defines an FOV smaller than, or equal to the second FOV, finding a corresponding pixel in the first Luma image for each pixel in the second Luma image and wherein the processor is further configured to form the output image by transferring information from the first image to the second image.

17. The imaging system of claim 13, wherein the second sensor includes a standard CFA and wherein the processing includes, for a ZF input that defines an FOV equal to or smaller than the second FOV, forming the output image based on the second image.

18. The imaging system of any of claims 13-17, wherein the standard CFA includes a Bayer filter.

19. The imaging system of any of claims 13-17, wherein the standard CFA includes a non-Bayer filter.

20. The imaging system of claim 19, wherein the non-Bayer filter is selected from the group consisting of a RGBE, a CYYM, a CYGM, a RGBW#1, a RGBW#2 and a RGBW#3 filter.

21. A multi-aperture imaging system comprising:

a) a first camera subset that provides a first image, the first camera subset having a first sensor with a first plurality of sensor pixels covered at least in part with a standard CFA;

b) a second camera subset that provides a second image, the second camera subset having a second sensor with a second plurality of sensor pixels, the second plurality of sensor pixels being either Clear or covered with a standard CFA; and

c) a processor configured to register first and second Luma images obtained respectively from the first and second images and to process the registered first and second Luma images together with color information into a combined output image.

22. The imaging system of claim 21, wherein the first and the second camera subsets have respectively identical fields of view.

23. The imaging system of claim 22, wherein the registration includes finding a corresponding pixel in the second Luma image for each pixel in the first Luma image and wherein the processor is further configured to form the output image by transferring information from the second image to the first image.

24. The imaging system of claim 22, wherein the registration includes finding a corresponding pixel in the first Luma image for each pixel in the second Luma image and wherein the processor is further configured to form the output image by transferring information from the first image to the second image.

25. The imaging system of claim 21, wherein the first camera subset has a first field of view (FOV), wherein the second camera subset has a second, smaller FOV than the first FOV, and wherein the processor is further configured to register the first and second Luma images based on a zoom factor (ZF) input.

26. The imaging system of claim 25, wherein the registration includes, for a ZF input that defines an FOV greater than the second FOV, finding a corresponding pixel in the second Luma image for each pixel in the first Luma image and wherein the processor is further configured to form the output image by transferring information from the second image to the first image.

27. The imaging system of claim 25, wherein the registration includes, for a ZF input that defines an FOV smaller than, or equal to the second FOV, finding a corresponding pixel in the first Luma image for each pixel in the second Luma image and wherein the processor is further configured to form the output image by transferring information from the first image to the second image.

28. The imaging system of claim 25, wherein the second sensor includes a standard CFA and wherein, for a ZF input that defines an FOV equal to or smaller than the second FOV, the processor is further configured to form the output image based on the second image.

29. The imaging system of any of claims 21-28, wherein the standard CFA includes a Bayer filter.

30. The imaging system of any of claims 21-28, wherein the standard CFA includes a non-Bayer filter.

31. The imaging system of claim 30, wherein the non-Bayer filter is selected from the group consisting of a RGBE, a CYYM, a CYGM, a RGBW#1, a RGBW#2 and a RGBW#3 filter.

32. A multi-aperture imaging system comprising:

a) a first camera subset that provides a first image, the first camera subset having a first field of view (FOV) and first sensor with a first plurality of sensor pixels covered at least in part with a standard CFA;

b) a second camera subset that provides a second image, the second camera subset having a second, smaller FOV than the first FOV and a second sensor with a second plurality of sensor pixels covered with a standard CFA; and

c) a processor configured to, for a zoom factor input that defines an FOV equal to or smaller than the second FOV, form an output image based on the second image.

ABSTRACT

A multi-aperture imaging system comprising a first camera with a first sensor that captures a first image and a second camera with a second sensor that captures a second image, the two cameras having either identical or different FOVs. The first sensor may have a standard color filter array (CFA) covering one sensor section and a non-standard color CFA covering another. The second sensor may have either Clear or standard CFA covered sections. Either image may be chosen to be a primary or an auxiliary image, based on a zoom factor. An output image with a point of view determined by the primary image is obtained by registering the auxiliary image to the primary image.

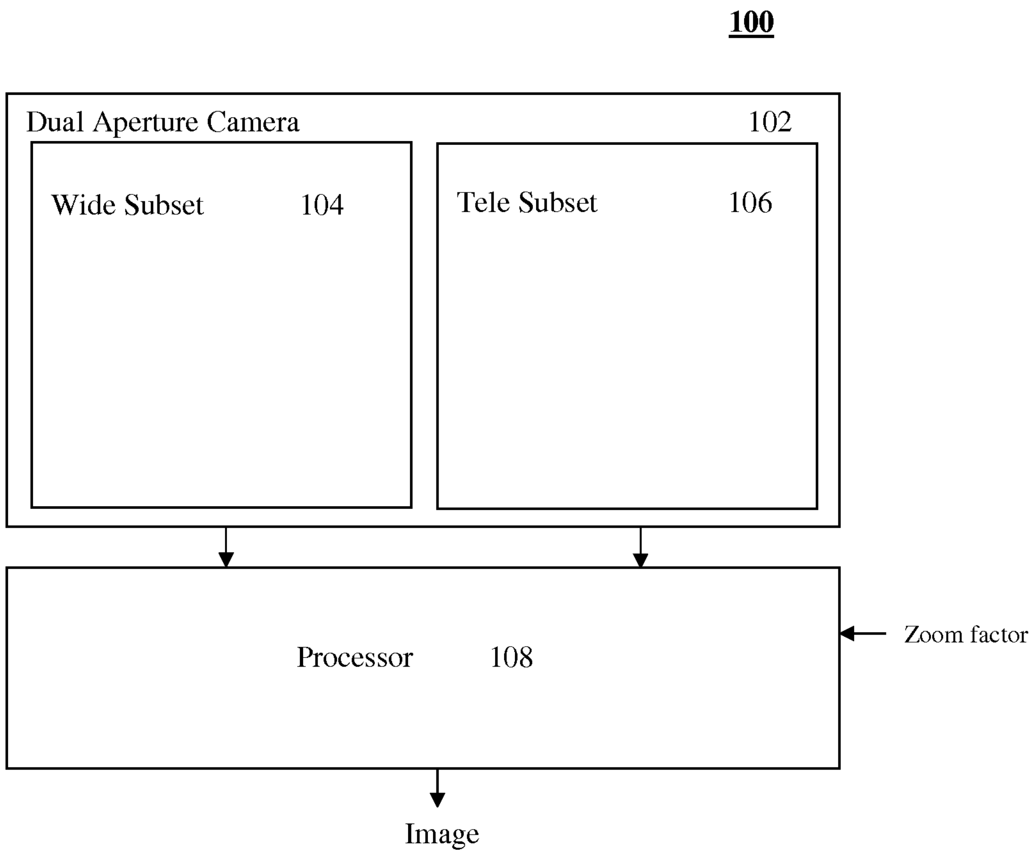

100
Dual Aperture Camera
102
Wide Subset
104
Tele Subset
106
Processor
108
Zoom factor
Image

FIG. 1A

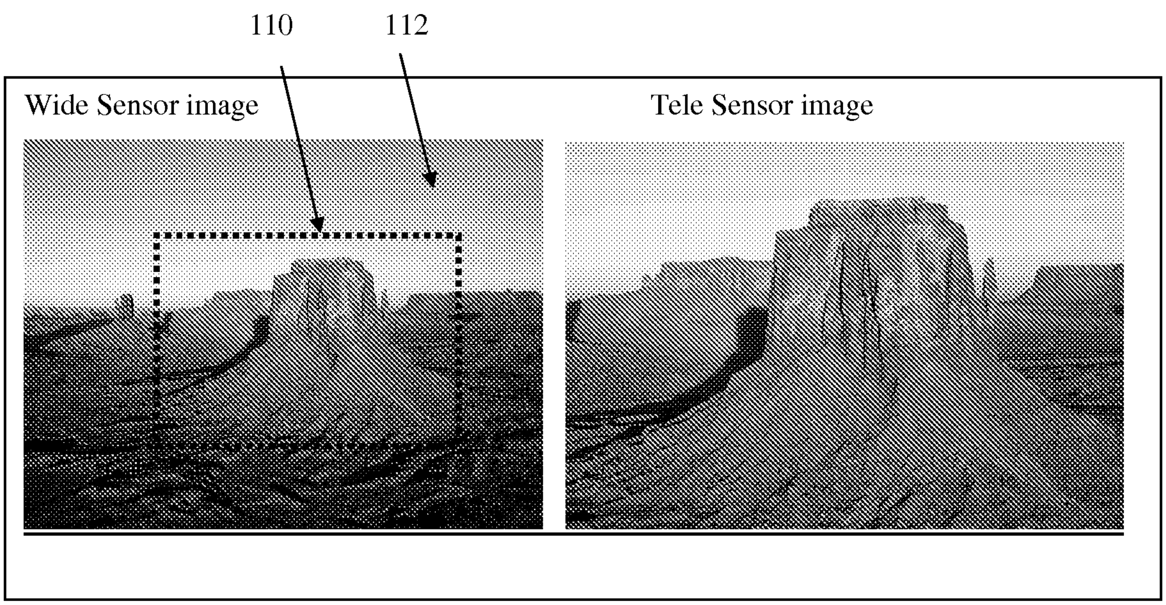

110
112
Wide Sensor image
Tele Sensor image

FIG. 1B

200

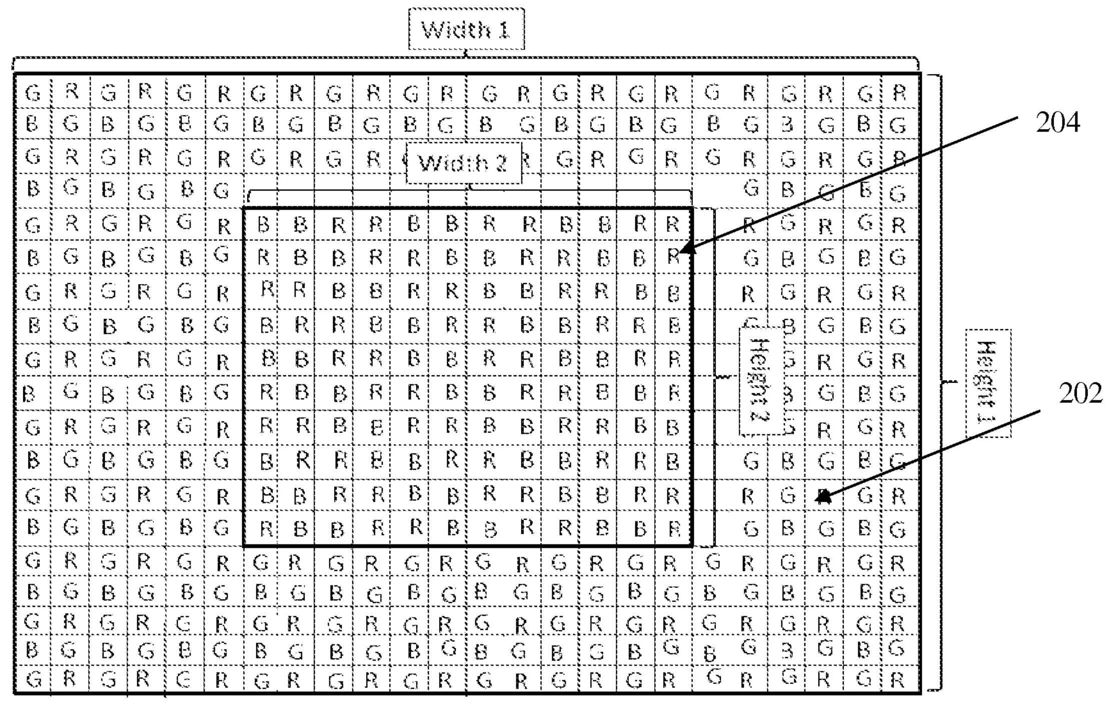


FIG. 2

300

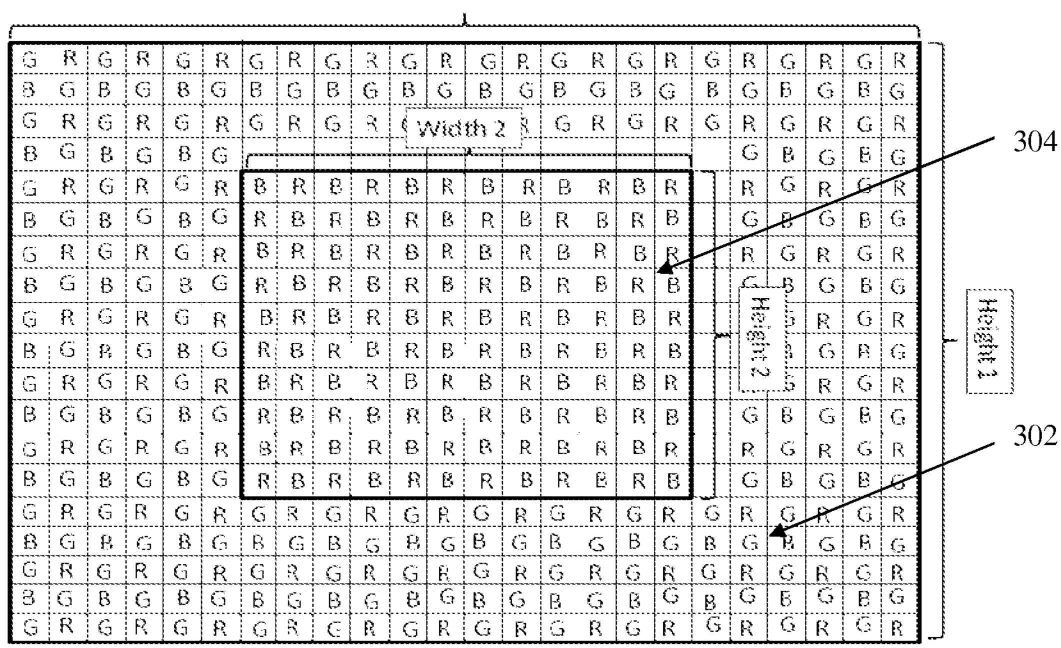
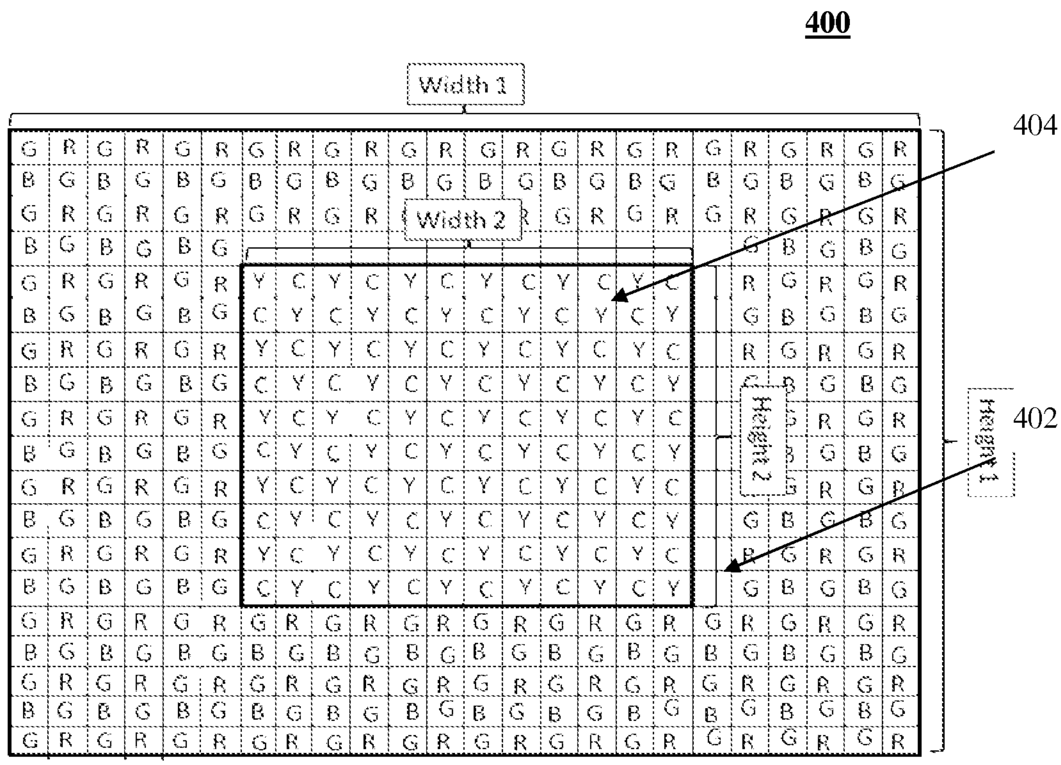


FIG. 3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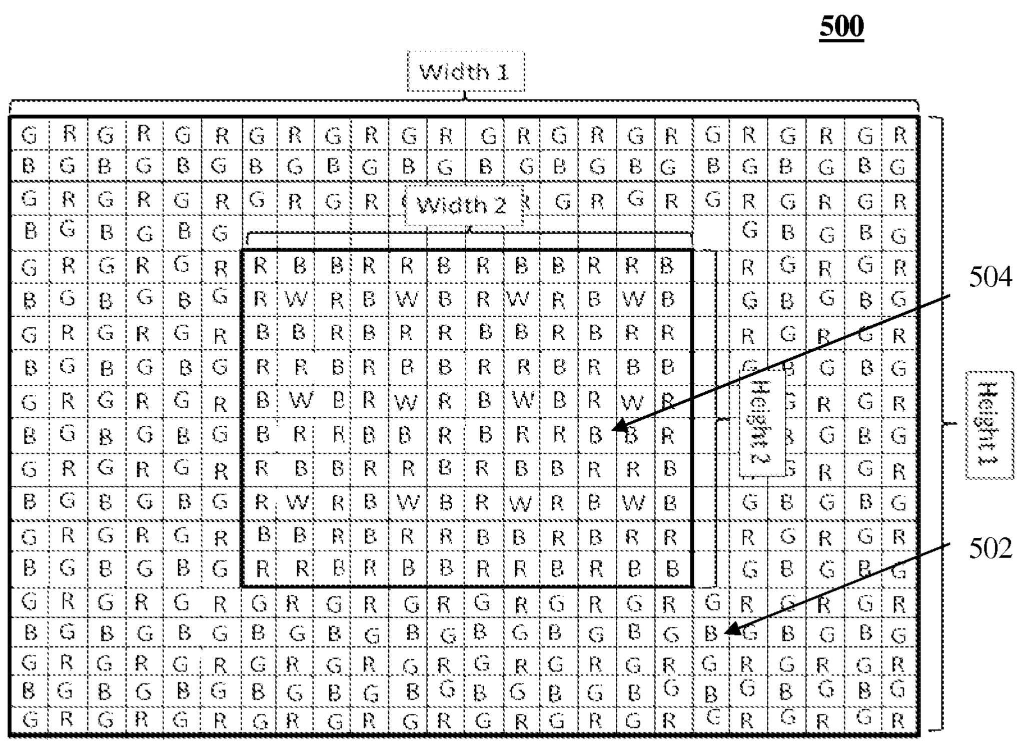
Width 2
Height 2
Height 1
404
402

FIG. 4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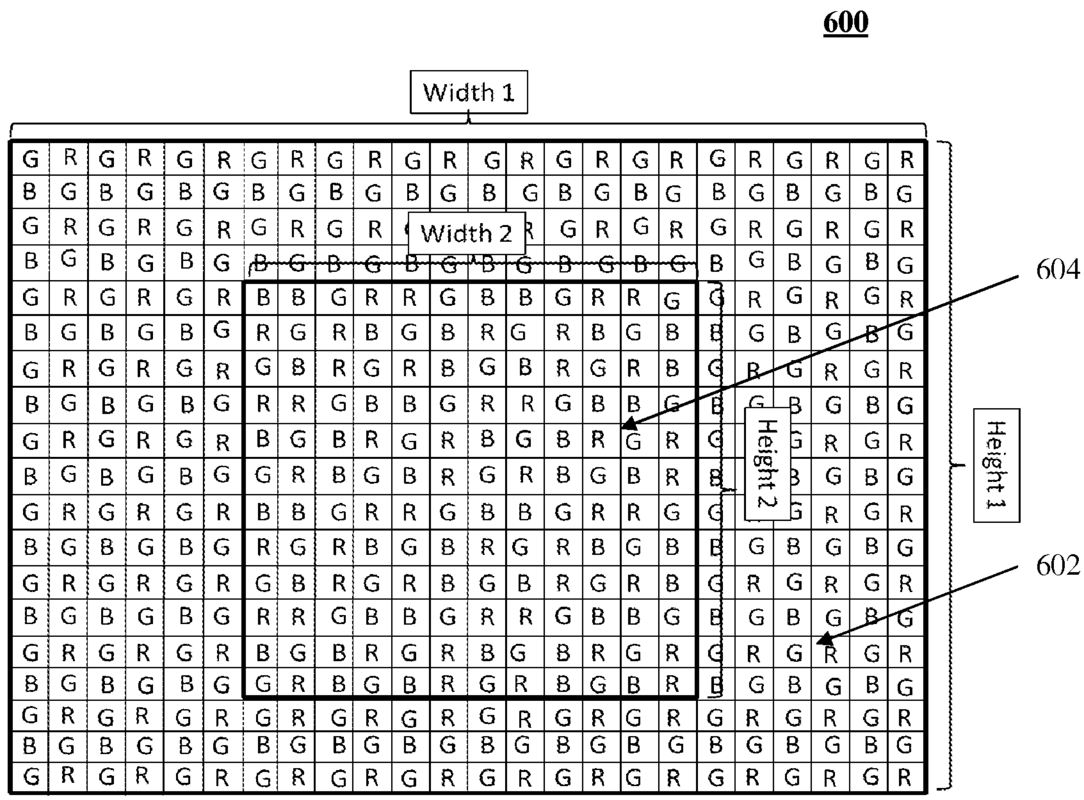
Width 2
Height 2
Height 1
504
502

FIG. 5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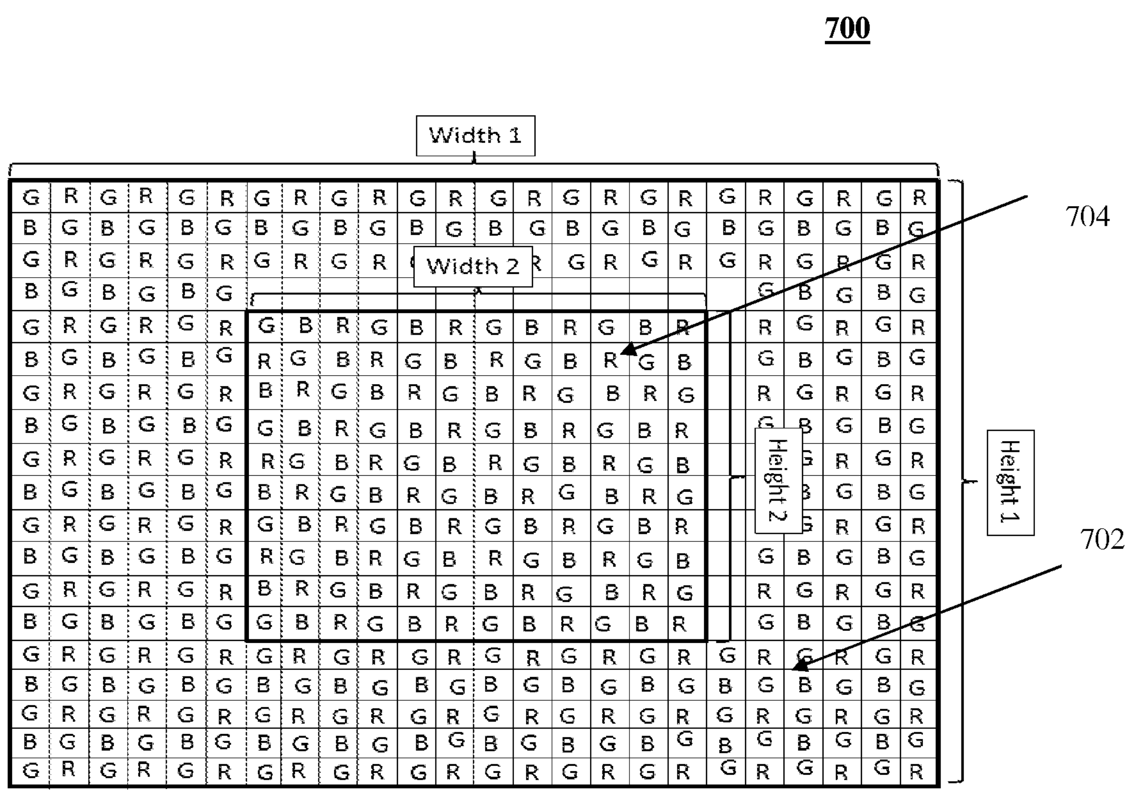
Width 2
604
602
Height 2
Height 1

FIG. 6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Width 1
Width 2
704
702
Height 2
Height 1

FIG. 7

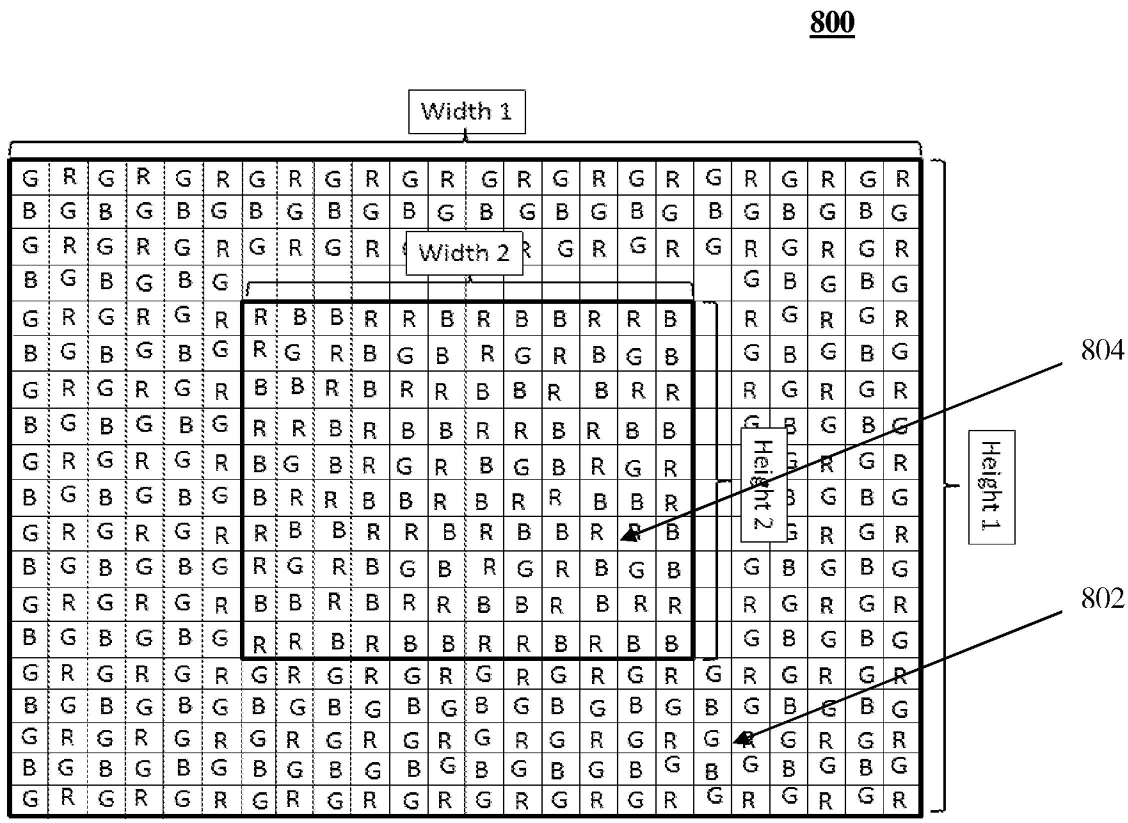
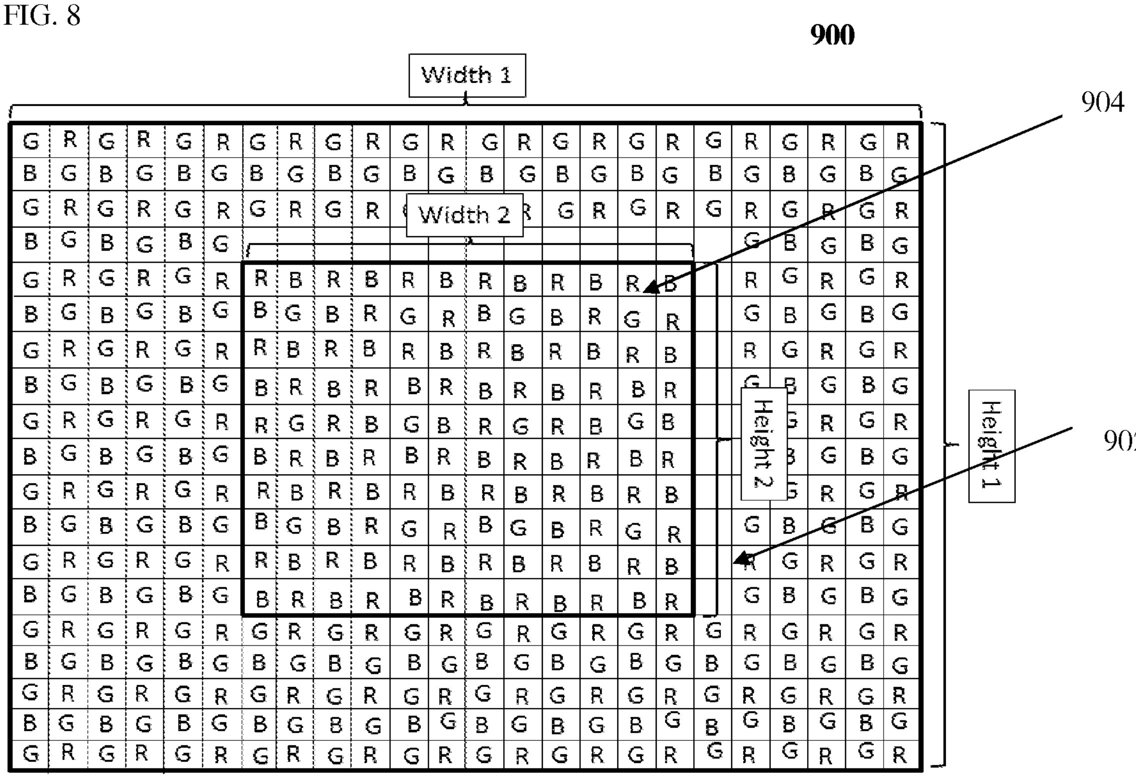

800
Width 1
Width 2
Height 2
Height 1
804
802

FIG. 8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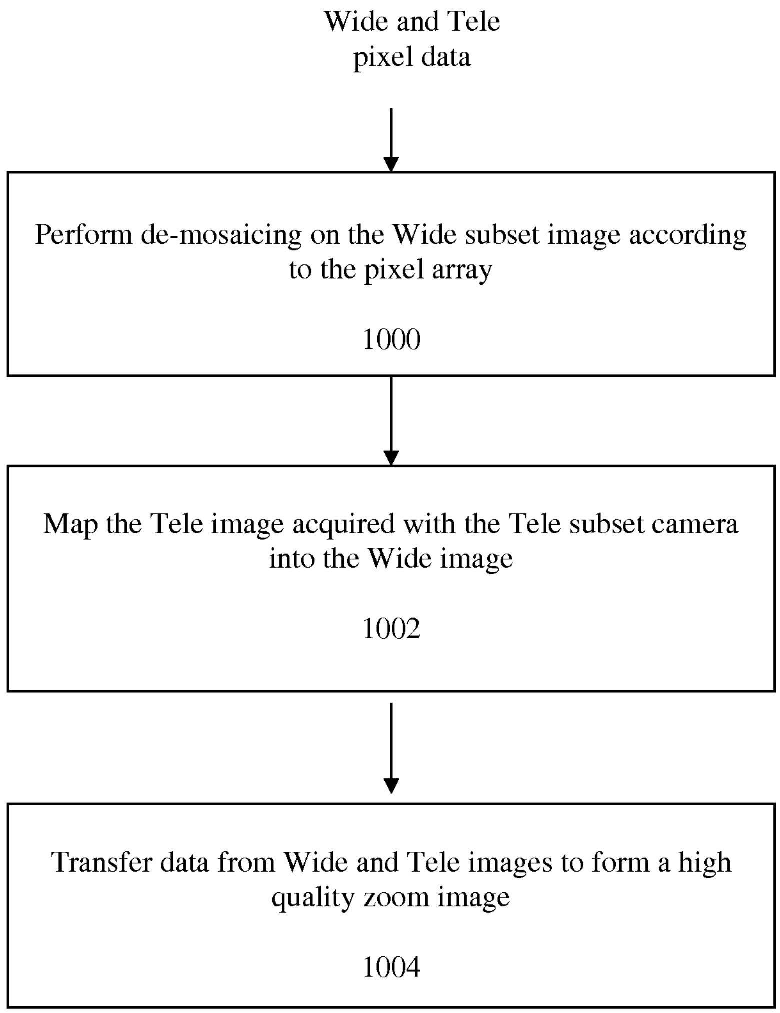
Width 2
Height 2
Height 1
904
902

FIG. 9



Wide and Tele
pixel data
Perform de-mosaicing on the Wide subset image according to the pixel array
1000
Map the Tele image acquired with the Tele subset camera into the Wide image
1002
Transfer data from Wide and Tele images to form a high quality zoom image
1004

FIG. 10

1100

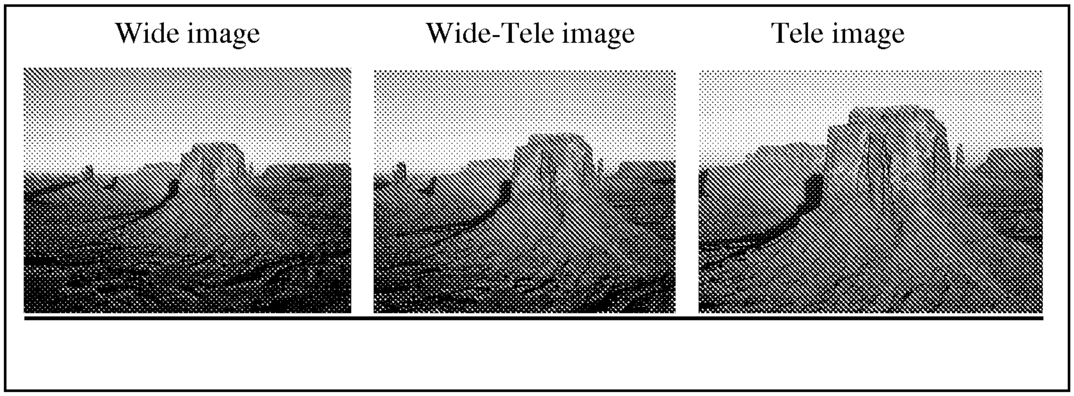


FIG. 11A

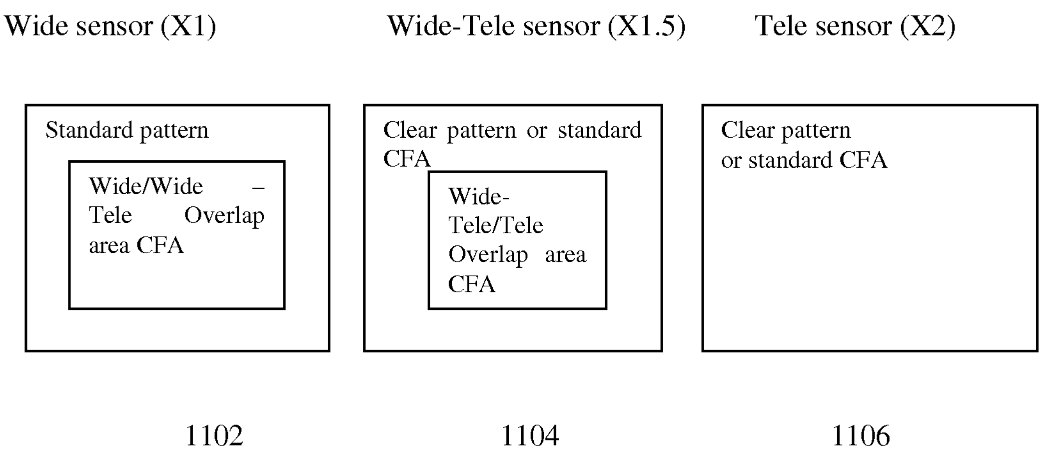


FIG. 11B

PTO-1390 (06-13)
Approved for use through 6/30/2013. OMB 0651-0021
U.S. Patent and Trademark Office; U.S. DEPARTMENT OF COMMERCE

TRANSMITTAL LETTER TO THE UNITED STATES DESIGNATED/ELECTED OFFICE (DO/EO/US) CONCERNING A SUBMISSION UNDER 35 U.S.C. 371

Attorney Docket No.: COREPH-0072 US NP

U.S. Application No. (if known, see 37 CFR 1.5):

International Application No.	International Filing Date	Priority Date Claimed
PCT/IB2013/060356	23/Nov/2013	28/Nov/2012

Title of Invention
HIGH RESOLUTION THIN MULTI-APERTURE IMAGING SYSTEMS

First Named Inventor
Gal Shabtay

Applicant herewith submits to the United States Designated/Elected Office (DO/EO/US) the following items and other information.

1. ☑ This is an express request to begin national examination procedures (35 U.S.C. 371(f)). NOTE: The express request under 35 U.S.C. 371(f) will not be effective unless the requirements under 35 U.S.C. 371(c)(1), (2), and (4) for payment of the basic national fee, copy of the International Application and English translation thereof (if required), and the oath or declaration of the inventor(s) have been received.
2. ☑ A copy of the International Application (35 U.S.C. 371(c)(2)) is attached hereto (not required if the International Application was previously communicated by the International Bureau or was filed in the United States Receiving Office (RO/US)).
3. An English language translation of the International Application (35 U.S.C. 371(c)(2))
   a. ☐ is attached hereto.
   b. ☐ has been previously submitted under 35 U.S.C. 154(d)(4).
4. An oath or declaration of the inventor(s) (35 U.S.C. 371(c)(4))
   a. ☑ is attached.
   b. ☐ was previously filed in the international phase under PCT Rule 4.17(iv).

Items 5 to 8 below concern amendments made in the international phase.

<u>PCT Article 19 and 34 amendments</u>

5. ☐ Amendments to the claims under PCT Article 19 are attached (not required if communicated by the International Bureau) (35 U.S.C. 371(c)(3)).
6. ☐ English translation of the PCT Article 19 amendment is attached (35 U.S.C. 371(c)(3)).
7. ☐ English translation of annexes (Article 19 and/or 34 amendments only) of the International Preliminary Examination Report is attached (35 U.S.C. 371(c)(5)).

<u>Cancellation of amendments made in the international phase</u>

8a. ☐ Do not enter the amendment made in the international phase under PCT Article 19.

8b. ☐ Do not enter the amendment made in the international phase under PCT Article 34.

NOTE: A proper amendment made in English under Article 19 or 34 will be entered in the U.S. national phase application absent a clear instruction from applicant not to enter the amendment(s).

The following items 9 to 17 concern a document(s) or information included.

9. ☐ An Information Disclosure Statement under 37 CFR 1.97 and 1.98.
10. ☑ A preliminary amendment.
11. ☑ An Application Data Sheet under 37 CFR 1.76.
12. ☐ A substitute specification. NOTE: A substitute specification cannot include claims. See 37 CFR 1.125(b).
13. ☑ A power of attorney and/or change of address letter.
14. ☐ A computer-readable form of the sequence listing in accordance with PCT Rule 13*ter*.3 and 37 CFR 1.821-1.825.
15. ☑ Assignment papers *(cover sheet and document(s))*. Name of Assignee: Corephotonics Ltd.
16. ☑ 37 CFR 3.73(c) Statement *(when there is an Assignee)*.

U.S. APPLN. No. (if known – see 37 CFR 1.5)	INTERNATIONAL APPLICATION No.	ATTORNEY DOCKET No.

17. ☐ Other items or information:

The following fees have been submitted.	CALCULATIONS	PTO USE ONLY
18. ☐ Basic national fee (37 CFR 1.492(a)) ………… **$280**	$	
19. ☐ Examination fee (37 CFR 1.492(c)) If the written opinion prepared by ISA/US or the international preliminary examination report prepared by IPEA/US indicates all claims satisfy provisions of PCT Article 33(1)-(4) ………… **$0** All other situations ………… **$720**	$	
20. ☐ Search fee (37 CFR 1.492(b)) If the written opinion prepared by ISA/US or the international preliminary examination report prepared by IPEA/US indicates all claims satisfy provisions of PCT Article 33(1)-(4) ………… **$0** Search fee (37 CFR 1.445(a)(2)) has been paid on the international application to the USPTO as an International Searching Authority ………… **$120** International Search Report prepared by an ISA other than the US and provided to the Office or previously communicated to the US by the IB ………… **$480** All other situations ………… **$600**	$	
TOTAL OF 18, 19, and 20 =	$	
☐ Additional fee for specification and drawings filed in paper over 100 sheets (excluding sequence listing in compliance with 37 CFR 1.821(c) or (e) in an electronic medium or computer program listing in an electronic medium) (37 CFR 1.492(j)). Fee for each additional 50 sheets of paper or fraction thereof ………… **$400**		

Total Sheets	Extra Sheets	Number of each addition 50 or fraction thereof (round **up** to a whole number)	RATE	CALCULATIONS	PTO USE ONLY
- 100 =	/ 50 =		x **$400**	$	

	CALCULATIONS	PTO USE ONLY
Surcharge of **$140.00** for furnishing any of the search fee, examination fee, or the oath or declaration after the date of commencement of the national stage (37 CFR 1.492(h)).	$	

CLAIMS	NUMBER FILED	NUMBER EXTRA	RATE	CALCULATIONS	PTO USE ONLY
Total claims	- 20 =		x **$80**	$	
Independent claims	- 3 =		x **$420**	$	
MULTIPLE DEPENDENT CLAIM(S) (if applicable)			**+ $780**	$	

	CALCULATIONS	PTO USE ONLY
Processing fee of **$140.00** for furnishing the English translation later than 30 months from the earliest claimed priority date (37 CFR 1.492(i)). **+**	$	
TOTAL OF ABOVE CALCULATIONS =	$	
☑ **Applicant asserts small entity status.** See 37 CFR 1.27. Fees above are reduced by ½.		
☐ **Applicant certifies micro entity status.** See 37 CFR 1.29. Fees above are reduced by ¾. Applicant must attach form PTO/SB/15A or B or equivalent.		
TOTAL NATIONAL FEE =	$	
Fee for recording the enclosed assignment (37 CFR 1.21(h)). The assignment must be accompanied by an appropriate cover sheet (37 CFR 3.28, 3.31). **$40.00** per property. **+**	$	
TOTAL FEES ENCLOSED =	$	
	Amount to be refunded:	$
	Amount to be charged:	$

a. ☐ A check in the amount of $____________________ to cover the above fees is enclosed.

b. ☐ Please charge my Deposit Account No. __________________ in the amount of $__________________ to cover the above fees.

c. ☐ The Director is hereby authorized to charge additional fees which may be required, or credit any overpayment, to Deposit Account No. __________________ as follows:

i. ☐ any required fee.

ii. ☐ any required fee except for excess claims fees required under 37 CFR 1.492(d) and (e) and multiple dependent claim fee required under 37 CFR 1.492(f).

d. ☐ Fees are to be charged to a credit card. **WARNING:** Information on this form may become public. Credit card information should not be included on this form. Provide credit card information and authorization on PTO-2038. The PTO-2038 should only be mailed or faxed to the USPTO. However, when paying the basic national fee, the PTO-2038 may NOT be faxed to the USPTO.

ADVISORY: If filing by EFS-Web, do **NOT** attach the PTO-2038 form as a PDF along with your EFS-Web submission. Please be advised that this is **not** recommended and by doing so your **credit card information may be displayed via PAIR**. To protect your information, it is recommended to pay fees online by using the electronic payment method.

NOTE: Where an appropriate time limit under 37 CFR 1.495 has not been met, a petition to revive (37 CFR 1.137(a) or (b)) must be filed and granted to restore the International Application to pending status.

Statement under 37 CFR 1.55 or 1.78 for AIA (First Inventor to File)Transition Applications

☐ This application (1) claims priority to or the benefit of an application filed before March 16, 2013, and (2) also contains, or contained at any time, a claim to a claimed invention that has an effective filing date on or after March 16, 2013.

NOTE 1: By providing this statement under 37 CFR 1.55 or 1.78, **this application, with a filing date on or after March 16, 2013, will be examined under the first inventor to file provisions of the AIA**.

NOTE 2: A U.S. national stage application may not claim priority to the international application of which it is the national phase. The filing date of a U.S. national stage application is the international filing date. See 35 U.S.C. 363.

Correspondence Address

☑ The address associated with Customer Number: 92342 **OR** ☐ Correspondence address below

Name					
Address					
City		State		Zip Code	
Country			Telephone		
Email					

Signature	/Menachem Nathan/	Date	09/20/2014
Name (Print/Type)	MENACHEM NATHAN	Registration No. (Attorney/Agent)	65392

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.

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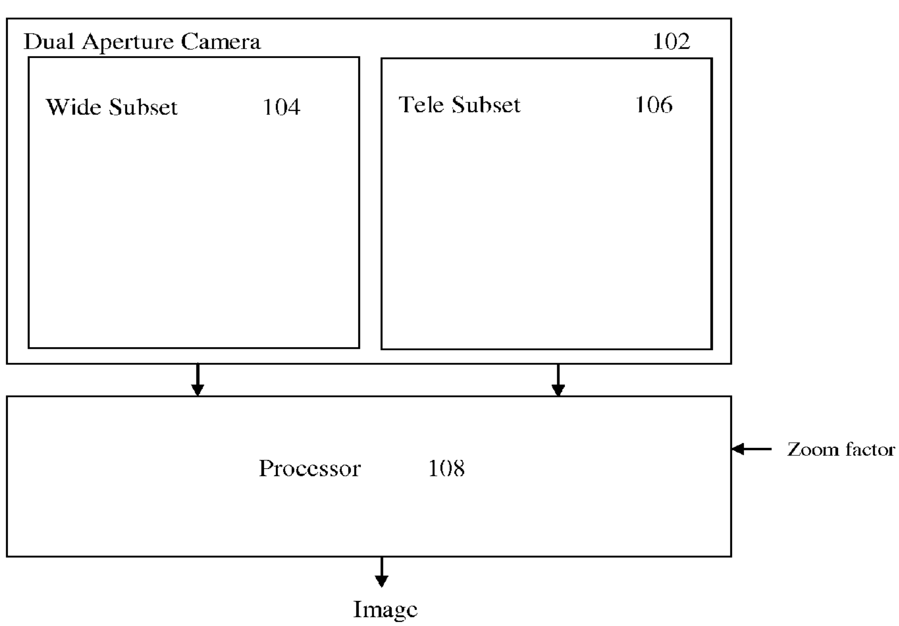

(57) Abstract: A multi-aperture imaging system comprising a first camera with a first sensor that captures a first image and a second camera with a second sensor that captures a second image, the two cameras having either identical or different FOVs. The first sensor may have a standard color filter array (CFA) covering one sensor section and a non-standard color CFA covering another. The second sensor may have either Clear or standard CFA covered sections. Either image may be chosen to be a primary or an auxiliary image, based on a zoom factor. An output image with a point of view determined by the primary image is obtained by registering the auxiliary image to the primary image.

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HIGH RESOLUTION THIN MULTI-APERTURE IMAGING SYSTEMS

CROSS REFERENCE TO RELATED APPLICATIONS

This application is related to and claims priority from US Provisional Patent Application No. 61/730,570 having the same title and filed November 28, 2013, which is incorporated herein by reference in its entirety.

FIELD

Embodiments disclosed herein relate in general to multi-aperture imaging ("MAI") systems (where “multi” refers to two or more apertures) and more specifically to thin MAI systems with high color resolution and/or optical zoom.

BACKGROUND

Small digital cameras integrated into mobile (cell) phones, personal digital assistants and music players are becoming ubiquitous. Each year, mobile phone manufacturers add more imaging features to their handsets, causing these mobile imaging devices to converge towards feature sets and image quality that customers expect from stand-alone digital still cameras. Concurrently, the size of these handsets is shrinking, making it necessary to reduce the total size of the camera accordingly while adding more imaging features. Optical Zoom is a primary feature of many digital still cameras but one that mobile phone cameras usually lack, mainly due to camera height constraints in mobile imaging devices, cost and mechanical reliability.

Mechanical zoom solutions are common in digital still cameras but are typically too thick for most camera phones. Furthermore, the F/# (“F number) in such systems typically increases with the zoom factor (ZF) resulting in poor light sensitivity and higher noise (especially in low-light scenarios). In mobile cameras, this also results in resolution compromise, due to the small pixel size of their image sensors and the diffraction limit optics associated with the F/#.

One way of implementing zoom in mobile cameras is by over-sampling the image and cropping and interpolating it in accordance with the desired ZF. While this method is mechanically reliable, it results in thick optics and in an expensive image sensor due to the large number of pixels associated therewith. As an example, if one is interested in implementing a 12 Megapixel camera with X3 ZF, one needs a sensor of 108 Megapixels.

Another way of implementing zoom, as well as increasing the output resolution, is by using a dual-aperture imaging ("DAI") system. In its basic form, a DAI system includes two optical apertures which may be formed by one or two optical modules, and one or two image sensors (e.g., CMOS or CCD) that grab the optical image or images and convert the data into the electronic domain, where the image can be processed and stored.

The design of a thin MAI system with improved resolution requires a careful choice of parameters coupled with advanced signal processing algorithms to support the output of a high quality image. Known MAI systems, in particular ones with short optical paths, often trade-off functionalities and properties, for example zoom and color resolution, or image resolution and quality for camera module height. Therefore, there is a need for, and it would be advantageous to have thin MAI systems that produce an image with high resolution (and specifically high color resolution) together with zoom functionality.

Moreover, known signal processing algorithms used together with existing MAI systems often further degrade the output image quality by introducing artifacts when combining information from different apertures. A primary source of these artifacts is the image registration process, which has to find correspondences between the different images that are often captured by different sensors with different color filter arrays (CFAs). There is therefore a need for, and it would be advantageous to have an image registration algorithm that is more robust to the type of CFA used by the cameras and which can produce better correspondence between images captured by a multi-aperture system.

SUMMARY

Embodiments disclosed herein teach the use of multi-aperture imaging systems to implement thin cameras (with short optical paths of less than about 9 mm) and/or to realize optical zoom systems in such thin cameras. Embodiments disclosed herein further teach new color filter arrays that optimize the color information which may be achieved in a multi-aperture imaging system with or without zoom. In various embodiments, a MAI system disclosed herein includes at least two sensors or a single sensor divided into at least two areas. Hereinafter, the description refers to “two sensors”, with the understanding that they may represent sections of a single physical sensor (imager chip). Exemplarily, in a dual-aperture imaging system, a left sensor (or left side of a single sensor) captures an image coming from a first aperture while a right sensor (or right side of a single sensor) captures an image coming

from a second aperture. In various embodiments disclosed herein, one sensor is a “Wide” sensor while another sensor is a “Tele” sensor, see e.g. FIG. 1A. The Wide sensor includes either a single standard CFA or two different CFAs: a non-standard CFA with higher color sampling rate positioned in an “overlap area” of the sensor (see below description of FIG. 1B) and a standard CFA with a lower color sampling rate surrounding the overlap area. When including a single standard CFA, the CFA may cover the entire Wide sensor area. A "standard CFA" may include a RGB (Bayer) pattern or a non-Bayer pattern such as RGBE, CYYM, CYGM, RGBW#1, RGBW#2 or RGBW#3. Thus, reference may be made to "standard Bayer" or "standard non-Bayer" patterns or filters. As used herein, “non-standard CFA” refers to a CFA that is different in its pattern that CFAs listed above as “standard”. Exemplary non-standard CFA patterns may include repetitions of a 2x2 micro-cell in which the color filter order is RR-BB, RB-BR or YC-CY where Y=Yellow = Green + Red, C = Cyan = Green + Blue; repetitions of a 3x3 micro-cell in which the color filter order is GBR-RGB-BRG; and repetitions of a 6x6 micro-cell in which the color filter order is
RBBRRB-RWRBWB-BBRBRR-RRBRBB-BWBRWR-BRRBBR, or
BBGRRG-RGRBGB-GBRGRB-RRGBBG-BGBRGR-GRBGBR, or
RBBRRB-RGRBGB-BBRBRR-RRBRBB-BGBRGR-BRRBBR, or,
RBRBRB-BGBRGR-RBRBRB-BRBRBR-RGRBGB-BRBRBR.

The Tele sensor may be a Clear sensor (i.e. a sensor without color filters) or a standard CFA sensor. This arrangement of the two (or more than two) sensors and of two (or more than two) Wide and Tele “subset cameras” (or simply “subsets”) related to the two Wide and Tele subsets. Each sensor provides a separate image (referred to respectively as a Wide image and a Tele image), except for the case of a single sensor, where two images are captured (grabbed) by the single sensor (example above). In some embodiments, zoom is achieved by fusing the two images, resulting in higher color resolution that approaches that of a high quality dual-aperture zoom camera. Some thin MAI systems disclosed herein therefore provide zoom, super-resolution, high dynamic range and enhanced user experience.

In some embodiments, in order to reach optical zoom capabilities, a different magnification image of the same scene is grabbed by each subset, resulting in field of view (FOV) overlap between the two subsets. In some embodiments, the two subsets have the same zoom (i.e. same FOV). In some embodiments, the Tele subset is the higher zoom subset and the Wide subset is the lower zoom subset. Post processing is applied on the two images grabbed by the MAI system to fuse and output one fused (combined) output zoom image processed according to a user ZF input request. In some embodiments, the resolution of the fused image may be higher than the resolution of the Wide/Tele sensors. As part of the fusion procedure, up-sampling may be applied on the Wide image to scale it to the Tele image.

In an embodiment there is provided a multi-aperture imaging system comprising a first camera subset that provides a first image, the first camera subset having a first sensor with a first plurality of sensor pixels covered at least in part with a non-standard CFA, the non-standard CFA used to increase a specific color sampling rate relative to a same color sampling rate in a standard CFA; a second camera subset that provides a second image, the second camera subset having a second sensor with a second plurality of sensor pixels either Clear or covered with a standard CFA; and a processor configured to process the first and second images into a combined output image.

In some embodiments, the first and the second camera subsets have identical FOVs and the non-standard CFA may cover an overlap area that includes all the pixels of first sensor, thereby providing increased color resolution. In some such embodiments, the processor is further configured to, during the processing of the first and second images into a combined output image, register respective first and second Luma images obtained from the first and second images, the registered first and second Luma images used together with color information to form the combined output image. In an embodiment, the registration includes finding a corresponding pixel in the second Luma image for each pixel in the first Luma image, whereby the output image is formed by transferring information from the second image to the first image. In another embodiment, the registration includes finding a corresponding pixel in the first Luma image for each pixel in the second Luma image, whereby the output image is formed by transferring information from the first image to the second image.

In some embodiments, the first camera subset has a first FOV, the second camera subset has a second, smaller FOV than the first FOV, and the non-standard CFA covers an overlap area on the first sensor that captures the second FOV, thereby providing both optical zoom and increased color resolution. In some such embodiments, the processor is further configured to, during the processing of the first and second images into a combined output image and based on a ZF input, register respective first and second Luma images obtained from the first and second images, the registered first and second Luma images used together with color information to form the combined output image. For a ZF input that defines an FOV greater than the second FOV, the registration includes finding a corresponding pixel in the second Luma image for each pixel in the first Luma image and the processing includes forming the output image by transferring information from the second image to the first image. For a ZF input that defines an FOV smaller than or equal to the second FOV, the registration includes finding a corresponding pixel in the first Luma image for each pixel in the second Luma image, and the processing includes forming the output image by transferring information from the first image to the second image.

In an embodiment there is provided a multi-aperture imaging system comprising a first camera subset that provides a first image, the first camera subset having a first sensor with a first plurality of sensor pixels covered at least in part with a standard CFA; a second camera subset that provides a second image, the second camera subset having a second sensor with a second plurality of sensor pixels either Clear or covered with a standard CFA; and a processor configured to register first and second Luma images obtained respectively from the first and second images and to process the registered first and second Luma images together with color information into a combined output image.

In some embodiments, the first and the second camera subsets have identical first and second FOVs. In some such embodiments, the registration includes finding a corresponding pixel in the second Luma image for each pixel in the first Luma image and the processing includes forming the output image by transferring information from the second image to the first image. In other such embodiments, the registration includes finding a corresponding pixel in the first Luma image for each pixel in the second Luma image and the processing includes forming the output image by transferring information from the first image to the second image.

In some embodiments, the first camera subset has a first FOV, the second camera subset has a second, smaller FOV than the first FOV, and the processor is further configured to register the first and second Luma images based on a ZF input. For a ZF input that defines an FOV greater than the second FOV, the registration includes finding a corresponding pixel in the second Luma image for each pixel in the first Luma image and the processing includes forming the output image by transferring information from the second image to the first image. For a ZF input that defines an FOV smaller than or equal to the second FOV, the registration includes finding a corresponding pixel in the first Luma image for each pixel in the second Luma image, and the processing includes forming the output image by transferring information from the first image to the second image.

BRIEF DESCRIPTION OF THE DRAWINGS

Non-limiting examples of embodiments disclosed herein are described below with reference to figures attached hereto that are listed following this paragraph. The drawings and descriptions are meant to illuminate and clarify embodiments disclosed herein, and should not be considered limiting in any way.

FIG. 1A shows schematically a block diagram illustrating a dual-aperture zoom imaging system disclosed herein;

FIG. 1B shows an example of an image captured by the Wide sensor and the Tele sensor while illustrating the overlap area on the Wide sensor;

FIG. 2 shows schematically an embodiment of a Wide sensor that may be implemented in a dual-aperture zoom imaging system disclosed herein;

FIG. 3 shows schematically another embodiment of a Wide camera sensor that may be implemented in a dual-aperture zoom imaging system disclosed herein;

FIG. 4 shows schematically yet another embodiment of a Wide camera sensor that may be implemented in a dual-aperture zoom imaging system disclosed herein;

FIG. 5 shows schematically yet another embodiment of a Wide camera sensor that may be implemented in a dual-aperture zoom imaging system disclosed herein;

FIG. 6 shows schematically yet another embodiment of a Wide camera sensor that may be implemented in a dual-aperture zoom imaging system disclosed herein;

FIG. 7 shows schematically yet another embodiment of a Wide camera sensor that may be implemented in a dual-aperture zoom imaging system disclosed herein;

FIG. 8 shows schematically yet another embodiment of a Wide camera sensor that may be implemented in a dual-aperture zoom imaging system disclosed herein;

FIG. 9 shows schematically yet another embodiment of a Wide camera sensor that may be implemented in a dual-aperture zoom imaging system disclosed herein;

FIG. 10 shows a schematically in a flow chart an embodiment of a method disclosed herein for acquiring and outputting a zoom image;

FIG. 11A shows exemplary images captured by a triple aperture zoom imaging system disclosed herein;

FIG. 11B illustrates schematically the three sensors of the triple aperture imaging system of FIG. 11A.

DETAILED DESCRIPTION

Embodiments disclosed herein relate to multi-aperture imaging systems that include at least one Wide sensor with a single CFA or with two different CFAs and at least one Tele sensor. The description continues with particular reference to dual-aperture imaging systems that include two (Wide and Tele) subsets with respective sensors. A three-aperture imaging system is described later with reference to FIGS. 11A-11B.

The Wide sensor includes an overlap area (see description of FIG. 1B) that captures the Tele FOV. The overlap area may cover the entire Wide sensor or only part of the sensor. The overlap area may include a standard CFA or a non-standard CFA. Since the Tele image is optically magnified compared to the Wide image, the effective sampling rate of the Tele image is higher than that of the Wide image. Thus, the effective color sampling rate in the Wide sensor is much lower than the Clear sampling rate in the Tele sensor. In addition, the Tele and Wide images fusion procedure (see below) requires up-scaling of the color data from the Wide sensor. Up-scaling will not improve color resolution. In some applications, it is therefore advantageous to use a non-standard CFA in the Wide overlap area that increases color resolution for cases in which the Tele sensor includes only Clear pixels. In some embodiments in which the Tele sensor includes a Bayer CFA, the Wide sensor may have a Bayer CFA in the overlap area. In such embodiments, color resolution improvement depends on using color information from the Tele sensor in the fused output image.

FIG. 1A shows schematically a block diagram illustrating a dual-aperture zoom imaging ("DAZI") system **100** disclosed herein. System **100** includes a dual-aperture camera **102** with a Wide subset **104** and a Tele subset **106** (each subset having a respective sensor), and a processor **108** that fuses two images, a Wide image obtained with the Wide subset and a Tele image obtained with the Tele subset, into a single fused output image according to a user-defined "applied" ZF input or request. The ZF is input to processor **108**. The Wide sensor may include a non-standard CFA in an overlap area illustrated by **110** in FIG. 1B. Overlap area **110** is surrounded by a non-overlap area **112** with a standard CFA (for example a Bayer pattern). FIG. 1B also shows an example of an image captured by both Wide and Tele sensors. Note that “overlap” and “non-overlap” areas refer to parts of the Wide image as well as to the CFA arrangements of the Wide sensor. The overlap area may cover different portions of a Wide sensor, for example half the sensor area, a third of the sensor area, a quarter of the sensor area, etc. A number of such Wide sensor CFA arrangements are described in more detail with reference to FIGS. 2-9. The non-standard CFA pattern increases the color resolution of the DAZI system.

The Tele sensor may be Clear (providing a Tele Clear image scaled relative to the Wide image) or may include a standard (Bayer or non-Bayer) CFA. It in the latter case, it is desirable to define primary and auxiliary sensors based on the applied ZF. If the ZF is such that the output FOV is larger than the Tele FOV, the primary sensor is the Wide sensor and the auxiliary sensor is the Tele sensor. If the ZF is such that the output FOV is equal to, or smaller than the Tele FOV, the primary sensor is the Tele sensor and the auxiliary sensor is the Wide sensor. The point of view defined by the output image is that of the primary sensor.

FIG. 2 shows schematically an embodiment of a Wide sensor **200** that may be implemented in a DAZI system such as system **100**. Sensor **200** has a non-overlap area **202** with a Bayer CFA and an overlap area **204** covered by a non-standard CFA with a repetition of a 4x4 micro-cell in which the color filter order is BBRR-RBBR-RRBB-BRRB. In this figure, as well as in FIGS. 3-9, “Width 1” and “Height 1” refer to the full Wide sensor dimension. “Width 2” and “Height 2” refer to the dimensions of the Wide sensor overlap area. Note that in FIG. 2 (as in following figures 3-5 and 7, 8) the empty row and column to the left and top of the overlap area are for clarity purposes only, and that the sensor pixels follow there the pattern of the non-overlap area (as shown in FIG. 6). In overlap area **204**, R and B are sampled at $1/2^{0.5}$ Nyquist frequency in the diagonal (left to right) direction with 2 pixel intervals instead of at 1/2 Nyquist frequency in a standard Bayer pattern.

FIG. 3 shows schematically an embodiment of a Wide sensor **300** that may be implemented in a DAZI system such as system **100.** Sensor **300** has a non-overlap area **302** with a Bayer CFA and an overlap area **304** covered by a non-standard CFA with a repetition of a 2x2 micro-cell in which the color filter order is BR-RB. In the overlap area, R and B are sampled at $1/2^{0.5}$ Nyquist frequency in both diagonal directions.

FIG. 4 shows schematically an embodiment of a Wide sensor **400** that may be implemented in a DAZI system such as system **100.** Sensor **400** has a non-overlap area **402** with a Bayer CFA and an overlap area **404** covered by a non-standard CFA with a repetition of a 2x2 micro-cell in which the color filter order is YC-CY, where Y=Yellow = Green + Red, C = Cyan = Green + Blue. As a result, in the overlap area, R and B are sampled at $1/2^{0.5}$ Nyquist frequency in a diagonal direction. The non-standard CFA includes green information for registration purposes. This allows for example registration between the two images where the object is green, since there is green information in both sensor images.

FIG. 5 shows schematically an embodiment of a Wide sensor **500** that may be implemented in a DAZI system such as system **100**. Sensor **500** has a non-overlap area **502** with a Bayer CFA and an overlap area **504** covered by a non-standard CFA with a repetition of a 6x6 micro-cell in which the color filter order is RBBRRB-RWRBWB-BBRBRR-RRBRBB-BWBRWR-BRRBBR, where “W” represents White or Clear pixels. In the overlap area, R and B are sampled at a higher frequency than in a standard CFA. For example, in a Bayer pixel order, the Red average sampling rate ("R_S") is 0.25 (sampled once for every 4 pixels). In the overlap area pattern, R_S is 0.44.

FIG. 6 shows schematically an embodiment of a Wide sensor **600** that may be implemented in a DAZI system such as system **100**. Sensor **600** has a non-overlap area **602** with a Bayer CFA and an overlap area **604** covered by a non-standard CFA with a repetition of a 6x6 micro-cell in which the color filter order is BBGRRG-RGRBGB-GBRGRB-RRGBBG-BGBRGR-GRBGBR. In the overlap area, R and B are sampled at a higher frequency than in a standard CFA. For example, in the overlap area pattern, R_S is 0. 33 vs. 0.25 in a Bayer pixel order.

FIG. 7 shows schematically an embodiment of a Wide sensor **700** that may be implemented in a DAZI system such as system **100**. Sensor **700** has a non-overlap area **702** with a Bayer CFA and an overlap area **704** covered by a non-standard CFA with a repetition of a 3x3 micro-cell in which the color filter order is GBR-RGB-BRG. In the overlap area, R and B are sampled at a higher frequency than in a standard CFA. For example, in the overlap area pattern, R_S is 0. 33 vs. 0.25 in a Bayer pixel order.

FIG. 8 shows schematically an embodiment of a Wide sensor **800** that may be implemented in a DAZI system such as system **100**. Sensor **800** has a non-overlap area **802** with a Bayer CFA and an overlap area **804** covered by a non-standard CFA with a repetition of a 6x6 micro-cell in which the color filter order is RBBRRB-RGRBGB-BBRBRR-RRBRBB-BGBRGR-BRRBBR. In the overlap area, R and B are sampled at a higher frequency than in a standard CFA. For example, in the overlap area pattern, R_S is 0. 44 vs. 0.25 in a Bayer pixel order.

FIG. 9 shows schematically an embodiment of a Wide sensor **900** that may be implemented in a DAZI system such as system **100**. Sensor **900** has a non-overlap area **902** with a Bayer CFA and an overlap area **904** covered by a non-standard CFA with a repetition of a 6x6 micro-cell in which the color filter order is RBRBRB-BGBRGR-RBRBRB-BRBRBR-RGRBGB-BRBRBR. In the overlap area, R and B are sampled at a higher frequency than in a standard CFA. For example, in the overlap area pattern, R_S is 0. 44 vs. 0.25 in a Bayer pixel order.

Processing flow

In use, an image is acquired with imaging system **100** and is processed according to steps illustrated in a flowchart shown in FIG. 10. In step **1000**, demosaicing is performed on the Wide overlap area pixels (which refer to the Tele image FOV) according to the specific CFA pattern. If the CFA in the Wide overlap area is a standard CFA, a standard demosaicing process may be applied to it. If the CFA in the Wide overlap area is non-standard CFA, the overlap and non-overlap subsets of pixels may need different demosaicing processes. That is, the Wide overlap area may need a non-standard demosaicing process and the Wide non-overlap area may need a standard demosaicing process. Exemplary and non-limiting non-standard demosaicing interpolations for the overlap area of each of the Wide sensors shown in FIGS. 2-9 are given in detail below. The aim of the demosaicing is to reconstruct missing colors in each pixel. Demosaicing is applied also to the Tele sensor pixels if the Tele sensor is not a Clear only sensor. This will result in a Wide subset color image where the colors (in the overlap area) hold higher resolution than those of a standard CFA pattern. In step **1002**, the Tele image is registered (mapped) into the Wide image. The mapping includes finding correspondences between pixels in the two images. In step **1002**, actual registration is performed on luminance Tele and Wide images (respectively $Luma_{Tele}$ and $Luma_{Wide)}$ calculated from the pixel information of the Tele and Wide cameras. These luminance images are estimates for the scene luminance as captured by each camera and do not include any color information. If the Wide or Tele sensors have CFAs, the calculation of the luminance images is performed on the respective demosaiced images. The calculation of the Wide luminance image varies according to the type of non-standard CFA used in the Wide overlap area. If the CFA permits calculation of a full RGB demosaiced image, the luminance image calculation is straightforward. If the CFA is such that it does not permit calculation of a full RGB demosaiced image, the luminance image is estimated from the available color channels. If the Tele sensor is a Clear sensor, the Tele luminance image is just the pixel information. Performing the registration on luminance images has the advantage of enabling registration between images captured by sensors with different CFAs or between images captured by a standard CFA or non-standard CFA sensor and a standard CFA or Clear sensor and avoiding color artifacts that may arise from erroneous registration.

In step **1004**, the data from the Wide and Tele images is processed together with the registration information from step **1002** to form a high quality output zoom image. In cases where the Tele sensor is a Clear only sensor, the high resolution luminance component is taken from the Tele sensor and color resolution is taken from the Wide sensor. In cases where the Tele sensor includes a CFA, both color and luminance data are taken from the Tele subset to form the high quality zoom image. In addition, color and luminance data is taken from the Wide subset.

Exemplary process for fusing a zoom image

1. Special demosaicing

In this step, the Wide image is interpolated to reconstruct the missing pixel values. Standard demosaicing is applied in the non-overlap area. If the overlap area includes a standard CFA, standard demosaicing is applied there as well. If the overlap area includes a non-standard CFA, a special demosaicing algorithm is applied, depending on the CFA pattern used. In addition, in case the Tele sensor has a CFA, standard demosaicing is applied to reconstruct the missing pixel values in each pixel location and to generate a full RGB color image.

2. Registration preparation

- Tele image: a luminance image $Luma_{Tele}$ is calculated from the Tele sensor pixels. If the Tele subset has a Clear sensor, $Luma_{Tele}$ is simply the sensor pixels data. If the Tele subset has a standard CFA, $Luma_{Tele}$ is calculated from the demosaiced Tele image.
- Wide image: as a first step, in case the Wide overlap CFA permits estimating the luminance component of the image, the luminance component is calculated from the demosaiced Wide image, $Luma_{Wide}$. If the CFA is one of those depicted in FIGS. 4-9, a luminance image is calculated first. If the CFA is one of the CFAs depicted in FIG. 2 or FIG. 3, a luminance image is not calculated. Instead, the following registration step is performed between a weighted average of the demosaiced channels of the Wide image and $Luma_{Tele}$. For convenience, this weighted average image is also denoted $Luma_{Wide}$. For example, if the Wide sensor CFA in the overlap region is as shown in FIG. 2, the demosaiced channels R_{Wide} and B_{Wide} are averaged to create $Luma_{Wide}$ according to $Luma_{Wide} = (f1*R_{Wide}+f2*B_{Wide})/(f1+f2)$, where f1 may be f1=1 and f2 may be f2=1.
- Low-pass filtering is applied on the Tele luminance image in order to match its spatial frequency content to that of the $Luma_{Wide}$ image. This improves the registration performance, as after low-pass filtering the luminance images become more similar. The calculation is $Luma_{Tele} \rightarrow$ Low pass filter $\rightarrow Luma_{Tele}^{LP}$, where "LP" denotes an image after low pass filtering.

3. Registration of $Luma_{Wide}$ and $Luma_{Tele}^{LP}$

This step of the algorithm calculates the mapping between the overlap areas in the two luminance images. The registration step does not depend on the type of CFA used (or the lack thereof), as it is applied on luminance images. The same registration step can therefore be applied on Wide and Tele images captured by standard CFA sensors, as well as by any combination of CFAs or Clear sensor pixels disclosed herein. The registration process chooses either the Wide image or the Tele image to be a primary image. The other image is defined as an auxiliary image. The registration process considers the primary image as the baseline image and registers the overlap area in the auxiliary image to it, by finding for each pixel in the overlap area of the primary image its corresponding pixel in the auxiliary image. The output image point of view is determined according to the primary image point of view (camera angle). Various correspondence metrics could be used for this purpose, among which are a sum of absolute differences and correlation.

In an embodiment, the choice of the Wide image or the Tele image as the primary and auxiliary images is based on the ZF chosen for the output image. If the chosen ZF is larger than the ratio between the focal-lengths of the Tele and Wide cameras, the Tele image is set to be the primary image and the Wide image is set to be the auxiliary image. If the chosen ZF is smaller than or equal to the ratio between the focal-lengths of the Tele and Wide cameras, the Wide image is set to be the primary image and the Tele image is set to be the auxiliary image. In another embodiment independent of a zoom factor, the Wide image is always the primary image and the Tele image is always the auxiliary image. The output of the registration stage is a map relating Wide image pixels indices to matching Tele image pixels indices.

4. Combination into a high resolution image

In this final step, the primary and auxiliary images are used to produce a high resolution image. One can distinguish between several cases:

a. If the Wide image is the primary image, and the Tele image was generated from a Clear sensor, $Luma_{Wide}$ is calculated and replaced or averaged with $Luma_{Tele}$ in the overlap area between the two images to create a luminance output image, matching corresponding pixels according to the registration map $Luma_{Out} = c1 * Luma_{Wide} + c2 * Luma_{Tele}$. The values of c1 and c2 may change between different pixels in the image. Then, RGB values of the output are calculated from $Luma_{Out}$ and R_{Wide}, G_{Wide}, and B_{Wide}.

b. If the Wide image is the primary image and the Tele image was generated from a CFA sensor, $Luma_{Tele}$ is calculated and is combined with $Luma_{Wide}$ in the overlap area between the two images, according to the flow described in 4a.

c. If the Tele image is the primary image generated from a Clear sensor, the RGB values of the output are calculated from the $Luma_{Tele}$ image and R_{Wide}, G_{Wide}, and B_{Wide} (matching pixels according to the registration map).

d. If the Tele image is the primary image generated from a CFA sensor, the RGB values of the output (matching pixels according to the registration map) are calculated either by using only the Tele image data, or by also combining data from the Wide image. The choice depends on the zoom factor.

Certain portions of the registered Wide and Tele images are used to generate the output image based on the ZF of the output image. In an embodiment, if the ZF of the output image defines a FOV smaller than the Tele FOV, the fused high resolution image is cropped to the required field of view and digital interpolation is applied to scale up the image to the required output image resolution.

Exemplary and non-limiting pixel interpolations specifications for the overlap area

FIG. 2

B11	B12	R13
R21	B22	B23
R31	R32	B33

In order to reconstruct the missing R22 pixel, we perform R22 = (R31+R13)/2. The same operation is performed for all missing Blue pixels.

FIG. 3

R11	B12	R13
B21	R22	B23
R31	B32	R33

In order to reconstruct the missing B22 pixel, we perform B22 = (B12+B21+B32+B23)/4. The same operation is performed for all missing Red pixels.

FIG. 4

Y11	C12	Y13
C21	Y22	C23
Y31	C32	Y33

In order to reconstruct the missing C22 pixel, we perform C22 = (C12+C21+C32+C23)/4. The same operation is performed for all missing Yellow pixels.

FIG. 5

Case 1: W is center pixel

R11	B12	B13
R21	W22	R23
B31	B32	R33

In order to reconstruct the missing 22 pixels, we perform the following:

B22 = (B12+B32)/2

R22 = (R21+R23)/2

G22= (W22-R22-B22) (assuming that W includes the same amount of R, G and B colors).

Case 2: R22 is center pixel

B11	B12	R13	R14
W21	R22	B23	W24
B31	R32	B33	R34

In order to reconstruct the missing 22 pixels, we perform the following:

B22 = (B11+R33)/2

W22 = (2*W21+W24)/3

G22 = (W22-R22-B22) (assuming that W contains the same amount of R, G and B colors). The same operation is performed for Blue as the center pixel.

FIG. 6

B11	B12	G13	R14
R21	G22	R23	B24
G31	B32	R33	G34
R41	R42	G43	B44

In order to reconstruct the missing 22 pixels, we perform the following:

B22 = (B12+B32)/2

R22 = (R21+R23)/2.

In order to reconstruct the missing 32 pixels, we perform the following:

G32 = (2*G31+2*G22+G43)/5

R32 = (R41+2*R42+2*R33+R23+R21)/7.

FIG. 7

G11	B12	R13	G14
R21	G22	B23	R24
B31	R32	G33	B34
G41	B42	R43	G44

In order to reconstruct the missing 22 pixels, we perform the following:

B22 = (2*B12+2*B23+B31)/5

R22 = (2*R21+2*R32+R13)/5

and similarly for all other missing pixels.

FIG. 8

R11	B12	B13	R14
R21	G22	R23	B24
B31	B32	R33	B34
R41	R42	B43	R44
B51	G52	B53	R54

In order to reconstruct the missing 22 pixels, we perform the following:

B22 = (2*B12+2*B32+B13)/5

R22 = (2*R21+2*R23+R11)/5.

In order to reconstruct the missing 32 pixels, we perform the following:

G32 = (2*G22+G52)/3

R32 = (2*R33+2*R42+R41+R21+R23)/7.

FIG. 9

R11	B12	R13	B14
B21	G22	B23	R24
R31	B32	R33	B34
B41	R42	B43	R44
R51	G52	R53	B54

In order to reconstruct the missing 22 pixels, we perform the following:

B22 = (B12+B32+B23+B21)/4

R22 = (R11+R13+R31+R33)/4.

In order to reconstruct the missing 32 pixels, we perform the following:

G32 = (2*G22+G52)/3

R32 = (R42+R31+R33)/3.

Triple-aperture zoom imaging system with improved color resolution

As mentioned, a multi-aperture zoom or non-zoom imaging system disclosed herein may include more than two apertures. A non-limiting and exemplary embodiment **1100** of a triple-aperture imaging system is shown in FIGS. 11A-11B. System **1100** includes a first Wide subset camera **1102** (with exemplarily X1), a second Wide subset camera (with exemplarily

X1.5, and referred to as a "Wide-Tele" subset) and a Tele subset camera (with exemplarily X2). FIG. 11A shows exemplary images captured by imaging system **1100**, while FIG. 11B illustrates schematically three sensors marked **1102**, **1104** and **1106**, which belong respectively to the Wide, Wide-Tele and Tele subsets. FIG. 11B also shows the CFA arrangements in each sensor: sensors **1102** and **1104** are similar to Wide sensors described above with reference to any of FIGS. 2-9, in the sense that they include an overlap area and a non-overlap area. The overlap area includes a non-standard CFA. In both Wide sensors, the non-overlap area may have a Clear pattern or a standard CFA. Thus, neither Wide subset is solely a Clear channel camera. The Tele sensor may be Clear or have a standard Bayer CFA or a standard non-Bayer CFA. In use, an image is acquired with imaging system **1100** and processed as follows: demosaicing is performed on the overlap area pixels of the Wide and Wide-Tele sensors according to the specific CFA pattern in each overlap area. The overlap and non-overlap subsets of pixels in each of these sensors may need different demosaicing. Exemplary and non-limiting demosaicing specifications for the overlap area for Wide sensors shown in FIGS. 2-9 are given above. The aim is to reconstruct the missing colors in each and every pixel. In cases in which the Tele subset sensor is not Clear only, demosaicing is performed as well. The Wide and Wide-Tele subset color images acquired this way will have colors (in the overlap area) holding higher resolution than that of a standard CFA pattern. Then, the Tele image acquired with the Tele sensor is registered (mapped) into the respective Wide image. The data from the Wide, Wide-Tele and Tele images is then processed to form a high quality zoom image. In cases where the Tele subset is Clear only, high Luma resolution is taken from the Tele sensor and color resolution is taken from the Wide sensor. In cases where the Tele subset includes a CFA, both color and Luma resolution is taken from the Tele subset. In addition, color resolution is taken from the Wide sensor. The resolution of the fused image may be higher than the resolution of both sensors.

While this disclosure has been described in terms of certain embodiments and generally associated methods, alterations and permutations of the embodiments and methods will be apparent to those skilled in the art. For example, multi-aperture imaging systems with more than two Wide or Wide-Tele subsets (and sensors) or with more than one Tele subset (and sensor) may be constructed and used according to principles set forth herein. Similarly, non-zoom multi-aperture imaging systems with more than two sensors, at least one of which has a non-standard CFA, may be constructed and used according to principles set forth herein. The disclosure is to be understood as not limited by the specific embodiments described herein, but only by the scope of the appended claims.

CLAIMS:

1. A multi-aperture imaging system comprising:

a) a first camera subset that provides a first image, the first camera subset having a first sensor with a first plurality of sensor pixels covered at least in part with a non-standard color filter array (CFA), the non-standard CFA used to increase a specific color sampling rate relative to a same color sampling rate in a standard CFA;

b) a second camera subset that provides a second image, the second camera subset having a second sensor with a second plurality of sensor pixels, the second plurality of sensor pixels being either Clear or covered with a standard CFA; and

c) a processor configured to process the first and second images into a combined output image.

2. The imaging system of claim 1, wherein the non-standard CFA includes a repetition of a 2x2 micro-cell in which a color filter order is either BR-RB or YC-CY.

3. The imaging system of claim 1, wherein the non-standard CFA includes a repetition of a 3x3 micro-cell in which a color filter order is GBR-RGB-BRG.

4. The imaging system of claim 1, wherein the non-standard CFA includes a repetition of a 4x4 micro-cell in which a color filter order is BBRR-RBBR-RRBB-BRRB.

5. The imaging system of claim 1, wherein the non-standard CFA includes a repetition of a 6x6 micro-cell in which a color filter order is selected from the group consisting of RBBRRB-RWRBWB-BBRBRR-RRBRBB-BWBRWR-BRRBBR, BBGRRG-RGRBGB-GBRGRB-RRGBBG-BGBRGR-GRBGBR, RBBRRB-RGRBGB-BBRBRR-RRBRBB-BGBRGR-BRRBBR and RBRBRB-BGBRGR-RBRBRB-BRBRBR-RGRBGB-BRBRBR.

6. The imaging system of any of claims 1-5, wherein the standard CFA includes a Bayer filter.

7. The imaging system of any of claims 1-5, wherein the standard CFA includes a non-Bayer filter.

8. The imaging system of claim 7, wherein the non-Bayer filter is selected from the group consisting of a RGBE, a CYYM, a CYGM, a RGBW#1, a RGBW#2 and a RGBW#3 filter.

9. The imaging system of claim 1, wherein the first and the second camera subsets have identical fields of view and wherein the non-standard CFA covers an overlap area that includes all the pixels of the first sensor, thereby providing increased color resolution.

10. The imaging system of claim 9, wherein the processor is further configured to register respective first and second Luma images obtained from the first and second images during the processing of the first and second images into a combined output image, the registered first and second Luma images used together with color information to form the combined output image.

11. The imaging system of claim 10, wherein the registration includes finding a corresponding pixel in the second Luma image for each pixel in the first Luma image and wherein the processor is further configured to form the output image by transferring information from the second image to the first image.

12. The imaging system of claim 10, wherein the registration includes finding a corresponding pixel in the first Luma image for each pixel in the second Luma image and wherein the processor is further configured to form the output image by transferring information from the first image to the second image.

13. The imaging system of claim 1, wherein the first camera subset has a first field of view (FOV), wherein the second camera subset has a second, smaller FOV than the first FOV, and wherein the non-standard CFA covers an overlap area on the first sensor that captures the second FOV, thereby providing both optical zoom and increased color resolution.

14. The imaging system of claim 13, wherein the processor is further configured to, during the processing of the first and second images into a combined output image and based on a zoom factor (ZF) input, register respective first and second Luma images obtained from the first and second images, the registered first and second Luma images used together with color information to form the combined output image.

15. The imaging system of claim 14, wherein the registration includes, for a ZF input that defines an FOV greater than the second FOV, finding a corresponding pixel in the second Luma image for each pixel in the first Luma image and wherein the processor is further configured to form the output image by transferring information from the second image to the first image.

16. The imaging system of claim 14, wherein the registration includes, for a ZF input that defines an FOV smaller than, or equal to the second FOV, finding a corresponding pixel in the first Luma image for each pixel in the second Luma image and wherein the processor is further configured to form the output image by transferring information from the first image to the second image.

17. The imaging system of claim 13, wherein the second sensor includes a standard CFA and wherein the processing includes, for a ZF input that defines an FOV equal to or smaller than the second FOV, forming the output image based on the second image.

18. The imaging system of any of claims 13-17, wherein the standard CFA includes a Bayer filter.

19. The imaging system of any of claims 13-17, wherein the standard CFA includes a non-Bayer filter.

20. The imaging system of claim 19, wherein the non-Bayer filter is selected from the group consisting of a RGBE, a CYYM, a CYGM, a RGBW#1, a RGBW#2 and a RGBW#3 filter.

21. A multi-aperture imaging system comprising:

a) a first camera subset that provides a first image, the first camera subset having a first sensor with a first plurality of sensor pixels covered at least in part with a standard CFA;

b) a second camera subset that provides a second image, the second camera subset having a second sensor with a second plurality of sensor pixels, the second plurality of sensor pixels being either Clear or covered with a standard CFA; and

c) a processor configured to register first and second Luma images obtained respectively from the first and second images and to process the registered first and second Luma images together with color information into a combined output image.

22. The imaging system of claim 21, wherein the first and the second camera subsets have respectively identical fields of view.

23. The imaging system of claim 22, wherein the registration includes finding a corresponding pixel in the second Luma image for each pixel in the first Luma image and wherein the processor is further configured to form the output image by transferring information from the second image to the first image.

24. The imaging system of claim 22, wherein the registration includes finding a corresponding pixel in the first Luma image for each pixel in the second Luma image and wherein the processor is further configured to form the output image by transferring information from the first image to the second image.

25. The imaging system of claim 21, wherein the first camera subset has a first field of view (FOV), wherein the second camera subset has a second, smaller FOV than the first FOV, and wherein the processor is further configured to register the first and second Luma images based on a zoom factor (ZF) input.

26. The imaging system of claim 25, wherein the registration includes, for a ZF input that defines an FOV greater than the second FOV, finding a corresponding pixel in the second Luma image for each pixel in the first Luma image and wherein the processor is further configured to form the output image by transferring information from the second image to the first image.

27. The imaging system of claim 25, wherein the registration includes, for a ZF input that defines an FOV smaller than, or equal to the second FOV, finding a corresponding pixel in the first Luma image for each pixel in the second Luma image and wherein the processor is further configured to form the output image by transferring information from the first image to the second image.

28. The imaging system of claim 25, wherein the second sensor includes a standard CFA and wherein, for a ZF input that defines an FOV equal to or smaller than the second FOV, the processor is further configured to form the output image based on the second image.

29. The imaging system of any of claims 21-28, wherein the standard CFA includes a Bayer filter.

30. The imaging system of any of claims 21-28, wherein the standard CFA includes a non-Bayer filter.

31. The imaging system of claim 30, wherein the non-Bayer filter is selected from the group consisting of a RGBE, a CYYM, a CYGM, a RGBW#1, a RGBW#2 and a RGBW#3 filter.

32. A multi-aperture imaging system comprising:

a) a first camera subset that provides a first image, the first camera subset having a first field of view (FOV) and first sensor with a first plurality of sensor pixels covered at least in part with a standard CFA;

b) a second camera subset that provides a second image, the second camera subset having a second, smaller FOV than the first FOV and a second sensor with a second plurality of sensor pixels covered with a standard CFA; and

c) a processor configured to, for a zoom factor input that defines an FOV equal to or smaller than the second FOV, form an output image based on the second image.

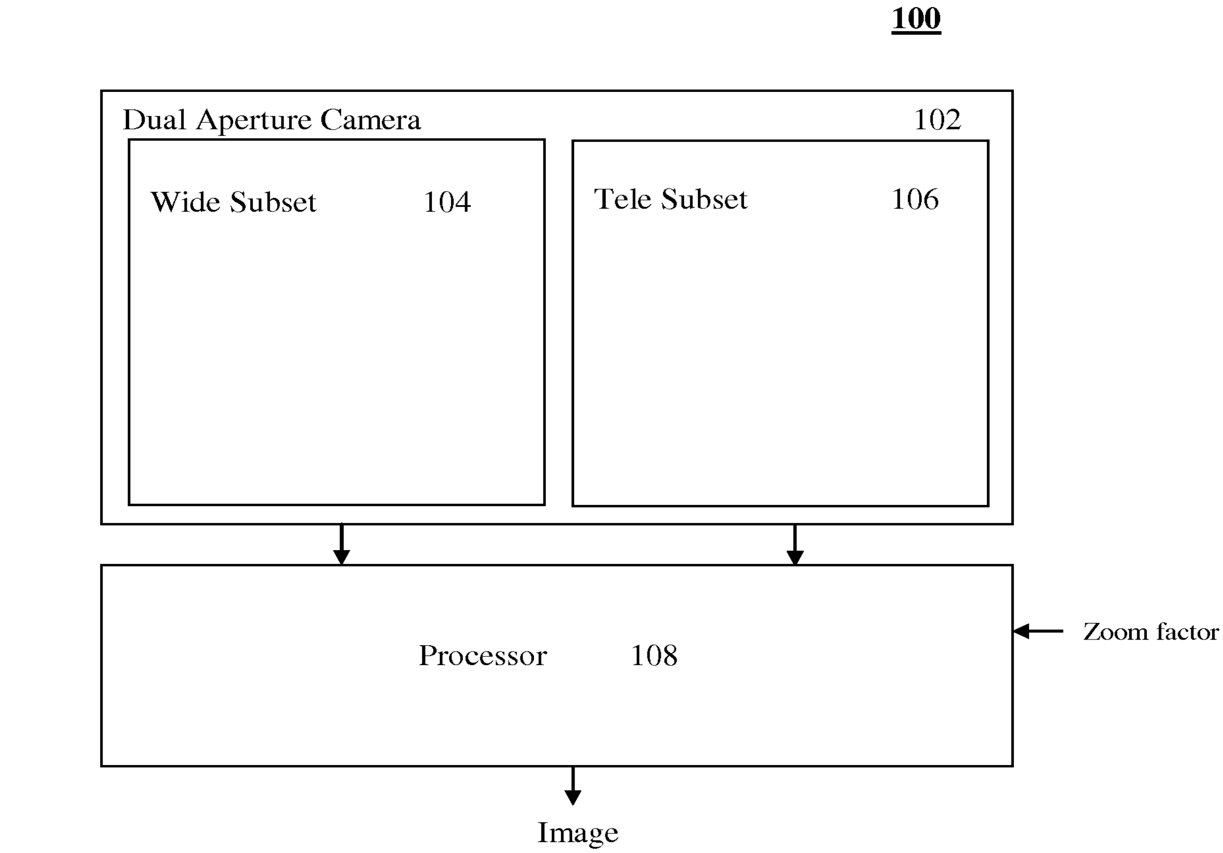
100
Dual Aperture Camera
102
Wide Subset
104
Tele Subset
106
Processor
108
Zoom factor
Image

FIG. 1A

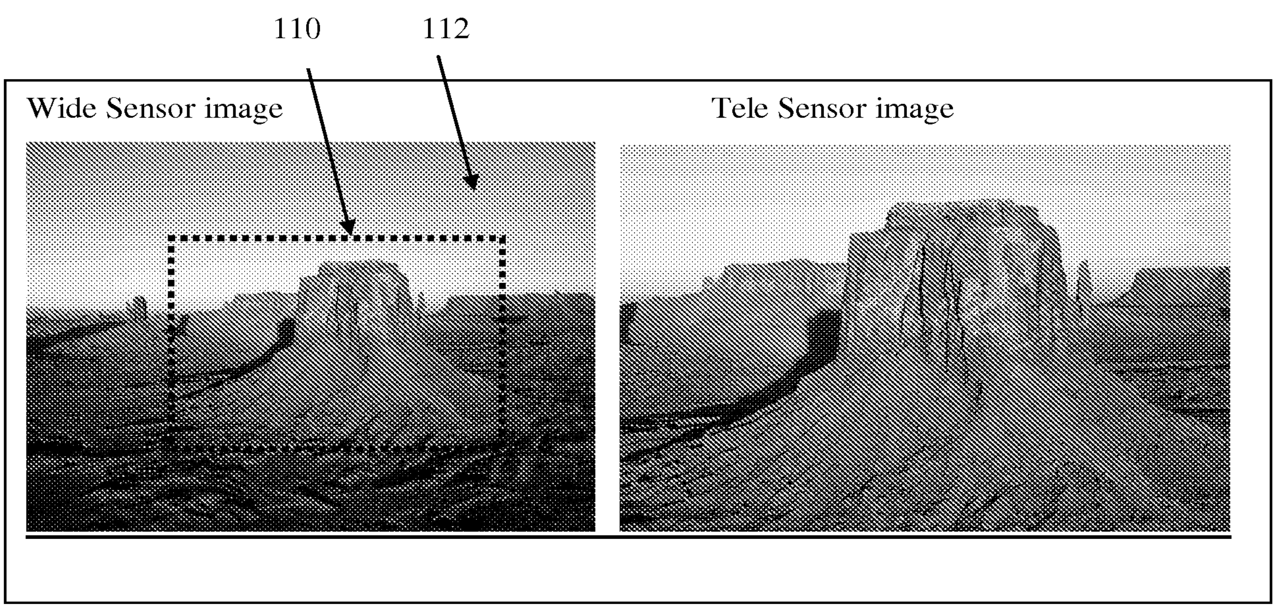
110
112
Wide Sensor image
Tele Sensor image

FIG. 1B

200

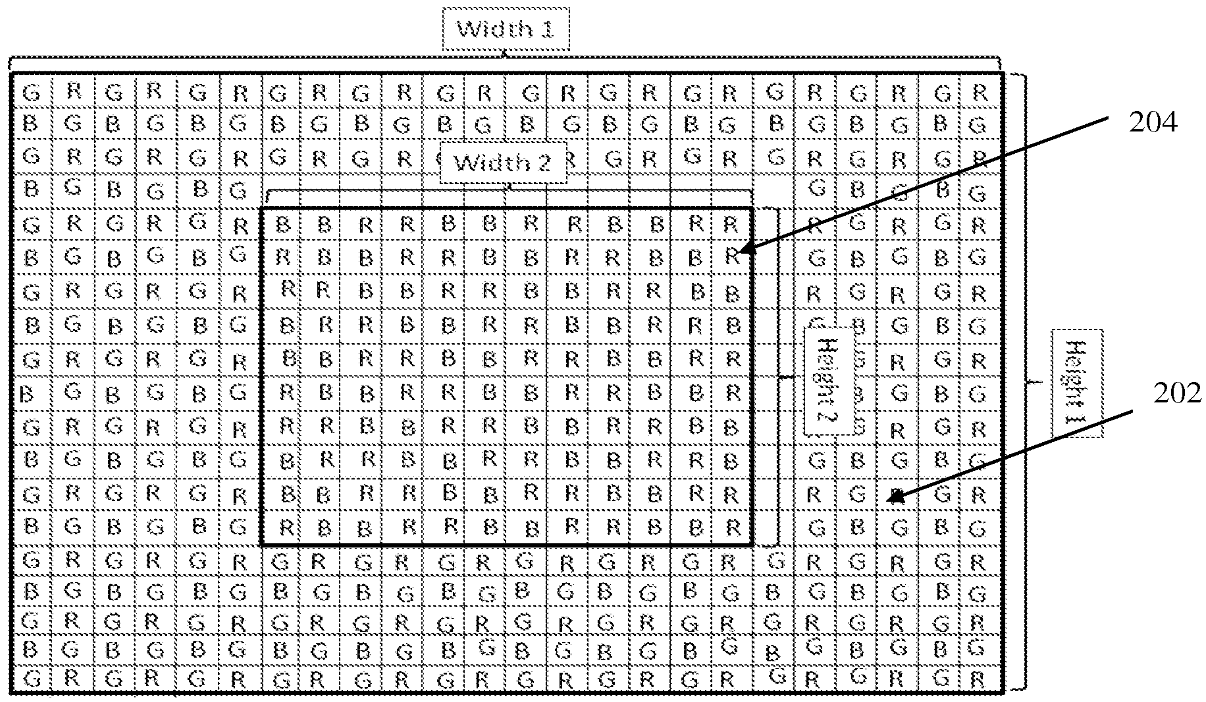

FIG. 2

300

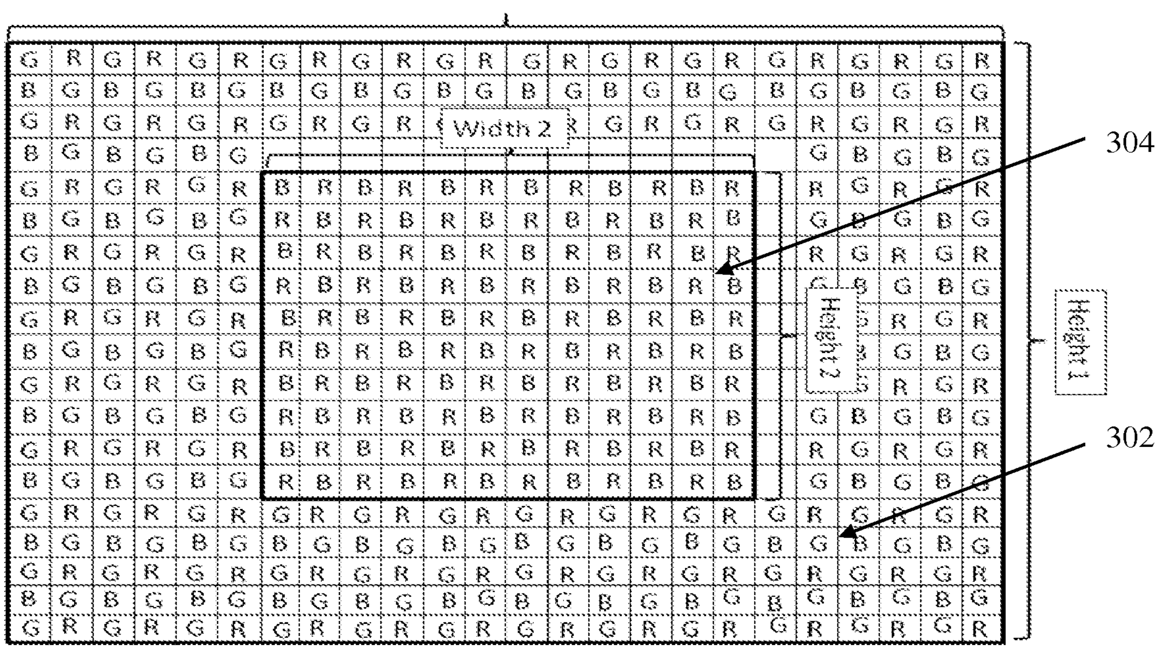

FIG. 3

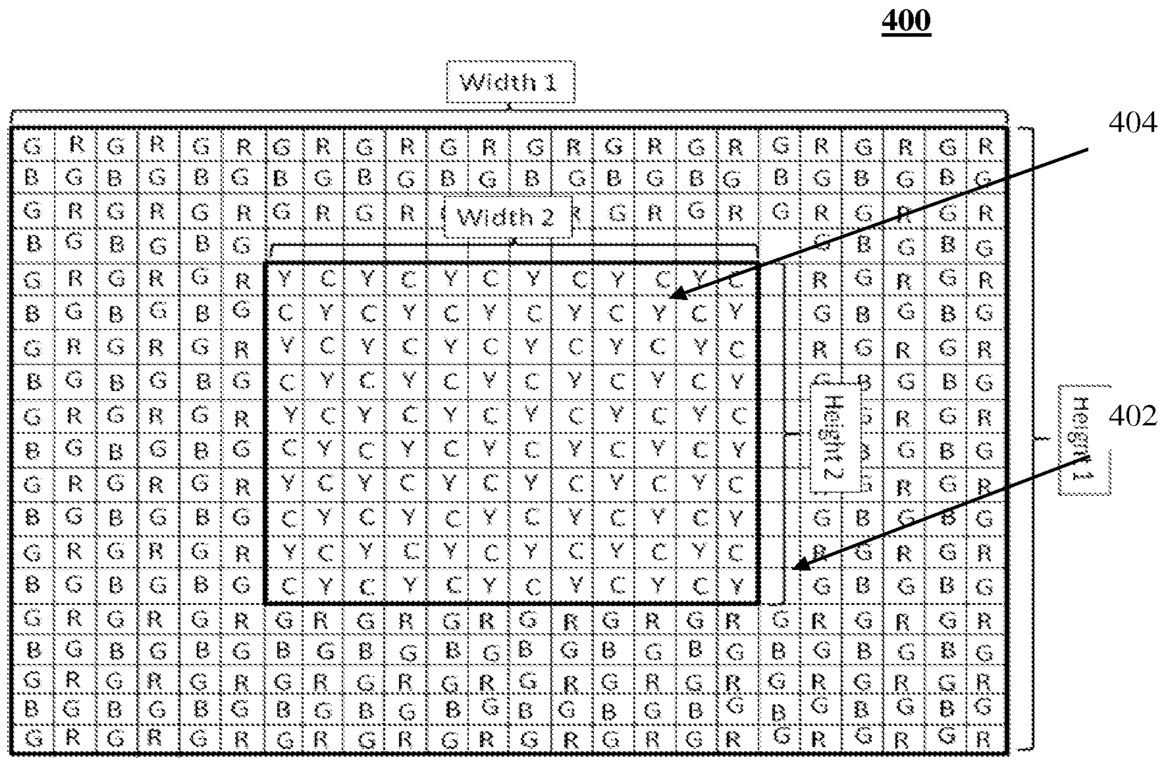
400
Width 1
Width 2
Height 2
Height 1
404
402

FIG. 4

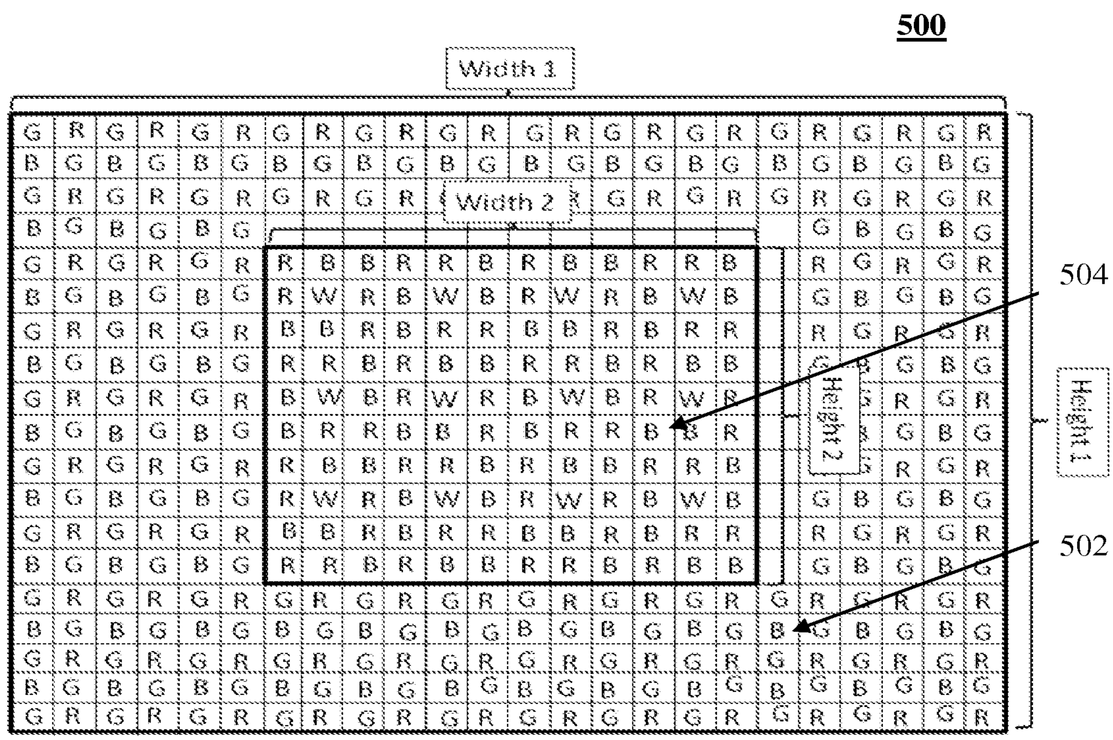
500
Width 1
Width 2
Height 2
Height 1
504
502

FIG. 5

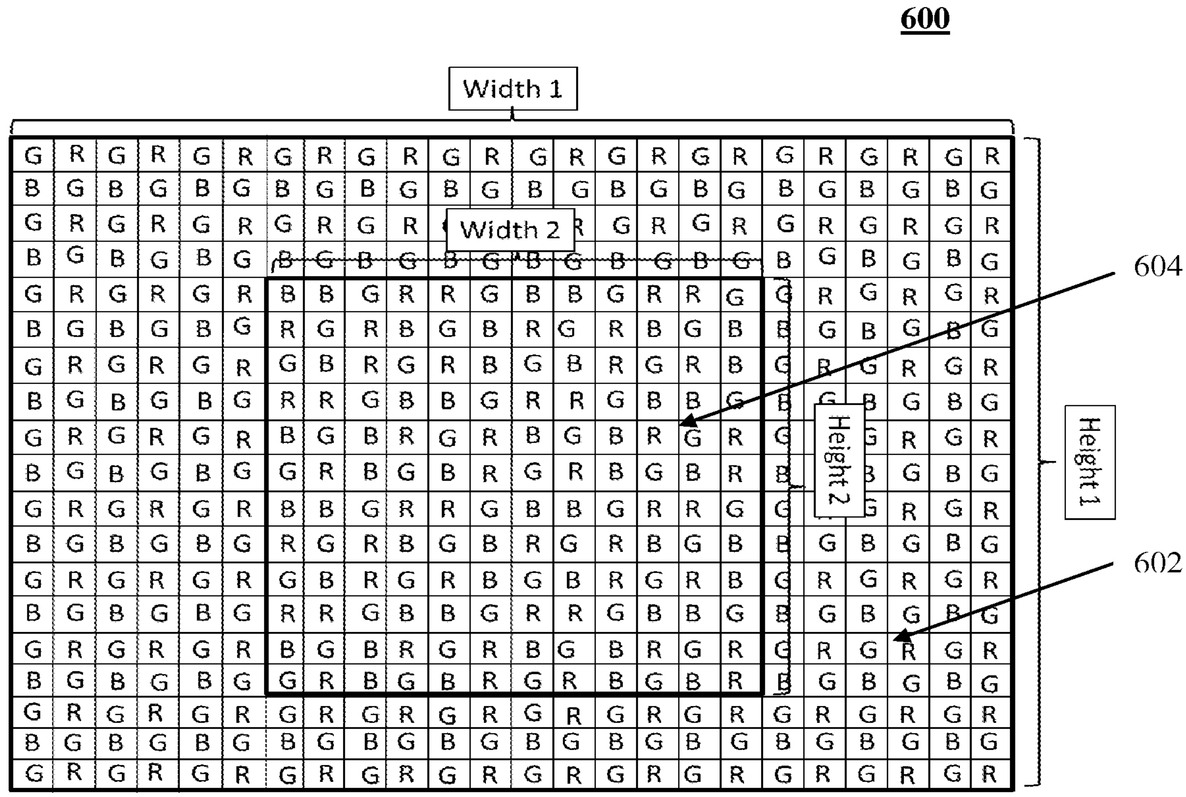
600
Width 1
Width 2
Height 1
Height 2
604
602

FIG. 6

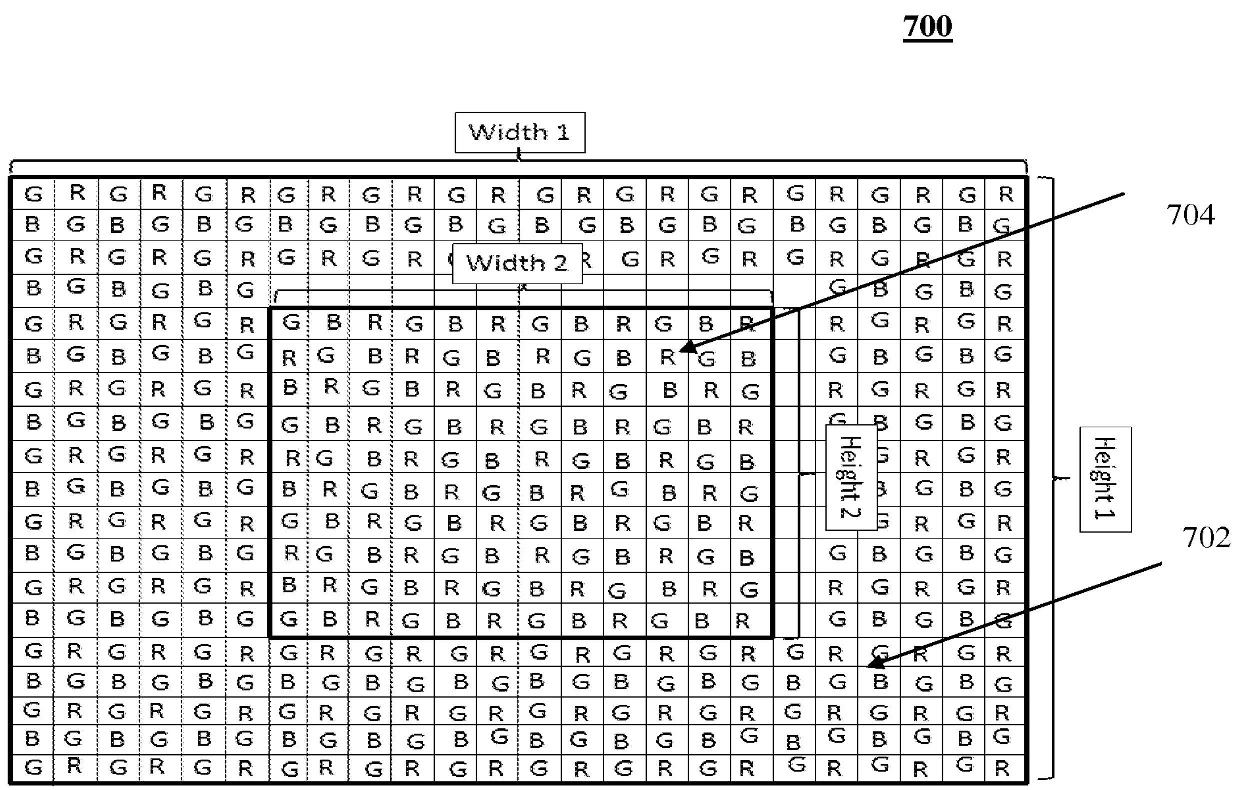
700
Width 1
Width 2
Height 1
Height 2
704
702

FIG. 7

800

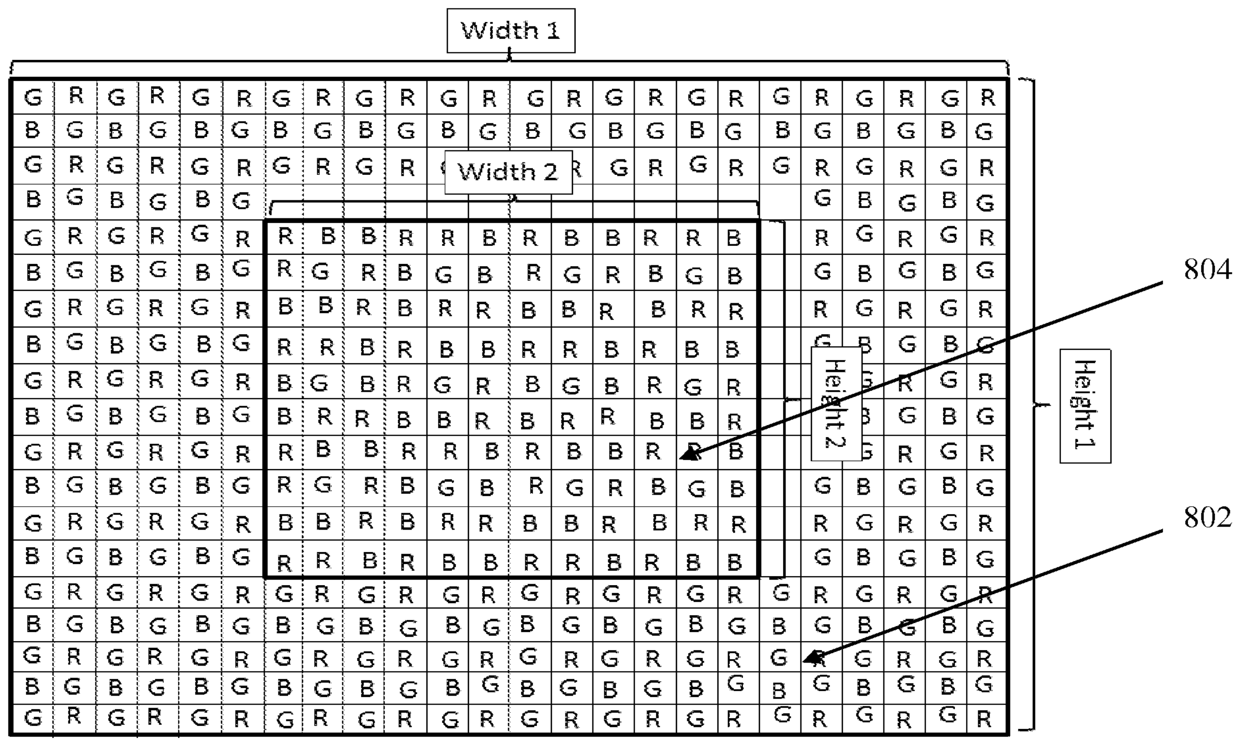

FIG. 8

900

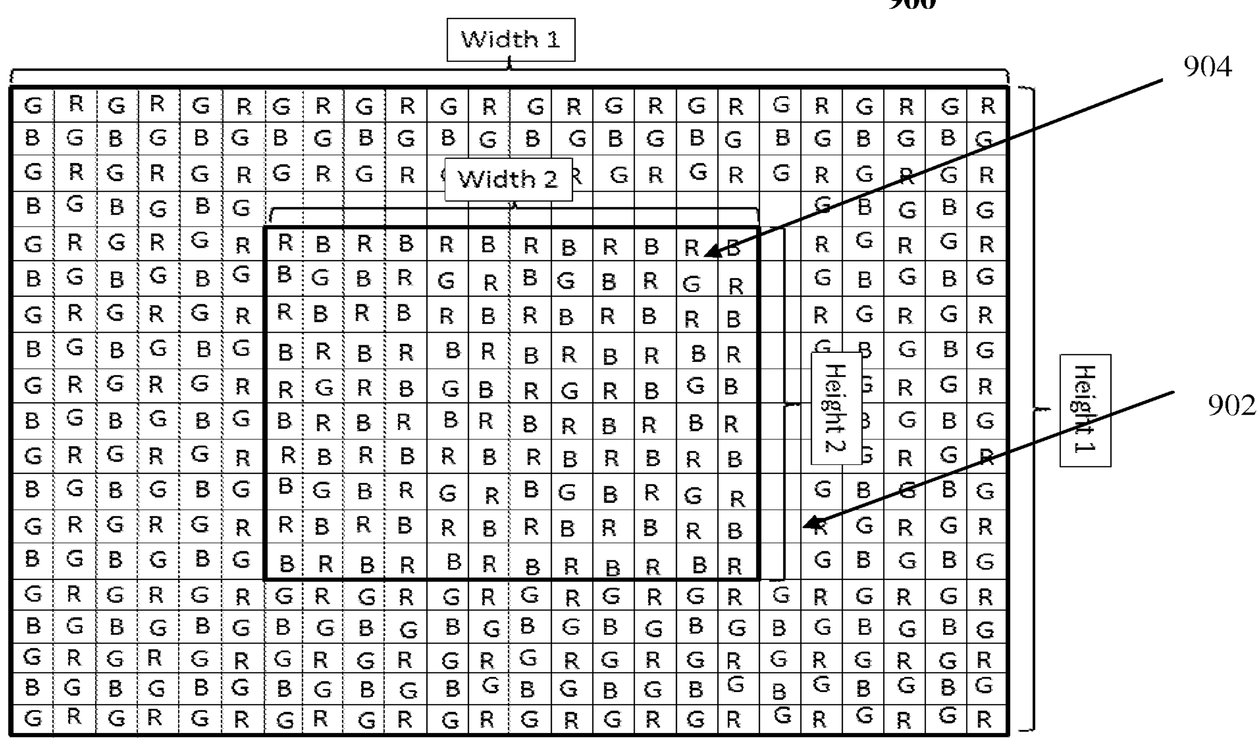

FIG. 9

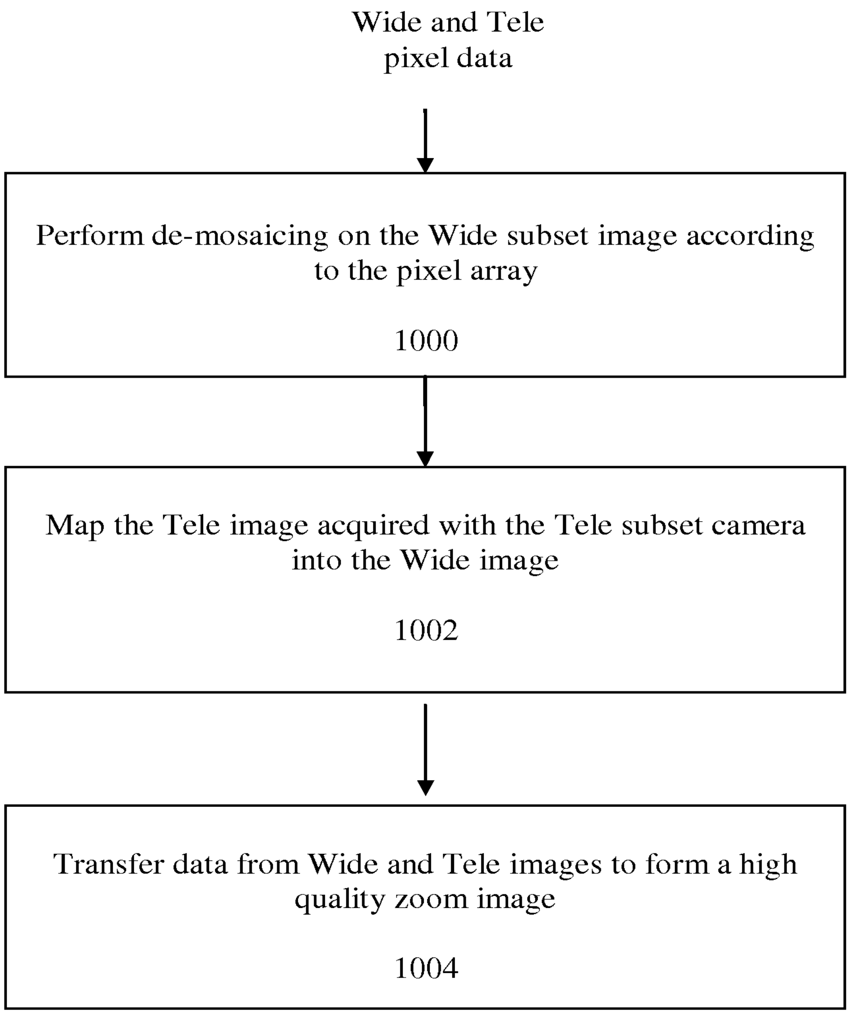
Wide and Tele
pixel data
Perform de-mosaicing on the Wide subset image according to the pixel array
1000
Map the Tele image acquired with the Tele subset camera into the Wide image
1002
Transfer data from Wide and Tele images to form a high quality zoom image
1004

FIG. 10

1100

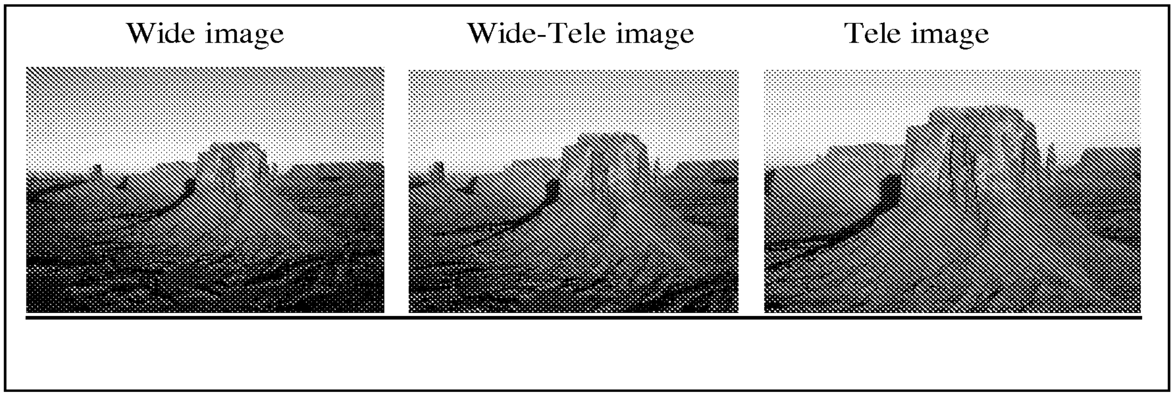

FIG. 11A

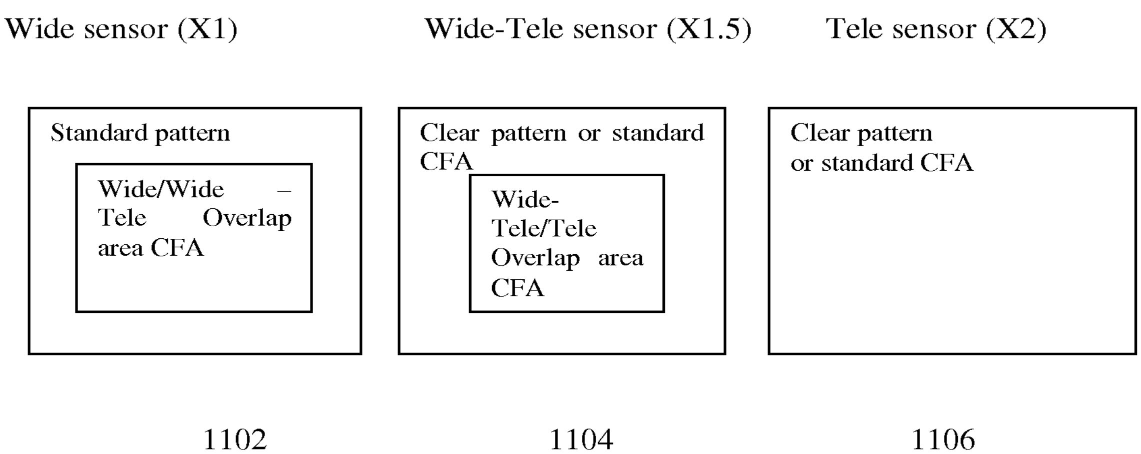

FIG. 11B

INTERNATIONAL SEARCH REPORT

International application No.
PCT/IB2013/060356

A. CLASSIFICATION OF SUBJECT MATTER
IPC(8) - H04N 9/09 (2014.01)
USPC - 348/277
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(8) - G06T 5/00; H01L 27/146; H04N 9/04, H04N 9/09, H04N 9/097 (2014.01)
USPC - 348/273, 348/274, 348/277, 348/279, 348/281, 348/283, 348/302

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched
CPC - G06T 2207/10148, G06T 2207/20221; G06T 3/4015; G06T 5/50; H01L 27/14621; H04N 9/04 (2013.01)

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)
PatBase, TotalPatent, Google Patents, Google Scholar

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 2011/0064327 A1 (DAGHER et al) 17 March 2011 (17.03.2011) entire document	21-29,32 ----- 1-20,30,31
Y	US 8,134,115 B2 (KOSKINEN et al) 13 March 2012 (13.03.2012) entire document	1-20,30,31
Y	US 8,094,208 B2 (MYHRVOLD) 10 January 2012 (10.01.2012) entire document	2-5
A	WO 2009/097552 A1 (DAGHER et al) 06 August 2009 (06.08.2009) entire document	1-32
A	US 8,179,457 B2 (KOSKINEN et al) 15 May 2012 (15.05.2012) entire document	1-32
A	US 2011/0285730 A1 (LAI et al) 24 November 2011 (24.11.2011) entire document	1-32
A	US 2011/0121421 A1 (CHARBON et al) 26 May 2011 (26.05.2011) entire document	1-32
A	US 2011/0292258 A1 (ADLER et al) 01 December 2011 (01.12.2011) entire document	1-32

☐ 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
27 March 2014	17 APR 2014

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	Blaine R. Copenheaver PCT Helpdesk: 571-272-4300 PCT OSP: 571-272-7774

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

PATENT COOPERATION TREATY

From the
INTERNATIONAL SEARCHING AUTHORITY

To: GAL SHABTAY
NATHAN & ASSOCIATES PATENT AGENTS LTD.
P.O. BOX 10178
6110101 TEL AVIV
ISRAEL

PCT

WRITTEN OPINION OF THE
INTERNATIONAL SEARCHING AUTHORITY

(PCT Rule 43*bis*.1)

Applicant's or agent's file reference: COREPH-72	Date of mailing (*day/month/year*): 17 APR 2014	
	FOR FURTHER ACTION See paragraph 2 below	
International application No.: PCT/IB2013/060356	International filing date (*day/month/year*): 23 November 2013	Priority date (*day/month/year*): 28 November 2012
International Patent Classification (IPC) or both national classification and IPC: IPC(8) - H04N9/09 (2014.01) USPC - 348/277		
Applicant: COREPHOTONICS LTD.		

1. This opinion contains indications relating to the following items:

- [x] Box No. I Basis of the opinion
- [ ] Box No. II Priority
- [ ] Box No. III Non-establishment of opinion with regard to novelty, inventive step and industrial applicability
- [ ] Box No. IV Lack of unity of invention
- [x] Box No. V Reasoned statement under Rule 43*bis*.1(a)(i) with regard to novelty, inventive step or industrial applicability; citations and explanations supporting such statement
- [ ] Box No. VI Certain documents cited
- [ ] Box No. VII Certain defects in the international application
- [ ] Box No. VIII Certain observations on the international application

2. **FURTHER ACTION**

If a demand for international preliminary examination is made, this opinion will be considered to be a written opinion of the International Preliminary Examining Authority ("IPEA") except that this does not apply where the applicant chooses an Authority other than this one to be the IPEA and the chosen IPEA has notified the International Bureau under Rule 66.1*bis*(b) that written opinions of this International Searching Authority will not be so considered.

If this opinion is, as provided above, considered to be a written opinion of the IPEA, the applicant is invited to submit to the IPEA a written reply together, where appropriate, with amendments, before the expiration of 3 months from the date of mailing of Form PCT/ISA/220 or before the expiration of 22 months from the priority date, whichever expires later.

For further options, see Form PCT/ISA/220.

Name and mailing address of the ISA/US Mail Stop PCT, Attn: ISA/US Commissioner for Patents P.O. Box 1450, Alexandria, Virginia 22313-1450 Facsimile No. 571-273-3201	Date of completion of this opinion 27 March 2014	Authorized officer: Blaine R. Copenheaver PCT Helpdesk: 571-272-4300 PCT OSP: 571-272-7774

Form PCT/ISA/237 (cover sheet) (July 2011)

WRITTEN OPINION OF THE INTERNATIONAL SEARCHING AUTHORITY

International application No.
PCT/IB2013/060356

Box No. I Basis of this opinion

1. With regard to the **language**, this opinion has been established on the basis of:
   - [X] the international application in the language in which it was filed.
   - [ ] a translation of the international application into ______________ which is the language of a translation furnished for the purposes of international search (Rules 12.3(a) and 23.1(b)).

2. [ ] This opinion has been established taking into account the **rectification of an obvious mistake** authorized by or notified to this Authority under Rule 91 (Rule 43*bis*.1(a))

3. With regard to any **nucleotide and/or amino acid sequence** disclosed in the international application, this opinion has been established on the basis of a sequence listing filed or furnished:

   a. (means)
   - [ ] on paper
   - [ ] in electronic form

   b. (time)
   - [ ] in the international application as filed
   - [ ] together with the international application in electronic form
   - [ ] subsequently to this Authority for the purposes of search

4. [ ] In addition, in the case that more than one version or copy of a sequence listing has been filed or furnished, the required statements that the information in the subsequent or additional copies is identical to that in the application as filed or does not go beyond the application as filed, as appropriate, were furnished.

5. Additional comments:

WRITTEN OPINION OF THE INTERNATIONAL SEARCHING AUTHORITY	International application No. PCT/IB2013/060356

Box No. V Reasoned statement under Rule 43*bis*.1(a)(i) with regard to novelty, inventive step or industrial applicability; citations and explanations supporting such statement

1. Statement

Novelty (N)	Claims	1-20,30,31	YES
	Claims	21-29,32	NO
Inventive step (IS)	Claims	None	YES
	Claims	1-32	NO
Industrial applicability (IA)	Claims	1-32	YES
	Claims	None	NO

2. Citations and explanations:

Claims 21-29, 32 lack lack novelty under PCT Article 33(2) as being anticipated by Dagher et al. (US 2011/0064327 A1), hereinafter Dagher.

Regarding claim 21, Dagher teaches a multi-aperture imaging system (... multi-aperture camera systems with the imaging characteristics [0041]-[0042], Fig.1; multi-aperture camera Fig.3) comprising:
a) a first camera subset that provides a first image, the first camera subset having a first sensor with a first plurality of sensor pixels (... A scene (5) is imaged by two cameras (10) and (12) that image fields of view (20) and (22)... cameras (10) and (12) may be... sub-cameras of a single multi-aperture camera [0046], Fig.1, Fig.2; ... It is contemplated that sensors of sub-cameras of a single multi-aperture camera may be shared in any manner... blocks of pixels adjacent one another in a single sensor chip... not limited to having identical shapes or sizes [0049], Fig.2; ... multi-aperture camera (100), each of first and second optical sub-systems (110) and (120) is shown imaging onto its own sensor (i.e., sensors (130) and (140), respectively) [0067], Fig.2) covered at least in part with a standard CFA (... Image sensors often utilize a Red-Green-Blue ("RGB") color filter array ("CFA"), such as a Bayer pattern... in FIG. 8, both the tele and the wide images are converted from RGB to YUV [0063], Fig.8; ... a CFA such as a Bayer filter, or be formed of individual color sensor elements (e.g., RGB or Cyan-Magenta-Yellow ("CMY")) [0067]);
b) a second camera subset that provides a second image, the second camera subset having a second sensor with a second plurality of sensor pixels (... A scene (5) is imaged by two cameras (10) and (12) that image fields of view (20) and (22)... cameras (10) and (12) may be... sub-cameras of a single multi-aperture camera [0046], Fig.1, Fig.2; ... It is contemplated that sensors of sub-cameras of a single multi-aperture camera may be shared in any manner... blocks of pixels adjacent one another in a single sensor chip... not limited to having identical shapes or sizes [0049], Fig.2; ... multi-aperture camera (100), each of first and second optical sub-systems (110) and (120) is shown imaging onto its own sensor (i.e., sensors (130) and (140), respectively) [0067], Fig.2), the second plurality of sensor pixels being either Clear or covered with a standard CFA (... Image sensors often utilize a Red-Green-Blue ("RGB") color filter array ("CFA"), such as a Bayer pattern... in FIG. 8, both the tele and the wide images are converted from RGB to YUV... the tele sub-camera may utilize an image sensor that does not have a color filter array... to utilize its entire sensor area [0063], Fig.8); and
c) a processor (... Multi aperture camera (100) provides first and second sets of image data (301) and (302) to a processor (166) which may, for example, be configured for combining or "fusing" the image data sets... to an image output device (167) [0053], Fig.3) configured to register first and second Luma images obtained respectively from the first and second images and to process the registered first and second Luma images together with color information into a combined output image (... FIG.8, both the tele and wide images are converted from RGB to YUV... one luminance (Y) channel and two chrominance channels (U, V) [0063], Fig.8; ... Process (338)... may be applied to full color images... an image registration procedure (342) is applied [0065], Fig.9; ... fusion of image data... may involve addition of color information from a color sub-camera image to luminance information from a grayscale sub-camera image... a complementary operation may be performed where luminance information from the grayscale sub-camera is added to the color image from the color sub-camera... FIG. 11, which illustrates an exemplary process (365) that utilizes processor (166) (see FIG. 3) for fusion of image data [0073]-[0077], Fig.11; ... a grayscale sub-camera generally produces only a luminance signal (e.g., Y information [0067]).
[The term "Luma" is synonymous with "luminance".]

Regarding claim 22, Dagher teaches the imaging system of claim 21 (... multi-aperture camera systems with the imaging characteristics [0041]-[0042], Fig.1; multi-aperture camera Fig.3), wherein the first and the second camera subsets (... cameras (10) and (12) may be... sub-cameras of a single multi-aperture camera [0046], Fig.1, Fig.2; ... It is contemplated that sensors of sub-cameras of a single multi-aperture camera may be shared in any manner... blocks of pixels adjacent one another in a single sensor chip... not limited to having identical shapes or sizes [0049]) have respectively identical fields of view (In a particular aspect, configuring the first sub-camera may include establishing a first focal length... configuring the second camera may include establishing a second focal length... The second focal length may be different than the first focal length such that the second camera exhibits a different field of view as compared to the first camera [0013]; ... each optical sub-system may have a different focal length resulting in different fields of view [0048], Fig.2).
[The first and second sub-cameras may have identical focal lengths and therefore identical fields of view.]

Supplemental Box

In case **the space in any of the preceding boxes is not sufficient.**
Continuation of:

Regarding claim 23, Dagher teaches the imaging system of claim 22 (... multi-aperture camera systems with the imaging characteristics [0041]-[0042], Fig.1; multi-aperture camera Fig.3), wherein the registration includes finding a corresponding pixel in the second Luma image for each pixel in the first Luma image (... Process (338)... may be applied to full color images... an image registration procedure (342) is applied [0065], Fig.9; ... FIG. 11, which illustrates an exemplary process (365) that utilizes processor (166) (see FIG. 3) for fusion of image data [0073]-[0077], Fig.11; ... image may be divided into overlapping or non-overlapping blocks of size Kx x Ky (i.e., Kx pixels in an x-direction and Ky pixels in a y-direction) [0083], Fig.12; ... knowledge of the sub-camera geometry for a multi-aperture camera (e.g., first and second sub-cameras (150) and (160) of FIG. 2B) and its sensor(s)... it is possible to estimate a parallax shift between the two or more sub-cameras [0084]; ... image registration step (369) (see FIG. 11) implemented with a block-wise sliding window transform [0090], Fig.13; ... image fusion step (373) (see FIG. 11)... registration information computed in image registration step (369)... may be 'merged' [0098], Fig.15) and wherein the processor is further configured to form the output image by transferring information from the second image to the first image (... Process (338)... may be applied to full color images... an image registration procedure (342) is applied [0065], Fig.9; ... fusion of image data... may involve addition of color information from a color sub-camera image to luminance information from a grayscale sub-camera image... a complementary operation may be performed where luminance information from the grayscale sub-camera is added to the color image from the color sub-camera... FIG. 11, which illustrates an exemplary process (365) that utilizes processor (166) (see FIG. 3) for fusion of image data [0073]-[0077], Fig.11).

Regarding claim 24, Dagher teaches the imaging system of claim 22 (... multi-aperture camera systems with the imaging characteristics [0041]-[0042], Fig.1; multi-aperture camera Fig.3), wherein the registration includes finding a corresponding pixel in the first Luma image for each pixel in the second Luma image (... Process (338)... may be applied to full color images... an image registration procedure (342) is applied [0065], Fig.9; ... FIG. 11, which illustrates an exemplary process (365) that utilizes processor (166) (see FIG. 3) for fusion of image data [0073]-[0077], Fig.11; ... image may be divided into overlapping or non-overlapping blocks of size Kx x Ky (i.e., Kx pixels in an x-direction and Ky pixels in a y-direction) [0083], Fig.12; ... knowledge of the sub-camera geometry for a multi-aperture camera (e.g., first and second sub-cameras (150) and (160) of FIG. 2B) and its sensor(s)... it is possible to estimate a parallax shift between the two or more sub-cameras [0084]; ... image registration step (369) (see FIG. 11) implemented with a block-wise sliding window transform [0090], Fig.13; ... image fusion step (373) (see FIG. 11)... registration information computed in image registration step (369)... may be 'merged' [0098], Fig.15) and wherein the processor is further configured to form the output image by transferring information from the first image to the second image (... Process (338)... may be applied to full color images... an image registration procedure (342) is applied [0065], Fig.9; ... fusion of image data... may involve addition of color information from a color sub-camera image to luminance information from a grayscale sub-camera image... a complementary operation may be performed where luminance information from the grayscale sub-camera is added to the color image from the color sub-camera... FIG. 11, which illustrates an exemplary process (365) that utilizes processor (166) (see FIG. 3) for fusion of image data [0073]-[0077], Fig.11).

Regarding claim 25, Dagher teaches the imaging system of claim 21 (... multi-aperture camera systems with the imaging characteristics [0041]-[0042], Fig.1; multi-aperture camera Fig.3), wherein the first camera subset has a first field of view (FOV), wherein the second camera subset has a second, smaller FOV than the first FOV (... two cameras (10) and (12) that image fields of view (20) and (22)... cameras (10) and (12) may be... sub-cameras of a single multi-aperture camera [0046], Fig.1, Fig.2; ... It is contemplated that sensors of sub-cameras of a single multi-aperture camera may be shared in any manner... blocks of pixels adjacent one another in a single sensor chip... not limited to having identical shapes or sizes [0049], Fig.2; In a particular aspect, configuring the first sub-camera may include establishing a first focal length... configuring the second camera may include establishing a second focal length... The second focal length may be different than the first focal length such that the second camera exhibits a different field of view as compared to the first camera [0013]; ... each optical sub-system may have a different focal length resulting in different fields of view [0048], Fig.2), and wherein the processor (... Multi aperture camera (100) provides first and second sets of image data (301) and (302) to a processor (166) which may, for example, be configured for combining or "fusing" the image data sets... to an image output device (167) [0053], Fig.3) is further configured to register the first and second Luma images (... FIG.8, both the tele and wide images are converted from RGB to YUV... one luminance (Y) channel and two chrominance channels (U, V) [0063], Fig.8; ... Process (338)... may be applied to full color images... an image registration procedure (342) is applied [0065], Fig.9; ... fusion of image data... may involve addition of color information from a color sub-camera image to luminance information from a grayscale sub-camera image... a complementary operation may be performed where luminance information from the grayscale sub-camera is added to the color image from the color sub-camera... FIG. 11, which illustrates an exemplary process (365) that utilizes processor (166) (see FIG. 3) for fusion of image data [0073]-[0077], Fig.11) based on a zoom factor (ZF) input (... "zoom" may be understood as a capability to provide different magnifications... by changing the focal length of an optical system [0004]; ... allows the user to choose any level of zoom and to utilize the multi-aperture camera as a continuous zoom camera [0062]).
[The first and second sub-cameras have variable focal lengths and therefore variable fields of view.]

Supplemental Box

In case the space in any of the preceding boxes is not sufficient.
Continuation of:

Regarding claim 26, Dagher teaches the imaging system of claim 25 (... multi-aperture camera systems with the imaging characteristics [0041]-[0042], Fig.1; multi-aperture camera Fig.3), wherein the registration includes, for a ZF input (... "zoom" may be understood as a capability to provide different magnifications... by changing the focal length of an optical system [0004]; ... allows the user to choose any level of zoom and to utilize the multi-aperture camera as a continuous zoom camera [0062]) that defines an FOV greater than the second FOV (... two cameras (10) and (12) that image fields of view (20) and (22)... cameras (10) and (12) may be... sub-cameras of a single multi-aperture camera [0046], Fig.1, Fig.2; ... It is contemplated that sensors of sub-cameras of a single multi-aperture camera may be shared in any manner... blocks of pixels adjacent one another in a single sensor chip... not limited to having identical shapes or sizes [0049], Fig.2; In a particular aspect, configuring the first sub-camera may include establishing a first focal length... configuring the second camera may include establishing a second focal length... The second focal length may be different than the first focal length such that the second camera exhibits a different field of view as compared to the first camera [0013]; ... each optical sub-system may have a different focal length resulting in different fields of view [0048], Fig.2), finding a corresponding pixel in the second Luma image for each pixel in the first Luma image (... Process (338)... may be applied to full color images... an image registration procedure (342) is applied [0065], Fig.9; ... FIG. 11, which illustrates an exemplary process (365) that utilizes processor (166) (see FIG. 3) for fusion of image data [0073]-[0077], Fig.11; ... image may be divided into overlapping or non-overlapping blocks of size Kx x Ky (i.e., Kx pixels in an x-direction and Ky pixels in a y-direction) [0083], Fig.12; ... knowledge of the sub-camera geometry for a multi-aperture camera (e.g., first and second sub-cameras (150) and (160) of FIG. 2B) and its sensor(s)... it is possible to estimate a parallax shift between the two or more sub-cameras [0084]; ... image registration step (369) (see FIG. 11) implemented with a block-wise sliding window transform [0090], Fig.13; ... image fusion step (373) (see FIG. 11)... registration information computed in image registration step (369)... may be 'merged' [0098], Fig.15) and wherein the processor is further configured to form the output image by transferring information from the second image to the first image (... Process (338)... may be applied to full color images... an image registration procedure (342) is applied [0065], Fig.9; ... fusion of image data... may involve addition of color information from a color sub-camera image to luminance information from a grayscale sub-camera image... a complementary operation may be performed where luminance information from the grayscale sub-camera is added to the color image from the color sub-camera... FIG. 11, which illustrates an exemplary process (365) that utilizes processor (166) (see FIG. 3) for fusion of image data [0073]-[0077], Fig.11).

Regarding claim 27, Dagher teaches the imaging system of claim 25 (... multi-aperture camera systems with the imaging characteristics [0041]-[0042], Fig.1; multi-aperture camera Fig.3), wherein the registration includes, for a ZF input (... "zoom" may be understood as a capability to provide different magnifications... by changing the focal length of an optical system [0004]; ... allows the user to choose any level of zoom and to utilize the multi-aperture camera as a continuous zoom camera [0062]) that defines an FOV smaller than, or equal to the second FOV (... two cameras (10) and (12) that image fields of view (20) and (22)... cameras (10) and (12) may be... sub-cameras of a single multi-aperture camera [0046], Fig.1, Fig.2; ... It is contemplated that sensors of sub-cameras of a single multi-aperture camera may be shared in any manner... blocks of pixels adjacent one another in a single sensor chip... not limited to having identical shapes or sizes [0049], Fig.2; In a particular aspect, configuring the first sub-camera may include establishing a first focal length... configuring the second camera may include establishing a second focal length... The second focal length may be different than the first focal length such that the second camera exhibits a different field of view as compared to the first camera [0013]; ... each optical sub-system may have a different focal length resulting in different fields of view [0048], Fig.2), finding a corresponding pixel in the first Luma image for each pixel in the second Luma image (... Process (338)... may be applied to full color images... an image registration procedure (342) is applied [0065], Fig.9; ... FIG. 11, which illustrates an exemplary process (365) that utilizes processor (166) (see FIG. 3) for fusion of image data [0073]-[0077], Fig.11; ... image may be divided into overlapping or non-overlapping blocks of size Kx x Ky (i.e., Kx pixels in an x-direction and Ky pixels in a y-direction) [0083], Fig.12; ... knowledge of the sub-camera geometry for a multi-aperture camera (e.g., first and second sub-cameras (150) and (160) of FIG. 2B) and its sensor(s)... it is possible to estimate a parallax shift between the two or more sub-cameras [0084]; ... image registration step (369) (see FIG. 11) implemented with a block-wise sliding window transform [0090], Fig.13; ... image fusion step (373) (see FIG. 11)... registration information computed in image registration step (369)... may be 'merged' [0098], Fig.15) and wherein the processor is further configured to form the output image by transferring information from the first image to the second image (... Process (338)... may be applied to full color images... an image registration procedure (342) is applied [0065], Fig.9; ... fusion of image data... may involve addition of color information from a color sub-camera image to luminance information from a grayscale sub-camera image... a complementary operation may be performed where luminance information from the grayscale sub-camera is added to the color image from the color sub-camera... FIG. 11, which illustrates an exemplary process (365) that utilizes processor (166) (see FIG. 3) for fusion of image data [0073]-[0077], Fig.11).

Supplemental Box

In case **the space in any of the preceding boxes is not sufficient.**
Continuation of:

Regarding claim 28, Dagher teaches the imaging system of claim 25, wherein the second sensor (... cameras (10) and (12) may be... sub-cameras of a single multi-aperture camera [0046], Fig.1, Fig.2; ... It is contemplated that sensors of sub-cameras of a single multi-aperture camera may be shared in any manner... blocks of pixels adjacent one another in a single sensor chip... not limited to having identical shapes or sizes [0049], Fig.2; ... first and second optical sub-systems (110) and (120) is shown imaging onto its own sensor (i.e., sensors (130) and (140), respectively) [0067], Fig.2) includes a standard CFA (... Image sensors often utilize a Red-Green-Blue ("RGB") color filter array ("CFA"), such as a Bayer pattern... in FIG. 8, both the tele and the wide images are converted from RGB to YUV [0063], Fig.8; ... a CFA such as a Bayer filter, or be formed of individual color sensor elements (e.g., RGB or Cyan-Magenta-Yellow ("CMY")) [0067]) and wherein, for a ZF input (... "zoom" may be understood as a capability to provide different magnifications... by changing the focal length of an optical system [0004]; ... allows the user to choose any level of zoom and to utilize the multi-aperture camera as a continuous zoom camera [0062]) that defines an FOV equal to or smaller than the second FOV (... two cameras (10) and (12) that image fields of view (20) and (22)... cameras (10) and (12) may be... sub-cameras of a single multi-aperture camera [0046], Fig.1, Fig.2; ... It is contemplated that sensors of sub-cameras of a single multi-aperture camera may be shared in any manner... blocks of pixels adjacent one another in a single sensor chip... not limited to having identical shapes or sizes [0049], Fig.2; In a particular aspect, configuring the first sub-camera may include establishing a first focal length... configuring the second camera may include establishing a second focal length... The second focal length may be different than the first focal length such that the second camera exhibits a different field of view as compared to the first camera [0013]; ... each optical sub-system may have a different focal length resulting in different fields of view [0048], Fig.2), the processor is further configured to form the output image based on the second image (... Process (338)... may be applied to full color images... an image registration procedure (342) is applied [0065], Fig.9; ... fusion of image data... may involve addition of color information from a color sub-camera image to luminance information from a grayscale sub-camera image... a complementary operation may be performed where luminance information from the grayscale sub-camera is added to the color image from the color sub-camera... FIG. 11, which illustrates an exemplary process (365) that utilizes processor (166) (see FIG. 3) for fusion of image data [0073]-[0077], Fig.11).

Regarding claim 29, Dagher teaches the imaging system of claim 21 (... multi-aperture camera systems with the imaging characteristics [0041]-[0042], Fig.1; multi-aperture camera Fig.3), wherein the standard CFA includes a Bayer filter (... Image sensors often utilize a Red-Green-Blue ("RGB") color filter array ("CFA"), such as a Bayer pattern... in FIG. 8, both the tele and the wide images are converted from RGB to YUV [0063], Fig.8; ... a CFA such as a Bayer filter, or be formed of individual color sensor elements (e.g., RGB or Cyan-Magenta-Yellow ("CMY")) [0067]).

Regarding claim 32, Dagher teaches a multi-aperture imaging system (... multi-aperture camera systems with the imaging characteristics [0041]-[0042], Fig.1; multi-aperture camera Fig.3) comprising:

a) a first camera subset that provides a first image, the first camera subset having a first field of view (FOV) (... two cameras (10) and (12) that image fields of view (20) and (22)... cameras (10) and (12) may be... sub-cameras of a single multi-aperture camera [0046], Fig.1, Fig.2; ... It is contemplated that sensors of sub-cameras of a single multi-aperture camera may be shared in any manner... blocks of pixels adjacent one another in a single sensor chip... not limited to having identical shapes or sizes [0049], Fig.2; In a particular aspect, configuring the first sub-camera may include establishing a first focal length... configuring the second camera may include establishing a second focal length... The second focal length may be different than the first focal length such that the second camera exhibits a different field of view as compared to the first camera [0013]; ... each optical sub-system may have a different focal length resulting in different fields of view [0048], Fig.2) and first sensor with a first plurality of sensor pixels (... multi-aperture camera (100), each of first and second optical sub-systems (110) and (120) is shown imaging onto its own sensor (i.e., sensors (130) and (140), respectively) [0067], Fig.2) covered at least in part with a standard CFA (... Image sensors often utilize a Red-Green-Blue ("RGB") color filter array ("CFA"), such as a Bayer pattern... in FIG. 8, both the tele and the wide images are converted from RGB to YUV [0063], Fig.8; ... a CFA such as a Bayer filter, or be formed of individual color sensor elements (e.g., RGB or Cyan-Magenta-Yellow ("CMY")) [0067]);

b) a second camera subset that provides a second image, the second camera subset having a second, smaller FOV than the first FOV (... two cameras (10) and (12) that image fields of view (20) and (22)... cameras (10) and (12) may be... sub-cameras of a single multi-aperture camera [0046], Fig.1, Fig.2; ... It is contemplated that sensors of sub-cameras of a single multi-aperture camera may be shared in any manner... blocks of pixels adjacent one another in a single sensor chip... not limited to having identical shapes or sizes [0049], Fig.2; In a particular aspect, configuring the first sub-camera may include establishing a first focal length... configuring the second camera may include establishing a second focal length... The second focal length may be different than the first focal length such that the second camera exhibits a different field of view as compared to the first camera [0013]; ... each optical sub-system may have a different focal length resulting in different fields of view [0048], Fig.2) and a second sensor with a second plurality of sensor pixels (... multi-aperture camera (100), each of first and second optical sub-systems (110) and (120) is shown imaging onto its own sensor (i.e., sensors (130) and (140), respectively) [0067], Fig.2) covered with a standard CFA (... Image sensors often utilize a Red-Green-Blue ("RGB") color filter array ("CFA"), such as a Bayer pattern... in FIG. 8, both the tele and the wide images are converted from RGB to YUV [0063], Fig.8; ... a CFA such as a Bayer filter, or be formed of individual color sensor elements (e.g., RGB or Cyan-Magenta-Yellow ("CMY")) [0067]); and

c) a processor (... Multi aperture camera (100) provides first and second sets of image data (301) and (302) to a processor (166) which may, for example, be configured for combining or "fusing" the image data sets... to an image output device (167) [0053], Fig.3) configured to, for a zoom factor input (... "zoom" may be understood as a capability to provide different magnifications... by changing the focal length of an optical system [0004]; ... allows the user to choose any level of zoom and to utilize the multi-aperture camera as a continuous zoom camera [0062]) that defines an FOV equal to or smaller than the second FOV (... two cameras (10) and (12) that image fields of view (20) and (22)... cameras (10) and (12) may be... sub-cameras of a single multi-aperture camera [0046], Fig.1, Fig.2; ... It is contemplated that sensors of sub-cameras of a single multi-aperture camera may be shared in any manner... blocks of pixels adjacent one another in a single sensor chip... not limited to having identical shapes or sizes [0049], Fig.2; In a particular aspect, configuring the first sub-camera may include establishing a first focal length... configuring the second camera may include establishing a second focal length... The second focal length may be different than the first focal length such that the second camera exhibits a different field of view as compared to the first camera [0013]; ... each optical sub-system may have a different focal length resulting in different fields of view [0048], Fig.2), form an output image based on the second image (... Process (338)... may be applied to full color images... an image registration procedure (342) is applied [0065], Fig.9; ... fusion of image data... may involve addition of color information from a color sub-camera image to luminance information from a grayscale sub-camera image... a complementary operation may be performed where luminance information from the grayscale sub-camera is added to the color image from the color sub-camera... FIG. 11, which illustrates an exemplary process (365) that utilizes processor (166) (see FIG. 3) for fusion of image data [0073]-[0077], Fig.11).

Supplemental Box

In case **the space in any of the preceding boxes is not sufficient.**
Continuation of:

Claims 1, 6-20, 30-31 lack an inventive step under PCT Article 33(3) as being obvious over Dagher et al. (US 2011/0064327 A1), hereinafter Dagher in view of Koskinen et al. (US 8,134,115 B2), hereinafter Koskinen.

Regarding claim 1, Dagher teaches a multi-aperture imaging system (... multi-aperture camera systems with the imaging characteristics [0041]-[0042], Fig.1; multi-aperture camera Fig.3) comprising:
a) a first camera subset that provides a first image, the first camera subset having a first sensor with a first plurality of sensor pixels (... A scene (5) is imaged by two cameras (10) and (12) that image fields of view (20) and (22)... cameras (10) and (12) may be... sub-cameras of a single multi-aperture camera [0046], Fig.1, Fig.2; ... It is contemplated that sensors of sub-cameras of a single multi-aperture camera may be shared in any manner... blocks of pixels adjacent one another in a single sensor chip... not limited to having identical shapes or sizes [0049], Fig.2; ... multi-aperture camera (100), each of first and second optical sub-systems (110) and (120) is shown imaging onto its own sensor (i.e., sensors (130) and (140), respectively) [0067], Fig.2) covered at least in part with a color filter array (CFA) (... Image sensors often utilize a Red-Green-Blue ("RGB") color filter array ("CFA"), such as a Bayer pattern... in FIG. 8, both the tele and the wide images are converted from RGB to YUV [0063], Fig.8; ... a CFA such as a Bayer filter, or be formed of individual color sensor elements (e.g., RGB or Cyan-Magenta-Yellow ("CMY")) [0067]), the CFA used to increase a specific color sampling rate relative to a same color sampling rate in a standard CFA (... upsampling and interpolation of the first and second sets of image data... increasing the sampling frequency... higher level of image quality... higher resolution [0054], Fig.4, Fig.5, Fig.6);
b) a second camera subset that provides a second image, the second camera subset having a second sensor with a second plurality of sensor pixels (... A scene (5) is imaged by two cameras (10) and (12) that image fields of view (20) and (22)... cameras (10) and (12) may be... sub-cameras of a single multi-aperture camera [0046], Fig.1, Fig.2; ... It is contemplated that sensors of sub-cameras of a single multi-aperture camera may be shared in any manner... blocks of pixels adjacent one another in a single sensor chip... not limited to having identical shapes or sizes [0049], Fig.2; ... multi-aperture camera (100), each of first and second optical sub-systems (110) and (120) is shown imaging onto its own sensor (i.e., sensors (130) and (140), respectively) [0067], Fig.2), the second plurality of sensor pixels being either Clear or covered with a standard CFA (... Image sensors often utilize a Red-Green-Blue ("RGB") color filter array ("CFA"), such as a Bayer pattern... in FIG. 8, both the tele and the wide images are converted from RGB to YUV... the tele sub-camera may utilize an image sensor that does not have a color filter array... to utilize its entire sensor area [0063], Fig.8); and
c) a processor configured to process the first and second images into a combined output image (... Multi aperture camera (100) provides first and second sets of image data (301) and (302) to a processor (166) which may, for example, be configured for combining or "fusing" the image data sets... to an image output device (167) [0053], Fig.3), but lacks the explicit teaching of a non-standard color filter array (CFA).
However, Koskinen is analogous to Dagher and has a non-standard color filter array (CFA) (Typical technologies for generating color images rely on the Bayer sensor and its variations... FIG. 1 shows a typical Bayer-type pattern... Other filter types include, by example, CYGM filters... and RGBE filters Col.1 ln.46-56, Fig.1; The exemplary embodiments of this invention use... sub-diffraction limit receptors in combination with a color filter array. The color filter array may be designed much more freely than conventional color filter arrays Col.3 ln.41-48, Fig.3; Contrasting FIG. 3 with FIG. 1, the optical filters... enable a plurality of different filter types to be used in any desired combinations Col.3 ln.59-63 Fig.3; It should be noted that the color filters do not have to be separate for each receptor (2)... each of three different filter types is shown overlaying a plurality of the receptors Col.7 ln.51-55, Fig.7, Fig.9).
It would have been obvious to one of ordinary skill in the art at the time of the invention to combine a non-standard color filter array (CFA) as taught by Koskinen with the invention of Dagher.
The motivation would have been an obvious design choice and allows the designer much more freedom than conventional or standard color filter arrays and enable a plurality of different filter types to be used in any desired combination (Koskinen, Col.3 ln.41-48, Col.3 ln.59-63, Fig.3).

Regarding claim 6, Dagher teaches the imaging system of claim 1 (... multi-aperture camera systems with the imaging characteristics [0041]-[0042], Fig.1; multi-aperture camera Fig.3), wherein the standard CFA includes a Bayer filter (... Image sensors often utilize a Red-Green-Blue ("RGB") color filter array ("CFA"), such as a Bayer pattern... in FIG. 8, both the tele and the wide images are converted from RGB to YUV [0063], Fig.8; ... a CFA such as a Bayer filter, or be formed of individual color sensor elements (e.g., RGB or Cyan-Magenta-Yellow ("CMY")) [0067]).

Regarding claim 7, Dagher teaches the imaging system of claim 1 (... multi-aperture camera systems with the imaging characteristics [0041]-[0042], Fig.1; multi-aperture camera Fig.3), wherein the standard CFA includes a Bayer filter (... Image sensors often utilize a Red-Green-Blue ("RGB") color filter array ("CFA"), such as a Bayer pattern... in FIG. 8, both the tele and the wide images are converted from RGB to YUV [0063], Fig.8; ... a CFA such as a Bayer filter, or be formed of individual color sensor elements (e.g., RGB or Cyan-Magenta-Yellow ("CMY")) [0067]), but lacks the explicit teaching of a non-Bayer filter.
However, Koskinen is analogous to Dagher and has a non-Bayer filter (Typical technologies for generating color images rely on the Bayer sensor and its variations... FIG. 1 shows a typical Bayer-type pattern... Other filter types include, by example, CYGM filters... and RGBE filters Col.1 ln.46-56, Fig.1).
It would have been obvious to one of ordinary skill in the art at the time of the invention to combine a non-Bayer filter as taught by Koskinen with the invention of Dagher.
The motivation would have been an obvious design choice and allows the designer much more freedom than a standard Bayer color filter array (Koskinen, Col.1 ln.46-56, Col.3 ln.41-48, Col.3 ln.59-63, Fig.1, Fig.3).

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Regarding claim 8, Dagher teaches the imaging system of claim 7 (... multi-aperture camera systems with the imaging characteristics [0041]-[0042], Fig.1; multi-aperture camera Fig.3; ... Image sensors often utilize a Red-Green-Blue ("RGB") color filter array ("CFA"), such as a Bayer pattern... in FIG. 8, both the tele and the wide images are converted from RGB to YUV [0063], Fig.8; ... a CFA such as a Bayer filter, or be formed of individual color sensor elements (e.g., RGB or Cyan-Magenta-Yellow ("CMY")) [0067]), but lacks the explicit teaching of wherein the non-Bayer filter is selected from the group consisting of a RGBE, a CYYM, a CYGM, a RGBW#1, a RGBW#2 and a RGBW#3 filter.
However, Koskinen is analogous to Dagher and has wherein the non-Bayer filter is selected from the group consisting of a RGBE, a CYYM, a CYGM, a RGBW#1, a RGBW#2 and a RGBW#3 filter (Typical technologies for generating color images rely on the Bayer sensor and its variations... FIG. 1 shows a typical Bayer-type pattern... Other filter types include, by example, CYGM filters... and RGBE filters Col.1 ln.46-56, Fig.1).
It would have been obvious to one of ordinary skill in the art at the time of the invention to combine wherein the non-Bayer filter is selected from the group consisting of a RGBE, a CYYM, a CYGM, a RGBW#1, a RGBW#2 and a RGBW#3 filter as taught by Koskinen with the invention of Dagher.
The motivation would have been an obvious design choice and allows the designer much more freedom than a standard Bayer color filter array (Koskinen, Col.1 ln.46-56, Col.3 ln.41-48, Col.3 ln.59-63, Fig.1, Fig.3).

Regarding claim 9, Dagher teaches the imaging system of claim 1 (... multi-aperture camera systems with the imaging characteristics [0041]-[0042], Fig.1; multi-aperture camera Fig.3), wherein the first and the second camera subsets (... cameras (10) and (12) may be... sub-cameras of a single multi-aperture camera [0046], Fig.1, Fig.2; ... It is contemplated that sensors of sub-cameras of a single multi-aperture camera may be shared in any manner... blocks of pixels adjacent one another in a single sensor chip... not limited to having identical shapes or sizes [0049]) have identical fields of view (In a particular aspect, configuring the first sub-camera may include establishing a first focal length... configuring the second camera may include establishing a second focal length... The second focal length may be different than the first focal length such that the second camera exhibits a different field of view as compared to the first camera [0013]; ... each optical sub-system may have a different focal length resulting in different fields of view [0048], Fig.2), but lacks the explicit teaching of and wherein the non-standard CFA covers an overlap area that includes all the pixels of the first sensor, thereby providing increased color resolution.
However, Koskinen is analogous to Dagher and has and wherein the non-standard CFA (The exemplary embodiments of this invention use... sub-diffraction limit receptors in combination with a color filter array. The color filter array may be designed much more freely than conventional color filter arrays Col.3 ln.41-48, Fig.3; Contrasting FIG. 3 with FIG. 1, the optical filters... enable a plurality of different filter types to be used in any desired combinations Col.3 ln.59-63, Fig.3) covers an overlap area that includes all the pixels of the first sensor (It should be noted that the color filters do not have to be separate for each receptor (2)... each of three different filter types is shown overlaying a plurality of the receptors Col.7 ln.51-55, Fig.7, Fig.9), thereby providing increased color resolution (This enables the use of the multiple filters... resolution is not degraded... A dynamic optimization between resolution and color fidelity and sensitivity may be achieved Col.3 ln.52-58; In certain cases it may be beneficial to vary the spectral characteristics of the filter array (6)... the center area of the filter array (6) may have higher resolution Col.7 ln.41-44, Fig.7, Fig.9).
It would have been obvious to one of ordinary skill in the art at the time of the invention to combine and wherein the non-standard CFA covers an overlap area that includes all the pixels of the first sensor, thereby providing increased color resolution as taught by Koskinen with the invention of Dagher.
The motivation would have been an obvious design choice and allows the designer much more freedom than conventional or standard color filter arrays and enable a plurality of different filter types to be used in any desired combination (Koskinen, Col.3 ln.41-48, Col.3 ln.59-63, Fig.3). In addition, a dynamic optimization between resolution and color fidelity may be achieved and designation of higher resolution in certain areas of the filter array (Koskinen, Col.3 ln.52-58, Col.7 ln.41-44).

Regarding claim 10, Dagher teaches the imaging system of claim 9 (... multi-aperture camera systems with the imaging characteristics [0041]-[0042], Fig.1; multi-aperture camera Fig.3), wherein the processor (... Multi aperture camera (100) provides first and second sets of image data (301) and (302) to a processor (166) which may, for example, be configured for combining or "fusing" the image data sets... to an image output device (167) [0053], Fig.3) is further configured to register respective first and second Luma images obtained from the first and second images during the processing of the first and second images into a combined output image, the registered first and second Luma images used together with color information to form the combined output image (... FIG.8, both the tele and wide images are converted from RGB to YUV... one luminance (Y) channel and two chrominance channels (U, V) [0063], Fig.8; ... Process (338)... may be applied to full color images... an image registration procedure (342) is applied [0065], Fig.9; ... fusion of image data... may involve addition of color information from a color sub-camera image to luminance information from a grayscale sub-camera image... a complementary operation may be performed where luminance information from the grayscale sub-camera is added to the color image from the color sub-camera... FIG. 11, which illustrates an exemplary process (365) that utilizes processor (166) (see FIG. 3) for fusion of image data [0073]-[0077], Fig.11; ... a grayscale sub-camera generally produces only a luminance signal (e.g., Y information [0067]).

Regarding claim 11, Dagher teaches the imaging system of claim 10, wherein the registration includes finding a corresponding pixel in the second Luma image for each pixel in the first Luma image (... Process (338)... may be applied to full color images... an image registration procedure (342) is applied [0065], Fig.9; ... FIG. 11, which illustrates an exemplary process (365) that utilizes processor (166) (see FIG. 3) for fusion of image data [0073]-[0077], Fig.11; ... image may be divided into overlapping or non-overlapping blocks of size Kx x Ky (i.e., Kx pixels in an x-direction and Ky pixels in a y-direction) [0083], Fig.12; ... knowledge of the sub-camera geometry for a multi-aperture camera (e.g., first and second sub-cameras (150) and (160) of FIG. 2B) and its sensor(s)... it is possible to estimate a parallax shift between the two or more sub-cameras [0084]; ... image registration step (369) (see FIG. 11) implemented with a block-wise sliding window transform [0090], Fig.13; ... image fusion step (373) (see FIG. 11)... registration information computed in image registration step (369)... may be 'merged' [0098], Fig.15) and wherein the processor is further configured to form the output image by transferring information from the second image to the first image (... Process (338)... may be applied to full color images... an image registration procedure (342) is applied [0065], Fig.9; ... fusion of image data... may involve addition of color information from a color sub-camera image to luminance information from a grayscale sub-camera image... a complementary operation may be performed where luminance information from the grayscale sub-camera is added to the color image from the color sub-camera... FIG. 11, which illustrates an exemplary process (365) that utilizes processor (166) (see FIG. 3) for fusion of image data [0073]-[0077], Fig.11).

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Regarding claim 12, Dagher teaches the imaging system of claim 10, wherein the registration includes finding a corresponding pixel in the first Luma image for each pixel in the second Luma image (... Process (338)... may be applied to full color images... an image registration procedure (342) is applied [0065], Fig.9; ... FIG. 11, which illustrates an exemplary process (365) that utilizes processor (166) (see FIG. 3) for fusion of image data [0073]-[0077], Fig.11; ... image may be divided into overlapping or non-overlapping blocks of size Kx x Ky (i.e., Kx pixels in an x-direction and Ky pixels in a y-direction) [0083], Fig.12; ... knowledge of the sub-camera geometry for a multi-aperture camera (e.g., first and second sub-cameras (150) and (160) of FIG. 2B) and its sensor(s)... it is possible to estimate a parallax shift between the two or more sub-cameras [0084]; ... image registration step (369) (see FIG. 11) implemented with a block-wise sliding window transform [0090], Fig.13; ... image fusion step (373) (see FIG. 11)... registration information computed in image registration step (369)... may be 'merged' [0098], Fig.15) and wherein the processor is further configured to form the output image by transferring information from the first image to the second image (... Process (338)... may be applied to full color images... an image registration procedure (342) is applied [0065], Fig.9; ... fusion of image data... may involve addition of color information from a color sub-camera image to luminance information from a grayscale sub-camera image... a complementary operation may be performed where luminance information from the grayscale sub-camera is added to the color image from the color sub-camera... FIG. 11, which illustrates an exemplary process (365) that utilizes processor (166) (see FIG. 3) for fusion of image data [0073]-[0077], Fig.11).

Regarding claim 13, Dagher teaches the imaging system of claim 1 (... multi-aperture camera systems with the imaging characteristics [0041]-[0042], Fig.1; multi-aperture camera Fig.3), wherein the first camera subset has a first field of view (FOV) (... two cameras (10) and (12) that image fields of view (20) and (22)... cameras (10) and (12) may be... sub-cameras of a single multi-aperture camera [0046], Fig.1, Fig.2; ... It is contemplated that sensors of sub-cameras of a single multi-aperture camera may be shared in any manner... blocks of pixels adjacent one another in a single sensor chip... not limited to having identical shapes or sizes [0049], Fig.2; In a particular aspect, configuring the first sub-camera may include establishing a first focal length... configuring the second camera may include establishing a second focal length... The second focal length may be different than the first focal length such that the second camera exhibits a different field of view as compared to the first camera [0013]; ... each optical sub-system may have a different focal length resulting in different fields of view [0048], Fig.2), wherein the second camera subset has a second, smaller FOV than the first FOV (... two cameras (10) and (12) that image fields of view (20) and (22)... cameras (10) and (12) may be... sub-cameras of a single multi-aperture camera [0046], Fig.1, Fig.2; ... It is contemplated that sensors of sub-cameras of a single multi-aperture camera may be shared in any manner... blocks of pixels adjacent one another in a single sensor chip... not limited to having identical shapes or sizes [0049], Fig.2; In a particular aspect, configuring the first sub-camera may include establishing a first focal length... configuring the second camera may include establishing a second focal length... The second focal length may be different than the first focal length such that the second camera exhibits a different field of view as compared to the first camera [0013]; ... each optical sub-system may have a different focal length resulting in different fields of view [0048], Fig.2; ... first sub-camera (150) has a wider field of view as compared to second sub-camera (160)... (160) may serve as a "tele" sub-camera having a higher level of zoom as compared to first sub-camera (150) [0051]), thereby providing both optical zoom and increased color resolution (... (160) may serve as a "tele" sub-camera having a higher level of zoom as compared to first sub-camera (150) [0051]; ... it is possible to combine... two or more images... to create a single, foveated high resolution image... images will have regions of higher resolution [0054]; ... the tele sub-camera... resulting in even higher image resolution in the overlap region [0063]; ... in order to ensure good color fidelity [0106]), but lacks the explicit teaching of and wherein the non-standard CFA covers an overlap area on the first sensor that captures the second FOV.
However, Koskinen is analogous to Dagher and has and wherein the non-standard CFA (The exemplary embodiments of this invention use... sub-diffraction limit receptors in combination with a color filter array. The color filter array may be designed much more freely than conventional color filter arrays Col.3 ln.41-48, Fig.3; Contrasting FIG. 3 with FIG. 1, the optical filters... enable a plurality of different filter types to be used in any desired combinations Col.3 ln.59-63, Fig.3) covers an overlap area on the first sensor that captures the second FOV (It should be noted that the color filters do not have to be separate for each receptor (2)... each of three different filter types is shown overlaying a plurality of the receptors Col.7 ln.51-55, Fig.7, Fig.9; The direction at which the light arrives is assumed to be within a field of view (FOV) of the sensor (1) Col.4 ln.46-47).
It would have been obvious to one of ordinary skill in the art at the time of the invention to combine and wherein the non-standard CFA covers an overlap area on the first sensor that captures the second FOV as taught by Koskinen with the invention of Dagher.
The motivation would have been an obvious design choice and allows the designer much more freedom than conventional or standard color filter arrays and enable a plurality of different filter types to be used in any desired combination (Koskinen, Col.3 ln.41-48, Col.3 ln.59-63, Fig.3). In addition, a dynamic optimization between resolution and color fidelity may be achieved and designation of higher resolution in certain areas of the filter array (Koskinen, Col.3 ln.52-58, Col.7 ln.41-44, Fig.7, Fig.9).

Regarding claim 14, Dagher teaches the imaging system of claim 13, wherein the processor is further configured to, during the processing of the first and second images into a combined output image (... Multi aperture camera (100) provides first and second sets of image data (301) and (302) to a processor (166) which may, for example, be configured for combining or "fusing" the image data sets... to an image output device (167) [0053], Fig.3) and based on a zoom factor (ZF) input (... "zoom" may be understood as a capability to provide different magnifications... by changing the focal length of an optical system [0004]; ... allows the user to choose any level of zoom and to utilize the multi-aperture camera as a continuous zoom camera [0062]), register respective first and second Luma images obtained from the first and second images, the registered first and second Luma images used together with color information to form the combined output image (... FIG.8, both the tele and wide images are converted from RGB to YUV... one luminance (Y) channel and two chrominance channels (U, V) [0063], Fig.8; ... Process (338)... may be applied to full color images... an image registration procedure (342) is applied [0065], Fig.9; ... fusion of image data... may involve addition of color information from a color sub-camera image to luminance information from a grayscale sub-camera image... a complementary operation may be performed where luminance information from the grayscale sub-camera is added to the color image from the color sub-camera... FIG. 11, which illustrates an exemplary process (365) that utilizes processor (166) (see FIG. 3) for fusion of image data [0073]-[0077], Fig.11; ... a grayscale sub-camera generally produces only a luminance signal (e.g., Y information [0067]).

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Regarding claim 15, Dagher teaches the imaging system of claim 14, wherein the registration includes, for a ZF input (... "zoom" may be understood as a capability to provide different magnifications... by changing the focal length of an optical system [0004]; ... allows the user to choose any level of zoom and to utilize the multi-aperture camera as a continuous zoom camera [0062]) that defines an FOV greater than the second FOV (... two cameras (10) and (12) that image fields of view (20) and (22)... cameras (10) and (12) may be... sub-cameras of a single multi-aperture camera [0046], Fig.1, Fig.2; ... It is contemplated that sensors of sub-cameras of a single multi-aperture camera may be shared in any manner... blocks of pixels adjacent one another in a single sensor chip... not limited to having identical shapes or sizes [0049], Fig.2; In a particular aspect, configuring the first sub-camera may include establishing a first focal length... configuring the second camera may include establishing a second focal length... The second focal length may be different than the first focal length such that the second camera exhibits a different field of view as compared to the first camera [0013]; ... each optical sub-system may have a different focal length resulting in different fields of view [0048], Fig.2), finding a corresponding pixel in the second Luma image for each pixel in the first Luma image (... Process (338)... may be applied to full color images... an image registration procedure (342) is applied [0065], Fig.9; ... FIG. 11, which illustrates an exemplary process (365) that utilizes processor (166) (see FIG. 3) for fusion of image data [0073]-[0077], Fig.11; ... image may be divided into overlapping or non-overlapping blocks of size Kx x Ky (i.e., Kx pixels in an x-direction and Ky pixels in a y-direction) [0083], Fig.12; ... knowledge of the sub-camera geometry for a multi-aperture camera (e.g., first and second sub-cameras (150) and (160) of FIG. 2B) and its sensor(s)... it is possible to estimate a parallax shift between the two or more sub-cameras [0084]; ... image registration step (369) (see FIG. 11) implemented with a block-wise sliding window transform [0090], Fig.13; ... image fusion step (373) (see FIG. 11)... registration information computed in image registration step (369)... may be 'merged' [0098], Fig.15) and wherein the processor is further configured to form the output image by transferring information from the second image to the first image (... Process (338)... may be applied to full color images... an image registration procedure (342) is applied [0065], Fig.9; ... fusion of image data... may involve addition of color information from a color sub-camera image to luminance information from a grayscale sub-camera image... a complementary operation may be performed where luminance information from the grayscale sub-camera is added to the color image from the color sub-camera... FIG. 11, which illustrates an exemplary process (365) that utilizes processor (166) (see FIG. 3) for fusion of image data [0073]-[0077], Fig.11).

Regarding claim 16, Dagher teaches the imaging system of claim 14, wherein the registration includes, for a ZF input (... "zoom" may be understood as a capability to provide different magnifications... by changing the focal length of an optical system [0004]; ... allows the user to choose any level of zoom and to utilize the multi-aperture camera as a continuous zoom camera [0062]) that defines an FOV smaller than, or equal to the second FOV (... two cameras (10) and (12) that image fields of view (20) and (22)... cameras (10) and (12) may be... sub-cameras of a single multi-aperture camera [0046], Fig.1, Fig.2; ... It is contemplated that sensors of sub-cameras of a single multi-aperture camera may be shared in any manner... blocks of pixels adjacent one another in a single sensor chip... not limited to having identical shapes or sizes [0049], Fig.2; In a particular aspect, configuring the first sub-camera may include establishing a first focal length... configuring the second camera may include establishing a second focal length... The second focal length may be different than the first focal length such that the second camera exhibits a different field of view as compared to the first camera [0013]; ... each optical sub-system may have a different focal length resulting in different fields of view [0048], Fig.2), finding a corresponding pixel in the first Luma image for each pixel in the second Luma image (... Process (338)... may be applied to full color images... an image registration procedure (342) is applied [0065], Fig.9; ... FIG. 11, which illustrates an exemplary process (365) that utilizes processor (166) (see FIG. 3) for fusion of image data [0073]-[0077], Fig.11; ... image may be divided into overlapping or non-overlapping blocks of size Kx x Ky (i.e., Kx pixels in an x-direction and Ky pixels in a y-direction) [0083], Fig.12; ... knowledge of the sub-camera geometry for a multi-aperture camera (e.g., first and second sub-cameras (150) and (160) of FIG. 2B) and its sensor(s)... it is possible to estimate a parallax shift between the two or more sub-cameras [0084]; ... image registration step (369) (see FIG. 11) implemented with a block-wise sliding window transform [0090], Fig.13; ... image fusion step (373) (see FIG. 11)... registration information computed in image registration step (369)... may be 'merged' [0098], Fig.15) and wherein the processor is further configured to form the output image by transferring information from the first image to the second image (... Process (338)... may be applied to full color images... an image registration procedure (342) is applied [0065], Fig.9; ... fusion of image data... may involve addition of color information from a color sub-camera image to luminance information from a grayscale sub-camera image... a complementary operation may be performed where luminance information from the grayscale sub-camera is added to the color image from the color sub-camera... FIG. 11, which illustrates an exemplary process (365) that utilizes processor (166) (see FIG. 3) for fusion of image data [0073]-[0077], Fig.11).

Regarding claim 17, Dagher teaches the imaging system of claim 13, wherein the second sensor (... cameras (10) and (12) may be... sub-cameras of a single multi-aperture camera [0046], Fig.1, Fig.2; ... It is contemplated that sensors of sub-cameras of a single multi-aperture camera may be shared in any manner... blocks of pixels adjacent one another in a single sensor chip... not limited to having identical shapes or sizes [0049], Fig.2; ... first and second optical sub-systems (110) and (120) is shown imaging onto its own sensor (i.e., sensors (130) and (140), respectively) [0067], Fig.2) includes a standard CFA (... Image sensors often utilize a Red-Green-Blue ("RGB") color filter array ("CFA"), such as a Bayer pattern... in FIG. 8, both the tele and the wide images are converted from RGB to YUV [0063], Fig.8; ... a CFA such as a Bayer filter, or be formed of individual color sensor elements (e.g., RGB or Cyan-Magenta-Yellow ("CMY")) [0067]) and wherein the processing includes, for a ZF input (... "zoom" may be understood as a capability to provide different magnifications... by changing the focal length of an optical system [0004]; ... allows the user to choose any level of zoom and to utilize the multi-aperture camera as a continuous zoom camera [0062]) that defines an FOV equal to or smaller than the second FOV (... two cameras (10) and (12) that image fields of view (20) and (22)... cameras (10) and (12) may be... sub-cameras of a single multi-aperture camera [0046], Fig.1, Fig.2; ... It is contemplated that sensors of sub-cameras of a single multi-aperture camera may be shared in any manner... blocks of pixels adjacent one another in a single sensor chip... not limited to having identical shapes or sizes [0049], Fig.2; In a particular aspect, configuring the first sub-camera may include establishing a first focal length... configuring the second camera may include establishing a second focal length... The second focal length may be different than the first focal length such that the second camera exhibits a different field of view as compared to the first camera [0013]; ... each optical sub-system may have a different focal length resulting in different fields of view [0048], Fig.2), forming the output image based on the second image (... Process (338)... may be applied to full color images... an image registration procedure (342) is applied [0065], Fig.9; ... fusion of image data... may involve addition of color information from a color sub-camera image to luminance information from a grayscale sub-camera image... a complementary operation may be performed where luminance information from the grayscale sub-camera is added to the color image from the color sub-camera... FIG. 11, which illustrates an exemplary process (365) that utilizes processor (166) (see FIG. 3) for fusion of image data [0073]-[0077], Fig.11).

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Regarding claim 18, Dagher teaches the imaging system of claim 13 (... Multi aperture camera (100) provides first and second sets of image data (301) and (302) to a processor (166) which may, for example, be configured for combining or "fusing" the image data sets... to an image output device (167) [0053], Fig.3; In a particular aspect, configuring the first sub-camera may include establishing a first focal length... configuring the second camera may include establishing a second focal length... The second focal length may be different than the first focal length such that the second camera exhibits a different field of view as compared to the first camera [0013]; ... each optical sub-system may have a different focal length resulting in different fields of view [0048], Fig.2), wherein the standard CFA includes a Bayer filter (... Image sensors often utilize a Red-Green-Blue ("RGB") color filter array ("CFA"), such as a Bayer pattern... in FIG. 8, both the tele and the wide images are converted from RGB to YUV [0063], Fig.8; ... a CFA such as a Bayer filter, or be formed of individual color sensor elements (e.g., RGB or Cyan-Magenta-Yellow ("CMY")) [0067]).

Regarding claim 19, Dagher teaches the imaging system of claim 13 (... Multi aperture camera (100) provides first and second sets of image data (301) and (302) to a processor (166) which may, for example, be configured for combining or "fusing" the image data sets... to an image output device (167) [0053], Fig.3; In a particular aspect, configuring the first sub-camera may include establishing a first focal length... configuring the second camera may include establishing a second focal length... The second focal length may be different than the first focal length such that the second camera exhibits a different field of view as compared to the first camera [0013]; ... each optical sub-system may have a different focal length resulting in different fields of view [0048], Fig.2), wherein the standard CFA includes a Bayer filter (... Image sensors often utilize a Red-Green-Blue ("RGB") color filter array ("CFA"), such as a Bayer pattern... in FIG. 8, both the tele and the wide images are converted from RGB to YUV [0063], Fig.8; ... a CFA such as a Bayer filter, or be formed of individual color sensor elements (e.g., RGB or Cyan-Magenta-Yellow ("CMY")) [0067]), but lacks the explicit teaching of a non-Bayer filter.
However, Koskinen is analogous to Dagher and has a non-Bayer filter (Typical technologies for generating color images rely on the Bayer sensor and its variations... FIG. 1 shows a typical Bayer-type pattern... Other filter types include, by example, CYGM filters... and RGBE filters Col.1 ln.46-56, Fig.1).
It would have been obvious to one of ordinary skill in the art at the time of the invention to combine a non-Bayer filter as taught by Koskinen with the invention of Dagher.
The motivation would have been an obvious design choice and allows the designer much more freedom than a standard Bayer color filter array (Koskinen, Col.1 ln.46-56, Col.3 ln.41-48, Col.3 ln.59-63, Fig.1, Fig.3).

Regarding claim 20, Dagher teaches the imaging system of claim 19 (... multi-aperture camera systems with the imaging characteristics [0041]-[0042], Fig.1; multi-aperture camera Fig.3; ... Image sensors often utilize a Red-Green-Blue ("RGB") color filter array ("CFA"), such as a Bayer pattern... in FIG. 8, both the tele and the wide images are converted from RGB to YUV [0063], Fig.8; ... a CFA such as a Bayer filter, or be formed of individual color sensor elements (e.g., RGB or Cyan-Magenta-Yellow ("CMY")) [0067]), but lacks the explicit teaching of wherein the non-Bayer filter is selected from the group consisting of a RGBE, a CYYM, a CYGM, a RGBW#1, a RGBW#2 and a RGBW#3 filter.
However, Koskinen is analogous to Dagher and has wherein the non-Bayer filter is selected from the group consisting of a RGBE, a CYYM, a CYGM, a RGBW#1, a RGBW#2 and a RGBW#3 filter (Typical technologies for generating color images rely on the Bayer sensor and its variations... FIG. 1 shows a typical Bayer-type pattern... Other filter types include, by example, CYGM filters... and RGBE filters Col.1 ln.46-56, Fig.1).
It would have been obvious to one of ordinary skill in the art at the time of the invention to combine wherein the non-Bayer filter is selected from the group consisting of a RGBE, a CYYM, a CYGM, a RGBW#1, a RGBW#2 and a RGBW#3 filter as taught by Koskinen with the invention of Dagher.
The motivation would have been an obvious design choice and allows the designer much more freedom than a standard Bayer color filter array (Koskinen, Col.1 ln.46-56, Col.3 ln.41-48, Col.3 ln.59-63, Fig.1, Fig.3).

Regarding claim 30, Dagher teaches the imaging system of claim 21 (... multi-aperture camera systems with the imaging characteristics [0041]-[0042], Fig.1; multi-aperture camera Fig.3), wherein the standard CFA includes a Bayer filter (... Image sensors often utilize a Red-Green-Blue ("RGB") color filter array ("CFA"), such as a Bayer pattern... in FIG. 8, both the tele and the wide images are converted from RGB to YUV [0063], Fig.8; ... a CFA such as a Bayer filter, or be formed of individual color sensor elements (e.g., RGB or Cyan-Magenta-Yellow ("CMY")) [0067]), but lacks the explicit teaching of a non-Bayer filter.
However, Koskinen is analogous to Dagher and has a non-Bayer filter (Typical technologies for generating color images rely on the Bayer sensor and its variations... FIG. 1 shows a typical Bayer-type pattern... Other filter types include, by example, CYGM filters... and RGBE filters Col.1 ln.46-56, Fig.1).
It would have been obvious to one of ordinary skill in the art at the time of the invention to combine a non-Bayer filter as taught by Koskinen with the invention of Dagher.
The motivation would have been an obvious design choice and allows the designer much more freedom than a standard Bayer color filter array (Koskinen, Col.1 ln.46-56, Col.3 ln.41-48, Col.3 ln.59-63, Fig.1, Fig.3).

Regarding claim 31, Dagher teaches the imaging system of claim 30 (... multi-aperture camera systems with the imaging characteristics [0041]-[0042], Fig.1; multi-aperture camera Fig.3; ... Image sensors often utilize a Red-Green-Blue ("RGB") color filter array ("CFA"), such as a Bayer pattern... in FIG. 8, both the tele and the wide images are converted from RGB to YUV [0063], Fig.8; ... a CFA such as a Bayer filter, or be formed of individual color sensor elements (e.g., RGB or Cyan-Magenta-Yellow ("CMY")) [0067]), but lacks the explicit teaching of wherein the non-Bayer filter is selected from the group consisting of a RGBE, a CYYM, a CYGM, a RGBW#1, a RGBW#2 and a RGBW#3 filter.
However, Koskinen is analogous to Dagher and has wherein the non-Bayer filter is selected from the group consisting of a RGBE, a CYYM, a CYGM, a RGBW#1, a RGBW#2 and a RGBW#3 filter (Typical technologies for generating color images rely on the Bayer sensor and its variations... FIG. 1 shows a typical Bayer-type pattern... Other filter types include, by example, CYGM filters... and RGBE filters Col.1 ln.46-56, Fig.1).
It would have been obvious to one of ordinary skill in the art at the time of the invention to combine wherein the non-Bayer filter is selected from the group consisting of a RGBE, a CYYM, a CYGM, a RGBW#1, a RGBW#2 and a RGBW#3 filter as taught by Koskinen with the invention of Dagher.
The motivation would have been an obvious design choice and allows the designer much more freedom than a standard Bayer color filter array (Koskinen, Col.1 ln.46-56, Col.3 ln.41-48, Col.3 ln.59-63, Fig.1, Fig.3).

Supplemental Box

In case the space in any of the preceding boxes is not sufficient.
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Claims 2-5 lack an inventive step under PCT Article 33(3) as being obvious over Dagher et al. (US 2011/0064327 A1), hereinafter Dagher in view of Koskinen et al. (US 8,134,115 B2), hereinafter Koskinen and further in view of Myhrvold (US 8,094,208 B2), hereinafter Myhrvold.

Regarding claim 2, Dagher teaches the imaging system of claim 1 (... multi-aperture camera systems with the imaging characteristics [0041]-[0042], Fig.1; multi-aperture camera Fig.3; ... cameras (10) and (12) may be... sub-cameras of a single multi-aperture camera [0046], Fig.1, Fig.2; ... It is contemplated that sensors of sub-cameras of a single multi-aperture camera may be shared in any manner... blocks of pixels adjacent one another in a single sensor chip... not limited to having identical shapes or sizes [0049]), but lacks the explicit teaching of wherein the non-standard CFA includes a repetition of a 2x2 micro-cell in which a color filter order is either BR-RB or YC-CY.
However, Koskinen is analogous to Dagher and has wherein the non-standard CFA (Typical technologies for generating color images rely on the Bayer sensor and its variations... FIG. 1 shows a typical Bayer-type pattern... Other filter types include, by example, CYGM filters... and RGBE filters Col.1 ln.46-56, Fig.1; The exemplary embodiments of this invention use... sub-diffraction limit receptors in combination with a color filter array. The color filter array may be designed much more freely than conventional color filter arrays Col.3 ln.41-48, Fig.3; Contrasting FIG. 3 with FIG. 1, the optical filters... enable a plurality of different filter types to be used in any desired combinations Col.3 ln.59-63 Fig.3; It should be noted that the color filters do not have to be separate for each receptor (2)... each of three different filter types is shown overlaying a plurality of the receptors Col.7 ln.51-55, Fig.7, Fig.9).
It would have been obvious to one of ordinary skill in the art at the time of the invention to combine wherein the non-standard CFA as taught by Koskinen with the invention of Dagher.
The motivation would have been an obvious design choice and allows the designer much more freedom than conventional or standard color filter arrays and enable a plurality of different filter types to be used in any desired combination (Koskinen, Col.3 ln.41-48, Col.3 ln.59-63 Fig.3).
Dagher as modified lacks includes a repetition of a 2x2 micro-cell in which a color filter order is either BR-RB or YC-CY.
Myhrvold is analogous to Dagher and has includes a repetition of a 2x2 micro-cell (Color mosaics or filter arrays (CFAs) and demosaicing techniques for digital imaging are disclosed herein... CFAs and demosaicing techniques described herein are not restricted to any particular color sensor Col.5 ln.44-53; FIG. 2 shows an exemplary RGB pattern (200) for a color filter array... may be used for CFAs based on other color combinations (e.g., RGBE, CYYM, CYGM, RGBW, etc.) Col.6 ln.56-Col.7 ln.1, Fig.2; Exemplary CFA patterns may include NxN repeat units... corresponding to a 2x2 array... a 3x3 array... a 4x4 array... a 5x5 array Col.7 ln.20-30, Col.8 ln.14-22, Fig.3; 2x2 array Fig.3A; 3x3 array Fig.3B, Fig.3C; 4x4 array Fig.2, Fig.3D, Fig.3E; 6x6 array Fig.1), but lacks the explicit teaching of in which a color filter order is either BR-RB or YC-CY.
However, it would have been obvious to one of ordinary skill in the art at the time of the invention was made to combine includes a repetition of a 2x2 micro-cell in which a color filter order is either BR-RB or YC-CY as taught by Myhrvold with the invention of Dagher, since rearranging parts of an invention involves only routine skill in the art.
The motivation for doing so would be to allow a designer CFAs based on other color combinations for NxN repeat units and not be restricted to any particular color sensor (Myhrvold Col.5 ln.44-53, Col.6 ln.56-Col.7 ln.1, Col.7 ln.20-30, Figs.1-3).

Regarding claim 3, Dagher teaches the imaging system of claim 1 (... multi-aperture camera systems with the imaging characteristics [0041]-[0042], Fig.1; multi-aperture camera Fig.3; ... cameras (10) and (12) may be... sub-cameras of a single multi-aperture camera [0046], Fig.1, Fig.2; ... It is contemplated that sensors of sub-cameras of a single multi-aperture camera may be shared in any manner... blocks of pixels adjacent one another in a single sensor chip... not limited to having identical shapes or sizes [0049]), but lacks the explicit teaching of wherein the non-standard CFA includes a repetition of a 3x3 micro-cell in which a color filter order is GBR-RGB-BRG.
However, Koskinen is analogous to Dagher and has wherein the non-standard CFA (Typical technologies for generating color images rely on the Bayer sensor and its variations... FIG. 1 shows a typical Bayer-type pattern... Other filter types include, by example, CYGM filters... and RGBE filters Col.1 ln.46-56, Fig.1; The exemplary embodiments of this invention use... sub-diffraction limit receptors in combination with a color filter array. The color filter array may be designed much more freely than conventional color filter arrays Col.3 ln.41-48, Fig.3; Contrasting FIG. 3 with FIG. 1, the optical filters... enable a plurality of different filter types to be used in any desired combinations Col.3 ln.59-63 Fig.3; It should be noted that the color filters do not have to be separate for each receptor (2)... each of three different filter types is shown overlaying a plurality of the receptors Col.7 ln.51-55, Fig.7, Fig.9).
It would have been obvious to one of ordinary skill in the art at the time of the invention to combine wherein the non-standard CFA as taught by Koskinen with the invention of Dagher.
The motivation would have been an obvious design choice and allows the designer much more freedom than conventional or standard color filter arrays and enable a plurality of different filter types to be used in any desired combination (Koskinen, Col.3 ln.41-48, Col.3 ln.59-63 Fig.3).
Dagher as modified lacks includes a repetition of a 3x3 micro-cell in which a color filter order is GBR-RGB-BRG.
Myhrvold is analogous to Dagher and has includes a repetition of a 3x3 micro-cell (Color mosaics or filter arrays (CFAs) and demosaicing techniques for digital imaging are disclosed herein... CFAs and demosaicing techniques described herein are not restricted to any particular color sensor Col.5 ln.44-53; FIG. 2 shows an exemplary RGB pattern (200) for a color filter array... may be used for CFAs based on other color combinations (e.g., RGBE, CYYM, CYGM, RGBW, etc.) Col.6 ln.56-Col.7 ln.1, Fig.2; Exemplary CFA patterns may include NxN repeat units... corresponding to a 2x2 array... a 3x3 array... a 4x4 array... a 5x5 array Col.7 ln.20-30, Col.8 ln.14-22, Fig.3; 2x2 array Fig.3A; 3x3 array Fig.3B, Fig.3C; 4x4 array Fig.2, Fig.3D, Fig.3E; 6x6 array Fig.1), but lacks the explicit teaching of in which a color filter order is GBR-RGB-BRG.
However, it would have been obvious to one of ordinary skill in the art at the time of the invention was made to combine includes a repetition of a 3x3 micro-cell in which a color filter order is GBR-RGB-BRG as taught by Myhrvold with the invention of Dagher, since rearranging parts of an invention involves only routine skill in the art.
The motivation for doing so would be to allow a designer CFAs based on other color combinations for NxN repeat units and not be restricted to any particular color sensor (Myhrvold Col.5 ln.44-53, Col.6 ln.56-Col.7 ln.1, Col.7 ln.20-30, Figs.1-3).

Supplemental Box

In case **the space in any of the preceding boxes is not sufficient.**
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Regarding claim 4, Dagher teaches the imaging system of claim 1 (... multi-aperture camera systems with the imaging characteristics [0041]-[0042], Fig.1; multi-aperture camera Fig.3; ... cameras (10) and (12) may be... sub-cameras of a single multi-aperture camera [0046], Fig.1, Fig.2; ... It is contemplated that sensors of sub-cameras of a single multi-aperture camera may be shared in any manner... blocks of pixels adjacent one another in a single sensor chip... not limited to having identical shapes or sizes [0049]), but lacks the explicit teaching of wherein the non-standard CFA includes a repetition of a 4x4 micro-cell in which a color filter order is BBRR-RBBR-RRBB-BRRB.

However, Koskinen is analogous to Dagher and has wherein the non-standard CFA (Typical technologies for generating color images rely on the Bayer sensor and its variations... FIG. 1 shows a typical Bayer-type pattern... Other filter types include, by example, CYGM filters... and RGBE filters Col.1 ln.46-56, Fig.1; The exemplary embodiments of this invention use... sub-diffraction limit receptors in combination with a color filter array. The color filter array may be designed much more freely than conventional color filter arrays Col.3 ln.41-48, Fig.3; Contrasting FIG. 3 with FIG. 1, the optical filters... enable a plurality of different filter types to be used in any desired combinations Col.3 ln.59-63 Fig.3; It should be noted that the color filters do not have to be separate for each receptor (2)... each of three different filter types is shown overlaying a plurality of the receptors Col.7 ln.51-55, Fig.7, Fig.9).

It would have been obvious to one of ordinary skill in the art at the time of the invention to combine wherein the non-standard CFA as taught by Koskinen with the invention of Dagher.

The motivation would have been an obvious design choice and allows the designer much more freedom than conventional or standard color filter arrays and enable a plurality of different filter types to be used in any desired combination (Koskinen, Col.3 ln.41-48, Col.3 ln.59-63 Fig.3).

Dagher as modified lacks includes a repetition of a 4x4 micro-cell in which a color filter order is BBRR-RBBR-RRBB-BRRB.

Myhrvold is analogous to Dagher and has includes a repetition of a 4x4 micro-cell (Color mosaics or filter arrays (CFAs) and demosaicing techniques for digital imaging are disclosed herein... CFAs and demosaicing techniques described herein are not restricted to any particular color sensor Col.5 ln.44-53; FIG. 2 shows an exemplary RGB pattern (200) for a color filter array... may be used for CFAs based on other color combinations (e.g., RGBE, CYYM, CYGM, RGBW, etc.) Col.6 ln.56-Col.7 ln.1, Fig.2; Exemplary CFA patterns may include NxN repeat units... corresponding to a 2x2 array... a 3x3 array... a 4x4 array... a 5x5 array Col.7 ln.20-30, Col.8 ln.14-22, Fig.3; 2x2 array Fig.3A; 3x3 array Fig.3B, Fig.3C; 4x4 array Fig.2, Fig.3D, Fig.3E; 6x6 array Fig.1), but lacks the explicit teaching of in which a color filter order is BBRR-RBBR-RRBB-BRRB.

However, it would have been obvious to one of ordinary skill in the art at the time of the invention was made to combine includes a repetition of a 4x4 micro-cell in which a color filter order is BBRR-RBBR-RRBB-BRRB as taught by Myhrvold with the invention of Dagher, since rearranging parts of an invention involves only routine skill in the art.

The motivation for doing so would be to allow a designer CFAs based on other color combinations for NxN repeat units and not be restricted to any particular color sensor (Myhrvold Col.5 ln.44-53, Col.6 ln.56-Col.7 ln.1, Col.7 ln.20-30, Figs.1-3).

Supplemental Box

In case the space in any of the preceding boxes is not sufficient.
Continuation of:

Regarding claim 5, Dagher teaches the imaging system of claim 1 (... multi-aperture camera systems with the imaging characteristics [0041]-[0042], Fig.1; multi-aperture camera Fig.3; ... cameras (10) and (12) may be... sub-cameras of a single multi-aperture camera [0046], Fig.1, Fig.2; ... It is contemplated that sensors of sub-cameras of a single multi-aperture camera may be shared in any manner... blocks of pixels adjacent one another in a single sensor chip... not limited to having identical shapes or sizes [0049]), but lacks the explicit teaching of wherein the non-standard CFA includes a repetition of a 6x6 micro-cell in which a color filter order is selected from the group consisting of RBBRRB-RWRBWB-BBRBRR-RRBRBB-BWBRWR-BRRBBR, BBGRRG-RGRBGBGBRGRB-RRGBBG-BGBRGR-GRBGBR, RBBRRB-RGRBGB-BBRBRR-RRBRBBBGBRGR-BRRBBR and RBRBRB-BGBRGR-RBRBRB-BRBRBR-RGRBGB-BRBRBR.
However, Koskinen is analogous to Dagher and has wherein the non-standard CFA (Typical technologies for generating color images rely on the Bayer sensor and its variations... FIG. 1 shows a typical Bayer-type pattern... Other filter types include, by example, CYGM filters... and RGBE filters Col.1 ln.46-56, Fig.1; The exemplary embodiments of this invention use... sub-diffraction limit receptors in combination with a color filter array. The color filter array may be designed much more freely than conventional color filter arrays Col.3 ln.41-48, Fig.3; Contrasting FIG. 3 with FIG. 1, the optical filters... enable a plurality of different filter types to be used in any desired combinations Col.3 ln.59-63 Fig.3; It should be noted that the color filters do not have to be separate for each receptor (2)... each of three different filter types is shown overlaying a plurality of the receptors Col.7 ln.51-55, Fig.7, Fig.9).
It would have been obvious to one of ordinary skill in the art at the time of the invention to combine wherein the non-standard CFA as taught by Koskinen with the invention of Dagher.
The motivation would have been an obvious design choice and allows the designer much more freedom than conventional or standard color filter arrays and enable a plurality of different filter types to be used in any desired combination (Koskinen, Col.3 ln.41-48, Col.3 ln.59-63 Fig.3).
Dagher as modified lacks includes a repetition of a 6x6 micro-cell in which a color filter order is selected from the group consisting of RBBRRB-RWRBWB-BBRBRR-RRBRBB-BWBRWR-BRRBBR, BBGRRG-RGRBGBGBRGRB-RRGBBG-BGBRGR-GRBGBR, RBBRRB-RGRBGB-BBRBRR-RRBRBBBGBRGR-BRRBBR and RBRBRB-BGBRGR-RBRBRB-BRBRBR-RGRBGB-BRBRBR.
Myhrvold is analogous to Dagher and has includes a repetition of a 6x6 micro-cell (Color mosaics or filter arrays (CFAs) and demosaicing techniques for digital imaging are disclosed herein... CFAs and demosaicing techniques described herein are not restricted to any particular color sensor Col.5 ln.44-53; FIG. 2 shows an exemplary RGB pattern (200) for a color filter array... may be used for CFAs based on other color combinations (e.g., RGBE, CYYM, CYGM, RGBW, etc.) Col.6 ln.56-Col.7 ln.1, Fig.2; Exemplary CFA patterns may include NxN repeat units... corresponding to a 2x2 array... a 3x3 array... a 4x4 array... a 5x5 array Col.7 ln.20-30, Col.8 ln.14-22, Fig.3; 2x2 array Fig.3A; 3x3 array Fig.3B, Fig.3C; 4x4 array Fig.2, Fig.3D, Fig.3E; 6x6 array Fig.1), but lacks the explicit teaching of in which a color filter order is selected from the group consisting of RBBRRB-RWRBWB-BBRBRR-RRBRBB-BWBRWR-BRRBBR, BBGRRG-RGRBGBGBRGRB-RRGBBG-BGBRGR-GRBGBR, RBBRRB-RGRBGB-BBRBRR-RRBRBBBGBRGR-BRRBBR and RBRBRB-BGBRGR-RBRBRB-BRBRBR-RGRBGB-BRBRBR.
However, it would have been obvious to one of ordinary skill in the art at the time of the invention was made to combine includes a repetition of a 6x6 micro-cell in which a color filter order is selected from the group consisting of RBBRRB-RWRBWB-BBRBRR-RRBRBB-BWBRWR-BRRBBR, BBGRRG-RGRBGBGBRGRB-RRGBBG-BGBRGR-GRBGBR, RBBRRB-RGRBGB-BBRBRR-RRBRBBBGBRGR-BRRBBR and RBRBRB-BGBRGR-RBRBRB-BRBRBR-RGRBGB-BRBRBR as taught by Myhrvold with the invention of Dagher, since rearranging parts of an invention involves only routine skill in the art.
The motivation for doing so would be to allow a designer CFAs based on other color combinations for NxN repeat units and not be restricted to any particular color sensor (Myhrvold Col.5 ln.44-53, Col.6 ln.56-Col.7 ln.1, Col.7 ln.20-30, Figs.1-3).

Claims 1-32 meet the criteria set out in PCT Article 33(4), and thus have industrial applicability because the subject matter claimed can be made or used in industry.

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APPLICATION NUMBER: ***61/730,570***
FILING DATE: ***November 28, 2012***

THE COUNTRY CODE AND NUMBER OF YOUR PRIORITY APPLICATION, TO BE USED FOR FILING ABROAD UNDER THE PARIS CONVENTION, IS ***US61/730,570***

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POWER OF ATTORNEY OR REVOCATION OF POWER OF ATTORNEY WITH A NEW POWER OF ATTORNEY AND CHANGE OF CORRESPONDENCE ADDRESS

Application Number	
Filing Date	
First Named Inventor	Gal Shabtay
Title	THIN MULTI-APERTURE IMAGING SYSTEMS WITH IM
Art Unit	
Examiner Name	
Attorney Docket Number	COREPH-0072 US PR

I hereby revoke all previous powers of attorney given in the above-identified application.

☐ A Power of Attorney is submitted herewith.

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I am the:

☐ Applicant/Inventor.

OR

☒ Assignee of record of the entire interest. See 37 CFR 3.71.
Statement under 37 CFR 3.73(b) (Form PTO/SB/96) submitted herewith or filed on ______________________________.

SIGNATURE of Applicant or Assignee of Record

Signature	/GS/	Date	11-28-2012
Name	GAL SHABTAY	Telephone	
Title and Company			

NOTE: Signatures of all the inventors or assignees of record of the entire interest or their representative(s) are required. Submit multiple forms if more than one signature is required, see below*.

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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.

ABSTRACT

Multi-aperture imaging systems with improved color resolution comprising a first camera subset having a first sensor with a first plurality of sensor pixels covered at least in part by a non-standard color filter array (CFA) operative to increase a specific color sampling rate relative to a same color sampling rate in a standard CFA and a second camera subset having a second sensor with a second plurality of sensor pixels, the second plurality of sensor pixels being either Luma or covered with a standard CFA. The first and second camera subsets may have identical or different fields of view. The standard CFA may include a Bayer or a non-Bayer pattern, while the non-standard CFA includes a repetition of a n x n micro-cell in which a color filter order is exemplarily RRBB, RBBR, YCCY (n = 2), RBBRWRBBR (n = 3), and RBBRRBRWRBWBBBRBRRRRBRBBBWBRWRBRRBBR, BBGRRGRGRBGBGBRGRBRRGBBGBGBRGRGRBGBR, RBBRRBRGRBGBBBRBRRRRBRBBBGBRGRBRRBBR or RBRBRBBGBRGRRBRBRBBRBRBRRGRBGBBRBRBR (n = 6).

CLAIMS:

1. A multi-aperture imaging system comprising:

a) a first camera subset having a respective first sensor with a first plurality of sensor pixels covered at least in part by a non-standard color filter array (CFA) operative to increase a specific color sampling rate relative to a same color sampling rate in a standard CFA; and

b) a second camera subset having a respective second sensor with a second plurality of sensor pixels, the second plurality of sensor pixels being either Luma or covered with a standard CFA.

2. The imaging system of claim 1, wherein the non-standard CFA includes a repetition of a 2x2 micro-cell in which a color filter order is RRBB.

3. The imaging system of claim 1, wherein the non-standard CFA includes a repetition of a 2x2 micro-cell in which a color filter order is RBBR.

4. The imaging system of claim 1, wherein the non-standard CFA includes a repetition of a 2x2 micro-cell in which a color filter order is YCCY.

5. The imaging system of claim 1, wherein the non-standard CFA includes a repetition of a 3x3 micro-cell in which a color filter order is RBBRWRBBR.

6. The imaging system of claim 1, wherein the non-standard CFA includes a repetition of a 6x6 micro-cell in which a color filter order is selected from the group consisting of RBBRRBRWRBWBBBRBRRRRBRBBBWBRWRBRRBBR, BBGRRGRGRBGBGBRGRBRRGBBGBGBRGRGRBGBR, RBBRRBRGRBGBBBRBRRRRBRBBBGBRGRBRRBBR and RBRBRBBGBRGRRBRBRBBRBRBRRGRBGBBRBRBR

7. The imaging system of claim 1, wherein the standard CFA includes a Bayer filter

8. The imaging system of claim 2, wherein the standard CFA includes a Bayer filter.

9. The imaging system of claim 3, wherein the standard CFA includes a Bayer filter.

10. The imaging system of claim 4, wherein the standard CFA includes a Bayer filter.

11. The imaging system of claim 5, wherein the standard CFA includes a Bayer filter.

12. The imaging system of claim 6, wherein the standard CFA includes a Bayer filter.

13. The imaging system of claim 1, wherein the standard CFA includes a non-Bayer filter.

14. The imaging system of claim 2, wherein the standard CFA includes a non-Bayer filter.

15. The imaging system of claim 3, wherein the standard CFA includes a non-Bayer filter.

16. The imaging system of claim 4, wherein the standard CFA includes a non-Bayer filter.

17. The imaging system of claim 5, wherein the standard CFA includes a non-Bayer filter.

18. The imaging system of claim 6, wherein the standard CFA includes a non-Bayer Bayer filter.

19. The imaging system of any of claims 13-18, wherein the non-Bayer filter is selected from the group consisting of a RGBE, a CYYM, a CYGM, a RGBW#1, a RGBW#2 and a RGBW#3 filter.

20. The imaging system of claim 1, wherein the first camera subset has a first field of view (FOV), wherein the second camera subset has a second, smaller FOV than the first FOV, and wherein the non-standard CFA covers an overlap area on the first sensor which captures the second FOV, thereby providing both optical zoom and increased color resolution.

21. The imaging system of claim 20, wherein the non-standard CFA includes a repetition of a 2x2 micro-cell in which a color filter order is RRBB.

22. The imaging system of claim 20, wherein the non-standard CFA includes a repetition of a 2x2 micro-cell in which a color filter order is RBBR.

23. The imaging system of claim 20, wherein the non-standard CFA includes a repetition of a 2x2 micro-cell in which a color filter order is YCCY.

24. The imaging system of claim 20, wherein the non-standard CFA includes a repetition of a 3x3 micro-cell in which a color filter order is RBBRWRBBR.

25. The imaging system of claim 20, wherein the non-standard CFA includes a repetition of a 6x6 micro-cell in which a color filter order is selected from the group consisting of RBBRRBRWRBWBBBRBRRRRBRBBBWBRWRBRRBBR, BBGRRGRGRBGBGBRGRBRRGBBGBGBRGRGRBGBR, RBBRRBRGRBGBBBRBRRRRBRBBBGBRGRBRRBBR and RBRBRBBGBRGRRBRBRBBRBRBRRGRBGBBRBRBR

26. The imaging system of claim 20, wherein the standard CFA includes a Bayer filter.

27. The imaging system of claim 21, wherein the standard CFA includes a Bayer filter.

28. The imaging system of claim 22, wherein the standard CFA includes a Bayer filter.

29. The imaging system of claim 23, wherein the standard CFA includes a Bayer filter.

30. The imaging system of claim 24, wherein the standard CFA includes a Bayer filter.

31. The imaging system of claim 25, wherein the standard CFA includes a Bayer filter.

32. The imaging system of claim 20, wherein the standard CFA includes a non-Bayer filter.

33. The imaging system of claim 21, wherein the standard CFA includes a non-Bayer filter.

34. The imaging system of claim 22, wherein the standard CFA includes a non-Bayer filter.

35. The imaging system of claim 23, wherein the standard CFA includes a non-Bayer filter.

36. The imaging system of claim 24, wherein the standard CFA includes a non-Bayer filter.

37. The imaging system of claim 25, wherein the standard CFA includes a non-Bayer filter.

38. The imaging system of any of claims 33-37, wherein the non-Bayer filter is selected from the group consisting of a RGBE, a CYYM, a CYGM, a RGBW#1, a RGBW#2 and a RGBW#3 filter.

39. The imaging system of claim 1, wherein the first and the second camera subsets have respectively identical first and second fields of view (FOVs), and wherein the non-standard CFA covers an overlap area on the first sensor which captures the second FOV, thereby providing increased color resolution.

40. The imaging system of claim 39, wherein the non-standard CFA includes a repetition of a 2x2 micro-cell in which a color filter order is RRBB.

41. The imaging system of claim 39, wherein the non-standard CFA includes a repetition of a 2x2 micro-cell in which a color filter order is RBBR.

42. The imaging system of claim 39, wherein the non-standard CFA includes a repetition of a 2x2 micro-cell in which a color filter order is YCCY.

43. The imaging system of claim 39, wherein the non-standard CFA includes a repetition of a 3x3 micro-cell in which a color filter order is RBBRWRBBR.

44. The imaging system of claim 39, wherein the non-standard CFA includes a repetition of a 6x6 micro-cell in which a color filter order is selected from the group consisting of RBBRRBRWRBWBBBRBRRRRBRBBBWBRWRBRRBBR, BBGRRGRGRBGBGBRGRBRRGBBGBGBRGRGRBGBR, RBBRRBRGRBGBBBRBRRRRBRBBBGBRGRBRRBBR and RBRBRBBGBRGRRBRBRBBRBRBRRGRBGBBRBRBR

45. The imaging system of claim 39, wherein the standard CFA includes a Bayer filter.

46. The imaging system of claim 40, wherein the standard CFA includes a Bayer filter.

47. The imaging system of claim 41, wherein the standard CFA includes a Bayer filter.

48. The imaging system of claim 42, wherein the standard CFA includes a Bayer filter.

49. The imaging system of claim 43, wherein the standard CFA includes a Bayer filter.

50. The imaging system of claim 44, wherein the standard CFA includes a Bayer filter.

51. The imaging system of claim 39, wherein the standard CFA includes a non-Bayer filter.

52. The imaging system of claim 40, wherein the standard CFA includes a non-Bayer filter.

53. The imaging system of claim 41, wherein the standard CFA includes a non-Bayer filter.

54. The imaging system of claim 42, wherein the standard CFA includes a non-Bayer filter.

55. The imaging system of claim 43, wherein the standard CFA includes a non-Bayer filter.

56. The imaging system of claim 44, wherein the standard CFA includes a non-Bayer filter.

57. The imaging system of any of claims 51-56, wherein the non-Bayer filter is selected from the group consisting of a RGBE, a CYYM, a CYGM, a RGBW#1, a RGBW#2 and a RGBW#3 filter.

Electronic Acknowledgement Receipt

EFS ID:	14324389
Application Number:	61730570
International Application Number:	
Confirmation Number:	6073
Title of Invention:	THIN MULTI-APERTURE IMAGING SYSTEMS WITH IMPROVED COLOR RESOLUTION
First Named Inventor/Applicant Name:	Gal Shabtay
Customer Number:	92342
Filer:	Menachem Nathan
Filer Authorized By:	
Attorney Docket Number:	COREPH-0072 US PR
Receipt Date:	28-NOV-2012
Filing Date:	
Time Stamp:	11:33:59
Application Type:	Provisional

Payment information:

Submitted with Payment	yes
Payment Type	Credit Card
Payment was successfully received in RAM	$125
RAM confirmation Number	10328
Deposit Account	
Authorized User	

File Listing:

Document Number	Document Description	File Name	File Size(Bytes)/ Message Digest	Multi Part /.zip	Pages (if appl.)

1	Provisional Cover Sheet (SB16)	CoverSheet.pdf	2074778 1e808a1494413f74d970f0747144ec410d59e60d	no	3
Warnings:					
Information:					
2	Application Data Sheet	Application_Data_Sheet.pdf	895664 e3f06e7348ce2cb06a448460f6b11b1263cd7fac	no	5
Warnings:					
Information:					
3		Application_filed.pdf	1959269 74eea234a9301cd324c0dc932c8b14cd87699140	yes	28

Multipart Description/PDF files in .zip description

Document Description	Start	End
Specification	1	13
Claims	14	19
Abstract	20	20
Drawings-only black and white line drawings	21	28

Warnings:					
Information:					
4	Assignee showing of ownership per 37 CFR 3.73.	STATEMENT_For_Assignment.pdf	429662 097b208485730c3cb71b280de7f6c227bb88b097	no	2
Warnings:					
Information:					
5	Assignee showing of ownership per 37 CFR 3.73.	ASSIGNMENT.pdf	15541 0429c088dc33a3c4727d85d27276d7fa59d9e184	no	1
Warnings:					
Information:					
6	Authorization to access Appl. by Trilateral Office	Authorization_Priority1.pdf	59621 59e83ae127ac261d5b17acd3af8fe73ea8a56983	no	2
Warnings:					
Information:					
7	Power of Attorney	POA.pdf	1464579 476e03a007a63fae97ef168274e36b600d0885cd	no	2
Warnings:					

Information:					
8	Fee Worksheet (SB06)	fee-info.pdf	29514 0ce496ac17643b152200b30ec9c6010bedd975b1	no	2
Warnings:					
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		Total Files Size (in bytes):	6928628		

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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.

Doc Code: **TR.PROV**
Document Description: Provisional Cover Sheet (SB16)

Provisional Application for Patent Cover Sheet

This is a request for filing a PROVISIONAL APPLICATION FOR PATENT under 37 CFR 1.53(c)

Inventor(s)

Inventor 1 — Remove

Given Name	Middle Name	Family Name	City	State	Country i
Gal		Shabtay	Tel Aviv		IL

Inventor 2 — Remove

Given Name	Middle Name	Family Name	City	State	Country i
Noy		Cohen	Tel Aviv		IL

Inventor 3 — Remove

Given Name	Middle Name	Family Name	City	State	Country i
Oded		Gigushinski	Tel Aviv		IL

Inventor 4 — Remove

Given Name	Middle Name	Family Name	City	State	Country i
Ephraim		Goldenberg	Ashdod		IL

All Inventors Must Be Listed – Additional Inventor Information blocks may be generated within this form by selecting the **Add** button. [Add]

Title of Invention	THIN MULTI-APERTURE IMAGING SYSTEMS WITH IMPROVED COLOR RESOLUTION
Attorney Docket Number (if applicable)	COREPH-0072 US PR

Correspondence Address

Direct all correspondence to (select one):

◉ The address corresponding to Customer Number	◯ Firm or Individual Name
Customer Number	92342

The invention was made by an agency of the United States Government or under a contract with an agency of the United States Government.

◉ No.

◯ Yes, the name of the U.S. Government agency and the Government contract number are:

Doc Code: **TR.PROV**
Document Description: Provisional Cover Sheet (SB16)

PTO/SB/16 (11-08)
Approved for use through 01/31/2014 OMB 0651-0032
U.S. Patent and Trademark Office: U.S. DEPARTMENT OF COMMERCE
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Entity Status

Applicant claims small entity status under 37 CFR 1.27

(●) Yes, applicant qualifies for small entity status under 37 CFR 1.27

( ) No

Warning

Petitioner/applicant is cautioned to avoid submitting personal information in documents filed in a patent application that may contribute to identity theft. Personal information such as social security numbers, bank account numbers, or credit card numbers (other than a check or credit card authorization form PTO-2038 submitted for payment purposes) is never required by the USPTO to support a petition or an application. If this type of personal information is included in documents submitted to the USPTO, petitioners/applicants should consider redacting such personal information from the documents before submitting them to USPTO. Petitioner/applicant is advised that the record of a patent application is available to the public after publication of the application (unless a non-publication request in compliance with 37 CFR 1.213(a) is made in the application) or issuance of a patent. Furthermore, the record from an abandoned application may also be available to the public if the application is referenced in a published application or an issued patent (see 37 CFR1.14). Checks and credit card authorization forms PTO-2038 submitted for payment purposes are not retained in the application file and therefore are not publicly available.

Signature

Please see 37 CFR 1.4(d) for the form of the signature.

Signature	/Menachem Nathan/			Date (YYYY-MM-DD)	2012-11-28
First Name	Menachem	Last Name	Nathan	Registration Number (If appropriate)	65392

This collection of information is required by 37 CFR 1.51. 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 1.11 and 1.14. This collection is estimated to take 8 hours 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. **This form can only be used when in conjunction with EFS-Web. If this form is mailed to the USPTO, it may cause delays in handling the provisional application.**

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 paten. 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, t o a n other 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.

Application Data Sheet 37 CFR 1.76	Attorney Docket Number	COREPH-0072 US PR
	Application Number	
Title of Invention	THIN MULTI-APERTURE IMAGING SYSTEMS WITH IMPROVED COLOR RESOLUTION	

The application data sheet is part of the provisional or nonprovisional application for which it is being submitted. The following form contains the bibliographic data arranged in a format specified by the United States Patent and Trademark Office as outlined in 37 CFR 1.76.
This document may be completed electronically and submitted to the Office in electronic format using the Electronic Filing System (EFS) or the document may be printed and included in a paper filed application.

Secrecy Order 37 CFR 5.2

☐ Portions or all of the application associated with this Application Data Sheet may fall under a Secrecy Order pursuant to 37 CFR 5.2 (Paper filers only. Applications that fall under Secrecy Order may not be filed electronically.)

Applicant Information:

Applicant 1 [Remove]

Applicant Authority	(●) Inventor	( ) Legal Representative under 35 U.S.C. 117	( ) Party of Interest under 35 U.S.C. 118	
Prefix	**Given Name**	**Middle Name**	**Family Name**	**Suffix**
	Gal		Shabtay	
Residence Information (Select One)	( ) US Residency	(●) Non US Residency	( ) Active US Military Service	
City	Tel Aviv	**Country Of Residence** i	IL	
Citizenship under 37 CFR 1.41(b) i	IL			
Mailing Address of Applicant:				
Address 1	4 Shmuel Shnitzer St.			
Address 2				
City	Tel Aviv	**State/Province**		
Postal Code	69583	**Country** i	IL	

Applicant 2 [Remove]

Applicant Authority	(●) Inventor	( ) Legal Representative under 35 U.S.C. 117	( ) Party of Interest under 35 U.S.C. 118	
Prefix	**Given Name**	**Middle Name**	**Family Name**	**Suffix**
	Noy		Cohen	
Residence Information (Select One)	( ) US Residency	(●) Non US Residency	( ) Active US Military Service	
City	Tel Aviv	**Country Of Residence** i	IL	
Citizenship under 37 CFR 1.41(b) i	IL			
Mailing Address of Applicant:				
Address 1	30 Shalom Ben Yosef St.			
Address 2				
City	Tel Aviv	**State/Province**		
Postal Code	69125	**Country** i	IL	

Applicant 3 [Remove]

Applicant Authority	(●) Inventor	( ) Legal Representative under 35 U.S.C. 117	( ) Party of Interest under 35 U.S.C. 118	
Prefix	**Given Name**	**Middle Name**	**Family Name**	**Suffix**
	Oded		Gigushinski	
Residence Information (Select One)	( ) US Residency	(●) Non US Residency	( ) Active US Military Service	
City	Tel Aviv	**Country Of Residence** i	IL	

Application Data Sheet 37 CFR 1.76	Attorney Docket Number	COREPH-0072 US PR
	Application Number	
Title of Invention	THIN MULTI-APERTURE IMAGING SYSTEMS WITH IMPROVED COLOR RESOLUTION	

Citizenship under 37 CFR 1.41(b) i	IL		
Mailing Address of Applicant:			
Address 1	14/6, Ben Gurion Avenue		
Address 2			
City	Tel Aviv	**State/Province**	
Postal Code	63454	**Country**i	IL

Applicant 4 [Remove]

Applicant Authority (●) Inventor ( ) Legal Representative under 35 U.S.C. 117 ( ) Party of Interest under 35 U.S.C. 118

Prefix	Given Name	Middle Name	Family Name	Suffix
	Ephraim		Goldenberg	

Residence Information (Select One) ( ) US Residency (●) Non US Residency ( ) Active US Military Service

City	Ashdod	**Country Of Residence**i	IL
Citizenship under 37 CFR 1.41(b) i	IL		
Mailing Address of Applicant:			
Address 1	32/2 Tel Chai Str.		
Address 2			
City	Ashdod	**State/Province**	
Postal Code	77510	**Country**i	IL

All Inventors Must Be Listed - Additional Inventor Information blocks may be generated within this form by selecting the **Add** button. [Add]

Correspondence Information:

Enter either Customer Number or complete the Correspondence Information section below.
For further information see 37 CFR 1.33(a).

☐ **An Address is being provided for the correspondence Information of this application.**

Customer Number	92342	
Email Address		[Add Email] [Remove Email]

Application Information:

Title of the Invention	THIN MULTI-APERTURE IMAGING SYSTEMS WITH IMPROVED COLOR RESOLUTION		
Attorney Docket Number	COREPH-0072 US PR	**Small Entity Status Claimed**	☒
Application Type	Provisional		
Subject Matter	Utility		
Suggested Class (if any)		**Sub Class (if any)**	
Suggested Technology Center (if any)			
Total Number of Drawing Sheets (if any)		**Suggested Figure for Publication (if any)**	

PTO/SB/14 (11-08)
Approved for use through 01/31/2014. OMB 0651-0032
U.S. Patent and Trademark Office; U.S. DEPARTMENT OF COMMERCE

Application Data Sheet 37 CFR 1.76	Attorney Docket Number	COREPH-0072 US PR
	Application Number	

Title of Invention	THIN MULTI-APERTURE IMAGING SYSTEMS WITH IMPROVED COLOR RESOLUTION

Publication Information:

☐ Request Early Publication (Fee required at time of Request 37 CFR 1.219)

☐ **Request Not to Publish.** I hereby request that the attached application not be published under 35 U.S. C. 122(b) and certify that the invention disclosed in the attached application **has not and will not** be the subject of an application filed in another country, or under a multilateral international agreement, that requires publication at eighteen months after filing.

Representative Information:

Representative information should be provided for all practitioners having a power of attorney in the application. Providing this information in the Application Data Sheet does not constitute a power of attorney in the application (see 37 CFR 1.32).
Enter either Customer Number or complete the Representative Name section below. If both sections are completed the Customer Number will be used for the Representative Information during processing.

Please Select One:	◉ Customer Number	○ US Patent Practitioner	○ Limited Recognition (37 CFR 11.9)
Customer Number	92342		

Domestic Benefit/National Stage Information:

This section allows for the applicant to either claim benefit under 35 U.S.C. 119(e), 120, 121, or 365(c) or indicate National Stage entry from a PCT application. Providing this information in the application data sheet constitutes the specific reference required by 35 U.S.C. 119(e) or 120, and 37 CFR 1.78(a)(2) or CFR 1.78(a)(4), and need not otherwise be made part of the specification.

Prior Application Status		Remove	
Application Number	Continuity Type	Prior Application Number	Filing Date (YYYY-MM-DD)

Additional Domestic Benefit/National Stage Data may be generated within this form by selecting the **Add** button. Add

Foreign Priority Information:

This section allows for the applicant to claim benefit of foreign priority and to identify any prior foreign application for which priority is not claimed. Providing this information in the application data sheet constitutes the claim for priority as required by 35 U.S.C. 119(b) and 37 CFR 1.55(a).

Remove

Application Number	Country i	Parent Filing Date (YYYY-MM-DD)	Priority Claimed
			○ Yes ◉ No

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Application Data Sheet 37 CFR 1.76	Attorney Docket Number	COREPH-0072 US PR
	Application Number	

Title of Invention	THIN MULTI-APERTURE IMAGING SYSTEMS WITH IMPROVED COLOR RESOLUTION

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PROVISIONAL PATENT APPLICATION

THIN MULTI-APERTURE IMAGING SYSTEMS WITH IMPROVED COLOR RESOLUTION

FIELD

Embodiments disclosed herein relate in general to multi-aperture imaging systems and more specifically to thin multi-aperture imaging systems with high color resolution and/or optical zoom.

BACKGROUND

Small digital cameras integrated into mobile (cell) phones, personal digital assistants and music players are becoming ubiquitous. Each year, mobile phone manufacturers add more imaging features to their handsets, causing these mobile imaging devices to converge towards feature sets and image quality that customers expect from stand-alone digital still cameras. Concurrently, the size of these handsets is shrinking, making it necessary to reduce the total size of the camera accordingly while adding more imaging features. Optical Zoom is a primary feature of many digital still cameras but one that mobile phone cameras usually lack, mainly due to camera height constraints in mobile imaging devices, cost and mechanical reliability.

Mechanical zoom solutions are common in digital still cameras. However, the F/# (“F number) in such systems typically increases with the zoom factor, resulting in poor light sensitivity and higher noise (especially in low-light scenarios). In mobile cameras, this also results in resolution compromise, due to the small pixel size of their image sensors and the diffraction limit optics associated with the F/#.

One way of implementing zoom in mobile cameras is by over-sampling the image and cropping and interpolating it in accordance with the desired zoom factor. While this method is mechanically reliable, it results in thick optics and in an expensive image sensor due to the large number of pixels associated therewith. As an example, if one is interested in implementing a 12 Megapixel camera with X3 zoom factor, one needs a sensor of 108 Megapixels.

Another way of implementing zoom is by using a dual-aperture imaging system. In its basic form, a dual-aperture imaging system includes two optical apertures which may be formed by one or two optical modules, and one or two image sensors (e.g., CMOS or CCD) which grab the optical image or images and convert the data to the electronic domain, where the image can be processed and stored.

Known multi-aperture imaging systems, in particular ones with with short optical paths, require a trade-off between various functionalities, for example between zoom and color resolution. There is therefore a need for, and it would be advantageous to have thin multi-aperture imaging systems implemented as cameras with increased color resolution, or multi-aperture imaging systems with both increased color resolution and zoom function.

SUMMARY

Embodiments disclosed herein teach the use of multi-aperture imaging systems (where "multi" refers to two or more) to implement thin cameras (with short optical paths of less than about 9mm) and/or to realize optical zoom systems in such thin cameras. Embodiments disclosed herein further teach new color filter arrays which optimize the color information which may be achieved in a multi-aperture imaging system with or without zoom. In various embodiments, a multi-aperture imaging system disclosed herein includes at least two sensors or a single sensor divided into at least two areas. Hereinafter, the description refers to "two sensors", with the understanding that they may be sections of a single physical sensor (imager chip). Exemplarily, in a dual-aperture imaging system, a left sensor (or left side of a single sensor) captures an image coming from a first aperture while a right sensor (or right side of a single sensor) captures an image coming from a second aperture. In various embodiments disclosed herein, one sensor is a "Wide" sensor while another sensor is a "Tele" sensor. The Wide sensor includes two different color filter arrays (CFAs): a non-standard CFA with higher color sampling rate positioned in an "overlap area" of the sensor (see below description of FIG. 1B), and a standard CFA with a lower color sampling rate surrounding the overlap area. As used herein, "non-standard CFA" refers to a CFA which is different in its pattern that CFAs listed above as "standard". Exemplary non-standard CFA patterns include repetitions of a 2x2 micro-cell in which the color filter order is RRBB, RBBR or YCCY where Y=Yellow = Green + Red, C = Cyan = Green + Blue; repetition of a 3x3 micro-cell in which the color filter order is GBRRGBBRG; and repetitions of a 6x6 micro-cell in which the color filter order is RBBRRBRWRBWBBBRBRRRRBRBBBWBRWRBRRBBR,

BBGRRGRGRBGBGBRGRBRRGBBGBGBRGRGRBGBR, RBBRRBRGRBGBBBRBRRRRBRBBBGBRGRBRRBBR or RBRBRBBGBRGRRBRBRBBRBRBRRGRBGBBRBRBR. As used herein, a "standard CFA" may include a known CFA such as Bayer, RGBE, CYYM, CYGM and different RGBW filters such as RGBW#1, RGBW#2 and RGBW#3.

The Tele sensor may be a gray scale sensor (with no CFA) or a standard CFA sensor. This arrangement of the two (or more than two) sensors and of two (or more than two) respective Wide and Tele "subset cameras" (or simply "subsets") related to the two sensors provides high color resolution through the combination of data obtained by the Tele and Wide subsets. Each sensor provides a separate image, except for the case of a single sensor, where two images are grabbed by the single sensor (example above). In some embodiments, zoom is achieved by fusing the two images, resulting in higher color resolution reaching that of a high quality dual-aperture zoom camera. Some thin multi-aperture imaging systems disclosed herein therefore provide zoom, super-resolution, high dynamic range and enhanced user experience

In some embodiments, in order to reach optical zoom capabilities, a different magnification image of the same scene is captured by each subset, resulting in field of view (FOV) overlap between the two subsets. In some embodiments, the Tele subset is the higher zoom subset and the Wide subset is the lower zoom subset. In some embodiments, the two subsets have the same zoom (i.e. same FOV). Post processing is applied on the two images grabbed by the multi-aperture imaging system to fuse and output one "fused" image processed according to a user zoom factor request. In some embodiments the resolution of the fused image may be higher than the resolution of the Wide/Tele sensors. As part of the fusion procedure, up-sampling may be applied on one of the images to scale it to the image grabbed by the Tele subset camera. In addition, each subset may capture different color channels. For example, in one embodiment, RGB channels may be captured by the Wide camera subset and a Luma channel may be captured by the Tele camera subset. In another embodiment, both subsets may capture RGB channels.

In an embodiment there is provided a multi-aperture imaging system comprising a first camera subset having a respective first sensor which includes a first plurality of sensor pixels covered at least in part by a non-standard CFA operative to increase a specific color sampling rate relative to a same color sampling rate in a standard CFA, and a second camera subset having a respective second sensor which includes a second plurality of sensor pixels, the second plurality of pixels being either Luma or covered with a standard CFA.

In some embodiments, the first camera subset has a first FOV, the second camera subset has a second, smaller FOV than the first FOV, and the non-standard CFA covers an overlap area on the first sensor which captures the second FOV, thereby providing both optical zoom and increased color resolution.

In some embodiments, the first and second camera subsets have the same FOV, and the non-standard CFA covers an overlap area on the first sensor which captures the second FOV, thereby providing increased color resolution.

BRIEF DESCRIPTION OF THE DRAWINGS

Non-limiting examples of embodiments disclosed herein are described below with reference to figures attached hereto that are listed following this paragraph. Identical structures, elements or parts that appear in more than one figure are generally labeled with a same numeral in all the figures in which they appear. The drawings and descriptions are meant to illuminate and clarify embodiments disclosed herein, and should not be considered limiting in any way.

FIG. 1A shows schematically a block diagram illustrating a dual-aperture zoom imaging system disclosed herein;

FIG. 1B shows an example of an image captured by the Wide sensor and the Tele sensor while illustrating the overlap area on the Wide sensor;

FIG. 2 shows schematically an embodiment of a Wide sensor which may be implemented in a dual-aperture zoom imaging system as in FIG. 1A;

FIG. 3 shows schematically another embodiment of a Wide camera sensor which may be implemented in a dual-aperture zoom imaging system as in FIG. 1A;

FIG. 4 shows schematically yet another embodiment of a Wide camera sensor which may be implemented in a dual-aperture zoom imaging system as in FIG. 1A;

FIG. 5 shows schematically yet another embodiment of a Wide camera sensor which may be implemented in a dual-aperture zoom imaging system as in FIG. 1A;

FIG. 6 shows schematically yet another embodiment of a Wide camera sensor which may be implemented in a dual-aperture zoom imaging system as in FIG. 1A;

FIG. 7 shows schematically yet another embodiment of a Wide camera sensor which may be implemented in a dual-aperture zoom imaging system as in FIG. 1A;

FIG. 8 shows schematically yet another embodiment of a Wide camera sensor which may be implemented in a dual-aperture zoom imaging system as in FIG. 1A;

FIG. 9 shows schematically yet another embodiment of a Wide camera sensor which may be implemented in a dual-aperture zoom imaging system as in FIG. 1A;

FIG. 10 shows a schematically in a flow chart an embodiment of a method disclosed herein for acquiring and outputting a zoom image;

FIG. 11A shows exemplary images captured by a triple aperture zoom imaging system disclosed herein;

FIG. 11B illustrates schematically the three sensors of the triple aperture imaging system of FIG. 7A;

FIG. 12 shows schematically a block diagram illustrating a dual-aperture imaging system with improved color resolution disclosed herein.

DETAILED DESCRIPTION

Embodiments disclosed herein relate to multi-aperture imaging systems which include at least one Wide sensor with two different CFAs and at least one Tele sensor. The description continues with particular reference to dual-aperture imaging systems which include two (Wide and Tele) subsets, each subset having a respective sensor. Specifically, in such dual-aperture systems, the Wide subset is not a Luma channel only camera. A three-aperture imaging systems is described later with reference to FIGS. 7A-7B.

The Wide sensor includes an “overlap area” (see description of FIG. 1B) covered by a non-standard CFA. The overlap area captures the Tele FOV. Since the Tele image is optically magnified compared to the Wide image, the effective sampling rate of the Tele image is higher than that of the Wide image. Thus, the effective color sampling rate in the Wide sensor is much lower than the Luma sampling rate in the Tele sensor. In addition, as part of the fusion procedure (of Tele and Wide images, see below), up-scaling of the color data is required. Upscaling will not improve color resolution.

FIG. 1A shows schematically a block diagram illustrating a dual-aperture zoom imaging system **100** disclosed herein. System **100** includes a dual-aperture camera **102** which has a Wide subset **104** and a Tele subset **106**, and a processor **108** which fuses two images, one obtained with the Wide subset and the other obtained with the Tele subset, into a single image according to a user zoom factor request. The Wide sensor includes a non-standard CFA (see e.g. FIGS. 2-9) in an overlap area illustrated by **110** in FIG. 1B, which is surrounded by a non-overlap area **112** with a standard CFA (for example a Bayer pattern). The non-standard CFA pattern increases the color resolution of the imaging system. The Tele subset camera may include a sensor with no filter array (which provides a Luma scaled image), a standard Bayer CFA or a standard non-Bayer CFA such as RGBE, CYYM, CYGM and different RGBW filters such as RGBW#1, RGBW#2 and RGBW#3.

FIG. 1B shows an example of an image captured by both Wide and Tele sensors, while illustrating overlap area **110** and surrounding non-overlap area **112** on the Wide sensor image. Note that "overlap" and "non-overlap" areas refer also to the CFA arrangements of the Wide sensor. The overlap area with the non-standard CFA may cover different portions of a Wide sensor, for example half the sensor area, a third of the sensor area, a quarter of the sensor area, etc. A number of such CFA arrangements are described in more detail with reference to FIGS. 2-9.

FIG. 2 shows schematically an embodiment of a Wide sensor **200** which may be implemented in a dual-aperture zoom imaging system **100**. In sensor **200**, a non-overlap area **202** includes a Bayer CFA. An overlap area **204** includes a non-standard CFA with a repetition of a 2x2 micro-cell in which the color filter order is RRBB. In overlap area **204**, the R and B are sampled at $1/2^{0.5}$ Nyquist in the diagonal (left to right) direction with 2 pixels intervals. For example, we keep a Nyquist sampling rate in the right down diagonal direction for the first 2 Blue pixels, and the same for the following Red pixels. In this figure, as well as in FIGS. 3-9, "Width 1" and "Height 1" refers to the full Wide sensor dimension. "Width 2" and "Height 2" refers to the dimensions of the Wide sensor overlap area.

FIG. 3 shows schematically an embodiment of a Wide camera subset sensor **300** which may be implemented in a dual-aperture zoom imaging system **100.** In sensor **300**, a non-overlap area **302** includes a Bayer CFA. An overlap area **304** includes a non-standard CFA with a repetition of a 2x2 micro-cell in which the color filter order is RBBR. In the overlap area, the R and B are sampled at $1/2^{0.5}$ Nyquist frequency in both diagonal directions..

FIG. 4 shows schematically an embodiment of a Wide camera subset sensor **400** which may be implemented in a dual-aperture zoom imaging system **100.** In sensor **400**, a non-overlap area **402** includes a Bayer CFA. An overlap area **404** includes a non-standard CFA with a repetition of a 2x2 micro-cell in which the color filter order is YCCY, where Y=Yellow = Green + Red, C = Cyan = Green + Blue. In the overlap area, the R and B are sampled at a $1/2^{0.5}$ Nyquist frequency in a diagonal direction; the non-standard CFA includes green information for registration purposes. This will allow for example to register between the two images where the object is green, since there is green information in both sensor images.

FIG. 5 shows schematically an embodiment of a Wide camera subset sensor **500** which may be implemented in a dual-aperture zoom imaging system **100.** In sensor **500**, a non-overlap area **502** is a Bayer pattern. An overlap area **504** includes a non-standard CFA with a repetition of a 6x6 micro-cell in which the color filter order is RBBRRBRWRBWBBBRBRRRRBRBBBWBRWRBRRBBR where "W" represents white or Luma. In the overlap area, the R and B are sampled at a higher frequency than a standard pixel array. For example, in a Bayer pixel order, the Red average sampling rate R is 0.25 (sampled once for every 4 pixels). In the overlap area **504** pattern, the Red average sampling rate is 0.44.

FIG. 6 shows schematically an embodiment of a Wide camera subset sensor **600** which may be implemented in a dual-aperture zoom imaging system **100.** In sensor **600**, a non-overlap area **602** is a Bayer pattern. An overlap area **604** includes a non-standard CFA with a repetition of a 6x6 micro-cell in which the color filter order is BBGRRGRGRBGBGBRGRBRRGBBGBGBRGRGRBGBR. In the overlap area, the R and B are sampled at a higher frequency than a standard pixel array. For example, in a Bayer pixel order, the Red average sampling rate R is 0.25 (sampled once for every 4 pixels). In the overlap area **604** pattern, the Red average sampling rate is 0.44.

FIG. 7 shows schematically an embodiment of a Wide camera subset sensor **700** which may be implemented in a dual-aperture zoom imaging system **100.** In sensor **700**, a non-overlap area **702** is a Bayer pattern. An overlap area **704** includes a non-standard CFA with a repetition of a 3x3 micro-cell in which the color filter order is GBRRGBBRG. In the overlap area, the R and B are sampled at a higher frequency than a standard pixel array. For example, in a Bayer pixel order, the Red average sampling rate R is 0.25 (sampled once for every 4 pixels). In the overlap area **704** pattern, the Red average sampling rate is 0.33.

FIG. 8 shows schematically an embodiment of a Wide camera subset sensor **800** which may be implemented in a dual-aperture zoom imaging system **100.** In sensor **800**, a non-overlap area **802** is a Bayer pattern. An overlap area **804** includes a non-standard CFA with a repetition of a 6x6 micro-cell in which the color filter order is RBBRRBRGRBGBBBRBRRRRBRBBBGBRGRBRRBBR. In the overlap area, the R and B are sampled at a higher frequency than a standard pixel array. For example, in a Bayer pixel order, the Red average sampling rate R is 0.25 (sampled once for every 4 pixels). In the overlap area **804** pattern, the Red average sampling rate is 0.44.

FIG. 9 shows schematically an embodiment of a Wide camera subset sensor **900** which may be implemented in a dual-aperture zoom imaging system **100.** In sensor **900**, a non-overlap area **902** is a Bayer pattern. An overlap area **904** includes a non-standard CFA with a repetition of a 6x6 micro-cell in which the color filter order is RBRBRBBGBRGRRBRBRBBRBRBRRGRBGBBRBRBR. In the overlap area, the R and B are sampled at a higher frequency than a standard pixel array. For example, in a Bayer pixel order, the Red average sampling rate R is 0.25 (sampled once for every 4 pixels). In the overlap area **904** pattern, the Red average sampling rate is 0.44.

Processing flow

In use, an image is acquired with imaging system **100** and is processed according to steps illustrated in a flowchart shown in FIG. 10 in step **1000**, de-mosaicing is performed on the overlap area pixels, (which refer to the Tele image FOV) according to the specific CFA pattern. The overlap and non-overlap subsets of pixels may need different de-mosaicing processes. Exemplary and non-limiting de-mosaicing specifications for the overlap area of each of the Wide sensors shown in FIGS. 2-5 are given in detail below. The aim is to reconstruct the missing colors in each and every pixel. In cases in which the Tele subset sensor is not a Luma only pattern, de-mosaicing is applied as well. This will result in Wide subset color image where the colors (in the overlap area) hold higher resolution than those of a standard CFA pattern. In step **1002**, the Tele image captured by the Wide sensor is registered (mapped into the Wide image). Then, in step **1004**, the data from the Wide and Tele images is processed to form a high quality zoom image. In cases where the Tele subset is Luma only, high Luma resolution is taken from the Tele sensor and color resolution is taken from the Wide sensor. In cases where the Tele subset includes a CFA, both color and Luma resolution are taken from the Tele subset. In addition, color resolution is taken from the Wide subset.

Exemplary process for fusing a zoom image using the Wide camera subset of FIG. 4

1. <u>Special de-mosaicing:</u>

<u>Wide</u>

- Reconstructing Yellow full map
- Reconstructing Cyan full map
- The non-overlap area requires standard (in this example, Bayer) de-mosaicing.

At this point, the demosaiced Wide overlap area has a sampling/resolution advantage of 1.41 ($2^{0.5}$) ratio. That is, in the proposed overlap area **404** pattern, the Red max frequency is in the diagonal direction. In a Bayer pattern, the Red max frequency is in the horizontal/vertical directions. It is easy to see that the proposed pattern achieves a sampling rate which is higher by a factor of 1.41 than that of the Bayer pattern.

<u>Tele</u>

- In case where the Tele subset has a CFA, standard de-mosaicing will be applied.

2. Registration preparation:

- $Luma_{Wide}$=Y+C= R+2G+B (converting Bayer pattern into Y data)
- $Luma_{Tele}$=R+G+B. (3 colors are sampled into one pixel)
- $Luma_{Tele}$→LP→ $Luma_{Tele}^{LP}$. To improve registration.
- Registration ($Luma_{Wide}$, $Luma_{Tele}^{LP}$) → mapping function between 2 sensors.

For every index in Wide sensor, we get an index in the Tele sensor

3. Color restoration – back to RGB:

- $G_{Wide}=Luma_{Wide}-Luma_{Tele}^{LP}$
- $R_{Wide}=Y- G_{Wide}$
- $B_{Wide}=C- G_{Wide}$
-

4. Producing a high resolution image.

- R_{Wide}, G_{Wide}, B_{Wide} → $Luma_{Wide}$
- Average or replace $Luma_{Tele}$ with $Luma_{Wide}$.
- Back to R,G,B

Exemplary and non-limiting de-mosaicing specifications for the overlap area

FIG. 2

B11	B12	R13
R21	B22	B23
R31	R32	B33

- In order to reconstruct the missing R22 pixel, we perform the following:
- R22=(R31+R13)/2
- Same operation for all missing Blue pixels.

FIG. 3

R11	B12	R13
B21	R22	B23
R31	B32	R33

- In order to reconstruct the missing B22 pixel, we perform the following:
- B22=(B12+B21+B32+B23)/4
- Same operation for all missing Blue pixels.

FIG. 4

Y11	C12	Y13
C21	Y22	C23
Y31	C32	Y33

- In order to reconstruct the missing Y22 pixel, we perform the following:
- C22=(C12+C21+C32+C23)/4
- Same operation for all missing Blue pixels.

FIG. 5

Case 1: W is center pixel

R11	B12	B13
R21	W22	R23
B31	B32	R33

- In order to reconstruct the missing 22 pixels, we perform the following:

1. B22=(B12+B32)/2
2. R22=(R21+R23)/2
3. G22= (W22-R22-B22)/2

Case 2: R22 is center pixel

B11	B12	R13	R14
W21	R22	B23	W24
B31	R32	B33	R34

-

- In order to reconstruct the missing 22 pixels, we perform the following:

1. B22=(B11+R33)/2
2. W22=(2*W21+W24)/3
3. G22= (W22-R22-B22)/2

- Same operation for Blue as the center pixel.

Triple-aperture zoom imaging system with improved color resolution

As mentioned, a multi-aperture zoom or non-zoom imaging system disclosed herein may include more than two apertures. A non-limiting and exemplary embodiment **1100** of a triple-aperture imaging system is shown in FIGS. 11A-11B. System **1100** includes a first Wide subset camera **1102** (with exemplarily X1), a second Wide subset camera (with exemplarily X1.5, and referred to as a "Wide-Tele" subset) and a Tele subset camera (with exemplarily X2). FIG. 11A shows exemplary images captured by imaging system **1100**, while FIG. 11B illustrates schematically three sensors marked **1102**, **1104** and **1106**, which belong respectively to the Wide, Wide-Tele and Tele subsets. FIG. 7B also shows the CFA arrangements in each sensor: sensors **1102** and **1104** are similar to Wide sensors described above with reference to any of FIGS. 2-9, in the sense that they include an overlap area and a non-overlap area. The overlap area includes a non-standard CFA. In both Wide sensors, the non-overlap area may have a Luma pattern or a standard CFA. Thus, neither Wide subset is solely a Luma channel camera. The Tele sensor may have no filter array (i.e. Luma), a standard Bayer CFA or a non-Bayer CFA such as RGBE, CYYM, CYGM and different RGBW filters such as RGBW#1, RGBW#2 and RGBW#3. In use, an image is acquired with imaging system **1100** and processed as follows: de-mosaicing is performed on the overlap area pixels of the Wide and Wide-Tele sensors according to the specific CFA pattern in each overlap area. The overlap and non-overlap subsets of pixels in each of these sensors may need different de-mosaicing. Exemplary and non-limiting de-mosaicing specifications for the overlap area for Wide sensors shown in FIGS. 2-9 are given above. The aim is to reconstruct the missing colors in each and every pixel. In cases in which the Tele subset sensor is not a Luma only pattern, de-mosaicing is performed as well. The Wide and Wide-Tele subset color images acquired this way will have colors (in the overlap area) holding higher resolution than that of a standard CFA pattern. Then, the Tele image acquired with the Tele is registered (mapped) into the respective Wide image. The data from the Wide, Wide-Tele and Tele images is then processed to form a high quality zoom image. In cases where the Tele subset is Luma only, high Luma resolution is taken from the Tele sensor and color resolution is taken from the Wide sensor. In cases where the Tele subset includes a CFA, both color and Luma resolution is taken from the Tele subset. In addition, color resolution is taken from the Wide sensor. The resolution of the fused image may be higher than the resolution of both sensors.

Dual-aperture imaging system with improved color resolution

According to principles and designs disclosed herein, improved color resolution with simplified sensors designs may be achieved in dual- or multi-aperture imaging systems without zoom. FIG. 12 shows schematically a block diagram illustrating a dual-aperture zoom imaging system **1200** disclosed herein. System **1200** includes a dual-aperture camera **1202** which has a first camera subset (and associated sensor) **1204,** a second camera subset (and associated sensor) **1206**, and a processor **1208** which fuses two images, one obtained with first subset and the other obtained with the second subset into a single "fused" image. One of the sensors (e.g. of subset **1204**) includes a non-standard CFA. The other sensor (in this case of subset **1206**) may have no filter array (thus providing a Luma scaled image), or it may have a standard Bayer CFA or standard non-Bayer CFA such as RGBE, CYYM, CYGM and different RGBW filters.

The non-standard filter pattern of the first sensor increase the general color resolution of the imaging system over a system with similar size (and pixels density) sensors, but in which one sensor has a standard CFA and the other has a Luma (or standard CFA). Thus, the resolution of the fused image may be higher than the resolution of both sensors. Advantageously, the simpler filter pattern (i.e. of only two colors instead of three or four colors) simplifies significantly sensor manufacturing costs and therefore the total systems manufacturing costs. This is done without sacrificing and even improving the system color resolution.

While this disclosure has been described in terms of certain embodiments and generally associated methods, alterations and permutations of the embodiments and methods will be apparent to those skilled in the art. For example, multi-aperture imaging systems with more than two Wide or Wide-Tele subsets (and sensors) or with more than one Tele subset (and sensor) may be constructed and used according to principles set forth herein. Similarly, non-zoom multi-aperture imaging systems with more than two sensors, at least one of which has a non-standard CFA, may be constructed and used according to principles set forth herein. The disclosure is to be understood as not limited by the specific embodiments described herein, but only by the scope of the appended claims.

100

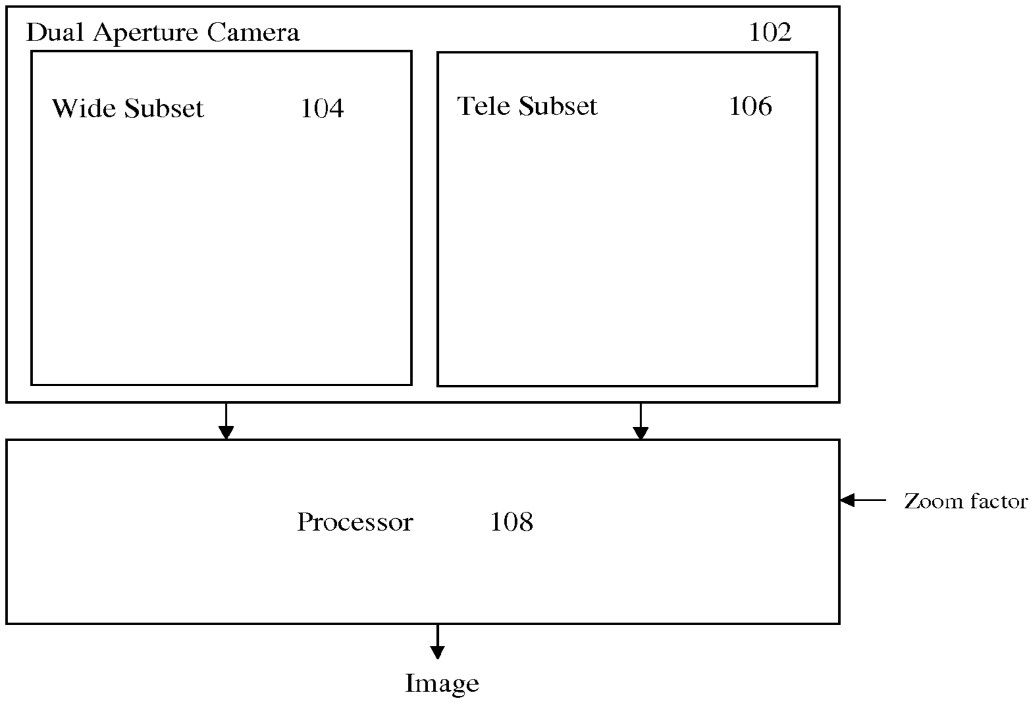


FIG. 1A

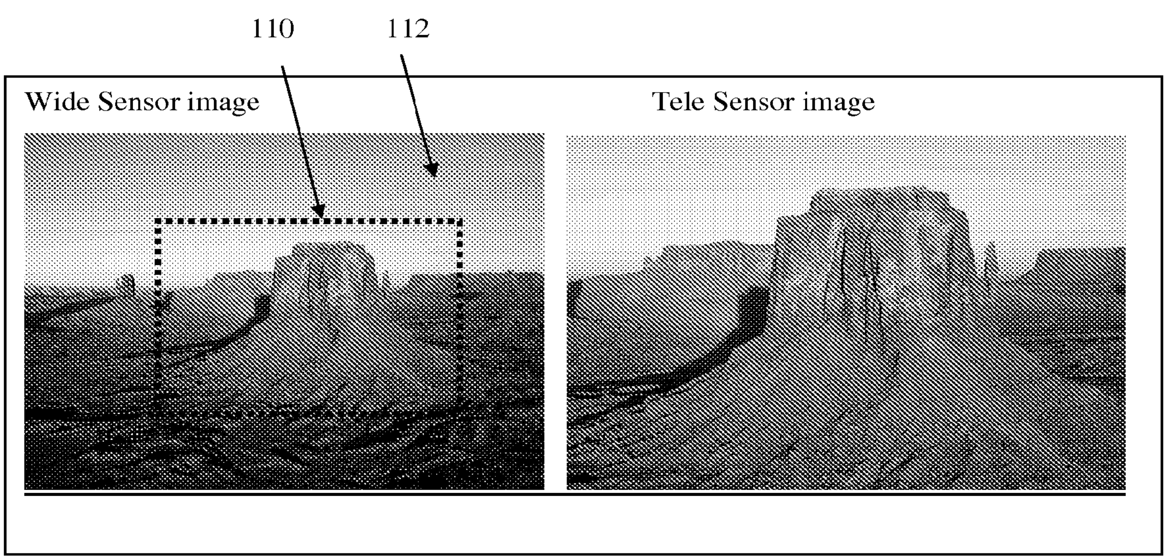
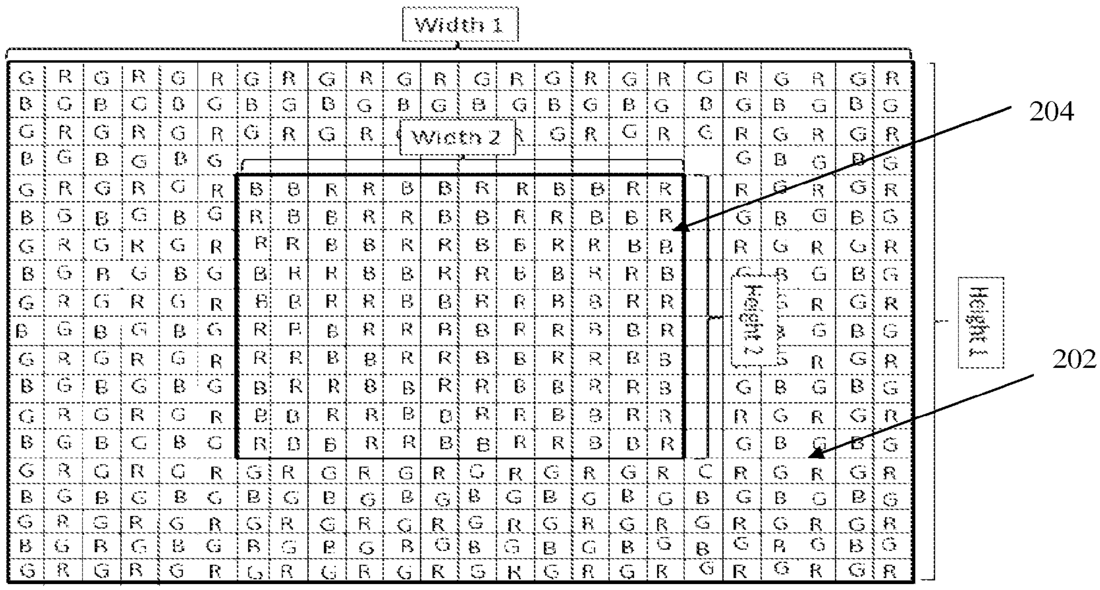


FIG. 1B

200



300

FIG. 2

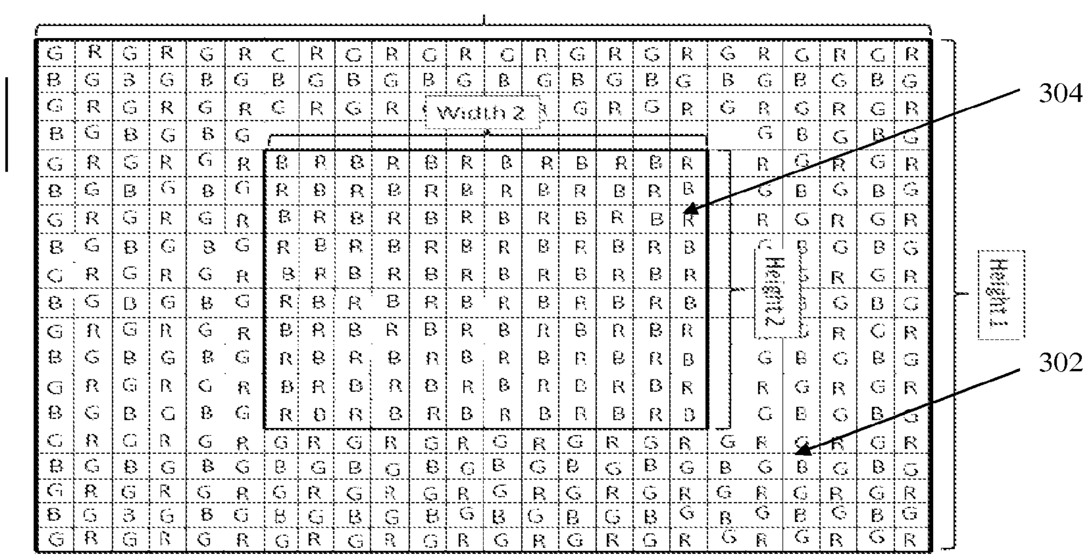


FIG. 3

400

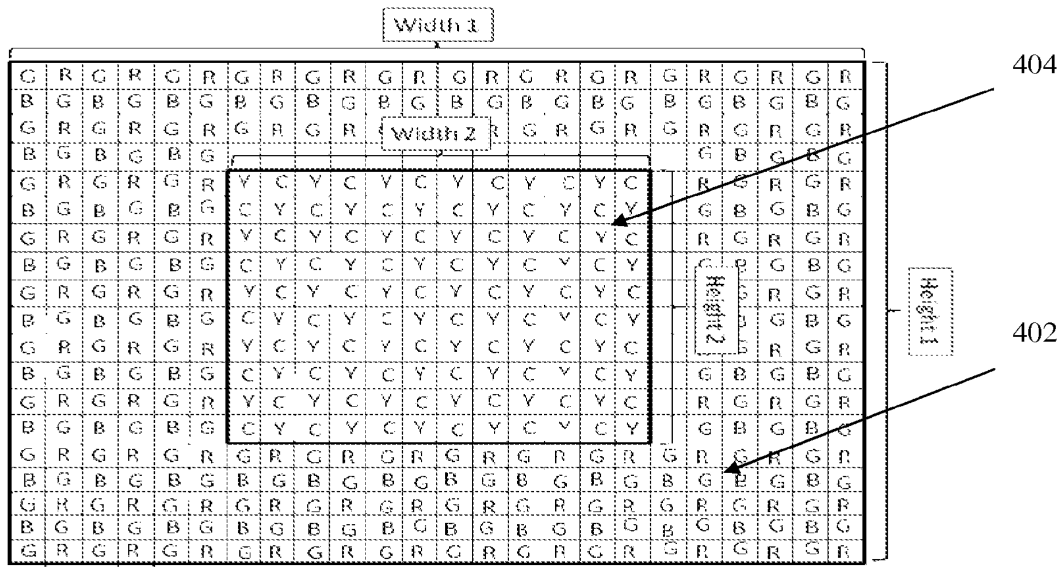


FIG. 4

500

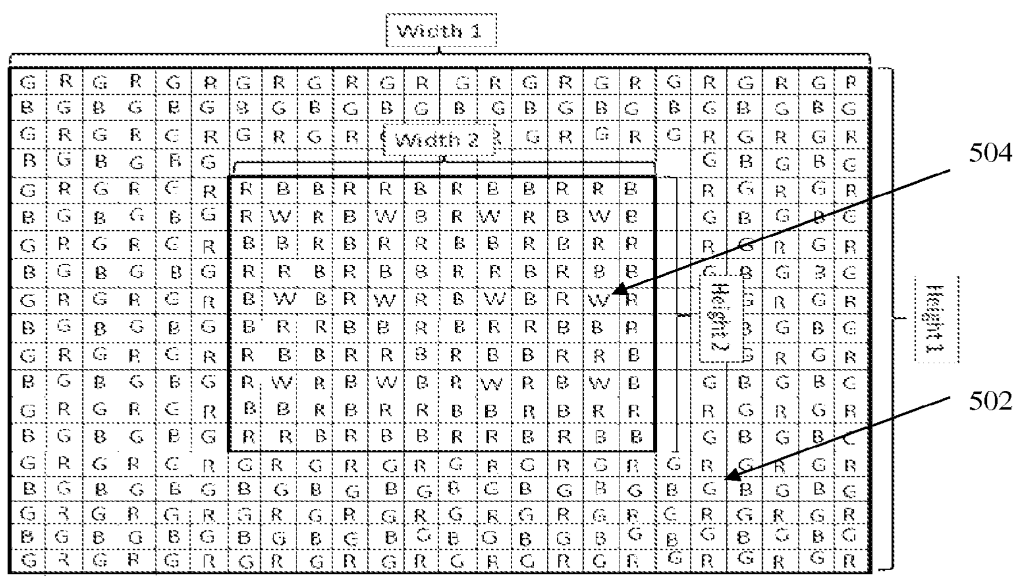


FIG. 5

600

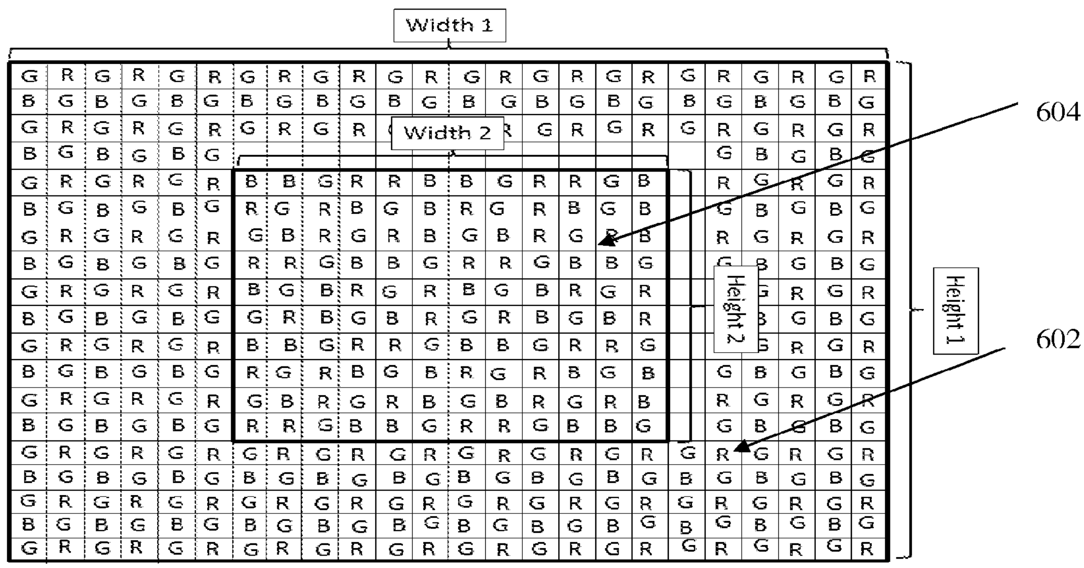


FIG. 6

700

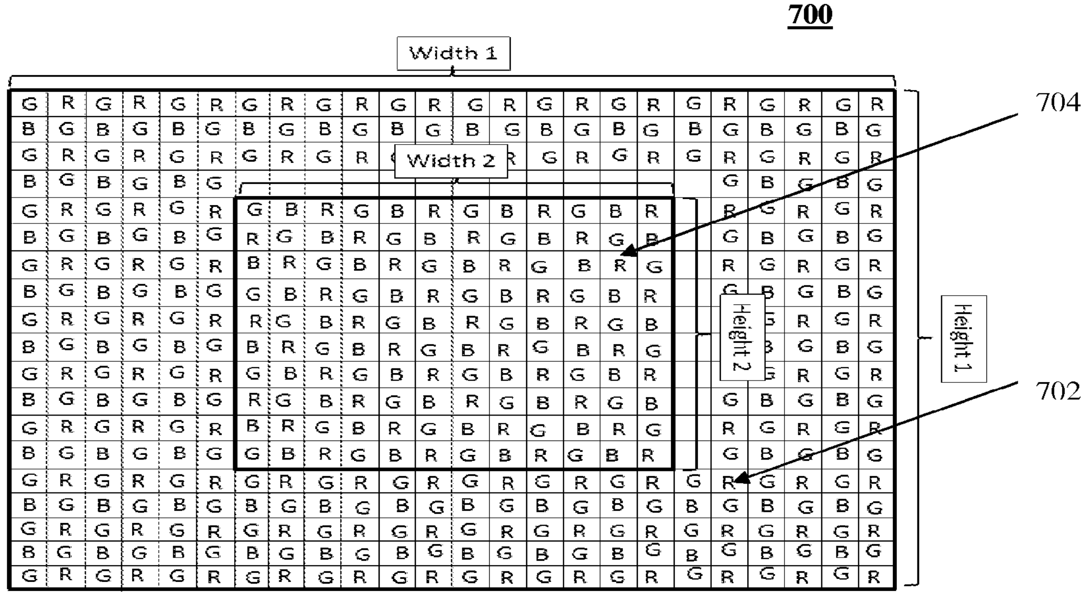


FIG. 7

800

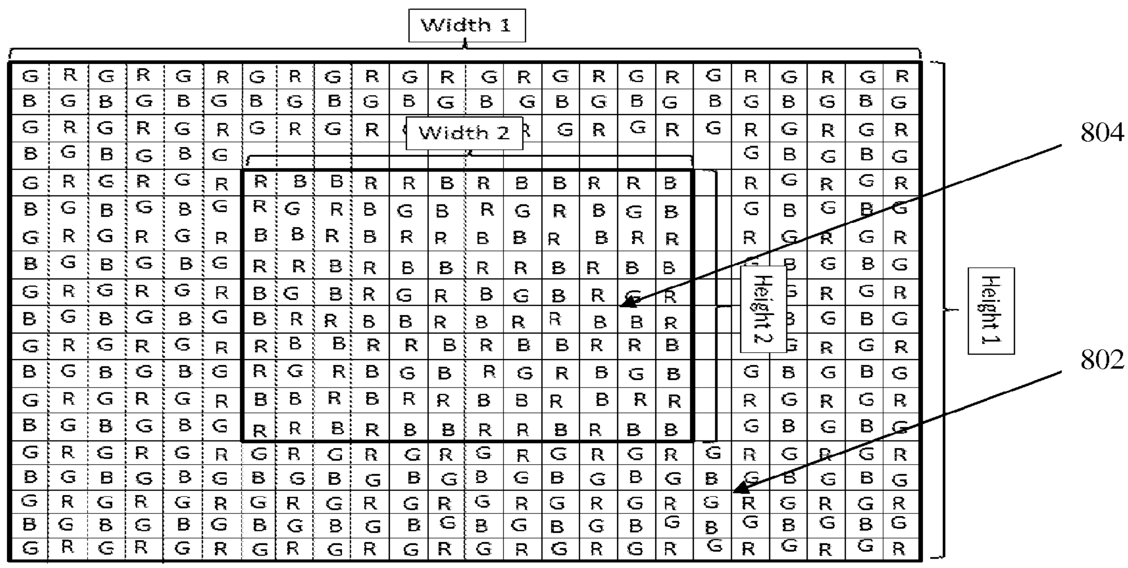


FIG. 8

900

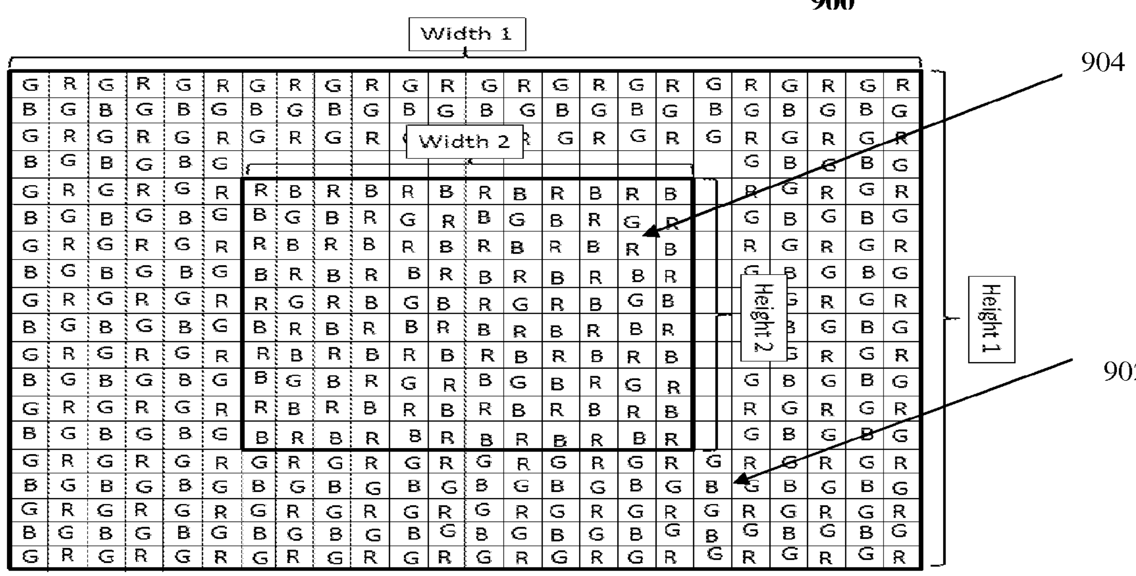


FIG. 9

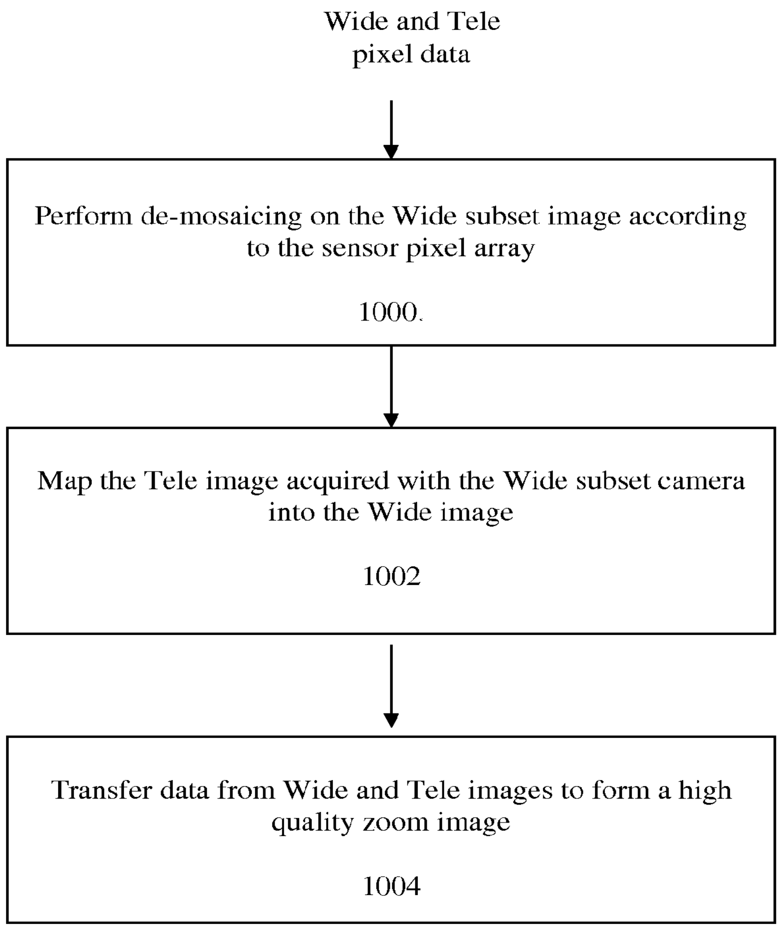

Wide and Tele
pixel data
Perform de-mosaicing on the Wide subset image according to the sensor pixel array
1000.
Map the Tele image acquired with the Wide subset camera into the Wide image
1002
Transfer data from Wide and Tele images to form a high quality zoom image
1004

FIG. 10

1100

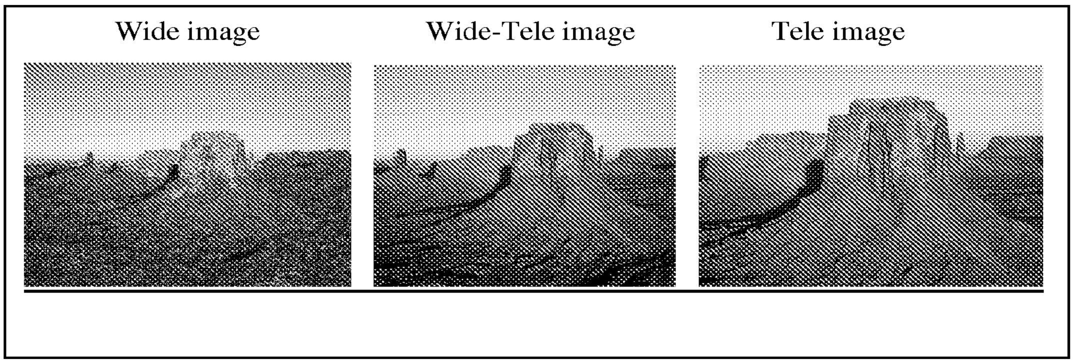


FIG. 11A

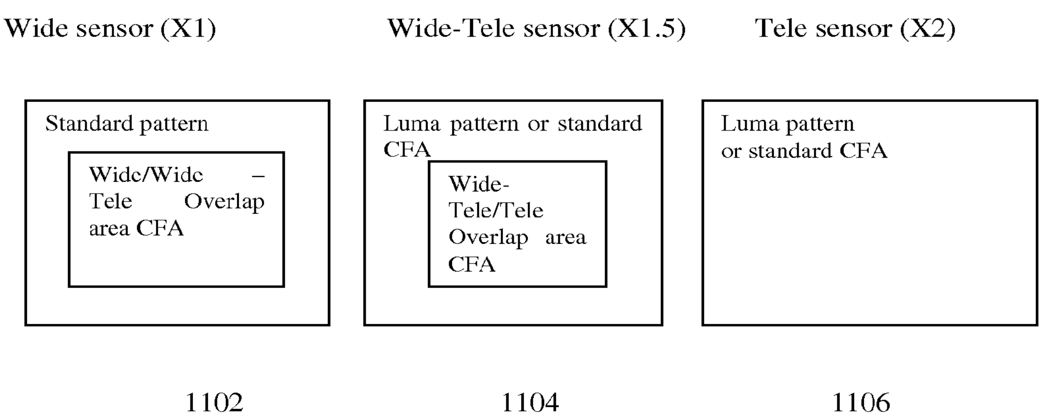


FIG. 11B

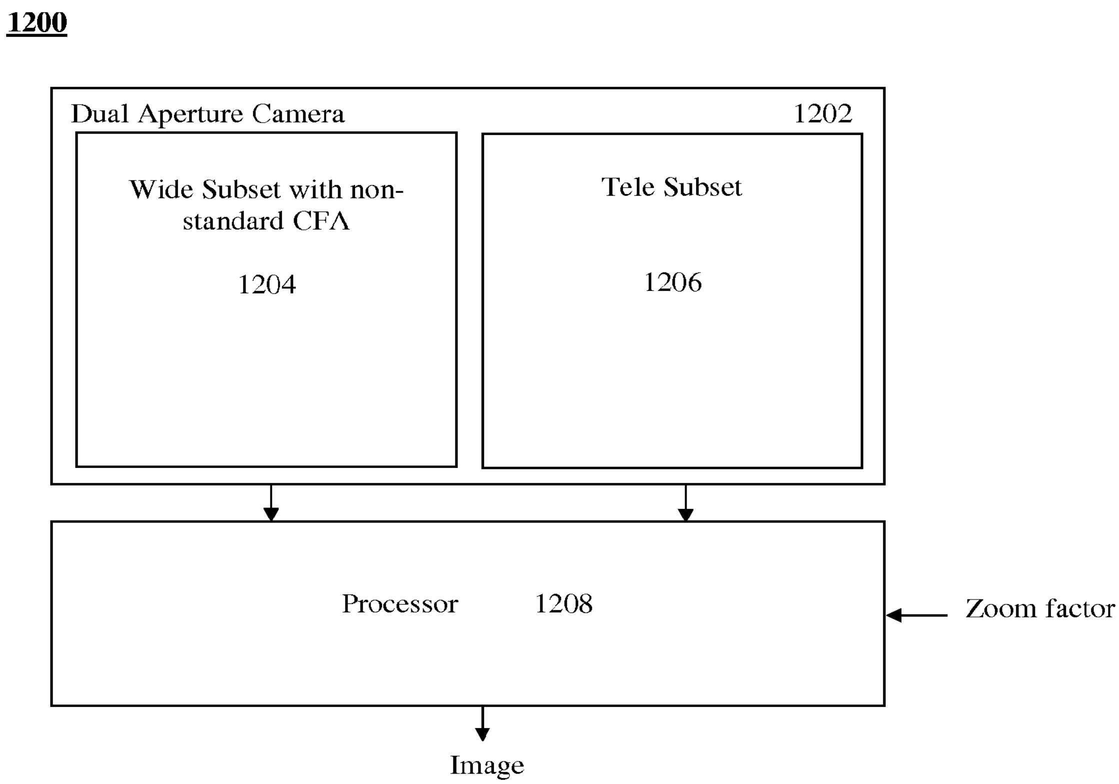

1200
Dual Aperture Camera
1202
Wide Subset with non-standard CFA
1204
Tele Subset
1206
Processor
1208
Zoom factor
Image

FIG. 12

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ORGANIZATION

DOCUMENT MADE AVAILABLE UNDER THE PATENT COOPERATION TREATY (PCT)

International application number:		**PCT/IB2013/060356**
International filing date:		**23 November 2013 (23.11.2013)**
Document type:		**Certified copy of priority document**
Document details:	Country/Office:	**US**
	Number:	**61/730,570**
	Filing date:	**28 November 2012 (28.11.2012)**
Date of receipt at the International Bureau:		**23 November 2013 (23.11.2013)**

Remark: Priority document submitted or transmitted to the International Bureau in compliance with Rule 17.1(a),(b) or (b-*bis*)

34, chemin des Colombettes
1211 Geneva 20, Switzerland
www.wipo.int

PATENT COOPERATION TREATY

ADVANCE E-MAIL

PCT

NOTIFICATION OF THE RECORDING OF A CHANGE

(PCT Rule 92*bis*.1 and Administrative Instructions, Section 422)

From the INTERNATIONAL BUREAU

To:

NATHAN & ASSOCIATES PATENT AGENTS LTD.
P.O. Box 10178
6110101 Tel Aviv
ISRAËL

Date of mailing *(day/month/year)* 13 January 2014 (13.01.2014)	
Applicant's or agent's file reference COREPH-72	**IMPORTANT NOTIFICATION**
International application No. PCT/IB2013/060356	International filing date *(day/month/year)* 23 November 2013 (23.11.2013)

1. The following indications appeared on record concerning:

☒ the applicant ☐ the inventor ☐ the agent ☐ the common representative

Name and Address	State of Nationality	State of Residence
COREPHOTONICS LTD. 3rd Floor 25 Habarzel St. Ramat Hachayal 6971035 Tel Aviv Israel		IL
	Telephone No.	
	Facsimile No.	
	E-mail address	

2. The International Bureau hereby notifies the applicant that the following change has been recorded concerning:

☐ the person ☐ the name ☐ the address ☒ the nationality ☐ the residence

Name and Address	State of Nationality	State of Residence
COREPHOTONICS LTD. 3rd Floor 25 Habarzel St. Ramat Hachayal 6971035 Tel Aviv Israel	IL	IL
	Telephone No.	
	Facsimile No.	
	E-mail address ☐ Notifications by e-mail authorized	

3. Further observations, if necessary:

4. A copy of this notification has been sent to:

☐ the receiving Office
☐ the International Searching Authority
☐ the Authority(ies) specified for supplementary search
☐ the International Preliminary Examining Authority
☐ the designated Offices concerned
☐ the elected Offices concerned
☐ other:

The International Bureau of WIPO 34, chemin des Colombettes 1211 Geneva 20, Switzerland Facsimile No. +41 22 338 80 40	Authorized officer Huynh Khuong Kari e-mail ept.pct@wipo.int Telephone No. +41 22 338 78 78

PCT REQUEST

Print Out (Original in Electronic Form)

0	**For receiving Office use only**	
0-1	International Application No.	PCT/IB2013/060356
0-2	International Filing Date	23 November 2013 (23.11.2013)
0-3	Name of receiving Office and "PCT International Application"	RO/IB

0-4	**Form PCT/RO/101 PCT Request**	
0-4-1	Prepared Using	PCT-SAFE Version 3.51.060.236 MT/FOP 20131001/0.20.5.21
0-5	**Petition** The undersigned requests that the present international application be processed according to the Patent Cooperation Treaty	
0-6	**Receiving Office (specified by the applicant)**	International Bureau of the World Intellectual Property Organization (RO/IB)
0-7	**Applicant's or agent's file reference**	COREPH-72
I	**Title of Invention**	HIGH-RESOLUTION THIN MULTI-APERTURE IMAGING SYSTEMS
II	**Applicant**	
II-1	This person is	Applicant only
II-2	Applicant for	All designated States
II-4	Name	COREPHOTONICS LTD.
II-5	Address	3rd Floor 25 Habarzel St. Ramat Hachayal 6971035 Tel Aviv Israel
II-6	State of nationality	
II-7	State of residence	IL
III-1	**Applicant and/or inventor**	
III-1-1	This person is	Inventor only
III-1-3	Inventor for	
III-1-4	Name (LAST, First)	SHABTAY, Gal
III-1-5	Address	4 Shmuel Shnitzer St. 6958313 Tel-Aviv Israel

III-2	**Applicant and/or inventor**	
III-2-1	This person is	Inventor only
III-2-3	Inventor for	
III-2-4	Name (LAST, First)	COHEN, Noy
III-2-5	Address	Apt. 20 30 Shlomo Ben Yossef St. 6912529 Tel-Aviv Israel
III-3	**Applicant and/or inventor**	
III-3-1	This person is	Inventor only
III-3-3	Inventor for	
III-3-4	Name (LAST, First)	GIGUSHINSKI, Oded
III-3-5	Address	23 Ahi Dakar St. 4670223 Herzlia Israel
III-4	**Applicant and/or inventor**	
III-4-1	This person is	Inventor only
III-4-3	Inventor for	
III-4-4	Name (LAST, First)	GOLDENBERG, Ephraim
III-4-5	Address	32 Tel Chai St. 7751025 Ashdod Israel
IV-1	**Agent or common representative; or address for correspondence** No agent or common representative is/ has been appointed; the following special address should be used as:	Address for correspondence
IV-1-1	Name	Nathan & Associates Patent Agents Ltd.
IV-1-2	Address	P.O.Box 10178 6110101 Tel Aviv Israel
IV-1-5	e-mail	info@natpatent.com
IV-1-5(a)	E-mail authorization The receiving Office, the International Searching Authority, the International Bureau and the International Preliminary Examining Authority are authorized to use this e-mail address, if the Office or Authority so wishes, to send notifications issued in respect of this international application:	as advance copies followed by paper notifications
V	**DESIGNATIONS**	
V-1	**The filing of this request constitutes under Rule 4.9(a), the designation of all Contracting States bound by the PCT on the international filing date, for the grant of every kind of protection available and, where applicable, for the grant of both regional and national patents.**	

PCT REQUEST

Print Out (Original in Electronic Form)

VI-1	**Priority claim of earlier national application**		
VI-1-1	Filing date	28 November 2012 (28.11.2012)	
VI-1-2	Number	61/730,570	
VI-1-3	Country	US	
VI-2	**Priority document request** The International Bureau is requested to obtain from a digital library a certified copy of the earlier application(s) identified above as item(s), using, where applicable, the access code(s) indicated:	VI-1 Access code: 6073	
VI-3	**Incorporation by reference :** where an element of the international application referred to in Article 11(1)(iii)(d) or (e) or a part of the description, claims or drawings referred to in Rule 20.5(a) is not otherwise contained in this international application but is completely contained in an earlier application whose priority is claimed on the date on which one or more elements referred to in Article 11(1)(iii) were first received by the receiving Office, that element or part is, subject to confirmation under Rule 20.6, incorporated by reference in this international application for the purposes of Rule 20.6.		
VII-1	**International Searching Authority Chosen**	United States Patent and Trademark Office (USPTO) (ISA/US)	
VIII	**Declarations**	Number of declarations	
VIII-1	Declaration as to the identity of the inventor	-	
VIII-2	Declaration as to the applicant's entitlement, as at the international filing date, to apply for and be granted a patent	-	
VIII-3	Declaration as to the applicant's entitlement, as at the international filing date, to claim the priority of the earlier application	-	
VIII-4	Declaration of inventorship (only for the purposes of the designation of the United States of America)	-	
VIII-5	Declaration as to non-prejudicial disclosures or exceptions to lack of novelty	-	
IX	**Check list**	Number of sheets	Electronic file(s) attached
IX-1	Request (including declaration sheets)	4	✓
IX-2	Description	17	✓
IX-3	Claims	5	✓
IX-4	Abstract	1	✓
IX-5	Drawings	7	✓
IX-7	TOTAL	34	

PCT REQUEST

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	Accompanying Items	Paper document(s) attached	Electronic file(s) attached
IX-8	Fee calculation sheet	-	✓
IX-18	PCT-SAFE physical media	-	-
IX-20	**Figure of the drawings which should accompany the abstract**	1	
IX-21	**Language of filing of the international application**	English	
X-1	**Signature of applicant, agent or common representative**	/GAL SHABTAY/	
X-1-1	Name	COREPHOTONICS LTD.	
X-1-2	Name of signatory	GAL SHABTAY	
X-1-3	Capacity (if such capacity is not obvious from reading the request)	VP-R&D	

FOR RECEIVING OFFICE USE ONLY

10-1	**Date of actual receipt of the purported international application**	23 November 2013 (23.11.2013)
10-2	**Drawings:**	
10-2-1	Received	
10-2-2	Not received	
10-3	**Corrected date of actual receipt due to later but timely received papers or drawings completing the purported international application**	
10-4	**Date of timely receipt of the required corrections under PCT Article 11(2)**	
10-5	**International Searching Authority**	ISA/US
10-6	**Transmittal of search copy delayed until search fee is paid**	

FOR INTERNATIONAL BUREAU USE ONLY

11-1	**Date of receipt of the record copy by the International Bureau**	

(12) INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

(19) World Intellectual Property Organization
International Bureau

(43) International Publication Date
5 June 2014 (05.06.2014)

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(30) Priority Data: 61/730,570 28 November 2012 (28.11.2012) US

(71) Applicant: **COREPHOTONICS LTD.** [IL/IL]; 3rd Floor, 25 Habarzel St., Ramat Hachayal, 6971035 Tel Aviv (IL).

(72) Inventors: **SHABTAY, Gal**; 4 Shmuel Shnitzer St., 6958313 Tel Aviv (IL). **COHEN, Noy**; Apt. 20, 30 Shlomo Ben Yossef St., 6912529 Tel Aviv (IL). **GIGUSHINSKI, Oded**; 23 Ahi Dakar St., 4670223 Herzlia (IL). **GOLDENBERG, Ephraim**; 32 Tel Chai St., 7751025 Ashdod (IL).

(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, BN, 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, IR, IS, JP, KE, KG, 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, PA, PE, PG, PH, PL, PT, QA, RO, RS, RU, RW, SA, SC, SD, SE, SG, SK, SL, SM, ST, SV, SY, TH, 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, LR, LS, MW, MZ, NA, RW, SD, SL, SZ, TZ, UG, ZM, ZW), Eurasian (AM, AZ, BY, KG, KZ, RU, TJ, TM), European (AL, AT, BE, BG, CH, CY, CZ, DE, DK, EE, ES, FI, FR, GB, GR, HR, HU, IE, IS, IT, LT, LU, LV, MC, MK, MT, NL, NO, PL, PT, RO, RS, SE, SI, SK, SM, TR), OAPI (BF, BJ, CF, CG, CI, CM, GA, GN, GQ, GW, KM, ML, MR, NE, SN, TD, TG).

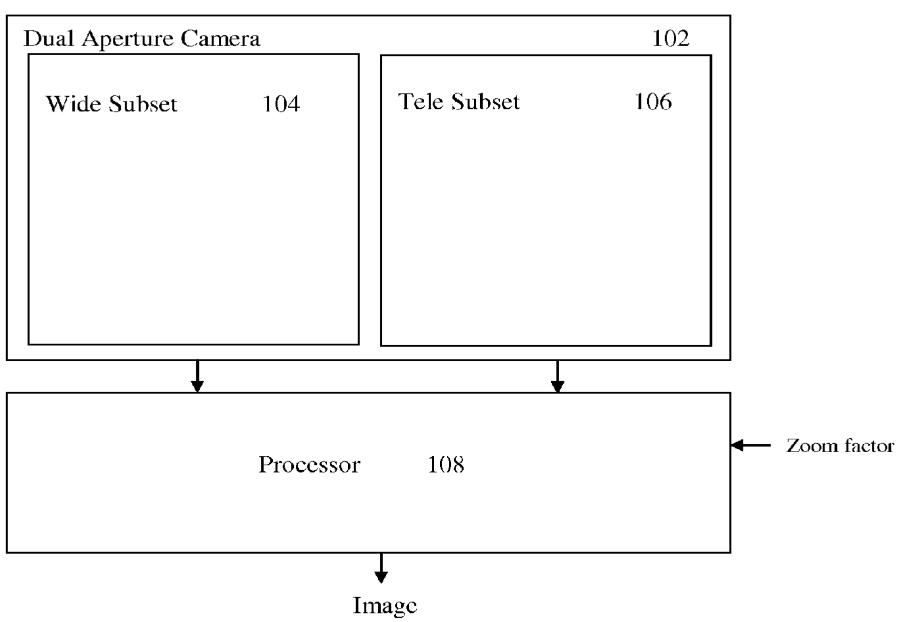
Published:

— *with international search report (Art. 21(3))*

— *before the expiration of the time limit for amending the claims and to be republished in the event of receipt of amendments (Rule 48.2(h))*

(54) **Title**: HIGH-RESOLUTION THIN MULTI-APERTURE IMAGING SYSTEMS

100



(57) **Abstract**: A multi-aperture imaging system comprising a first camera with a first sensor that captures a first image and a second camera with a second sensor that captures a second image, the two cameras having either identical or different FOVs. The first sensor may have a standard color filter array (CFA) covering one sensor section and a non-standard color CFA covering another. The second sensor may have either Clear or standard CFA covered sections. Either image may be chosen to be a primary or an auxiliary image, based on a zoom factor. An output image with a point of view determined by the primary image is obtained by registering the auxiliary image to the primary image.

WO 2014/083489 A1

HIGH RESOLUTION THIN MULTI-APERTURE IMAGING SYSTEMS

CROSS REFERENCE TO RELATED APPLICATIONS

This application is related to and claims priority from US Provisional Patent Application No. 61/730,570 having the same title and filed November 28, 2013, which is incorporated herein by reference in its entirety.

FIELD

Embodiments disclosed herein relate in general to multi-aperture imaging ("MAI") systems (where “multi” refers to two or more apertures) and more specifically to thin MAI systems with high color resolution and/or optical zoom.

BACKGROUND

Small digital cameras integrated into mobile (cell) phones, personal digital assistants and music players are becoming ubiquitous. Each year, mobile phone manufacturers add more imaging features to their handsets, causing these mobile imaging devices to converge towards feature sets and image quality that customers expect from stand-alone digital still cameras. Concurrently, the size of these handsets is shrinking, making it necessary to reduce the total size of the camera accordingly while adding more imaging features. Optical Zoom is a primary feature of many digital still cameras but one that mobile phone cameras usually lack, mainly due to camera height constraints in mobile imaging devices, cost and mechanical reliability.

Mechanical zoom solutions are common in digital still cameras but are typically too thick for most camera phones. Furthermore, the F/# (“F number) in such systems typically increases with the zoom factor (ZF) resulting in poor light sensitivity and higher noise (especially in low-light scenarios). In mobile cameras, this also results in resolution compromise, due to the small pixel size of their image sensors and the diffraction limit optics associated with the F/#.

One way of implementing zoom in mobile cameras is by over-sampling the image and cropping and interpolating it in accordance with the desired ZF. While this method is mechanically reliable, it results in thick optics and in an expensive image sensor due to the large number of pixels associated therewith. As an example, if one is interested in implementing a 12 Megapixel camera with X3 ZF, one needs a sensor of 108 Megapixels.

Another way of implementing zoom, as well as increasing the output resolution, is by using a dual-aperture imaging ("DAI") system. In its basic form, a DAI system includes two optical apertures which may be formed by one or two optical modules, and one or two image sensors (e.g., CMOS or CCD) that grab the optical image or images and convert the data into the electronic domain, where the image can be processed and stored.

The design of a thin MAI system with improved resolution requires a careful choice of parameters coupled with advanced signal processing algorithms to support the output of a high quality image. Known MAI systems, in particular ones with short optical paths, often trade-off functionalities and properties, for example zoom and color resolution, or image resolution and quality for camera module height. Therefore, there is a need for, and it would be advantageous to have thin MAI systems that produce an image with high resolution (and specifically high color resolution) together with zoom functionality.

Moreover, known signal processing algorithms used together with existing MAI systems often further degrade the output image quality by introducing artifacts when combining information from different apertures. A primary source of these artifacts is the image registration process, which has to find correspondences between the different images that are often captured by different sensors with different color filter arrays (CFAs). There is therefore a need for, and it would be advantageous to have an image registration algorithm that is more robust to the type of CFA used by the cameras and which can produce better correspondence between images captured by a multi-aperture system.

SUMMARY

Embodiments disclosed herein teach the use of multi-aperture imaging systems to implement thin cameras (with short optical paths of less than about 9 mm) and/or to realize optical zoom systems in such thin cameras. Embodiments disclosed herein further teach new color filter arrays that optimize the color information which may be achieved in a multi-aperture imaging system with or without zoom. In various embodiments, a MAI system disclosed herein includes at least two sensors or a single sensor divided into at least two areas. Hereinafter, the description refers to “two sensors”, with the understanding that they may represent sections of a single physical sensor (imager chip). Exemplarily, in a dual-aperture imaging system, a left sensor (or left side of a single sensor) captures an image coming from a first aperture while a right sensor (or right side of a single sensor) captures an image coming

from a second aperture. In various embodiments disclosed herein, one sensor is a “Wide” sensor while another sensor is a “Tele” sensor, see e.g. FIG. 1A. The Wide sensor includes either a single standard CFA or two different CFAs: a non-standard CFA with higher color sampling rate positioned in an “overlap area” of the sensor (see below description of FIG. 1B) and a standard CFA with a lower color sampling rate surrounding the overlap area. When including a single standard CFA, the CFA may cover the entire Wide sensor area. A "standard CFA" may include a RGB (Bayer) pattern or a non-Bayer pattern such as RGBE, CYYM, CYGM, RGBW#1, RGBW#2 or RGBW#3. Thus, reference may be made to "standard Bayer" or "standard non-Bayer" patterns or filters. As used herein, “non-standard CFA” refers to a CFA that is different in its pattern that CFAs listed above as “standard”. Exemplary non-standard CFA patterns may include repetitions of a 2x2 micro-cell in which the color filter order is RR-BB, RB-BR or YC-CY where Y=Yellow = Green + Red, C = Cyan = Green + Blue; repetitions of a 3x3 micro-cell in which the color filter order is GBR-RGB-BRG; and repetitions of a 6x6 micro-cell in which the color filter order is
RBBRRB-RWRBWB-BBRBRR-RRBRBB-BWBRWR-BRRBBR, or
BBGRRG-RGRBGB-GBRGRB-RRGBBG-BGBRGR-GRBGBR, or
RBBRRB-RGRBGB-BBRBRR-RRBRBB-BGBRGR-BRRBBR, or,
RBRBRB-BGBRGR-RBRBRB-BRBRBR-RGRBGB-BRBRBR.

The Tele sensor may be a Clear sensor (i.e. a sensor without color filters) or a standard CFA sensor. This arrangement of the two (or more than two) sensors and of two (or more than two) Wide and Tele “subset cameras” (or simply “subsets”) related to the two Wide and Tele subsets. Each sensor provides a separate image (referred to respectively as a Wide image and a Tele image), except for the case of a single sensor, where two images are captured (grabbed) by the single sensor (example above). In some embodiments, zoom is achieved by fusing the two images, resulting in higher color resolution that approaches that of a high quality dual-aperture zoom camera. Some thin MAI systems disclosed herein therefore provide zoom, super-resolution, high dynamic range and enhanced user experience.

In some embodiments, in order to reach optical zoom capabilities, a different magnification image of the same scene is grabbed by each subset, resulting in field of view (FOV) overlap between the two subsets. In some embodiments, the two subsets have the same zoom (i.e. same FOV). In some embodiments, the Tele subset is the higher zoom subset and the Wide subset is the lower zoom subset. Post processing is applied on the two images grabbed by the MAI system to fuse and output one fused (combined) output zoom image processed according to a user ZF input request. In some embodiments, the resolution of the fused image may be higher than the resolution of the Wide/Tele sensors. As part of the fusion procedure, up-sampling may be applied on the Wide image to scale it to the Tele image.

In an embodiment there is provided a multi-aperture imaging system comprising a first camera subset that provides a first image, the first camera subset having a first sensor with a first plurality of sensor pixels covered at least in part with a non-standard CFA, the non-standard CFA used to increase a specific color sampling rate relative to a same color sampling rate in a standard CFA; a second camera subset that provides a second image, the second camera subset having a second sensor with a second plurality of sensor pixels either Clear or covered with a standard CFA; and a processor configured to process the first and second images into a combined output image.

In some embodiments, the first and the second camera subsets have identical FOVs and the non-standard CFA may cover an overlap area that includes all the pixels of first sensor, thereby providing increased color resolution. In some such embodiments, the processor is further configured to, during the processing of the first and second images into a combined output image, register respective first and second Luma images obtained from the first and second images, the registered first and second Luma images used together with color information to form the combined output image. In an embodiment, the registration includes finding a corresponding pixel in the second Luma image for each pixel in the first Luma image, whereby the output image is formed by transferring information from the second image to the first image. In another embodiment, the registration includes finding a corresponding pixel in the first Luma image for each pixel in the second Luma image, whereby the output image is formed by transferring information from the first image to the second image.

In some embodiments, the first camera subset has a first FOV, the second camera subset has a second, smaller FOV than the first FOV, and the non-standard CFA covers an overlap area on the first sensor that captures the second FOV, thereby providing both optical zoom and increased color resolution. In some such embodiments, the processor is further configured to, during the processing of the first and second images into a combined output image and based on a ZF input, register respective first and second Luma images obtained from the first and second images, the registered first and second Luma images used together with color information to form the combined output image. For a ZF input that defines an FOV greater than the second FOV, the registration includes finding a corresponding pixel in the second Luma image for each pixel in the first Luma image and the processing includes forming the output image by transferring information from the second image to the first image. For a ZF input that defines an FOV smaller than or equal to the second FOV, the registration includes finding a corresponding pixel in the first Luma image for each pixel in the second Luma image, and the processing includes forming the output image by transferring information from the first image to the second image.

In an embodiment there is provided a multi-aperture imaging system comprising a first camera subset that provides a first image, the first camera subset having a first sensor with a first plurality of sensor pixels covered at least in part with a standard CFA; a second camera subset that provides a second image, the second camera subset having a second sensor with a second plurality of sensor pixels either Clear or covered with a standard CFA; and a processor configured to register first and second Luma images obtained respectively from the first and second images and to process the registered first and second Luma images together with color information into a combined output image.

In some embodiments, the first and the second camera subsets have identical first and second FOVs. In some such embodiments, the registration includes finding a corresponding pixel in the second Luma image for each pixel in the first Luma image and the processing includes forming the output image by transferring information from the second image to the first image. In other such embodiments, the registration includes finding a corresponding pixel in the first Luma image for each pixel in the second Luma image and the processing includes forming the output image by transferring information from the first image to the second image.

In some embodiments, the first camera subset has a first FOV, the second camera subset has a second, smaller FOV than the first FOV, and the processor is further configured to register the first and second Luma images based on a ZF input. For a ZF input that defines an FOV greater than the second FOV, the registration includes finding a corresponding pixel in the second Luma image for each pixel in the first Luma image and the processing includes forming the output image by transferring information from the second image to the first image. For a ZF input that defines an FOV smaller than or equal to the second FOV, the registration includes finding a corresponding pixel in the first Luma image for each pixel in the second Luma image, and the processing includes forming the output image by transferring information from the first image to the second image.

BRIEF DESCRIPTION OF THE DRAWINGS

Non-limiting examples of embodiments disclosed herein are described below with reference to figures attached hereto that are listed following this paragraph. The drawings and descriptions are meant to illuminate and clarify embodiments disclosed herein, and should not be considered limiting in any way.

FIG. 1A shows schematically a block diagram illustrating a dual-aperture zoom imaging system disclosed herein;

FIG. 1B shows an example of an image captured by the Wide sensor and the Tele sensor while illustrating the overlap area on the Wide sensor;

FIG. 2 shows schematically an embodiment of a Wide sensor that may be implemented in a dual-aperture zoom imaging system disclosed herein;

FIG. 3 shows schematically another embodiment of a Wide camera sensor that may be implemented in a dual-aperture zoom imaging system disclosed herein;

FIG. 4 shows schematically yet another embodiment of a Wide camera sensor that may be implemented in a dual-aperture zoom imaging system disclosed herein;

FIG. 5 shows schematically yet another embodiment of a Wide camera sensor that may be implemented in a dual-aperture zoom imaging system disclosed herein;

FIG. 6 shows schematically yet another embodiment of a Wide camera sensor that may be implemented in a dual-aperture zoom imaging system disclosed herein;

FIG. 7 shows schematically yet another embodiment of a Wide camera sensor that may be implemented in a dual-aperture zoom imaging system disclosed herein;

FIG. 8 shows schematically yet another embodiment of a Wide camera sensor that may be implemented in a dual-aperture zoom imaging system disclosed herein;

FIG. 9 shows schematically yet another embodiment of a Wide camera sensor that may be implemented in a dual-aperture zoom imaging system disclosed herein;

FIG. 10 shows a schematically in a flow chart an embodiment of a method disclosed herein for acquiring and outputting a zoom image;

FIG. 11A shows exemplary images captured by a triple aperture zoom imaging system disclosed herein;

FIG. 11B illustrates schematically the three sensors of the triple aperture imaging system of FIG. 11A.

DETAILED DESCRIPTION

Embodiments disclosed herein relate to multi-aperture imaging systems that include at least one Wide sensor with a single CFA or with two different CFAs and at least one Tele sensor. The description continues with particular reference to dual-aperture imaging systems that include two (Wide and Tele) subsets with respective sensors. A three-aperture imaging system is described later with reference to FIGS. 11A-11B.

The Wide sensor includes an overlap area (see description of FIG. 1B) that captures the Tele FOV. The overlap area may cover the entire Wide sensor or only part of the sensor. The overlap area may include a standard CFA or a non-standard CFA. Since the Tele image is optically magnified compared to the Wide image, the effective sampling rate of the Tele image is higher than that of the Wide image. Thus, the effective color sampling rate in the Wide sensor is much lower than the Clear sampling rate in the Tele sensor. In addition, the Tele and Wide images fusion procedure (see below) requires up-scaling of the color data from the Wide sensor. Up-scaling will not improve color resolution. In some applications, it is therefore advantageous to use a non-standard CFA in the Wide overlap area that increases color resolution for cases in which the Tele sensor includes only Clear pixels. In some embodiments in which the Tele sensor includes a Bayer CFA, the Wide sensor may have a Bayer CFA in the overlap area. In such embodiments, color resolution improvement depends on using color information from the Tele sensor in the fused output image.

FIG. 1A shows schematically a block diagram illustrating a dual-aperture zoom imaging ("DAZI") system **100** disclosed herein. System **100** includes a dual-aperture camera **102** with a Wide subset **104** and a Tele subset **106** (each subset having a respective sensor), and a processor **108** that fuses two images, a Wide image obtained with the Wide subset and a Tele image obtained with the Tele subset, into a single fused output image according to a user-defined "applied" ZF input or request. The ZF is input to processor **108**. The Wide sensor may include a non-standard CFA in an overlap area illustrated by **110** in FIG. 1B. Overlap area **110** is surrounded by a non-overlap area **112** with a standard CFA (for example a Bayer pattern). FIG. 1B also shows an example of an image captured by both Wide and Tele sensors. Note that “overlap” and “non-overlap” areas refer to parts of the Wide image as well as to the CFA arrangements of the Wide sensor. The overlap area may cover different portions of a Wide sensor, for example half the sensor area, a third of the sensor area, a quarter of the sensor area, etc. A number of such Wide sensor CFA arrangements are described in more detail with reference to FIGS. 2-9. The non-standard CFA pattern increases the color resolution of the DAZI system.

The Tele sensor may be Clear (providing a Tele Clear image scaled relative to the Wide image) or may include a standard (Bayer or non-Bayer) CFA. It in the latter case, it is desirable to define primary and auxiliary sensors based on the applied ZF. If the ZF is such that the output FOV is larger than the Tele FOV, the primary sensor is the Wide sensor and the auxiliary sensor is the Tele sensor. If the ZF is such that the output FOV is equal to, or smaller than the Tele FOV, the primary sensor is the Tele sensor and the auxiliary sensor is the Wide sensor. The point of view defined by the output image is that of the primary sensor.

FIG. 2 shows schematically an embodiment of a Wide sensor **200** that may be implemented in a DAZI system such as system **100**. Sensor **200** has a non-overlap area **202** with a Bayer CFA and an overlap area **204** covered by a non-standard CFA with a repetition of a 4x4 micro-cell in which the color filter order is BBRR-RBBR-RRBB-BRRB. In this figure, as well as in FIGS. 3-9, “Width 1” and “Height 1” refer to the full Wide sensor dimension. “Width 2” and “Height 2” refer to the dimensions of the Wide sensor overlap area. Note that in FIG. 2 (as in following figures 3-5 and 7, 8) the empty row and column to the left and top of the overlap area are for clarity purposes only, and that the sensor pixels follow there the pattern of the non-overlap area (as shown in FIG. 6). In overlap area **204**, R and B are sampled at $1/2^{0.5}$ Nyquist frequency in the diagonal (left to right) direction with 2 pixel intervals instead of at 1/2 Nyquist frequency in a standard Bayer pattern.

FIG. 3 shows schematically an embodiment of a Wide sensor **300** that may be implemented in a DAZI system such as system **100.** Sensor **300** has a non-overlap area **302** with a Bayer CFA and an overlap area **304** covered by a non-standard CFA with a repetition of a 2x2 micro-cell in which the color filter order is BR-RB. In the overlap area, R and B are sampled at $1/2^{0.5}$ Nyquist frequency in both diagonal directions.

FIG. 4 shows schematically an embodiment of a Wide sensor **400** that may be implemented in a DAZI system such as system **100.** Sensor **400** has a non-overlap area **402** with a Bayer CFA and an overlap area **404** covered by a non-standard CFA with a repetition of a 2x2 micro-cell in which the color filter order is YC-CY, where Y=Yellow = Green + Red, C = Cyan = Green + Blue. As a result, in the overlap area, R and B are sampled at $1/2^{0.5}$ Nyquist frequency in a diagonal direction. The non-standard CFA includes green information for registration purposes. This allows for example registration between the two images where the object is green, since there is green information in both sensor images.

FIG. 5 shows schematically an embodiment of a Wide sensor **500** that may be implemented in a DAZI system such as system **100**. Sensor **500** has a non-overlap area **502** with a Bayer CFA and an overlap area **504** covered by a non-standard CFA with a repetition of a 6x6 micro-cell in which the color filter order is RBBRRB-RWRBWB-BBRBRR-RRBRBB-BWBRWR-BRRBBR, where “W” represents White or Clear pixels. In the overlap area, R and B are sampled at a higher frequency than in a standard CFA. For example, in a Bayer pixel order, the Red average sampling rate ("R_S") is 0.25 (sampled once for every 4 pixels). In the overlap area pattern, R_S is 0.44.

FIG. 6 shows schematically an embodiment of a Wide sensor **600** that may be implemented in a DAZI system such as system **100**. Sensor **600** has a non-overlap area **602** with a Bayer CFA and an overlap area **604** covered by a non-standard CFA with a repetition of a 6x6 micro-cell in which the color filter order is BBGRRG-RGRBGB-GBRGRB-RRGBBG-BGBRGR-GRBGBR. In the overlap area, R and B are sampled at a higher frequency than in a standard CFA. For example, in the overlap area pattern, R_S is 0. 33 vs. 0.25 in a Bayer pixel order.

FIG. 7 shows schematically an embodiment of a Wide sensor **700** that may be implemented in a DAZI system such as system **100**. Sensor **700** has a non-overlap area **702** with a Bayer CFA and an overlap area **704** covered by a non-standard CFA with a repetition of a 3x3 micro-cell in which the color filter order is GBR-RGB-BRG. In the overlap area, R and B are sampled at a higher frequency than in a standard CFA. For example, in the overlap area pattern, R_S is 0. 33 vs. 0.25 in a Bayer pixel order.

FIG. 8 shows schematically an embodiment of a Wide sensor **800** that may be implemented in a DAZI system such as system **100**. Sensor **800** has a non-overlap area **802** with a Bayer CFA and an overlap area **804** covered by a non-standard CFA with a repetition of a 6x6 micro-cell in which the color filter order is RBBRRB-RGRBGB-BBRBRR-RRBRBB-BGBRGR-BRRBBR. In the overlap area, R and B are sampled at a higher frequency than in a standard CFA. For example, in the overlap area pattern, R_S is 0. 44 vs. 0.25 in a Bayer pixel order.

FIG. 9 shows schematically an embodiment of a Wide sensor **900** that may be implemented in a DAZI system such as system **100**. Sensor **900** has a non-overlap area **902** with a Bayer CFA and an overlap area **904** covered by a non-standard CFA with a repetition of a 6x6 micro-cell in which the color filter order is RBRBRB-BGBRGR-RBRBRB-BRBRBR-RGRBGB-BRBRBR. In the overlap area, R and B are sampled at a higher frequency than in a standard CFA. For example, in the overlap area pattern, R_S is 0. 44 vs. 0.25 in a Bayer pixel order.

Processing flow

In use, an image is acquired with imaging system **100** and is processed according to steps illustrated in a flowchart shown in FIG. 10. In step **1000**, demosaicing is performed on the Wide overlap area pixels (which refer to the Tele image FOV) according to the specific CFA pattern. If the CFA in the Wide overlap area is a standard CFA, a standard demosaicing process may be applied to it. If the CFA in the Wide overlap area is non-standard CFA, the overlap and non-overlap subsets of pixels may need different demosaicing processes. That is, the Wide overlap area may need a non-standard demosaicing process and the Wide non-overlap area may need a standard demosaicing process. Exemplary and non-limiting non-standard demosaicing interpolations for the overlap area of each of the Wide sensors shown in FIGS. 2-9 are given in detail below. The aim of the demosaicing is to reconstruct missing colors in each pixel. Demosaicing is applied also to the Tele sensor pixels if the Tele sensor is not a Clear only sensor. This will result in a Wide subset color image where the colors (in the overlap area) hold higher resolution than those of a standard CFA pattern. In step **1002**, the Tele image is registered (mapped) into the Wide image. The mapping includes finding correspondences between pixels in the two images. In step **1002**, actual registration is performed on luminance Tele and Wide images (respectively $Luma_{Tele}$ and $Luma_{Wide)}$ calculated from the pixel information of the Tele and Wide cameras. These luminance images are estimates for the scene luminance as captured by each camera and do not include any color information. If the Wide or Tele sensors have CFAs, the calculation of the luminance images is performed on the respective demosaiced images. The calculation of the Wide luminance image varies according to the type of non-standard CFA used in the Wide overlap area. If the CFA permits calculation of a full RGB demosaiced image, the luminance image calculation is straightforward. If the CFA is such that it does not permit calculation of a full RGB demosaiced image, the luminance image is estimated from the available color channels. If the Tele sensor is a Clear sensor, the Tele luminance image is just the pixel information. Performing the registration on luminance images has the advantage of enabling registration between images captured by sensors with different CFAs or between images captured by a standard CFA or non-standard CFA sensor and a standard CFA or Clear sensor and avoiding color artifacts that may arise from erroneous registration.

In step **1004**, the data from the Wide and Tele images is processed together with the registration information from step **1002** to form a high quality output zoom image. In cases where the Tele sensor is a Clear only sensor, the high resolution luminance component is taken from the Tele sensor and color resolution is taken from the Wide sensor. In cases where the Tele sensor includes a CFA, both color and luminance data are taken from the Tele subset to form the high quality zoom image. In addition, color and luminance data is taken from the Wide subset.

Exemplary process for fusing a zoom image

1. Special demosaicing

In this step, the Wide image is interpolated to reconstruct the missing pixel values. Standard demosaicing is applied in the non-overlap area. If the overlap area includes a standard CFA, standard demosaicing is applied there as well. If the overlap area includes a non-standard CFA, a special demosaicing algorithm is applied, depending on the CFA pattern used. In addition, in case the Tele sensor has a CFA, standard demosaicing is applied to reconstruct the missing pixel values in each pixel location and to generate a full RGB color image.

2. Registration preparation

- Tele image: a luminance image $Luma_{Tele}$ is calculated from the Tele sensor pixels. If the Tele subset has a Clear sensor, $Luma_{Tele}$ is simply the sensor pixels data. If the Tele subset has a standard CFA, $Luma_{Tele}$ is calculated from the demosaiced Tele image.

- Wide image: as a first step, in case the Wide overlap CFA permits estimating the luminance component of the image, the luminance component is calculated from the demosaiced Wide image, $Luma_{Wide}$. If the CFA is one of those depicted in FIGS. 4-9, a luminance image is calculated first. If the CFA is one of the CFAs depicted in FIG. 2 or FIG. 3, a luminance image is not calculated. Instead, the following registration step is performed between a weighted average of the demosaiced channels of the Wide image and $Luma_{Tele}$. For convenience, this weighted average image is also denoted $Luma_{Wide}$. For example, if the Wide sensor CFA in the overlap region is as shown in FIG. 2, the demosaiced channels R_{Wide} and B_{Wide} are averaged to create $Luma_{Wide}$ according to $Luma_{Wide} = (f1*R_{Wide}+f2*B_{Wide})/(f1+f2)$, where f1 may be f1=1 and f2 may be f2=1.

- Low-pass filtering is applied on the Tele luminance image in order to match its spatial frequency content to that of the $Luma_{Wide}$ image. This improves the registration performance, as after low-pass filtering the luminance images become more similar. The calculation is $Luma_{Tele} \rightarrow$ Low pass filter $\rightarrow Luma_{Tele}^{LP}$, where "LP" denotes an image after low pass filtering.

3. Registration of $Luma_{Wide}$ and $Luma_{Tele}^{LP}$

This step of the algorithm calculates the mapping between the overlap areas in the two luminance images. The registration step does not depend on the type of CFA used (or the lack thereof), as it is applied on luminance images. The same registration step can therefore be applied on Wide and Tele images captured by standard CFA sensors, as well as by any combination of CFAs or Clear sensor pixels disclosed herein. The registration process chooses either the Wide image or the Tele image to be a primary image. The other image is defined as an auxiliary image. The registration process considers the primary image as the baseline image and registers the overlap area in the auxiliary image to it, by finding for each pixel in the overlap area of the primary image its corresponding pixel in the auxiliary image. The output image point of view is determined according to the primary image point of view (camera angle). Various correspondence metrics could be used for this purpose, among which are a sum of absolute differences and correlation.

In an embodiment, the choice of the Wide image or the Tele image as the primary and auxiliary images is based on the ZF chosen for the output image. If the chosen ZF is larger than the ratio between the focal-lengths of the Tele and Wide cameras, the Tele image is set to be the primary image and the Wide image is set to be the auxiliary image. If the chosen ZF is smaller than or equal to the ratio between the focal-lengths of the Tele and Wide cameras, the Wide image is set to be the primary image and the Tele image is set to be the auxiliary image. In another embodiment independent of a zoom factor, the Wide image is always the primary image and the Tele image is always the auxiliary image. The output of the registration stage is a map relating Wide image pixels indices to matching Tele image pixels indices.

4. Combination into a high resolution image

In this final step, the primary and auxiliary images are used to produce a high resolution image. One can distinguish between several cases:

a. If the Wide image is the primary image, and the Tele image was generated from a Clear sensor, $Luma_{Wide}$ is calculated and replaced or averaged with $Luma_{Tele}$ in the overlap area between the two images to create a luminance output image, matching corresponding pixels according to the registration map $Luma_{Out} = c1* Luma_{Wide} + c2* Luma_{Tele}$. The values of c1 and c2 may change between different pixels in the image. Then, RGB values of the output are calculated from $Luma_{Out}$ and R_{Wide}, G_{Wide}, and B_{Wide}.

b. If the Wide image is the primary image and the Tele image was generated from a CFA sensor, $Luma_{Tele}$ is calculated and is combined with $Luma_{Wide}$ in the overlap area between the two images, according to the flow described in 4a.

c. If the Tele image is the primary image generated from a Clear sensor, the RGB values of the output are calculated from the $Luma_{Tele}$ image and R_{Wide}, G_{Wide}, and B_{Wide} (matching pixels according to the registration map).

d. If the Tele image is the primary image generated from a CFA sensor, the RGB values of the output (matching pixels according to the registration map) are calculated either by using only the Tele image data, or by also combining data from the Wide image. The choice depends on the zoom factor.

Certain portions of the registered Wide and Tele images are used to generate the output image based on the ZF of the output image. In an embodiment, if the ZF of the output image defines a FOV smaller than the Tele FOV, the fused high resolution image is cropped to the required field of view and digital interpolation is applied to scale up the image to the required output image resolution.

Exemplary and non-limiting pixel interpolations specifications for the overlap area

FIG. 2

B11	B12	R13
R21	B22	B23
R31	R32	B33

In order to reconstruct the missing R22 pixel, we perform R22 = (R31+R13)/2. The same operation is performed for all missing Blue pixels.

FIG. 3

R11	B12	R13
B21	R22	B23
R31	B32	R33

In order to reconstruct the missing B22 pixel, we perform B22 = (B12+B21+B32+B23)/4. The same operation is performed for all missing Red pixels.

FIG. 4

Y11	C12	Y13
C21	Y22	C23
Y31	C32	Y33

In order to reconstruct the missing C22 pixel, we perform C22 = (C12+C21+C32+C23)/4. The same operation is performed for all missing Yellow pixels.

FIG. 5

<u>Case 1</u>: W is center pixel

R11	B12	B13
R21	W22	R23
B31	B32	R33

In order to reconstruct the missing 22 pixels, we perform the following:

B22 = (B12+B32)/2

R22 = (R21+R23)/2

G22= (W22-R22-B22) (assuming that W includes the same amount of R, G and B colors).

<u>Case 2</u>: R22 is center pixel

B11	B12	R13	R14
W21	R22	B23	W24
B31	R32	B33	R34

In order to reconstruct the missing 22 pixels, we perform the following:

B22 = (B11+R33)/2

W22 = (2*W21+W24)/3

G22 = (W22-R22-B22) (assuming that W contains the same amount of R, G and B colors). The same operation is performed for Blue as the center pixel.

FIG. 6

B11	B12	G13	R14
R21	G22	R23	B24
G31	B32	R33	G34
R41	R42	G43	B44

In order to reconstruct the missing 22 pixels, we perform the following:

B22 = (B12+B32)/2

R22 = (R21+R23)/2.

In order to reconstruct the missing 32 pixels, we perform the following:

G32 = (2*G31+2*G22+G43)/5

R32 = (R41+2*R42+2*R33+R23+R21)/7.

FIG. 7

G11	B12	R13	G14
R21	G22	B23	R24
B31	R32	G33	B34
G41	B42	R43	G44

In order to reconstruct the missing 22 pixels, we perform the following:

B22 = (2*B12+2*B23+B31)/5

R22 = (2*R21+2*R32+R13)/5

and similarly for all other missing pixels.

FIG. 8

R11	B12	B13	R14
R21	G22	R23	B24
B31	B32	R33	B34
R41	R42	B43	R44
B51	G52	B53	R54

In order to reconstruct the missing 22 pixels, we perform the following:

B22 = (2*B12+2*B32+B13)/5

R22 = (2*R21+2*R23+R11)/5.

In order to reconstruct the missing 32 pixels, we perform the following:

G32 = (2*G22+G52)/3

R32 = (2*R33+2*R42+R41+R21+R23)/7.

FIG. 9

R11	B12	R13	B14
B21	G22	B23	R24
R31	B32	R33	B34
B41	R42	B43	R44
R51	G52	R53	B54

In order to reconstruct the missing 22 pixels, we perform the following:

B22 = (B12+B32+B23+B21)/4

R22 = (R11+R13+R31+R33)/4.

In order to reconstruct the missing 32 pixels, we perform the following:

G32 = (2*G22+G52)/3

R32 = (R42+R31+R33)/3.

Triple-aperture zoom imaging system with improved color resolution

As mentioned, a multi-aperture zoom or non-zoom imaging system disclosed herein may include more than two apertures. A non-limiting and exemplary embodiment **1100** of a triple-aperture imaging system is shown in FIGS. 11A-11B. System **1100** includes a first Wide subset camera **1102** (with exemplarily X1), a second Wide subset camera (with exemplarily

X1.5, and referred to as a “Wide-Tele” subset) and a Tele subset camera (with exemplarily X2). FIG. 11A shows exemplary images captured by imaging system **1100**, while FIG. 11B illustrates schematically three sensors marked **1102**, **1104** and **1106**, which belong respectively to the Wide, Wide-Tele and Tele subsets. FIG. 11B also shows the CFA arrangements in each sensor: sensors **1102** and **1104** are similar to Wide sensors described above with reference to any of FIGS. 2-9, in the sense that they include an overlap area and a non-overlap area. The overlap area includes a non-standard CFA. In both Wide sensors, the non-overlap area may have a Clear pattern or a standard CFA. Thus, neither Wide subset is solely a Clear channel camera. The Tele sensor may be Clear or have a standard Bayer CFA or a standard non-Bayer CFA. In use, an image is acquired with imaging system **1100** and processed as follows: demosaicing is performed on the overlap area pixels of the Wide and Wide-Tele sensors according to the specific CFA pattern in each overlap area. The overlap and non-overlap subsets of pixels in each of these sensors may need different demosaicing. Exemplary and non-limiting demosaicing specifications for the overlap area for Wide sensors shown in FIGS. 2-9 are given above. The aim is to reconstruct the missing colors in each and every pixel. In cases in which the Tele subset sensor is not Clear only, demosaicing is performed as well. The Wide and Wide-Tele subset color images acquired this way will have colors (in the overlap area) holding higher resolution than that of a standard CFA pattern. Then, the Tele image acquired with the Tele sensor is registered (mapped) into the respective Wide image. The data from the Wide, Wide-Tele and Tele images is then processed to form a high quality zoom image. In cases where the Tele subset is Clear only, high Luma resolution is taken from the Tele sensor and color resolution is taken from the Wide sensor. In cases where the Tele subset includes a CFA, both color and Luma resolution is taken from the Tele subset. In addition, color resolution is taken from the Wide sensor. The resolution of the fused image may be higher than the resolution of both sensors.

While this disclosure has been described in terms of certain embodiments and generally associated methods, alterations and permutations of the embodiments and methods will be apparent to those skilled in the art. For example, multi-aperture imaging systems with more than two Wide or Wide-Tele subsets (and sensors) or with more than one Tele subset (and sensor) may be constructed and used according to principles set forth herein. Similarly, non-zoom multi-aperture imaging systems with more than two sensors, at least one of which has a non-standard CFA, may be constructed and used according to principles set forth herein. The disclosure is to be understood as not limited by the specific embodiments described herein, but only by the scope of the appended claims.

CLAIMS:

1. A multi-aperture imaging system comprising:

a) a first camera subset that provides a first image, the first camera subset having a first sensor with a first plurality of sensor pixels covered at least in part with a non-standard color filter array (CFA), the non-standard CFA used to increase a specific color sampling rate relative to a same color sampling rate in a standard CFA;

b) a second camera subset that provides a second image, the second camera subset having a second sensor with a second plurality of sensor pixels, the second plurality of sensor pixels being either Clear or covered with a standard CFA; and

c) a processor configured to process the first and second images into a combined output image.

2. The imaging system of claim 1, wherein the non-standard CFA includes a repetition of a 2x2 micro-cell in which a color filter order is either BR-RB or YC-CY.

3. The imaging system of claim 1, wherein the non-standard CFA includes a repetition of a 3x3 micro-cell in which a color filter order is GBR-RGB-BRG.

4. The imaging system of claim 1, wherein the non-standard CFA includes a repetition of a 4x4 micro-cell in which a color filter order is BBRR-RBBR-RRBB-BRRB.

5. The imaging system of claim 1, wherein the non-standard CFA includes a repetition of a 6x6 micro-cell in which a color filter order is selected from the group consisting of RBBRRB-RWRBWB-BBRBRR-RRBRBB-BWBRWR-BRRBBR, BBGRRG-RGRBGB-GBRGRB-RRGBBG-BGBRGR-GRBGBR, RBBRRB-RGRBGB-BBRBRR-RRBRBB-BGBRGR-BRRBBR and RBRBRB-BGBRGR-RBRBRB-BRBRBR-RGRBGB-BRBRBR.

6. The imaging system of any of claims 1-5, wherein the standard CFA includes a Bayer filter.

7. The imaging system of any of claims 1-5, wherein the standard CFA includes a non-Bayer filter.

8. The imaging system of claim 7, wherein the non-Bayer filter is selected from the group consisting of a RGBE, a CYYM, a CYGM, a RGBW#1, a RGBW#2 and a RGBW#3 filter.

9. The imaging system of claim 1, wherein the first and the second camera subsets have identical fields of view and wherein the non-standard CFA covers an overlap area that includes all the pixels of the first sensor, thereby providing increased color resolution.

10. The imaging system of claim 9, wherein the processor is further configured to register respective first and second Luma images obtained from the first and second images during the processing of the first and second images into a combined output image, the registered first and second Luma images used together with color information to form the combined output image.

11. The imaging system of claim 10, wherein the registration includes finding a corresponding pixel in the second Luma image for each pixel in the first Luma image and wherein the processor is further configured to form the output image by transferring information from the second image to the first image.

12. The imaging system of claim 10, wherein the registration includes finding a corresponding pixel in the first Luma image for each pixel in the second Luma image and wherein the processor is further configured to form the output image by transferring information from the first image to the second image.

13. The imaging system of claim 1, wherein the first camera subset has a first field of view (FOV), wherein the second camera subset has a second, smaller FOV than the first FOV, and wherein the non-standard CFA covers an overlap area on the first sensor that captures the second FOV, thereby providing both optical zoom and increased color resolution.

14. The imaging system of claim 13, wherein the processor is further configured to, during the processing of the first and second images into a combined output image and based on a zoom factor (ZF) input, register respective first and second Luma images obtained from the first and second images, the registered first and second Luma images used together with color information to form the combined output image.

15. The imaging system of claim 14, wherein the registration includes, for a ZF input that defines an FOV greater than the second FOV, finding a corresponding pixel in the second Luma image for each pixel in the first Luma image and wherein the processor is further configured to form the output image by transferring information from the second image to the first image.

16. The imaging system of claim 14, wherein the registration includes, for a ZF input that defines an FOV smaller than, or equal to the second FOV, finding a corresponding pixel in the first Luma image for each pixel in the second Luma image and wherein the processor is further configured to form the output image by transferring information from the first image to the second image.

17. The imaging system of claim 13, wherein the second sensor includes a standard CFA and wherein the processing includes, for a ZF input that defines an FOV equal to or smaller than the second FOV, forming the output image based on the second image.

18. The imaging system of any of claims 13-17, wherein the standard CFA includes a Bayer filter.

19. The imaging system of any of claims 13-17, wherein the standard CFA includes a non-Bayer filter.

20. The imaging system of claim 19, wherein the non-Bayer filter is selected from the group consisting of a RGBE, a CYYM, a CYGM, a RGBW#1, a RGBW#2 and a RGBW#3 filter.

21. A multi-aperture imaging system comprising:

a) a first camera subset that provides a first image, the first camera subset having a first sensor with a first plurality of sensor pixels covered at least in part with a standard CFA;

b) a second camera subset that provides a second image, the second camera subset having a second sensor with a second plurality of sensor pixels, the second plurality of sensor pixels being either Clear or covered with a standard CFA; and

c) a processor configured to register first and second Luma images obtained respectively from the first and second images and to process the registered first and second Luma images together with color information into a combined output image.

22. The imaging system of claim 21, wherein the first and the second camera subsets have respectively identical fields of view.

23. The imaging system of claim 22, wherein the registration includes finding a corresponding pixel in the second Luma image for each pixel in the first Luma image and wherein the processor is further configured to form the output image by transferring information from the second image to the first image.

24. The imaging system of claim 22, wherein the registration includes finding a corresponding pixel in the first Luma image for each pixel in the second Luma image and wherein the processor is further configured to form the output image by transferring information from the first image to the second image.

25. The imaging system of claim 21, wherein the first camera subset has a first field of view (FOV), wherein the second camera subset has a second, smaller FOV than the first FOV, and wherein the processor is further configured to register the first and second Luma images based on a zoom factor (ZF) input.

26. The imaging system of claim 25, wherein the registration includes, for a ZF input that defines an FOV greater than the second FOV, finding a corresponding pixel in the second Luma image for each pixel in the first Luma image and wherein the processor is further configured to form the output image by transferring information from the second image to the first image.

27. The imaging system of claim 25, wherein the registration includes, for a ZF input that defines an FOV smaller than, or equal to the second FOV, finding a corresponding pixel in the first Luma image for each pixel in the second Luma image and wherein the processor is further configured to form the output image by transferring information from the first image to the second image.

28. The imaging system of claim 25, wherein the second sensor includes a standard CFA and wherein, for a ZF input that defines an FOV equal to or smaller than the second FOV, the processor is further configured to form the output image based on the second image.

29. The imaging system of any of claims 21-28, wherein the standard CFA includes a Bayer filter.

30. The imaging system of any of claims 21-28, wherein the standard CFA includes a non-Bayer filter.

31. The imaging system of claim 30, wherein the non-Bayer filter is selected from the group consisting of a RGBE, a CYYM, a CYGM, a RGBW#1, a RGBW#2 and a RGBW#3 filter.

32. A multi-aperture imaging system comprising:

a) a first camera subset that provides a first image, the first camera subset having a first field of view (FOV) and first sensor with a first plurality of sensor pixels covered at least in part with a standard CFA;

b) a second camera subset that provides a second image, the second camera subset having a second, smaller FOV than the first FOV and a second sensor with a second plurality of sensor pixels covered with a standard CFA; and

c) a processor configured to, for a zoom factor input that defines an FOV equal to or smaller than the second FOV, form an output image based on the second image.

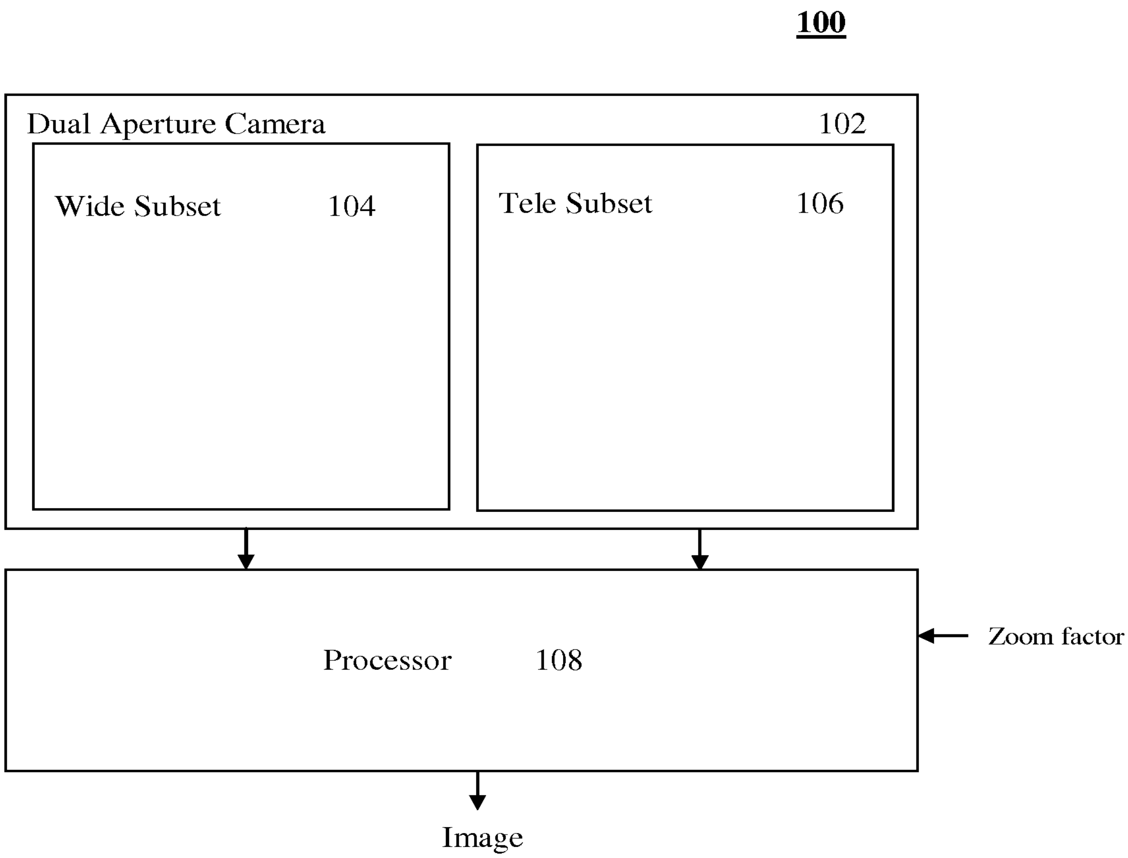

100
Dual Aperture Camera 102
Wide Subset 104
Tele Subset 106
Processor 108
Zoom factor
Image

FIG. 1A

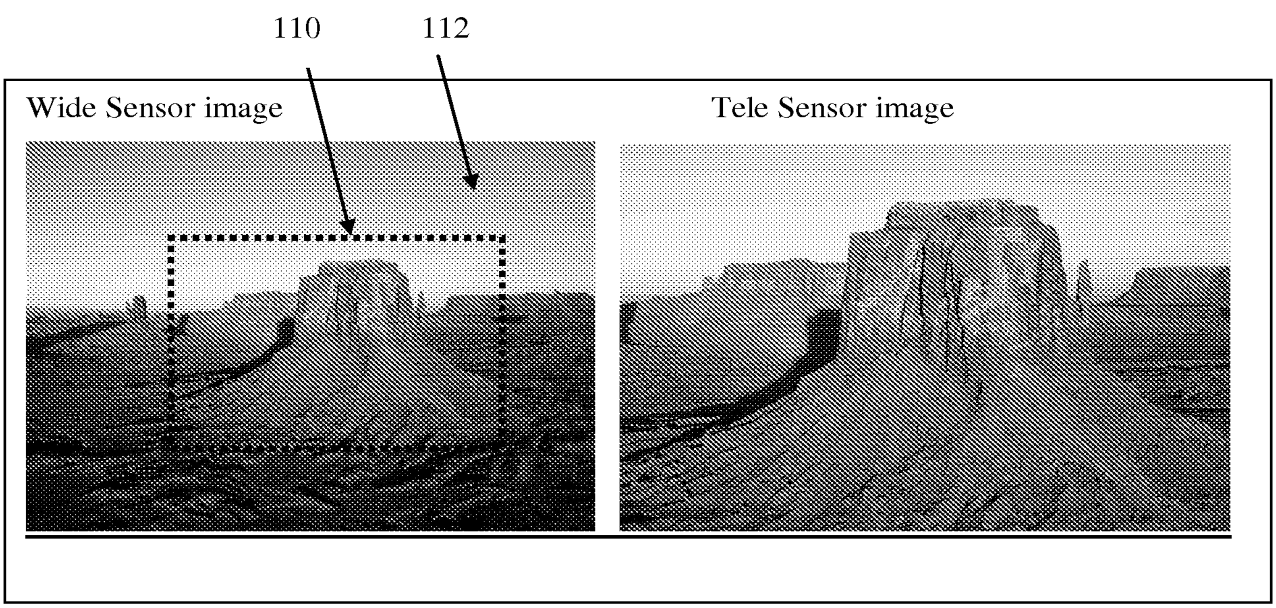

110
112
Wide Sensor image
Tele Sensor image

FIG. 1B

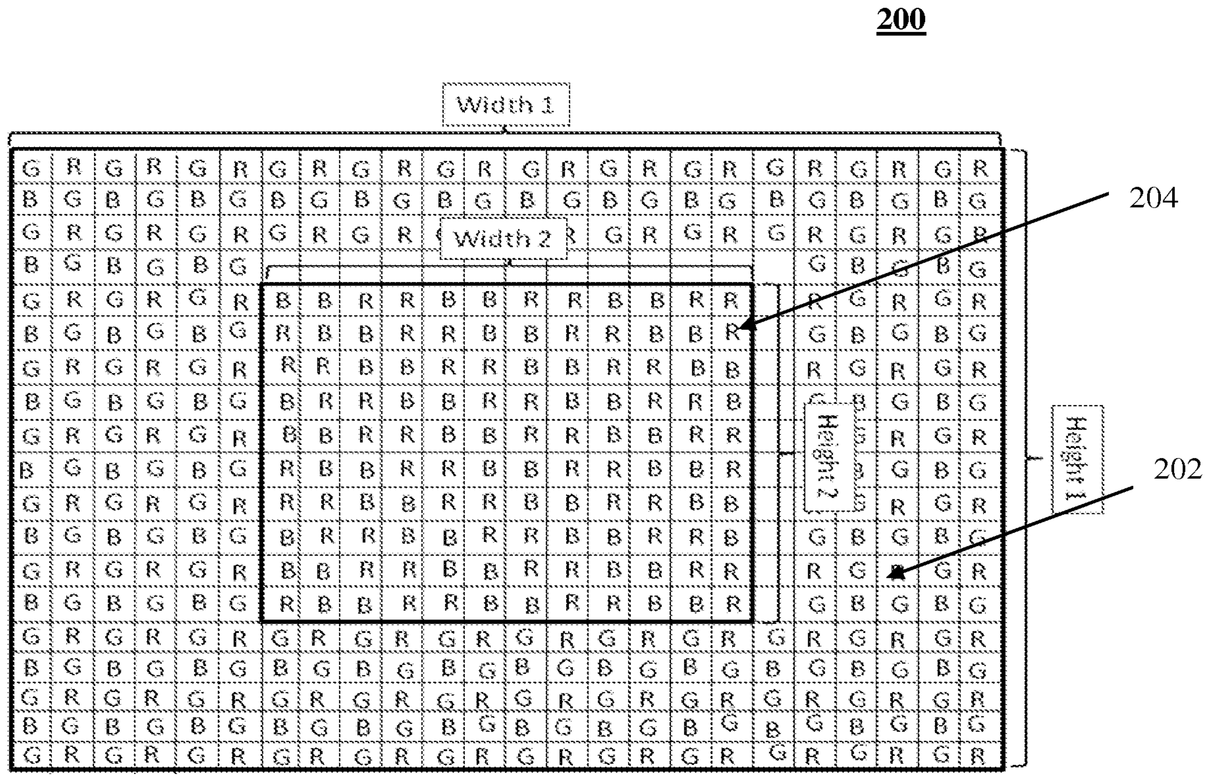

200
Width 1
Width 2
Height 2
Height 1
204
202

FIG. 2

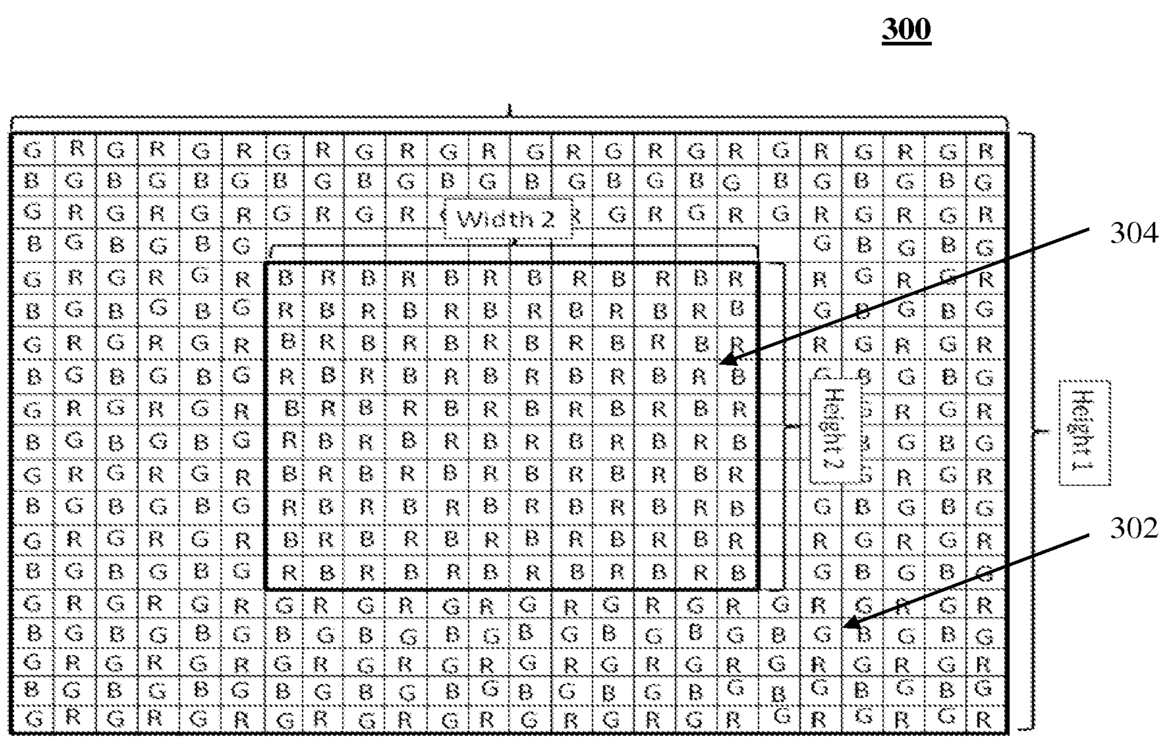

300
Width 2
Height 2
Height 1
304
302

FIG. 3

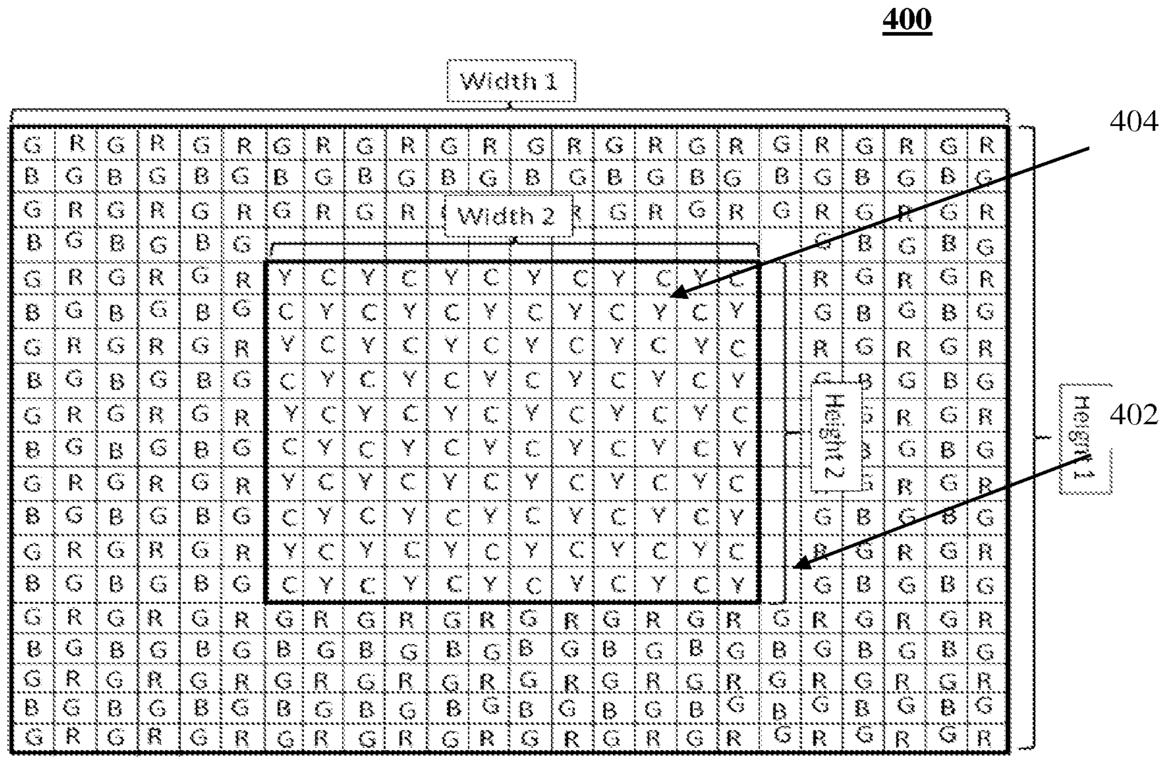

400
Width 1
Width 2
Height 2
Height 1
404
402

FIG. 4

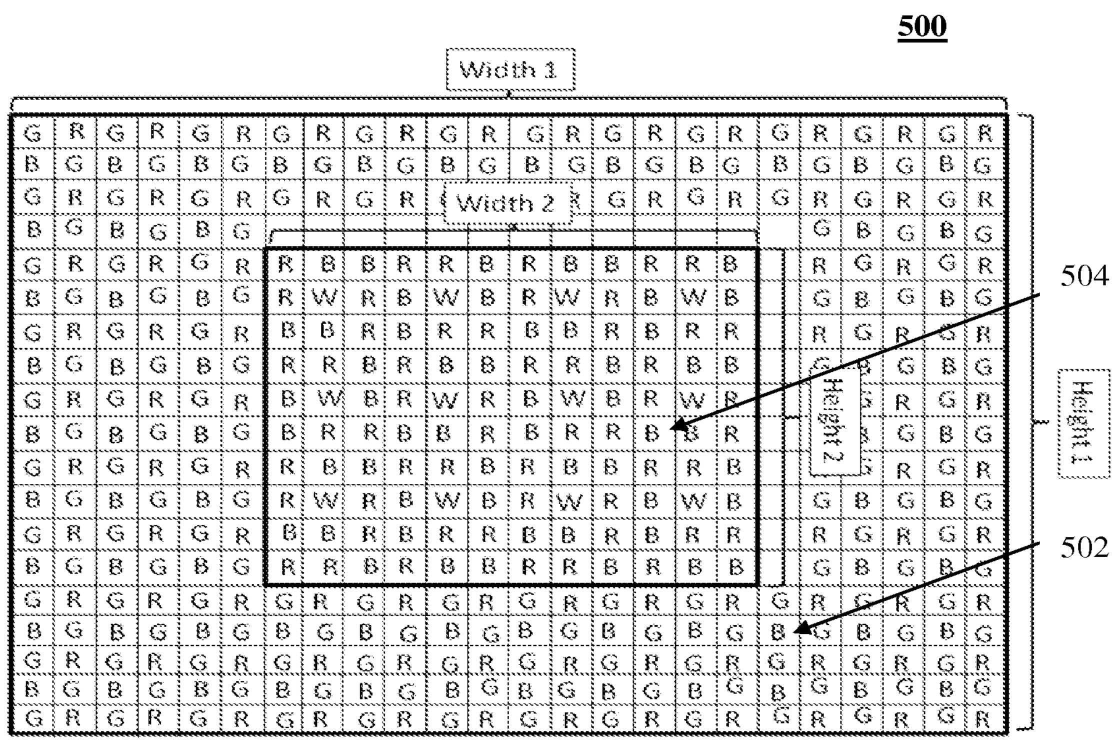

500
Width 1
Width 2
Height 2
Height 1
504
502

FIG. 5

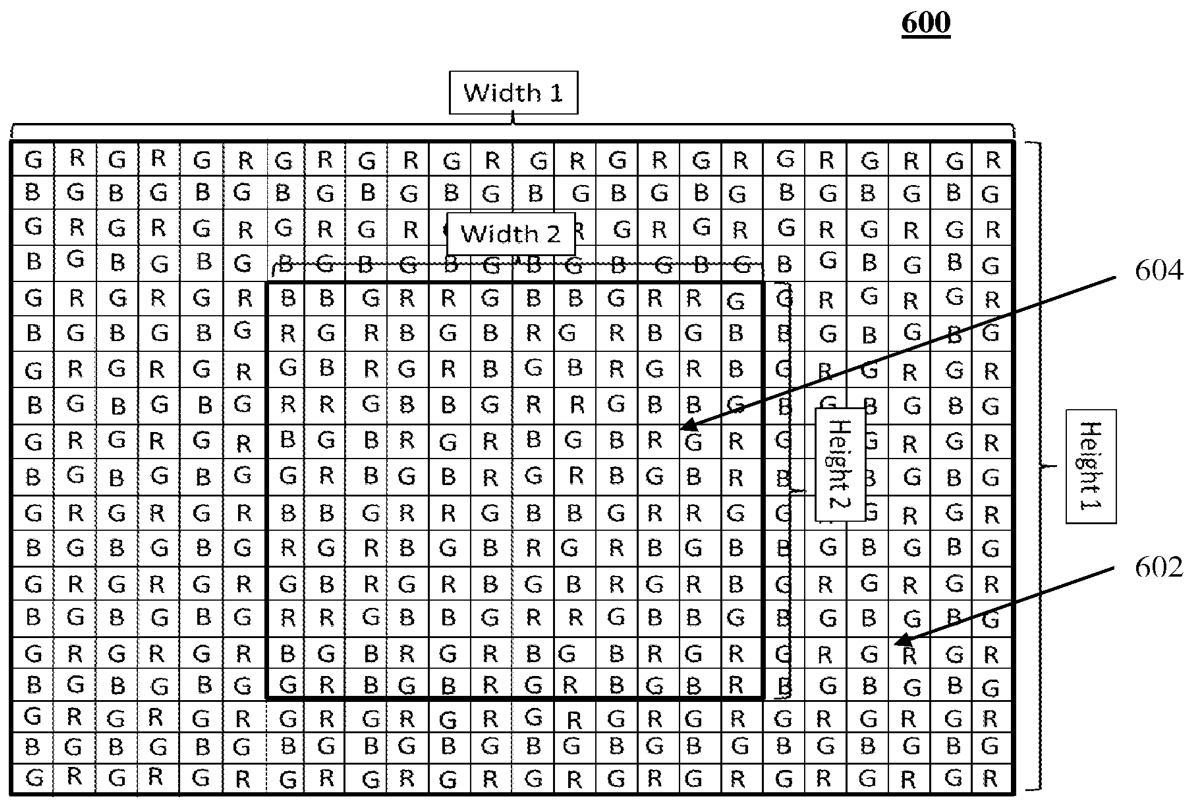

600
Width 1
Width 2
604
Height 2
Height 1
602

FIG. 6

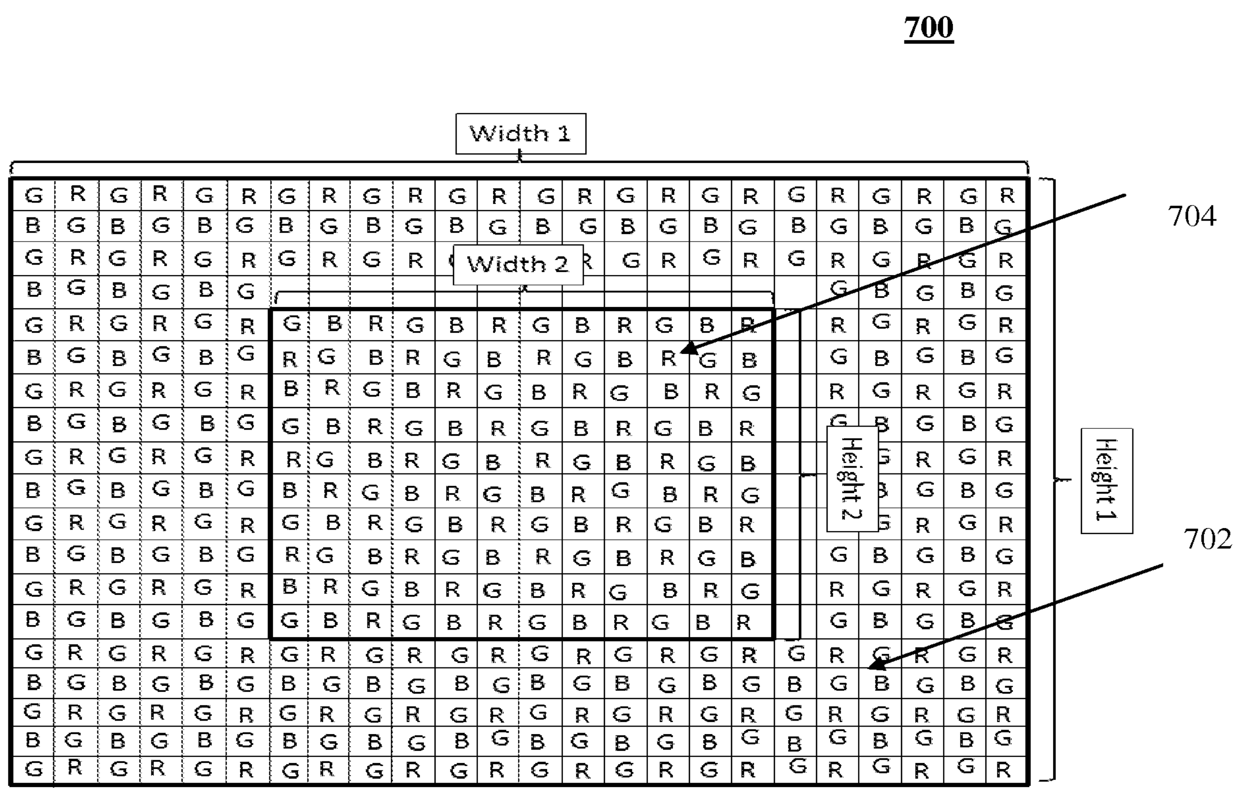

700
Width 1
Width 2
704
Height 2
Height 1
702

FIG. 7

800

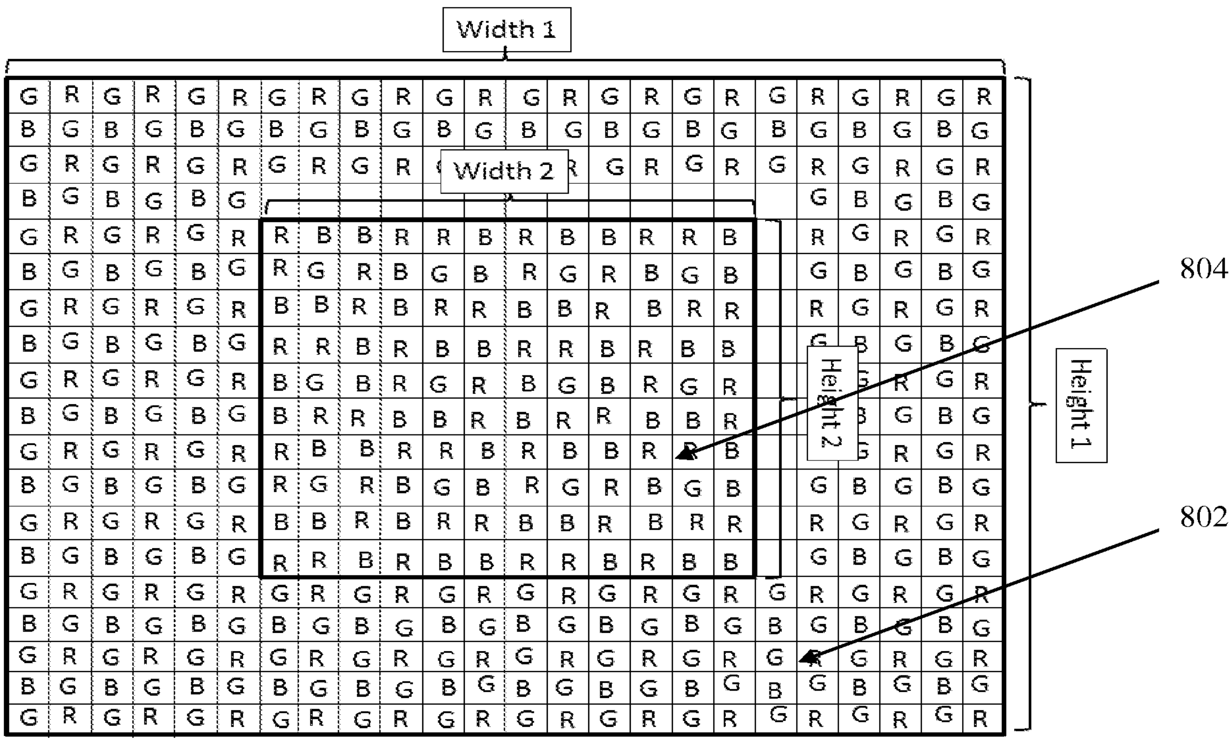


FIG. 8

900

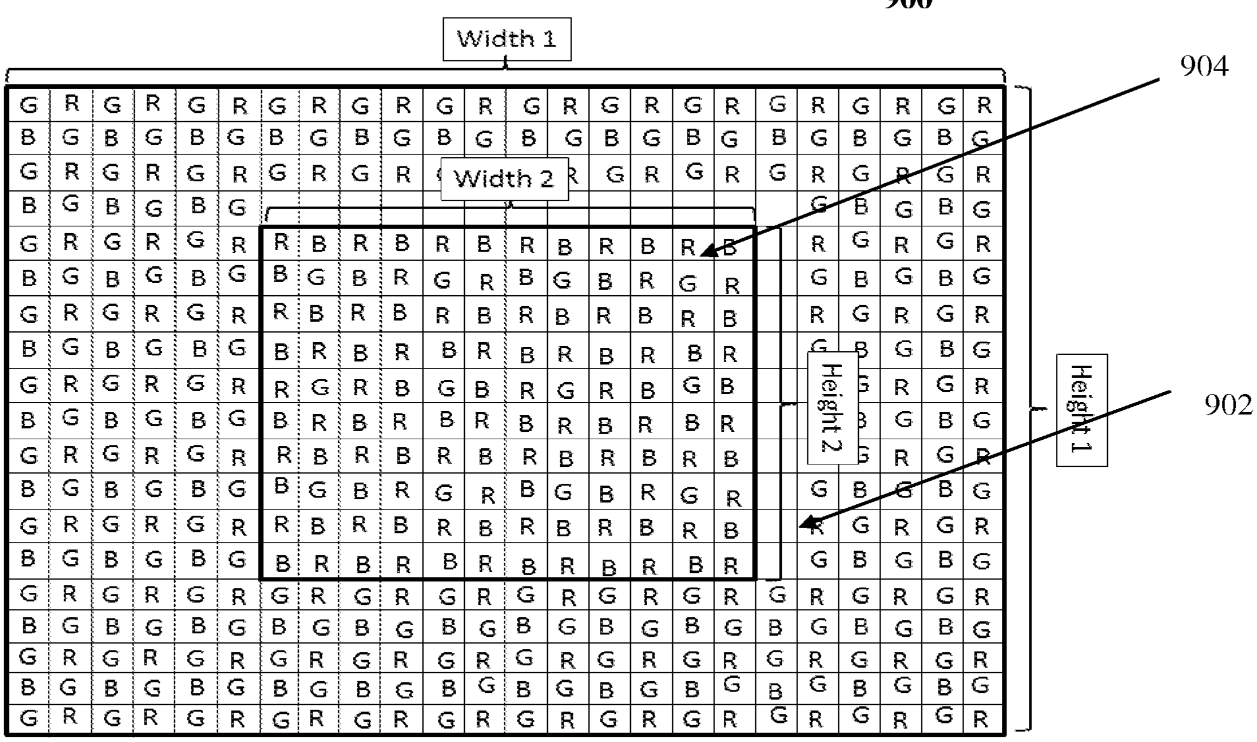


FIG. 9

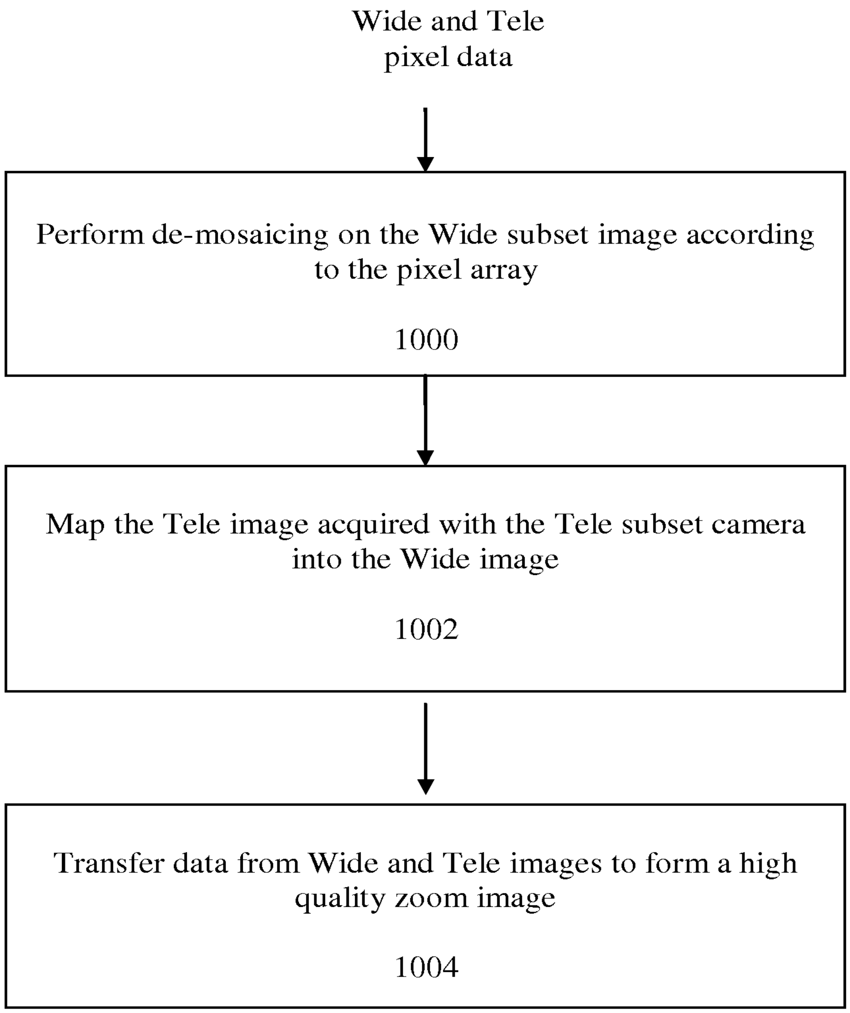

Wide and Tele
pixel data
Perform de-mosaicing on the Wide subset image according to the pixel array
1000
Map the Tele image acquired with the Tele subset camera into the Wide image
1002
Transfer data from Wide and Tele images to form a high quality zoom image
1004

FIG. 10

1100

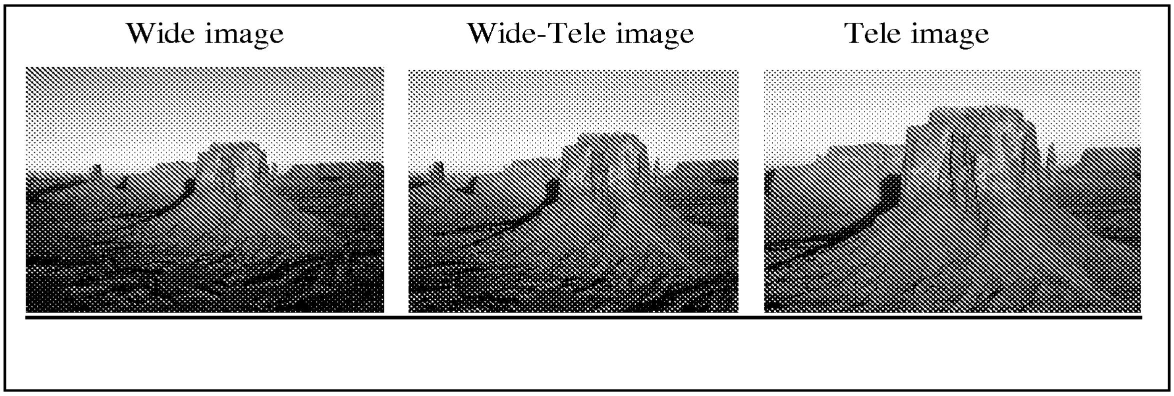


FIG. 11A

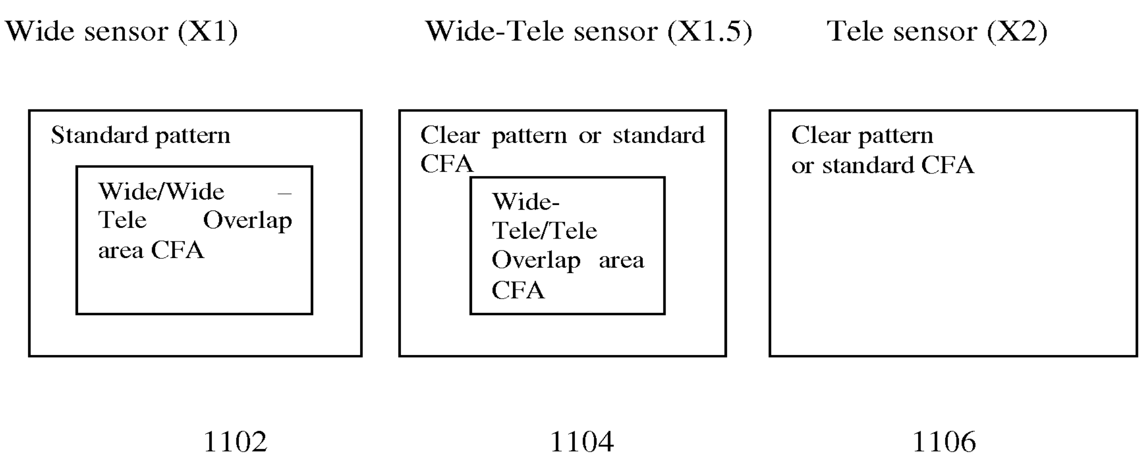


FIG. 11B

SCORE Placeholder Sheet for IFW Content

Application Number: 14386823 Document Date: 09/22/2014

The presence of this form in the IFW record indicates that the following document type was received in electronic format on the date identified above. This content is stored in the SCORE database.

- Drawings – Other than Black and White Line Drawings

Since this was an electronic submission, there is no physical artifact folder, no artifact folder is recorded in PALM, and no paper documents or physical media exist. The TIFF images in the IFW record were created from the original documents that are stored in SCORE.

To access the documents in the SCORE database, refer to instructions below.

At the time of document entry (noted above):

- Examiners may access SCORE content via the eDAN interface.
- Other USPTO employees can bookmark the current SCORE URL (http://Score.uspto.gov/ScoreAccessWeb/).
- External customers may access SCORE content via the Public and Private PAIR interfaces.

Form Revision Date: September 30, 2013

PATENT APPLICATION FEE DETERMINATION RECORD Substitute for Form PTO-875	Application or Docket Number 14/386,823	Filing Date 09/22/2014	☐ To be Mailed

ENTITY: ☐ LARGE ☒ SMALL ☐ MICRO

APPLICATION AS FILED – PART I

FOR	NUMBER FILED (Column 1)	NUMBER EXTRA (Column 2)	RATE ($)	FEE ($)
☐ BASIC FEE (37 CFR 1.16(a), (b), or (c))	N/A	N/A	N/A	
☐ SEARCH FEE (37 CFR 1.16(k), (i), or (m))	N/A	N/A	N/A	
☐ EXAMINATION FEE (37 CFR 1.16(o), (p), or (q))	N/A	N/A	N/A	
TOTAL CLAIMS (37 CFR 1.16(i))	minus 20 =	*	X $ =	
INDEPENDENT CLAIMS (37 CFR 1.16(h))	minus 3 =	*	X $ =	
☐ APPLICATION SIZE FEE (37 CFR 1.16(s))	If the specification and drawings exceed 100 sheets of paper, the application size fee due is $310 ($155 for small entity) for each additional 50 sheets or fraction thereof. See 35 U.S.C. 41(a)(1)(G) and 37 CFR 1.16(s).			
☐ MULTIPLE DEPENDENT CLAIM PRESENT (37 CFR 1.16(j))				
* If the difference in column 1 is less than zero, enter "0" in column 2.			TOTAL	

APPLICATION AS AMENDED – PART II

AMENDMENT	09/22/2014	CLAIMS REMAINING AFTER AMENDMENT (Column 1)		HIGHEST NUMBER PREVIOUSLY PAID FOR (Column 2)	PRESENT EXTRA (Column 3)	RATE ($)	ADDITIONAL FEE ($)
	Total (37 CFR 1.16(i))	* 16	Minus	** 20	= 0	x $40 =	0
	Independent (37 CFR 1.16(h))	* 3	Minus	***3	= 0	x $210 =	0
	☐ Application Size Fee (37 CFR 1.16(s))						
	☐ FIRST PRESENTATION OF MULTIPLE DEPENDENT CLAIM (37 CFR 1.16(j))						
						TOTAL ADD'L FEE	**0**

AMENDMENT		CLAIMS REMAINING AFTER AMENDMENT (Column 1)		HIGHEST NUMBER PREVIOUSLY PAID FOR (Column 2)	PRESENT EXTRA (Column 3)	RATE ($)	ADDITIONAL FEE ($)
	Total (37 CFR 1.16(i))	*	Minus	**	=	X $ =	
	Independent (37 CFR 1.16(h))	*	Minus	***	=	X $ =	
	☐ Application Size Fee (37 CFR 1.16(s))						
	☐ FIRST PRESENTATION OF MULTIPLE DEPENDENT CLAIM (37 CFR 1.16(j))						
						TOTAL ADD'L FEE	

* If the entry in column 1 is less than the entry in column 2, write "0" in column 3.
** If the "Highest Number Previously Paid For" IN THIS SPACE is less than 20, enter "20".
*** If the "Highest Number Previously Paid For" IN THIS SPACE is less than 3, enter "3".
The "Highest Number Previously Paid For" (Total or Independent) is the highest number found in the appropriate box in column 1.

LIE
/ROLITA WIMBUSH/