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INFORMATION DISCLOSURE STATEMENT BY APPLICANT (**Not for submission under 37 CFR 1.99)**		
	Application Number	
	Filing Date	
	First Named Inventor	Jean-Claude ARTONNE
	Art Unit	
	Examiner Name	
	Attorney Docket Number	688266-21RX

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	6128145		2000-10-03	Nagaoka	
	2	5686957		1997-11-11	Baker	
	3	3953111		1976-04-27	Fisher, et al.	
	4	6031670		2000-02-29	Inoue	

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INFORMATION DISCLOSURE STATEMENT BY APPLICANT (**Not for submission under 37 CFR 1.99)**	Application Number	
	Filing Date	
	First Named Inventor	Jean-Claude ARTONNE
	Art Unit	
	Examiner Name	
	Attorney Docket Number	688266-21RX

	1	1028389	EP	A2	2000-08-16	Shiota, et al.		☐
	2	2000-242773	JP	A	2000-09-08	Matsui, et al.		☒
	3	11-261868	JP	A	1999-09-24	Enami		☒

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Examiner Signature		Date Considered	

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

INFORMATION DISCLOSURE STATEMENT BY APPLICANT (Not for submission under 37 CFR 1.99)		
	Application Number	
	Filing Date	
	First Named Inventor	Jean-Claude ARTONNE
	Art Unit	
	Examiner Name	
	Attorney Docket Number	688266-21RX

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	/Stephen E. Murray/	Date (YYYY-MM-DD)	2014-11-26
Name/Print	Stephen E. Murray	Registration Number	63,206

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Electronic Patent Application Fee Transmittal

Application Number:	
Filing Date:	
Title of Invention:	METHOD FOR CAPTURING AND DISPLAYING A VARIABLE RESOLUTION DIGITAL PANORAMIC IMAGE
First Named Inventor/Applicant Name:	Jean-Claude ARTONNE
Filer:	Stephen Murray/Kathy Higgins
Attorney Docket Number:	688266-21RX

Filed as Large Entity

ex parte reexam Filing Fees

Description	Fee Code	Quantity	Amount	Sub-Total in USD($)
Basic Filing:				
REQUEST FOR EX PARTE REEXAMINATION	1812	1	12000	12000
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($)
Miscellaneous:				
	Total in USD ($)			**12000**

Electronic Acknowledgement Receipt

EFS ID:	20798335
Application Number:	90013410
International Application Number:	
Confirmation Number:	4682
Title of Invention:	METHOD FOR CAPTURING AND DISPLAYING A VARIABLE RESOLUTION DIGITAL PANORAMIC IMAGE
First Named Inventor/Applicant Name:	Jean-Claude ARTONNE
Customer Number:	00570
Filer:	Stephen Murray/Kathy Higgins
Filer Authorized By:	Stephen Murray
Attorney Docket Number:	688266-21RX
Receipt Date:	26-NOV-2014
Filing Date:	
Time Stamp:	12:21:10
Application Type:	Reexam (Patent Owner)

Payment information:

Submitted with Payment	yes
Payment Type	Credit Card
Payment was successfully received in RAM	$12000
RAM confirmation Number	642
Deposit Account	501017
Authorized User	MURRAY, STEPHEN

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File Listing:

Document Number	Document Description	File Name	File Size(Bytes)/ Message Digest	Multi Part /.zip	Pages (if appl.)
1	Other Reference-Patent/App/Search documents	Exhibit_7a.PDF	889846 dfa6bd5b495da9129d05789e38090842f8cd02ee	no	18
Warnings:					
Information:					
2	Other Reference-Patent/App/Search documents	Exhibit_8.PDF	398349 f382129017f2a365bea02d716ea0bf23379c00d3	no	13
Warnings:					
Information:					
3	Other Reference-Patent/App/Search documents	Exhibit_6a.PDF	426274 9312b2732433c0c1cb4bb04255188380395b73bf	no	9
Warnings:					
Information:					
4	Other Reference-Patent/App/Search documents	Exhibit_5.PDF	488374 adbbcddebe4f897ac332989493866a5534f29ae1	no	11
Warnings:					
Information:					
5	Other Reference-Patent/App/Search documents	Exhibit_4.PDF	683264 092e55a86b086b0b87ba689eb43ce5ad98b5d7e5	no	10
Warnings:					
Information:					
6	Other Reference-Patent/App/Search documents	Exhibit_3.PDF	1504648 38eb775e76df416740b444b0cbb9fd9357a715ca	no	19
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Information:					
7	Other Reference-Patent/App/Search documents	Exhibit_2.PDF	753750 f4be4fd93262208c740a9a8428015474351bcf20	no	16
Warnings:					
Information:					
8	Reexam Miscellaneous Incoming Letter	Appendix_H.PDF	83932 158479fba5b2c63ec94ed306b7ae9ef401e977b1	no	4
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Information:

9	Reexam Miscellaneous Incoming Letter	Appendix_G.PDF	84025 28425720b0669bf22affd9b823304e854ff087fc	no	4

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10	Reexam Miscellaneous Incoming Letter	Appendix_F.PDF	73718 b58b39437d520e3afcbd820da8bb968cbd90f438	no	3

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11	Reexam Miscellaneous Incoming Letter	Appendix_E.PDF	72679 e14fa66fd11019176b53ddaae378be301a063345	no	2

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13	Reexam Miscellaneous Incoming Letter	Appendix_J.PDF	67285 3850483b0e0004f88a94010485b7106f21be63b2	no	2

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Information:

14	Reexam Miscellaneous Incoming Letter	Appendix_I.PDF	67224 a9238fdf795a8b3f67f19f4b5fc12432acbcf863	no	2

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Information:

15	Reexam Miscellaneous Incoming Letter	Appendix_C.PDF	1650458 da5142adc09a8506bc5790a54f1a335e67d313a0	no	6
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Information:					
16	Reexam Miscellaneous Incoming Letter	Appendix_B.PDF	1204260 afae456c15a02b6acbc6ecfb8ca39763b20e2908	no	7
Warnings:					
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Information:					
17	Reexam Miscellaneous Incoming Letter	Appendix_A.PDF	81432 9da431c64e80d61e6d993c0489f991d4471e0459	no	4
Warnings:					
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Information:					
18	Other Reference-Patent/App/Search documents	00680294.PDF	15348642 d02bbab4e137bd4f610c17246629a0ddf386d5db	no	35
Warnings:					
Information:					
19	Other Reference-Patent/App/Search documents	00680289.PDF	1231557 c6fffd637f75ad9d218fbee8cdc6f8cdf985997a	no	19
Warnings:					
Information:					
20	Copy of patent for which reexamination is requested	00677943.PDF	1432481 ea7c7209ce5175e2975a37cfcdca7b961f85e578	no	25
Warnings:					
Information:					
21	Transmittal Letter	00680646.PDF	80215 de2fd883fcd1630dedf9eb41f5824eff05f2bfa9	no	2
Warnings:					
Information:					
22	Receipt of Original Ex Parte Reexam Request	00680645.PDF	129414 60f0216cd88b50a058f0d9f6aa20fb143652341a	no	12
Warnings:					

Information:					
23	Trans Letter filing of a response in a reexam	Proposed_Amendment.PDF	128722 1d50ac6340669e5e6e4c7b943b69b0ebbe5516d7	no	15
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Information:					
24	Information Disclosure Statement (IDS) Form (SB08)	00675157.PDF	612428 f63a43a775249b13e8d46c24be0f9c9e1e198ca9	no	4
Warnings:					
Information:					
25	Fee Worksheet (SB06)	fee-info.pdf	29578 33e6352d552b7cdb024f6aa7bac041a6e21e0ad8	no	2
Warnings:					
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		Total Files Size (in bytes):	27595976		

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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.

EXHIBIT 7a

(19)日本国特許庁（ＪＰ）　　(12) **公開特許公報**（Ａ）　　(11)特許出願公開番号

特開平11－261868

(43)公開日　平成11年(1999) 9月24日

(51)Int.Cl.[6]		識別記号	ＦＩ		
Ｈ０４Ｎ	5/225		Ｈ０４Ｎ	5/225	Ｚ
					Ｄ
	5/765			7/18	Ｋ
	5/781			5/781	５２０Ｃ
	7/18				５２０Ｂ

審査請求　未請求　請求項の数18　ＯＬ　（全 17 頁）　最終頁に続く

(21)出願番号　特願平10－62531

(22)出願日　平成10年(1998) 3月13日

(71)出願人　000005223
富士通株式会社
神奈川県川崎市中原区上小田中４丁目１番１号

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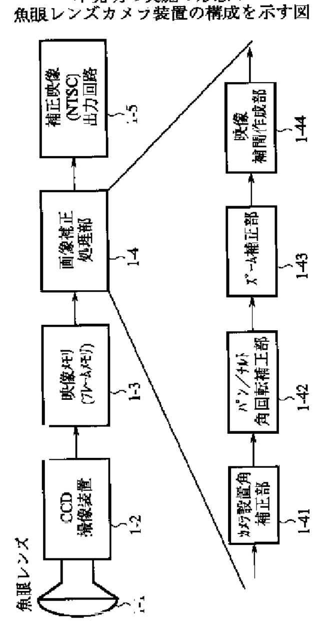
(74)代理人　弁理士　柏谷　昭司　（外２名）

(54)【発明の名称】　魚眼レンズカメラ装置及びその画像歪み補正方法及び画像抽出方法

(57)【要約】
【課題】　魚眼レンズカメラ装置及びその画像歪み補正方法及び画像抽出方法に関し、魚眼レンズカメラを任意の設置アングルで取り付けた場合の魚眼レンズ画像の歪み補正の画像変形処理を高速化し、又、人物像等の移動する像を精度よく検出して抽出し、モニタテレビ等に高精度で表示させる。
【解決手段】　魚眼レンズ１－１、ＣＣＤ撮像装置１－２で撮影した画像を映像メモリ１－３に記憶させ、画像補正処理部１－４は、魚眼レンズカメラの設置角を補正する座標変換と、魚眼レンズ画像の歪みを補正する座標変換とを組み合わせて演算する構成を備え、等面積射影の魚眼レンズ像を高速に写像変換する。更に魚眼レンズ画像内の領域に対応した重み付けを行って、人物像等の特徴量を抽出し、表示エリアを抽出する構成を備えている。

本発明の実施の形態の魚眼レンズカメラ装置の構成を示す図



【特許請求の範囲】
【請求項１】　魚眼レンズカメラにより撮影された画像の歪みを補正する画像補正処理部を備えた魚眼レンズカメラ装置において、
前記画像補正処理部は、魚眼レンズカメラの設置角を補正する座標変換と、魚眼レンズ画像の歪みを補正する座標変換とを組み合わせて演算する構成を有することを特徴とする魚眼レンズカメラ装置。
【請求項２】　前記画像補正処理部は、等面積写像の魚眼レンズ画像の歪みを補正する座標変換を演算する構成を有することを特徴とする請求項１記載の魚眼レンズカメラ装置。
【請求項３】　魚眼レンズカメラにより撮影された画像の歪みを補正する画像補正処理部を備えた魚眼レンズカメラ装置において、
魚眼レンズ画像の歪み補正のための、表示画像の中心位置、魚眼レンズ画像の縦横比、魚眼レンズ画像エリアの半径等のパラメータを、撮像された魚眼レンズ画像自体から抽出し、該パラメータにより魚眼レンズ画像の歪み補正を行う構成を備えたことを特徴とする魚眼レンズカメラ装置。
【請求項４】　魚眼レンズカメラにより撮影した画像から、移動する像を抽する魚眼レンズカメラ装置において、
魚眼レンズ画像内の相互の位置関係を利用して領域を統合し、像の変化した領域を抽出する構成を備えたことを特徴とする魚眼レンズカメラ装置。
【請求項５】　魚眼レンズカメラにより撮影した画像から、移動する像を抽出する魚眼レンズカメラ装置において、
魚眼レンズ画像をパノラマ状の横長映像に変換し、その映像のフレーム間差分の信号又はフレーム間差分とフレーム内差分とを結合した信号を抽出し、該信号により領域抽出を行い、複数の移動像の領域抽出を同時に行う構成を備えたことを特徴とする魚眼レンズカメラ装置。
【請求項６】　魚眼レンズカメラにより撮影した画像から、移動する像を抽出する魚眼レンズカメラ装置において、
フレーム間差分の信号又はフレーム間差分とフレーム内差分とを結合した信号等の特徴量の抽出演算を魚眼レンズ画像の映像をもとに行い、特徴検出領域に対する領域抽出処理において、極座標と直交座標とのアドレス変換を行って魚眼レンズ画像の映像内を走査し、円形の魚眼レンズ画像の映像の中から複数の移動像の領域抽出を行う構成を備えたことを特徴とする魚眼レンズカメラ装置。
【請求項７】　魚眼レンズカメラにより撮影した画像から、移動する像を抽出する魚眼レンズカメラ装置において、
魚眼レンズ画像の映像の中から得られる複数の人物像の領域について、各人物像の形状を正規化し、各像の形状内の色情報を記憶し、個々の像の色情報をもとに移動する複数の人物像を個別に追尾する映像を作成する構成を備えたことを特徴とする魚眼レンズカメラ装置。
【請求項８】　魚眼レンズカメラにより撮影した画像から、移動する像を抽出する魚眼レンズカメラ装置において、
魚眼レンズ画像の中心部分と周辺部分との歪みの大きさに応じて異なる重み係数を乗じた特徴量をもとに領域抽出を行う構成を備えたことを特徴とする魚眼レンズカメラ装置。
【請求項９】　前記重み係数として、更に魚眼レンズ画像の映像内の領域に対応して異なる値を与え、非抽出領域をマスクして領域抽出を行う構成を備えたことを特徴とする請求項８記載の魚眼レンズカメラ装置。
【請求項１０】　魚眼レンズカメラにより撮影された画像の歪みの補正において、
魚眼レンズカメラの設置角を補正する座標変換と、魚眼レンズ画像の歪みを補正する座標変換とを組み合わせて演算する過程を含むことを特徴とする魚眼レンズカメラの画像歪み補正方法。
【請求項１１】　前記魚眼レンズカメラの画像歪み補正において、等面積写像の魚眼レンズ画像の歪みを補正する座標変換を演算する過程を含むことを特徴とする請求項１０記載の魚眼レンズカメラの画像歪み補正方法。
【請求項１２】　魚眼レンズカメラにより撮影された画像の歪みの補正において、
魚眼レンズ画像の歪み補正のための、表示画像の中心位置、魚眼レンズ画像の縦横比、魚眼レンズ画像エリアの半径等のパラメータを、撮像された魚眼レンズ画像自体から抽出し、該パラメータにより魚眼レンズ画像の歪み補正を行う過程を含むことを特徴とする魚眼レンズカメラの画像歪み補正方法。
【請求項１３】　魚眼レンズカメラにより撮影した画像から、移動する像を抽出する画像抽出方法において、
魚眼レンズ画像内の相互の位置関係を利用して領域を統合し、像の変化した領域を抽出する過程を含むことを特徴とする魚眼レンズカメラの画像抽出方法。
【請求項１４】　魚眼レンズカメラにより撮影した画像から、移動する像を抽出する画像抽出方法において、
魚眼レンズ画像をパノラマ状の横長映像に変換し、その映像のフレーム間差分の信号又はフレーム間差分とフレーム内差分とを結合した信号を抽出し、該信号により領域抽出を行い、複数の移動像の領域抽出を同時に行う過程を含むことを特徴とする魚眼レンズカメラの画像抽出方法。
【請求項１５】　魚眼レンズカメラにより撮影した画像から、移動する像を抽出する画像抽出方法において、
フレーム間差分の信号又はフレーム間差分とフレーム内差分とを結合した信号等の特徴量の抽出演算を魚眼レン

ズ画像の映像をもとに行い、特徴検出領域に対する領域抽出処理において、極座標と直交座標とのアドレス変換を行って魚眼レンズ画像の映像内を走査し、円形の魚眼レンズ画像の映像の中から複数の移動像の領域抽出を行う過程を含むことを特徴とする魚眼レンズカメラの画像抽出方法。

【請求項１６】　魚眼レンズカメラにより撮影した画像から、移動する像を抽出する画像抽出方法において、

魚眼レンズ画像の映像の中から得られる複数の人物像の領域について、各人物像の形状を正規化し、各像の形状内の色情報を記憶し、個々の像の色情報をもとに移動する複数の人物像を個別に追尾する映像を作成する過程を含むことを特徴とする魚眼レンズカメラの画像抽出方法。

【請求項１７】　魚眼レンズカメラにより撮影した画像から、移動する像を抽出する画像抽出方法において、

魚眼レンズ画像の中心部分と周辺部分との歪みの大きさに応じて異なる重み係数を乗じた特徴量をもとに領域抽出を行う過程を含むことを特徴とする魚眼レンズカメラの画像抽出方法。

【請求項１８】　前記重み係数として、更に魚眼レンズ画像の映像内の領域に対応して異なる値を与え、非抽出領域をマスクして領域抽出を行う過程を含むことを特徴とする請求項１７記載の魚眼レンズカメラの画像抽出方法。

【発明の詳細な説明】

【０００１】

【発明の属する技術分野】本発明は、魚眼レンズカメラ装置及びその画像歪み補正方法及び画像抽出方法に関し、特に、魚眼レンズカメラにより画像を取り込み、その一部の画像を切り出してモニタテレビに表示するテレビ会議システム又は遠隔監視システム等における魚眼レンズカメラ装置及びその画像歪み補正方法及び画像抽出方法に関する。

【０００２】魚眼レンズは約１８０度の画角を有し、広範囲の画像を映し出すことができるが、その画像はたる型に歪曲し、特に周辺部は歪みが著しい。本発明は、魚眼レンズの撮像範囲が広範囲であることを利用し、１台の魚眼レンズカメラで取り込んだ画像の中から、注目する画像の部分を切り出し、画像の歪みを補正してモニタテレビ画面に表示するものである。

【０００３】更に、本発明は、魚眼レンズカメラで映し取った映像の中から、人物の侵入等の動きを伴う像を検出し、その像のモニタ表示領域（切り出し領域）を自動的に決定してその移動像を追尾させるものであり、遠隔監視システムやテレビ会議システムのカメラ装置に好適に用いられるものである。

【０００４】

【従来の技術】図１３は従来の魚眼レンズカメラ装置の構成及びそれを用いた遠隔監視システム及びテレビ会議システムを示す図である。図の（ａ）は魚眼レンズカメラ装置の構成を示し、図の（ｂ）は魚眼レンズカメラ装置を用いた遠隔監視システムを示し、図の（ｃ）は魚眼レンズカメラ装置を用いたテレビ会議システムを示す。

【０００５】同図において、１３－１０は魚眼レンズカメラ装置、１３－１は魚眼レンズ、１３－２はＣＣＤ撮像装置、１３－３は映像メモリ（フレームメモリ）、１３－４は画像補正処理回路、１３－５は補正映像（ＮＴＳＣ）出力回路である。

【０００６】魚眼レンズ１３－１は約１８０度の画角で対象物を光学的に映し出し、ＣＣＤ撮像装置１３－２は光学的な映像から電気的な画像信号を生成し、映像メモリ（フレームメモリ）１３－３はその画像信号をフレーム単位に記憶する。

【０００７】画像補正処理回路１３－４は、モニタ表示する領域について、魚眼レンズの歪んだ画像を補正して元の像に戻し、補正映像（ＮＴＳＣ）出力回路１３－５は、補正された画像信号をＮＴＳＣ方式等の通常のテレビ映像信号として出力する。

【０００８】魚眼レンズは画角が広いため、そのレンズを用いたカメラ装置により広範囲のエリアの映像を取り込む遠隔監視システムやテレビ会議システムを構成することができる。図の（ｂ），（ｃ）に示すように、魚眼レンズカメラ装置１３－１０に符号化装置１３－２０を取付け、又は符号化装置付きの魚眼レンズカメラ装置１３－３０により、映像信号を公衆回線１３－４０を介して伝送し、復号化装置１３－５０を介してモニタテレビ画面１３－６０等に表示することにより、それらのシステムを構成することができる。但し、魚眼レンズは画角が広い分、映像の歪みが大きくその歪みを補正してモニタテレビ画面１３－６０等に表示しなけらばならない。

【０００９】図１４は従来の魚眼レンズカメラ画像の歪み補正の説明図である。同図において、１４－１は仮想の画像フレーム、１４－２は仮想の半球面、１４－３は魚眼レンズ撮像画面である。又、ｘ，ｙ，ｚ軸で示す３次元空間の原点Ｏに魚眼レンズが置かれ、且つ、魚眼レンズはｚ軸の方向に向けて置かれているものとする。

【００１０】又、仮想の半球面１４－２は、魚眼レンズが正射影方式のレンズでその焦点距離がｆであるとすると、半径ｆの仮想的な半球の球面であり、その平面部はｘ－ｙ平面上に置かれ、その中心は原点Ｏの位置に置かれる。

【００１１】仮想の画像フレーム１４－１は、魚眼レンズの位置（原点）から撮影対象物へ向かう視線方向ベクトルＤＯＶ（Ｄｉｒｅｃｔｉｏｎ　Ｏｆ　Ｖｉｅｗ）と直交する仮想的な平面上のフレームで、所定の大きさの枠を持ち、後に説明するように、この枠内の映像が魚眼レンズ画像から切り出されてモニタテレビ画面に表示されることとなる。即ち、モニタテレビ等の表示フレームの枠と同じ大きさの枠を持つ。

【００１２】又、画像フレーム１４－１は、そのフレーム内に視線方向ベクトルＤＯＶと交差する点を原点とする２次元座標軸（ｐ，ｑ）を持ち、仮想画像フレーム１４－１内の点はこの座標の成分（ｐ，ｑ）によって表される。

【００１３】魚眼レンズによって映し出される像（魚眼レンズ画像）は、レンズの射影方式（projection fomula）によっていくつかのタイプに分けられるが、以下、正射影（orthographic projection）方式の魚眼レンズについて説明する。

【００１４】魚眼レンズの置かれた位置（原点Ｏ）から前記仮想の半球面１４－２を通して見える像を、そのまま該仮想の半球面１４－２に貼り付けたと仮定する。そして、その半球面１４－２上に貼り付けた３次元空間の像を、図のｘ軸及びｙ軸からなる２次元空間の平面上に、該平面に垂直に（ｚ方向から原点方向に）押し潰して貼り付けた像が、正射影方式の魚眼レンズの画像である。

【００１５】なお、実際には、魚眼レンズの画像は上下左右逆転した位置に像を結ぶが、像の歪曲の相対的な関係は変わらないので、説明を簡略化するため前述したように結像するものとする。

【００１６】前記半球面１４－２上の像を垂直に押し潰した２次元空間の平面が魚眼レンズ撮像画面１４－３であり、該魚眼レンズ撮像画面１４－３の円の内側の画像が魚眼レンズで撮影された画像である。外側の四角の枠は、ＣＣＤ撮像装置から得られる全体の撮像画面の外枠である。

【００１７】魚眼レンズの画像は歪曲しているため、魚眼レンズカメラで撮影した像を表示するには、その一部を切り出して正常な画像に補正する必要がある。そこで、表示するフレームに対応するフレームを仮想の画像フレーム１４－１として想定する。

【００１８】魚眼レンズが向いているｚ軸の方向が、鉛直線の上方の方向であるとし、前記視線方向ベクトルＤＯＶがｚ軸と成す頂点角（天頂角）をφ、水平面の基準軸（ｘ軸又はｙ軸）と成す方位角をθとする。又、焦点距離（魚眼レンズ画像の円の半径）をｆ、画像フレームの回転角をω、拡大率をｍとする。拡大率ｍは、魚眼レンズの位置（原点Ｏ）から画像フレーム１４－１内の原点までの距離をＤとすると、ｍ＝Ｄ／ｆである。

【００１９】魚眼レンズ画像平面１４－３内の点（ｘ，ｙ）と画像フレーム１４－１内の点（ｐ，ｑ）との対応関係は、式（１）の関係式によって表わされる。

【００２０】

【数１】

$$\left.\begin{aligned}
x &= \frac{R\{pA - qB + mR\sin\phi\sin\theta\}}{\sqrt{p^2+q^2+m^2R^2}}\\
y &= \frac{R\{pC - qD - mR\sin\phi\sin\theta\}}{\sqrt{p^2+q^2+m^2R^2}}\\
A &= (\cos\omega\cos\theta - \sin\omega\sin\theta\cos\phi)\\
B &= (\sin\omega\cos\theta + \cos\omega\sin\theta\cos\phi)\\
C &= (\cos\omega\sin\theta + \sin\omega\cos\theta\cos\phi)\\
D &= (\sin\omega\sin\theta - \cos\omega\cos\theta\cos\phi)
\end{aligned}\right\}\cdots(1)$$

【００２１】式（１）の対応関係を利用して魚眼レンズ画像の歪みを補正し、元の画像を復元してモニタテレビ画面に表示させることができる。即ち、先ず前記画像フレームを１４－１を定位させ、モニタ表示する領域（切り出し領域）を定める。この定位操作は、画像フレームの頂点角φ、方位角θ、回転角φ及び拡大率ｍを外部から画像補正処理回路１３－４に入力することによって設定する。

【００２２】画像補正処理回路１３－４は、画像フレーム１４－１内の点（ｐ，ｑ）に対応する魚眼レンズ画像平面１４－３内の点（ｘ，ｙ）を、前記式（１）の関係式により求め、その点の色情報信号を映像メモリ（フレームメモリ）１３－３から読み出して、画像フレーム１４－１内の点（ｐ，ｑ）に対応するアドレスを有する出力用の映像メモリ（図示省略）に該色情報信号を書き込む。

【００２３】この映像メモリ間の色情報転送操作を、画像フレーム１４－１内の全ての点（ｐ，ｑ）について行い、出力用の映像メモリから順次、色情報信号を補正映像（ＮＴＳＣ）出力回路１３－５に送出することにより、補正映像（ＮＴＳＣ）出力回路１３－５は、原点Ｏから仮想の画像フレーム１４－１の枠を通して見た実物象の画像を、歪みなく表示することができる。（米国特許第５，１８５，６６７号明細書等参照）

【００２４】

【発明が解決しようとする課題】前述の魚眼レンズ画像の歪み補正は、対象とする魚眼レンズが正射影の像となるときの補正であり、実際の魚眼レンズとして多く使用されている等面積写像の像となる魚眼レンズのときは、座標変換の演算が更に複雑なものとなる。

【００２５】魚眼レンズ画像の歪み補正の演算は、表示する画像フレームの座標点毎に座標変換の演算を行うため膨大な演算量となり、又、画像の解像度を上げると更に演算量が増大することになるので、座標変換の演算量は極力少ないものとしなけらばならない。

【００２６】又、前述の魚眼レンズ画像の歪み補正は、魚眼レンズカメラを机等に設置して天井方向に真上に向ける、或いは、天井に取り付けて床方向に真下に向ける等、鉛直方向に向けて置くことを前提としているため、

魚眼レンズカメラの設置アングルを自由に選定して設置することができない。一方、魚眼レンズカメラを壁に横向きに取り付けたり、天井の隅に斜めの角度で取り付けたりした方が、監視領域等の撮像領域を魚眼レンズ画像のより有効な撮像エリアに取り込むことができる場合が多い。

【００２７】更に、魚眼レンズカメラを使って撮影される映像は、実際には個々の魚眼レンズカメラの特性により変動する。この魚眼レンズカメラカメラの特性の相違は、魚眼レンズ画像の歪み補正による画像変換を行っても、変換後の画像に画像歪みとして残って表示されてしまう。

【００２８】従来は魚眼レンズカメラの映像パラメータである、ＣＣＤ撮像装置の撮像画面における魚眼レンズ画像の左右方向のずれの補正や、ＣＣＤの撮像装置の構造等に起因する縦横比の補正については、手動で調整しなければならなかった。

【００２９】又、魚眼レンズカメラを使った追尾型の遠隔監視システムにおいて、人物像等の検出とモニタ表示領域（切り出し領域）の決定を自動的に行なわなければならないが、単に魚眼レンズ画像のフレーム間差分によりモニタ表示領域（切り出し領域）を決定する方法では、動く物が１つのみである場合の検出が限界であり、領域内に複数の物が移動する場合にその各々を追尾する映像を作成することは不可能であった。

【００３０】又、魚眼レンズ画像は、その中心部と周辺部とで明るさや歪曲の大きさが違っているため、追尾の際の切り出し領域が変化するに伴い、モニタ表示される画像についても不自然になり易いという欠点があった。

【００３１】本発明は、魚眼レンズカメラを任意の設置アングルで取り付けた場合の魚眼レンズ画像の歪み補正の画像変形処理を高速化するとともに、又、魚眼レンズカメラで撮影した人物像等の移動する像を精度よく検出して抽出し、モニタテレビ等に高精度で表示させることを目的とする。

【００３２】

【課題を解決するための手段】本発明の魚眼レンズカメラ装置は、（１）魚眼レンズカメラにより撮影された画像の歪みを補正する画像補正処理部を備えた魚眼レンズカメラ装置において、前記画像補正処理部は、魚眼レンズカメラの設置角を補正する座標変換と、魚眼レンズ画像の歪みを補正する座標変換とを組み合わせて演算する構成を有するものである。又、（２）前記画像補正処理部は、等面積写像の魚眼レンズ画像の歪みを補正する座標変換を演算する構成を有するものである。

【００３３】又、（３）魚眼レンズカメラにより撮影された画像の歪みを補正する画像補正処理部を備えた魚眼レンズカメラ装置において、魚眼レンズ画像の歪み補正のための、表示画像の中心位置、魚眼レンズ画像の縦横比、魚眼レンズ画像エリアの半径等のパラメータを、撮像された魚眼レンズ画像自体から抽出し、該パラメータにより魚眼レンズ画像の歪み補正を行う構成を備えたものである。

【００３４】又、（４）魚眼レンズカメラにより撮影した画像から、移動する像を抽する魚眼レンズカメラ装置において、魚眼レンズ画像内の相互の位置関係を利用して領域を統合し、像の変化した領域を抽出する構成を備えたものである。

【００３５】又、（５）魚眼レンズカメラにより撮影した画像から、移動する像を抽出する魚眼レンズカメラ装置において、魚眼レンズ画像をパノラマ状の横長映像に変換し、その映像のフレーム間差分の信号又はフレーム間差分とフレーム内差分とを結合した信号を抽出し、該信号により領域抽出を行い、複数の移動像の領域抽出を同時に行う構成を備えたものである。

【００３６】又、（６）魚眼レンズカメラにより撮影した画像から、移動する像を抽出する魚眼レンズカメラ装置において、フレーム間差分の信号又はフレーム間差分とフレーム内差分とを結合した信号等の特徴量の抽出演算を魚眼レンズ画像の映像をもとに行い、特徴検出領域に対する領域抽出処理において、極座標と直交座標とのアドレス変換を行って魚眼レンズ画像の映像内を走査し、円形の魚眼レンズ画像の映像の中から複数の移動像の領域抽出を行う構成を備えたものである。

【００３７】又、（７）魚眼レンズカメラにより撮影した画像から、移動する像を抽出する魚眼レンズカメラ装置において、魚眼レンズ画像の映像の中から得られる複数の人物像の領域について、各人物像の形状を正規化し、各像の形状内の色情報を記憶し、個々の像の色情報をもとに移動する複数の人物像を個別に追尾する映像を作成する構成を備えたものである。

【００３８】又、（８）魚眼レンズカメラにより撮影した画像から、移動する像を抽出する魚眼レンズカメラ装置において、魚眼レンズ画像の中心部分と周辺部分との歪みの大きさに応じて異なる重み係数を乗じた特徴量をもとに領域抽出を行う構成を備えたものである。又、（９）前記重み係数として、更に魚眼レンズ画像の映像内の領域に対応して異なる値を与え、非抽出領域をマスクして領域抽出を行う構成を備えたものである。

【００３９】又、本発明の魚眼レンズカメラの画像歪み補正方法は、（１０）魚眼レンズカメラにより撮影された画像の歪みの補正において、魚眼レンズカメラの設置角を補正する座標変換と、魚眼レンズ画像の歪みを補正する座標変換とを組み合わせて演算する過程を含むものである。又、（１１）前記魚眼レンズカメラの画像歪み補正において、等面積写像の魚眼レンズ画像の歪みを補正する座標変換を演算する過程を含むものである。

【００４０】又、（１２）魚眼レンズカメラにより撮影された画像の歪みの補正において、魚眼レンズ画像の歪み補正のための、表示画像の中心位置、魚眼レンズ画像

の縦横比、魚眼レンズ画像エリアの半径等のパラメータを、撮像された魚眼レンズ画像自体から抽出し、該パラメータにより魚眼レンズ画像の歪み補正を行う過程を含むものである。

【００４１】又、本発明の魚眼レンズカメラの画像抽出方法は、（１３）魚眼レンズカメラにより撮影した画像から、移動する像を抽出する画像抽出方法において、魚眼レンズ画像内の相互の位置関係を利用して領域を統合し、像の変化した領域を抽出する過程を含むものである。

【００４２】又、（１４）魚眼レンズカメラにより撮影した画像から、移動する像を抽出する画像抽出方法において、魚眼レンズ画像をパノラマ状の横長映像に変換し、その映像のフレーム間差分の信号又はフレーム間差分とフレーム内差分とを結合した信号を抽出し、該信号により領域抽出を行い、複数の移動像の領域抽出を同時に行う過程を含むものである。

【００４３】又、（１５）魚眼レンズカメラにより撮影した画像から、移動する像を抽出する画像抽出方法において、フレーム間差分の信号又はフレーム間差分とフレーム内差分とを結合した信号等の特徴量の抽出演算を魚眼レンズ画像の映像をもとに行い、特徴検出領域に対する領域抽出処理において、極座標と直交座標とのアドレス変換を行って魚眼レンズ画像の映像内を走査し、円形の魚眼レンズ画像の映像の中から複数の移動像の領域抽出を行う過程を含むものである。

【００４４】又、（１６）魚眼レンズカメラにより撮影した画像から、移動する像を抽出する画像抽出方法において、魚眼レンズ画像の映像の中から得られる複数の人物像の領域について、各人物像の形状を正規化し、各像の形状内の色情報を記憶し、個々の像の色情報をもとに移動する複数の人物像を個別に追尾する映像を作成する過程を含むものである。

【００４５】又、（１７）魚眼レンズカメラにより撮影した画像から、移動する像を抽出する画像抽出方法において、魚眼レンズ画像の中心部分と周辺部分との歪みの大きさに応じて異なる重み係数を乗じた特徴量をもとに領域抽出を行う過程を含むものである。

【００４６】又、（１８）前記重み係数として、更に魚眼レンズ画像の映像内の領域に対応して異なる値を与え、非抽出領域をマスクして領域抽出を行う過程を含むものである。

【００４７】

【発明の実施の形態】図１は、本発明の実施の形態の魚眼レンズカメラ装置の構成を示す図である。同図において、１－１は魚眼レンズ、１－２はＣＣＤ撮像装置、１－３は映像メモリ（フレームメモリ）、１－４は画像補正処理部、１－４１はカメラ設置角補正部、１－４２はパン／チルト角回転補正部、１－４３はズーム補正部、１－４４は映像補間作成部、１－５は補正映像（ＮＴＳＣ）出力回路である。

【００４８】魚眼レンズ１－１により広範囲の像を光学的に取り込み、ＣＣＤ撮像装置１－２により光学的な像から電気的な画像信号を生成し、映像メモリ（フレームメモリ）１－３はその画像信号をフレーム単位に記憶する。

【００４９】画像補正処理部１－４は、魚眼レンズによる歪んだ画像を補正して元の像に戻す処理を行い、補正映像（ＮＴＳＣ）出力回路１－５は、補正された像の信号を通常のＮＴＳＣ方式等のテレビ映像信号として出力する。又、この信号を符号化装置により符号化して送信し、遠隔地で映像表示することもできる。

【００５０】画像補正処理部１－４のカメラ設置角補正部１－４１は、任意の方向を向いた魚眼レンズカメラ装置の設置角を補正し、パン／チルト角回転補正部１－４２は、映像表示エリア（切り取りエリア）のパン・チルト角の回転量を制御し、ズーム補正部１－４３は、表示映像の拡大率を制御し、映像補間作成部１－４４は、座標点の間の補間を行い、映像表示エリア（切り取りエリア）の画像について歪みを補正して元の像に戻す処理を行う。

【００５１】図２は本発明の実施の形態の魚眼レンズカメラで撮影される映像の説明図である。図の（ａ）は、魚眼レンズカメラが直上を向いた場合の魚眼レンズ画像ｉｍｇを示し、図の（ｂ）は、表示対象の魚眼レンズ画像ｉｍｇを、画像フレームｆｒｍの平面へ写像する様子を模式的に表し、図の（ｃ）はｙ軸方向から図の（ｂ）の球を見通した図を示している。魚眼レンズ画像ｉｍｇが正射影方式の画像の場合、図の（ａ）の魚眼レンズ画像ｉｍｇはｚ軸方向から図２の（ｂ）の球を見通した画像となる。

【００５２】魚眼レンズカメラをｘ軸，ｙ軸，ｚ軸の原点に上方に（ｚ軸方向に）向けて置いたとすると、魚眼レンズカメラで映される映像は、先ず、原点の周りの距離Ｒの半径の球の内側に、映像が貼り付けられた状態を想定して解析することができる。

【００５３】このように物体までの距離は無視されて、魚眼レンズカメラによる画像ｉｍｇは、特定の方角（ｒ，θ，ϕ）から入射された像が、２次元のｘ－ｙ平面で、式（２）の写像変換式により表される点（ｘ″，ｙ″）へ写像されるものとみなすことができる。式（２）においてθは方位角、ϕは頂点角（天頂角）であり、Ｌは頂点角ϕで入射した像が魚眼レンズ画像上に結像したときの、原点Ｏからの距離（像高）である。

【００５４】

【数２】

$$\left.\begin{aligned} x'' &= L\cos\theta \\ y'' &= L\sin\theta \end{aligned}\right\} \cdots\cdots (2)$$

【００５５】即ち、魚眼レンズ画像ｉｍｇは、３次元極座標（ｒ，θ，φ）の点から、二次元の（ｘ″，ｙ″）への写像と考えることができる。距離（像高）Ｌは魚眼レンズの射影方式によって異なり、前述の正射影方式の場合は式（３－１）、等面積射影の場合は式（３－２）、等距離射影の場合は式（３－３）のように表わされる。なお、ｆはレンズの焦点距離である。

【００５６】

【数３】

$$L = f\sin\phi \quad \cdots\cdots (3\text{-}1)$$

$$L = 2f\sin\frac{\phi}{2} \quad \cdots\cdots (3\text{-}2)$$

$$L = f\phi \quad \cdots\cdots (3\text{-}3)$$

【００５７】図2の（ｂ）において、歪み補正して表示する画像フレームｆｒｍの方位角をθ、頂点角をφとすると、表示画像をパン／チルト操作させることは、この仮想の画像フレームｆｒｍを、３次元座標内で回転した場合に、そこに投影される映像を表示することに一致する。

【００５８】即ち、画像フレームｆｒｍ内のラスター上に並んだ各点の座標に対応する、魚眼レンズ画像ｉｍｇの点の座標を特定し、その座標の点の色情報信号を、表示フレームｆｒｍの座標の点の色情報信号に対応させることにより、魚眼レンズ画像ｉｍｇを元の画像に変換する補正処理を行うことができる。カメラが、直上または直下を向いている場合には、画像フレームｆｒｍのパンの操作は方位角θを所定量変化させ、又、チルトの操作は頂点角φを所定量変化させて、対応する魚眼レンズ画像ｉｍｇ内の２次元座標の色情報信号のマッピングを行えばよい。

【００５９】図3は、横方向に向けた魚眼レンズカメラの撮影画像の説明図である。同図は魚眼レンズカメラをｘ軸方向に向けた場合を示している。この場合魚眼レンズ画像ｉｍｇは垂直面に形成されることとなる。

【００６０】この場合でも前述したような歪み補正により、歪みのない画像を表示させることはできるが、そのまま、直上の映像として魚眼レンズ画像の変換を行うと、パン／チルトの操作を行ったとき、回転方向が実際の映像のパン／チルトの方向と違った方向に回転することになる。即ち、直上の映像の場合、ｚ軸との角度φを変化させてチルトの操作を行ったが、横方向に魚眼レンズカメラが向いている場合には角度φを変化させてもチルトの操作にはならない。

【００６１】そのため、先ず、歪み補正を行う前に、魚眼レンズカメラの向き、即ち、カメラ設置角について補正を行う。この補正処理は前記カメラ設置角補正部１－４１により行う。

【００６２】図4は横方向を向けたた魚眼レンズカメラ画像の補正の説明図である。図３に示したように魚眼レンズカメラが横軸のｘ軸の方向を向いている場合、座標系をｙ軸の回りに予め９０度回転させ、魚眼レンズ画像面ｉｍｇがｚ軸と垂直に交わる位置に回転移動させることにより、パン／チルトの操作に対して、前述した直上の画像の場合と同等の処理を行うことが可能になる。即ち、前記角度φを変化させることによりチルト操作を行うことができ、又、前記角度θを変化させることによりパン操作を行うことができる。

【００６３】図4に示した例は、魚眼レンズカメラが横方向を向いている場合であったが、魚眼レンズカメラを上、下、横、斜めの任意の方向に向いているとき、鉛直方向をｚ′軸とする座標系を（ｘ′，ｙ′，ｚ′）とし、画像フレームｆｒｍ上の点の座標を（ｘ′，ｙ′，ｚ′）で表し、この画像フレームｆｒｍ上の点（ｘ′，ｙ′，ｚ′）と魚眼レンズカメラの向き（ｚ軸方向）との角度をφ、画像フレームｆｒｍ上の点（ｘ′，ｙ′，ｚ′）とｘ軸との角度をθ、画像フレームｆｒｍ上の点（ｘ′，ｙ′，ｚ′）とｙ軸との角度をρとすると、式（４）の回転行列の式を用いて回転座標変換を行うことにより、パン／チルトの操作方向を実際の映像と一致させることができる。ここで、式（４）の回転行列の式の行列Ｒｘ，Ｒｚ，Ｒｙはそれぞれｘ軸、ｙ軸、ｚ軸の回りに回転を与える行列であり、行列Ｒｘはカメラアングルに対応した回転を与える。

【００６４】

【数４】

$$\left.\begin{aligned}
\begin{bmatrix} x \\ y \\ z \end{bmatrix} &= Rx \cdot Ry \cdot Rz \cdot \begin{bmatrix} x' \\ y' \\ z' \end{bmatrix} \\
Rx &= \begin{bmatrix} \cos\theta & -\sin\theta & 0 \\ \sin\theta & \cos\theta & 0 \\ 0 & 0 & 1 \end{bmatrix} \\
Ry &= \begin{bmatrix} \cos\phi & 0 & -\sin\phi \\ 0 & 1 & 0 \\ \sin\phi & 0 & \cos\phi \end{bmatrix} \\
Rz &= \begin{bmatrix} 1 & 0 & 0 \\ 0 & \cos\rho & -\sin\rho \\ 0 & \sin\rho & \cos\rho \end{bmatrix}
\end{aligned}\right\} \cdots (4)$$

【００６５】同一の方位角及びカメラアングル（頂点角）について、前記式（４）の回転行列の式を一度計算することにより、回転後の座標が（ｘ，ｙ，ｚ）として得られる。次にこの点の２次元座標上の魚眼レンズ画像の点（ｘ″，ｙ″）への写像を計算するにより、画像フ

レーム上の点と魚眼レンズ画像の点と対応させることができる。魚眼レンズカメラの設置角についての計算量の増加は、一度だけ回転行列を生成することによる増加であり僅かである。

【００６６】３次元座標の点（ｘ，ｙ，ｚ）から２次元座標上の魚眼レンズ画像の点Ｐ（ｘ″，ｙ″）への写像は、先ず、点（ｘ，ｙ，ｚ）を極座標表現の点（ｒ，θ，φ）に変換する。この変換は、式（５）の極座標変換の式により変換することができる。

【００６７】

【数５】

$$\left.\begin{aligned} r &= \sqrt{x^2+y^2+z^2} \\ \theta &= \tan^{-1}(x/y) = \cos^{-1}(x/\sqrt{x^2+y^2}) \\ \phi &= \cos^{-1}(z/r) = \tan^{-1}(\sqrt{x^2+y^2}/z) \end{aligned}\right\} \cdots (5)$$

【００６８】更に、等面積写像方式の魚眼レンズの場合は、式（３－２）の式で表されるため、この式を式（２）に代入することにより、式（６）の式が得られる。$x^2+y^2+z^2=x'^2+y'^2+z'^2=r^2$であること及び式（５）更に三角関数の基本式を利用して、式（６）の式は式（７）の式のように簡素化される。

【００６９】

【数６】

$$\left.\begin{aligned} x'' &= 2f\sin\frac{\phi}{2}\cos\theta \\ y'' &= 2f\sin\frac{\phi}{2}\cos\theta \end{aligned}\right\} \cdots\cdots (6)$$

【００７０】

【数７】

$$\left.\begin{aligned} u &= \frac{\sqrt{2}\,fx\sqrt{r-z}}{\sqrt{r}\sqrt{x^2+y^2}} = \frac{\sqrt{2}\,fx\sqrt{r-z}}{\sqrt{r}\sqrt{r^2-z^2}} = \frac{\sqrt{2}\,fx}{\sqrt{r}\,(r+z)} \\ v &= \frac{fy\sqrt{r-z}}{\sqrt{r}\sqrt{x^2+y^2}} = \frac{fy\sqrt{r-z}}{\sqrt{r}\sqrt{r^2-z^2}} = \frac{\sqrt{2}\,fy}{\sqrt{r}\,\sqrt{r}(r+z)} \end{aligned}\right\} \cdots (7)$$

【００７１】このようにして、魚眼レンズカメラ設置角の補正は、先ず、画像変形処理を行う前に、画像フレームｆｒｍの矩形領域の座標（ｘ′，ｙ′，ｚ′）を、回転座標変換により（ｘ，ｙ，ｚ）の座標に変換し、その後、該（ｘ，ｙ，ｚ）座標の点を、魚眼レンズ画像の座標上の点（ｘ″，ｙ″）へ変換する。なお、ｚ軸の成分はズーム率に相当するため、基本的には（ｘ，ｙ）から（ｘ″，ｙ″）への２次元２次元変換となる。式（７）の式に関する座標の変換式は、座標軸回転に伴う座標変換と魚眼レンズの特性に伴った写像変換とを一度に計算することにより、計算回数の削減が図られている。

【００７２】ここで、前記の演算により求めた魚眼レンズ画像の座標上の点（ｘ″，ｙ″）を（ｕ，ｖ）と記す。この座標点（ｕ，ｖ）を滑らかに補間するために、以下のような補間処理を行う。映像信号の３色の色情報信号成分をＹ，Ｕ，Ｖとし、点（ｕ，ｖ）のそれらの成分を、Ｙｕ，ｖ、Ｕｕ，ｖ、Ｖｕ，ｖとし、又、点（ｕ，ｖ）の座標成分ｕ，ｖの小数点を切り捨てて整数化した値をｕ０、ｖ０とし、座標（ｕ０，ｖ０）の点における色情報信号Ｙの値をＹｕ０ｖ０とする。同様に、色情報信号Ｕ，ＶについてもＵｕ０ｖ０，Ｖｕ０ｖ０により同様な内容を表す。更に、座標成分ｕ，ｖをそれぞれ小数点を切り上げした値をｕ１，ｖ１とし、それに対応した座標の色情報信号Ｙ，Ｕ，Ｖの値を、それぞれＹｕ１ｖ１，Ｕｕ１ｖ１，Ｖｕ１ｖ１と表す。そして、座標成分ｕ，ｖの小数部をそれぞれｄｕ，ｄｖとする。

【００７３】入力映像信号を式（８）の一次変換の式により補間してマッピングすることにより、滑らかな画像を表示させることができる。

【００７４】

【数８】

$$\left.\begin{aligned} Yu,v &= (1-du)(1-dv)\cdot Yu0v0 + du(1-dv)\cdot Yu0v1 \\ &\quad + (1-du)dy\cdot Yu0v1 + dudyYu1v1 \\ Uu,v &= (1-du)(1-dv)\cdot Uu0v0 + du(1-dv)\cdot Uu0v1 \\ &\quad + (1-du)dy\cdot Uu0v1 + dudyUu1v1 \\ Vu,v &= (1-du)(1-dv)\cdot Vu0v0 + du(1-dv)\cdot Vu0v1 \\ &\quad + (1-du)dy\cdot Vu0v1 + dudyVu1v1 \end{aligned}\right\} \cdots (8)$$

【００７５】次に、魚眼レンズカメラの撮像エリアから、魚眼レンズカメラのパラメータである画像中心位置（Ｘｂａｓｅ，Ｙｂａｓｅ）及び焦点距離に対応した値ｆを自動抽出する手法について説明する。前記のパラメ

ータは魚眼レンズカメラ画像の歪み補正において使用されるパラメータである。

【0076】図5は魚眼レンズカメラのパラメータ抽出の説明図である。同図において5－1は魚眼レンズカメラの撮像エリア、5－2は魚眼レンズ画像エリアである。円像魚眼レンズを用いたカメラの撮像エリア5－1内には、円形の魚眼レンズ画像エリア5－2が観測される。この魚眼レンズ画像エリア5－2はカメラ撮像エリア5－1内の所定の位置に観測され、又、魚眼レンズ画像エリア5－2の外周は光が到達しないため非常に輝度の低いエリアとなる。

【0077】そこで、カメラ撮像エリア5－1の全体について、水平及び垂直のそれぞれの方向に関してヒストグラムを抽出し、魚眼レンズ画像エリアの位置及びその半径を測定することができる。

【0078】水平方向のヒストグラムHh（n）と垂直方向のヒストグラムHv（n）とに関して適度な閾値Th，Tvを設定し、撮像エリア画面の両端からヒストグラムを測定して最初に閾値Tv，Thを越す点を探索する。

【0079】その点を水平、垂直それぞれに対して2点ずつ抽出し、水平ヒストグラムから魚眼レンズ画像エリアの左端Xleft及び右端Xrightの点を検出することができる。又、垂直ヒストグラムから魚眼レンズ画像エリアの上端Yup及び下端Ydownの点を検出することができる。

【0080】上記魚眼レンズ画像エリアの左端Xleft、右端Xright、Yup及び下端Ydownのそれぞれの位置から、水平方向の半径Rhと垂直方向の半径Rvとを式（9）により抽出することができる。又、画像中心位置（Xbase，Ybase）は式（10）により抽出することができる。

【0081】

【数9】

$$\left.\begin{aligned} Rh &= (Xright - Xleft)/2 \\ Rv &= (Ydown - Yup)/2 \end{aligned}\right\} \cdots\cdots (9)$$

【0082】

【数10】

$$\left.\begin{aligned} Xbase &= (Xright + Xleft)/2 \\ Ybase &= (Ydown + Yup)/2 \end{aligned}\right\} \cdots\cdots (10)$$

【0083】魚眼レンズ画像エリア5－2は基本的には円形であり、水平方向の半径Rhと垂直方向の半径Rvとは等しく、Rh＝Rvとなるが、CCD等の撮像素子の縦横方向のアスペクト比の違いにより、水平方向の半径Rhと垂直方向の半径Rvとに相違が生じる場合がある。

【0084】魚眼レンズ画像エリア5－2の半径Rは、本来、魚眼レンズの焦点距離ｆによって定まる値で、例えば、正射影方式の魚眼レンズでは式（11－1）で表され、等面積射影方式の魚眼レンズでは式（11－2）で表される。

【0085】

【数11】

$$R = f \quad \cdots\cdots (11\text{-}1)$$

$$R = \sqrt{2}\,f \quad \cdots\cdots (11\text{-}2)$$

【0086】従って、前述の魚眼レンズ画像の座標上の点（x″，y″）を求める式（6）の式の計算において、水平方向の半径Rhと垂直方向の半径Rvとに相違が生じる場合、焦点距離ｆの値として同一の値を使用することなく、方向毎に水平方向の半径Rh又は垂直方向の半径Rvの値を、式（11－1）又は式（11－2）のRの値に代入することによりｆの値を修正し、アスペクト比の違いを考慮した魚眼レンズの歪み補正を行うことができる。

【0087】図6は本発明の第1の実施の形態の移動像検出装置の構成を示す図である。同図において、6－1は魚眼レンズカメラ、6－2，6－3はフレームバッファ、6－4，6－5はフレーム間差分計算部、6－6は領域重みテーブル、6－7は領域抽出部である。

【0088】魚眼レンズカメラ6－1により撮影した画像信号を第1のフレームバッファ6－2に格納し、第1のフレームバッファ6－2に格納した画像信号を第2のフレームバッファ6－3に格納する。第2のフレームバッファ6－3には1フレーム前の画像信号が格納される。

【0089】そして、第1のフレームバッファ6－2から出力される画像信号と第2のフレームバッファ6－3から出力される画像信号とにより、そのフレーム間差分を第1のフレーム間差分計算部6－4により計算し、移動像に対して大きな値となるフレーム間差分信号を第2のフレーム間差分計算部6－5に出力する。

【0090】第2のフレーム間差分計算部6－5は、第1のフレーム間差分計算部6－4から出力されるフレーム間差分信号と、領域重みテーブル6－6から出力される領域に対応した値とにより、フレーム間差分信号に領域に応じた重み付けを行い、その信号を領域抽出部6－7に出力する。

【0091】領域抽出部6－7は、領域に応じた重み付けを持つフレーム間差分信号により、移動像の検出を行って検出フラグ信号を出力するとともにその検出領域を抽出し、領域情報を出力する。

【0092】図7は本発明の第2の実施の形態の移動像検出装置の構成を示す図である。同図において、7－1は魚眼レンズカメラ、7－2，7－3はフレームバッファ、7－4はフレーム間差分計算部、7－5はフレーム

内差分計算部、７－６は動輪郭抽出部、７－７は領域重みテーブル、７－８は領域抽出判定部、７－９は領域抽出部である。

【００９３】魚眼レンズカメラ７－１により撮影した画像信号を第１のフレームバッファ７－２に格納し、第１のフレームバッファ７－２に格納した画像信号を第２のフレームバッファ７－３に格納する。第２のフレームバッファ７－３には１フレーム前の画像信号が格納される。

【００９４】そして、第１のフレームバッファ７－２から出力される画像信号と第２のフレームバッファ７－３から出力される画像信号とにより、そのフレーム間差分をフレーム間差分計算部７－４により計算し、移動像に対して大きな値となるフレーム間差分信号を動輪郭抽出部７－６に出力する。

【００９５】フレーム内差分計算部７－５は、第１のフレームバッファ７－２から出力される画像信号のフレーム内の差分を計算し、像の輪郭部で大きな値となるフレーム内差分信号を動輪郭抽出部７－６に出力する。

【００９６】動輪郭抽出部７－６は、フレーム間差分計算部７－４からのフレーム間差分信号と、フレーム内差分計算部７－５からのフレーム内差分信号とを線形結合させ、輪郭部が強調された移動像の信号を生成し、その信号を領域抽出判定部７－８に出力する。

【００９７】領域抽出判定部７－８は、動輪郭抽出部７－６から出力される輪郭部が強調された移動像の信号と、領域重みテーブル７－７から出力される領域に対応した値とにより、移動像の信号に領域に応じた重み付けを行い、その信号を領域抽出部７－９に出力する。

【００９８】領域抽出部７－９は、領域に応じた重み付けを持つ移動像の信号により、移動像の検出を行って検出フラグ信号を出力するとともにその検出領域を抽出し、領域情報を出力する。

【００９９】図６及び図７に示した本発明の実施の形態の移動像検出装置は、移動像の領域抽出において領域に対応して映像信号に重み付けを行い、魚眼レンズによる画像の歪みによる検出パラメータ信号への影響を低減している。

【０１００】即ち、通常、ｎフレームの映像信号P_n（ｘ，ｙ）とｎ－１フレームの映像信号P_{n-1}（ｘ，ｙ）とのフレーム間差分D_n（ｘ，ｙ）を計算する場合に、式（１２）により計算を行うが、本発明は、魚眼レンズ画像の領域に対応した特徴抽出の重み係数Ｗ（ｘ，ｙ）を格納した領域重みテーブル６－６，７－７を備え、この重み係数Ｗ（ｘ，ｙ）を前記フレーム間差分D_n（ｘ，ｙ）に乗じた値G_n（ｘ，ｙ）を用いて移動像の抽出処理を行う。

$$D_n(x, y) = P_n(x, y) - P_{n-1}(x, y) \quad \cdots (12)$$

式（１３）により、この特徴量D_n（ｘ，ｙ）と魚眼レンズ画像の領域に応じた重み係数Ｗ（ｘ，ｙ）との積G_n（ｘ，ｙ）を移動像抽出のための特徴量として用いる。

【０１０１】即ち、図６に示した第１のフレーム間差分計算部６－４から出力されるフレーム間差分信号、又は図７に示した動輪郭抽出部７－６から出力されるフレーム間差分及びフレーム内差分を線形結合させた信号を、移動像抽出のための特徴量D_n（ｘ，ｙ）をとすると、

$$G_n(x, y) = W(x, y) \cdot D_n(x, y) \quad \cdots (13)$$

【０１０２】このように魚眼レンズ画像の領域に応じて重み付けられた特徴量Ｇｎ（ｘ，ｙ）を用いて抽出を行う処理により、魚眼レンズ画像エリア内の領域毎に対応した等価的なマスク及び強調操作を行うことができる。

【０１０３】図８は魚眼レンズ画像の領域に応じた重み係数Ｗ（ｘ，ｙ）の説明図である。同図は魚眼レンズ画像の領域内を３つの領域８－１，８－２，８－３に分割し、を領域８－１には重み係数０、領域８－２には重み係数１、領域８－３には重み係数２を割り当てた例を示している。

【０１０４】魚眼レンズ画像の周辺部分では中心部分に比べて同一面積の領域が小さな領域に表示される。そのため周辺部における移動像検出の精度が低下するが、周辺部の重み係数Ｗ（ｘ，ｙ）を大きな値としておくことにより、周辺部における精度低下を補償することができる。更に、通常、周辺部分に人物像が存在する確率が高いので、周辺部分を大きな値をとし、中心部分で０に近い値としておく。

【０１０５】又、魚眼レンズカメラでは撮像エリアが広大であるため、照明等が直接撮像エリア内に入ることが多い。このような場合でも極端な輝度の違いを、等価的な領域マスクにより補償して移動像の誤検出を低減させることができる。

【０１０６】領域域抽出部６－７，７－９は、領域対応の重み付けがされた特徴量を、予め設定された閾値（Ｔｈｍ）と比較することにより、人物像等の像検出判定処理を行う。この像検出判定処理を伴う領域抽出処理は魚眼レンズ画像の全画面について行う。

【０１０７】図９は領域抽出された人物等の像の例を示す図である。図の（ａ）は魚眼レンズ画像エリアを示し、魚眼レンズカメラが机上等に上を向けて置かれ、そのカメラの周りに４人の人物が着席している場合の魚眼レンズ画像の例を示している。９－１乃至９－４は人物像検出エリア（Ａ）乃至人物像検出エリア（Ｄ）である。図の（ｂ）は魚眼レンズ画像の人物像の形状を示し、人物を下側から魚眼レンズで撮影した場合には体底部が長く、頭長部の短い略台形状のような形状となり、人物像を該形状に正規化することができる。

【０１０８】図の（ａ）に示すような魚眼レンズ画像エリアのイメージ上をラスタースキャンし、人物像としての特徴量の大きい点を検出すると、その点から下方へ略台形状のような形の像の探索を行い、その領域を切り出す。

【０１０９】切り出された領域に対して大きさ及び形状についての照合を行い、人物像の領域であるかどうかの判定を行う。同様の処理を複数の領域に対して同時に処理し、複数の人物像が検出されたときは複数の人物像の同時切り出しを行う。

【０１１０】又、個々の切り出された領域について、図の（ｂ）に示すような人物の頭頂部、体底部及び体高のそれぞれのパラメータ及びその内側の色データを左右及び高さ方向にサンプリングすることにより、画像毎の人物像識別のためのデータベースとすることができる。

【０１１１】抽出された特徴量から人物像等の領域を抽出する処理に関しては、基本的に通常のカメラ映像での領域抽出のためのアルゴリズムを使用することができるが、魚眼レンズ画像が円形に歪曲して配置されているため、座標変換を施す必要がある。

【０１１２】座標変換の方法として以下の二つの方式がある。第一の方式は、魚眼レンズ画像を、３６０度のパノラマ映像として座標変換された映像へと写像変換を行う方式である。この方式は円形の魚眼レンズ撮像エリアを矩形エリアへ変換する。

【０１１３】第二の方式としては、領域抽出を通常のラスタースキャンとして走査し、走査時の座標系のみを直交座標（ｘ，ｙ）から極座標（ｒ，θ）へと変換する方式である。即ち、ｘ＝ｒｃｏｓθ，ｙ＝ｒｓｉｎθとして領域抽出の処理を行う。

【０１１４】第一の方式は、パノラマ映像に展開するための大きなメモリが必要になる欠点があるが、変換後は通常の画像に対する領域抽出処理をそのまま適用することができる。第二の方式は領域抽出処理時に常に座標変換を行いながら処理しなければならないが、使用するメモリ量は原画としての魚眼レンズ画像を与えるメモリ量のみでよくコンパクトなシステムを構築することができる。

【０１１５】そして、特徴量を抽出し、上下関係等、既知の映像の相互関係を利用して領域の統合処理を行う。例えば、真上を向いた魚眼レンズカメラの場合は、魚眼レンズ画像の中心を上、周辺を下とした映像の位置関係を利用して領域を統合し、その領域が背景像から人物像に変化した領域を抽出する。

【０１１６】人物の侵入等の移動像の追尾処理に関しては、切り出された略台形状の人物領域内を上下左右に前もって決められた分割数で等分する格子点を算出し、その格子点での色情報信号を人物像の特徴量として保存する。そして、この人物像の特徴量の登録処理と人物像の切り出し処理とを任意の時間間隔で繰り返し行い、複数の人物像が魚眼レンズカメラ撮像エリア内に存在する場合でも、各人物像を個別に追尾することができる。

【０１１７】図１０は本発明の実施の形態の人物像抽出位置決定の処理のフローチャートである。先ず、魚眼レンズ画像内の人物像等の切り出し処理のコマンドを与え（１０－１）、フレームについてのループ処理（１０－２）により、フレーム間差分による又はフレーム間差分とフレーム内差分とによる人物像等の特徴量を抽出し（１０－３）、魚眼レンズ画像内の領域に対応した重み付け処理を行い（１０－４）、魚眼レンズ画面内のラスターループ処理を行い（１０－５）、特徴点を検出し（１０－６）、略台形上のエリアについて魚眼レンズ画像の座標変換を行って特徴点を抽出の処理を行い（１０－７）、特徴点があるかどうかを判定し（１０－８）、特徴点がある場合には、抽出点を消去し（１０－９）、（ｘ，ｙ）座標の領域の最大値と最小値とを記憶し（１０－１０）、最終ラインかどうかを判定し（１０－１１）、最終ラインであれば終了する（１０－１２）。

【０１１８】前記特徴点があるかどうかの判定（１０－８）において、特徴点がない場合、複数ライン連続して特徴点がないかどうかを判定し（１０－１３）、連続して特徴点がない場合は領域数をカウントして人物領域を記憶し（１０－１４）、前述の最終ラインかどうかの判定し（１０－１１）に移る。

【０１１９】前記複数ライン連続して特徴点がないかどうかの判定（１０－１３）において、複数ライン連続していなければ前記特徴点を検出する処理（１０－６）に戻る。又、前記最終ラインかどうかの判定（１０－１１）において、最終ラインでないときは前記特徴点を検出する処理（１０－６）に戻る。

【０１２０】人物像の存在領域を抽出すると、その領域から魚眼レンズ画像を補正して表示するためのパラメータを求めることができる。図１１は本発明の実施の形態の領域切り出し及び表示画面作成を行う構成の説明図である。同図において、１１－１は領域抽出部、１１－２は領域切り出し部、１１－３は魚眼レンズ画像パラメータ決定部、１１－４は表示画面作成部である。

【０１２１】領域抽出部１１－１は、前述の図６及び図７に示した領域抽出部６－７，７－９と同一のものであり、特徴量により人物像等を検出し、その領域を抽出すると、検出フラグ及び領域情報の信号を出力する。検出フラグの信号は警報又は通知用の信号として使用することができる。領域情報の信号は領域切り出し部１１－２に出力される。

【０１２２】領域切り出し部１１－２は、領域情報の信号に基づいて領域を切り出し、魚眼レンズ画像パラメータ決定部１１－３は、切り出された全領域について魚眼レンズ画像を補正して表示するためのパラメータを決定し、そのパラメータの信号を画面作成部１１－４に送出する。画面作成部１１－４は、パラメータの信号に基づ

いて表示画面を生成し、映像信号を出力する。

【０１２３】ここで、簡単化のために、真上を向いたカメラアングルの場合の魚眼レンズ画像の前記パラメータの決定について説明する。魚眼レンズ画像の補正のためのパラメータとしては、画像フレームの方位角θ、頂点角φ及び拡大率ｍが必要である。

【０１２４】魚眼レンズ画像の領域から、例えば、図９の（ａ）の人物像検出エリア（Ｂ）９－２を抽出して表示するとする。この場合、人物像検出エリア（Ｂ）９－２の中心位置に関する角度α及び魚眼レンズ画像の中心Ｏから人物像検出エリア（Ｂ）９－２を挟む角度（立体角）βを計算する。又、魚眼レンズ画像の中心Ｏから領域最上部までの距離Ｌを計算する。

【０１２５】前記角度α及び距離Ｌにより、人物像検出エリア（Ｂ）９－２を表示する画像フレームの方位角θと頂点角φの値を求めることができる。即ち、方位角θは前記角度αに等しく、θ＝α　である。又、頂点角φは魚眼レンズ画像の半径Ｒと前記距離Ｌとの比から式（３－１）乃至式（３－３）を用いて求めることができる。又、ズーム率であるｍについては、領域の左端及び右端と魚眼レンズ画像の中心Ｏとの立体角βにより求めることができる。これらのパラメータを元に、個々の人物の表示領域を切り出し、魚眼レンズ画像の歪曲を補正してモニタテレビ等に映像信号を送出する。

【０１２６】図１２は１台の魚眼レンズカメラで撮影した画像を合成した映像を示す図である。前述したように魚眼レンズ画像から人物像をその特徴量により抽出し、抽出した画像に歪み補正の処理を行い、１台のモニタテレビ画面を４分割して前記抽出した人物像を表示させた様子を模式的に示している。

【０１２７】

【発明の効果】以上説明したように、本発明によれば、約１８０度の広い画角を持つ魚眼レンズカメラにより映像を取り込むので、１台のカメラにより広範囲のエリアを監視することができ、設置カメラ台数を削減することができるとともに、その画像を精度よく高速に補正して表示することができる。

【０１２８】又、魚眼レンズカメラの設置角を補正する座標変換と、魚眼レンズ画像の歪みを補正する座標変換とを組み合わせて演算することにより、設置角度によらず画像補正の演算処理を高速に行うことができる。又、魚眼レンズ画像の歪み補正のためのパラメータを、撮像された魚眼レンズ画像自体から抽出して魚眼レンズ画像の歪み補正を行うことにより、設置時の調整や経年変化に対して、安定した歪み補正を行うことができる。

【０１２９】魚眼レンズ画像の中心部分と周辺部分との歪みの大きさに応じて異なる重み係数を乗じた特徴量をもとに領域抽出を行うことにより、歪みの大きい周辺部分での人物像等の検出を安定して行うことができ、更に、重み係数として、更に魚眼レンズ画像の映像内の領域に対応して異なる値を与えて非抽出領域をマスクすることにより、人物像等の抽出処理における不安定要素を予め取り除くことができる。

【０１３０】又、魚眼レンズカメラにより取り込んだ広範囲の画像の中から、任意の部分を切り出してモニタテレビ画面に表示するなど映像作成の自由度が大きく、遠隔監視システムやテレビ会議システムのカメラに適用することにより、利便性の向上を図ることができる。

【０１３１】更に、魚眼レンズカメラで映し取った映像の中から、人物の侵入等の動きを伴う像を検出し、その像のモニタ表示領域（切り出し領域）を自動的に決定して滑らかな動きで追尾する電子追尾型の遠隔監視システム又はテレビ会議システムを構成することができる。

【図面の簡単な説明】

【図１】本発明の実施の形態の魚眼レンズカメラ装置の構成を示す図である。

【図２】本発明の実施の形態の魚眼レンズカメラで撮影される映像の説明図である。

【図３】横方向に向けた魚眼レンズカメラの撮影画像の説明図である。

【図４】横方向を向けた魚眼レンズカメラ画像の補正の説明図である。

【図５】魚眼レンズカメラのパラメータ抽出の説明図である。

【図６】本発明の第１の実施の形態の移動像検出装置の構成を示す図である。

【図７】本発明の第２の実施の形態の移動像検出装置の構成を示す図である。

【図８】魚眼レンズ画像の領域に応じた重み係数Ｗ（ｘ，ｙ）の説明図である。

【図９】領域抽出された人物等の像の例を示す図である。

【図１０】本発明の実施の形態の人物像抽出位置決定の処理のフローチャートである。

【図１１】本発明の実施の形態の領域切り出し及び表示画面作成を行う構成の説明図である。

【図１２】１台の魚眼レンズカメラで撮影した画像を合成した映像を示す図である。

【図１３】従来の魚眼レンズカメラ装置の構成及びそれを用いた遠隔監視システム及びテレビ会議システムを示す図である。

【図１４】従来の魚眼レンズカメラ画像の歪み補正の説明図である。

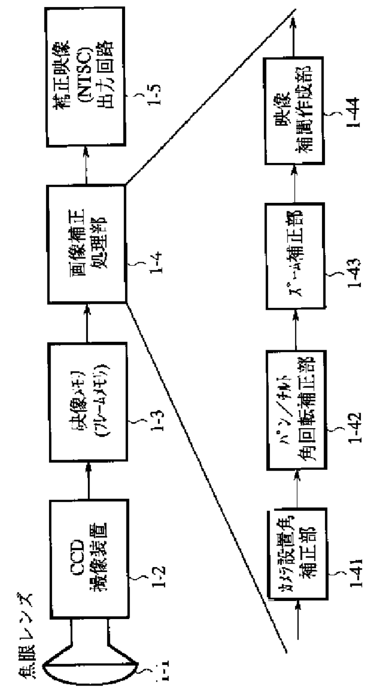
【符号の説明】

１－１　魚眼レンズ
１－２　ＣＣＤ撮像装置
１－３　映像メモリ（フレームメモリ）
１－４　画像補正処理部
１－４１　カメラ設置角補正部
１－４２　パン／チルト角回転補正部

１－４３　ズーム補正部
１－４４　映像補間作成部
１－５　補正映像（ＮＴＳＣ）出力回路

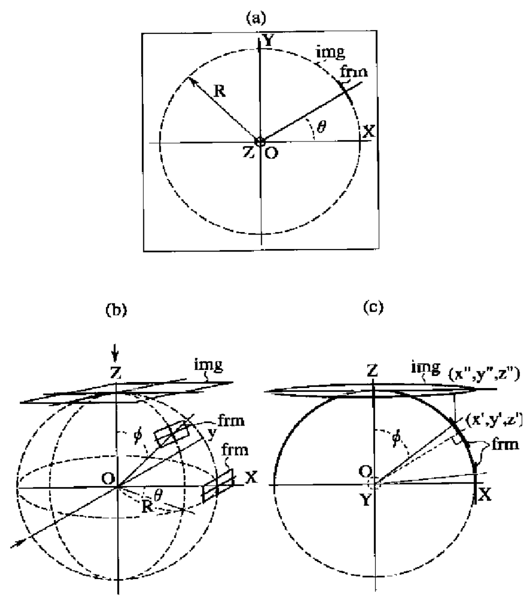
【図１】

本発明の実施の形態の
魚眼レンズカメラ装置の構成を示す図



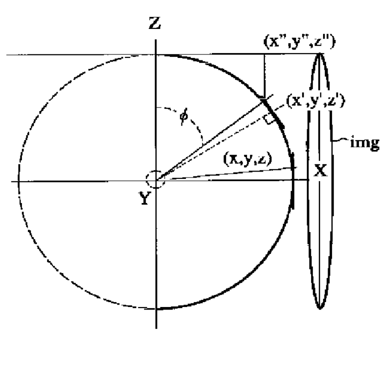
【図２】

本発明の実施の形態の
魚眼レンズカメラで撮影される映像の説明図



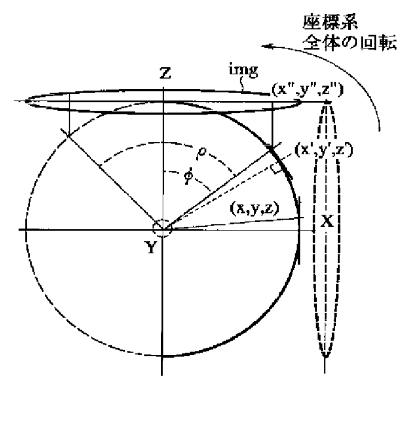
【図３】

横方向に向けた魚眼レンズカメラの撮影画像の説明図



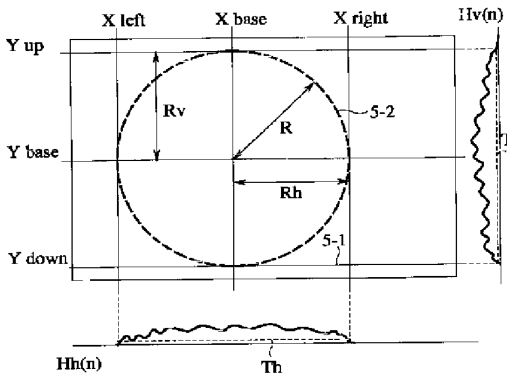
【図４】

横方向を向けた魚眼レンズカメラ画像の補正の説明図



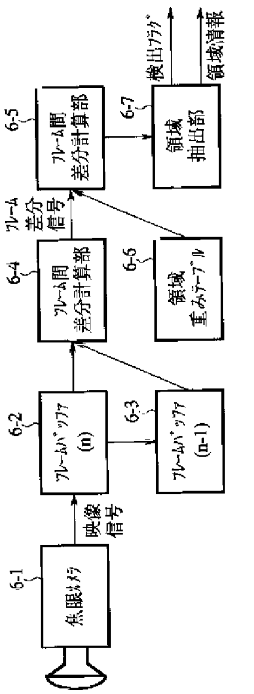
【図5】

魚眼レンズカメラのパラメータ抽出の説明図



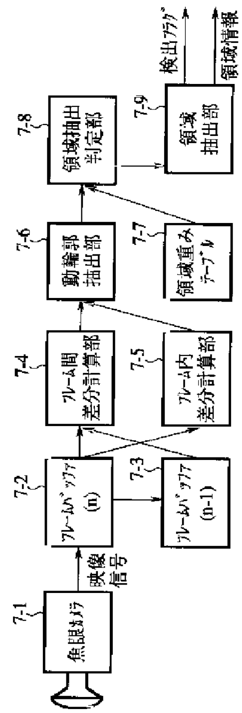
【図6】

本発明の第1の実施の形態の
移動像検出装置の構成を示す図



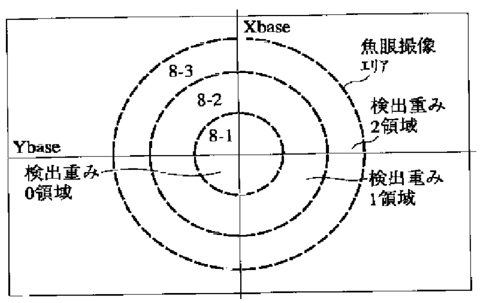
【図7】

本発明の第2の実施の形態の
移動像検出装置の構成を示す図



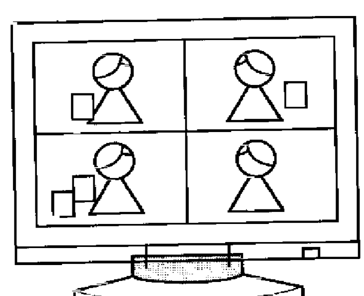
【図8】

魚眼レンズ画像の
領域に応じた重み係数W(x,y)の説明図



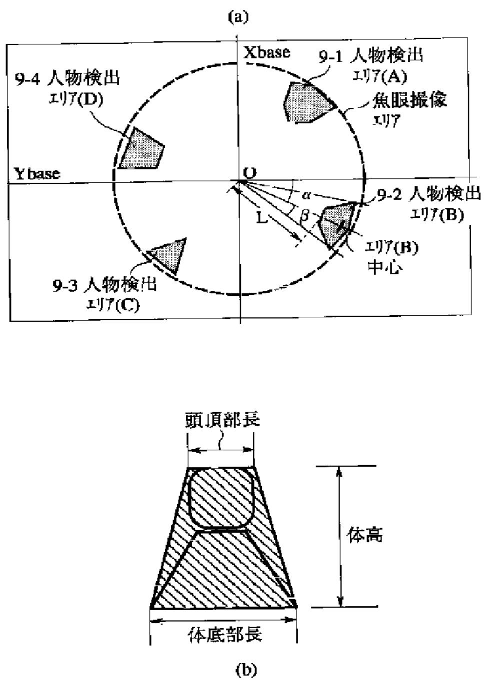
【図12】

1台の魚眼レンズカメラで撮影した画像を
合成した映像を示す図



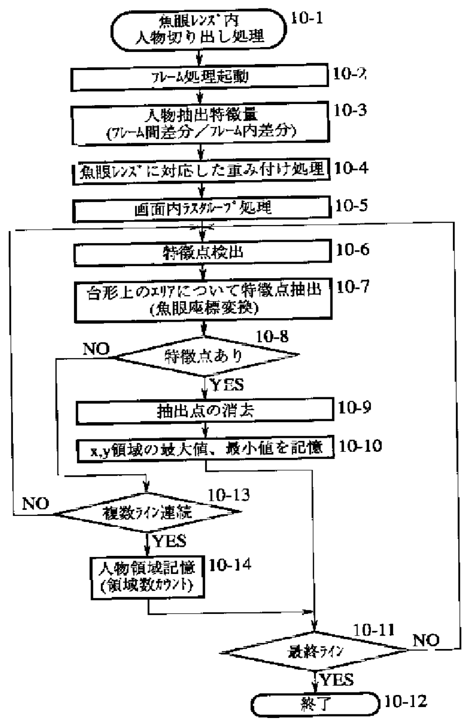
【図９】

領域抽出された人物等の像の例を示す図



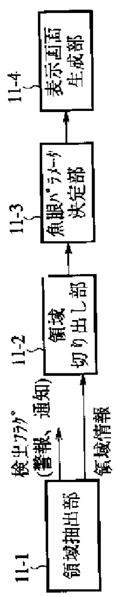
【図１０】

本発明の実施の形態の人物像抽出位置決定の処理のフローチャート



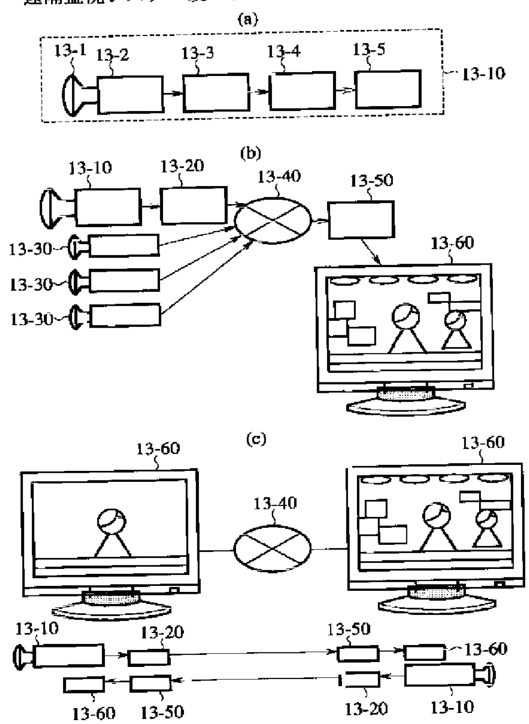
【図11】

本発明の実施の形態の
領域切り出し及び表示画面作成を行う構成の説明図



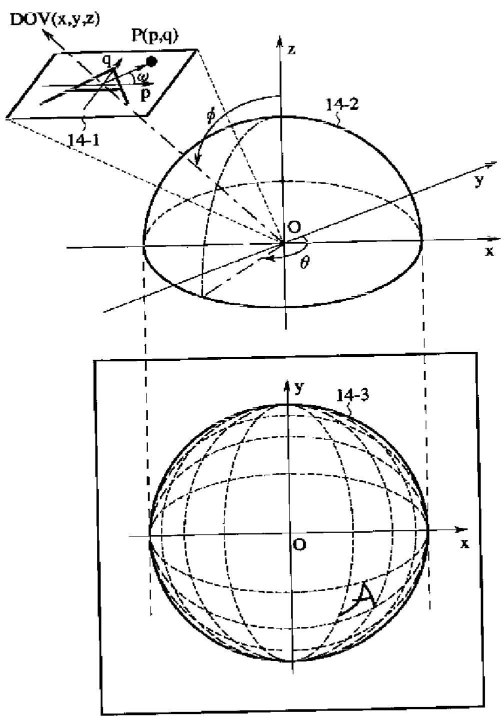
【図13】

従来の魚眼レンズカメラ装置の構成及びそれを用いた
遠隔監視システム及びテレビ会議システムを示す図



【図１４】

従来の魚眼レンズカメラ画像の歪み補正の説明図



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(51)Int.Cl.⁶	識別記号	ＦＩ	
		ＨＯ４Ｎ　5/781	５２０Ａ

EXHIBIT 8

US006031670A

United States Patent [19]

Inoue

[11] **Patent Number: 6,031,670**

[45] **Date of Patent: *Feb. 29, 2000**

[54] **WIDE-ANGLE LENS**

[75] Inventor: **Toshiyuki Inoue**, Nagano, Japan

[73] Assignee: **Sankyo Seiki Mfg. Co., Ltd.**, Nagano-ken, Japan

[*] Notice: This patent issued on a continued prosecution application filed under 37 CFR 1.53(d), and is subject to the twenty year patent term provisions of 35 U.S.C. 154(a)(2).

This patent is subject to a terminal disclaimer.

[21] Appl. No.: **08/757,192**

[22] Filed: **Nov. 27, 1996**

Related U.S. Application Data

[63] Continuation-in-part of application No. 08/590,725, Jan. 24, 1996, abandoned, which is a continuation of application No. 08/251,623, May 31, 1994, abandoned, which is a continuation of application No. 07/738,854, Jul. 31, 1994, abandoned.

[30] **Foreign Application Priority Data**

Aug. 28, 1990 [JP] Japan 2-225975

[51] **Int. Cl.**^{7} **G02B 13/18**

[52] **U.S. Cl.** **359/717**; 359/739; 359/793

[58] **Field of Search** 359/642–648, 359/664, 670, 708, 713–717, 744–753, 793

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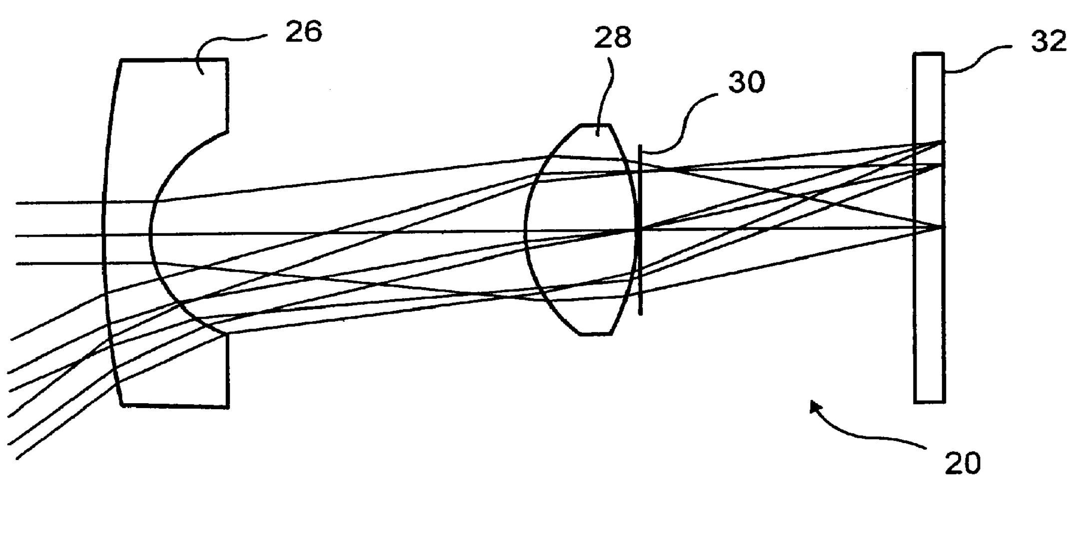
Primary Examiner—Thong Nguyen

Attorney, Agent, or Firm—McAulay Nissen Goldberg Kiel & Hand, LLP

[57] **ABSTRACT**

The present invention is directed toward a wide-angle lens. Because of a small quantity (two) of lens elements, the wide-angle lens facilitates size and weight reduction and permits low-cost manufacture. The lens is made from plastic, which permits further cost reduction. The lens is particularly useful when employed in CCD cameras.

15 Claims, 7 Drawing Sheets



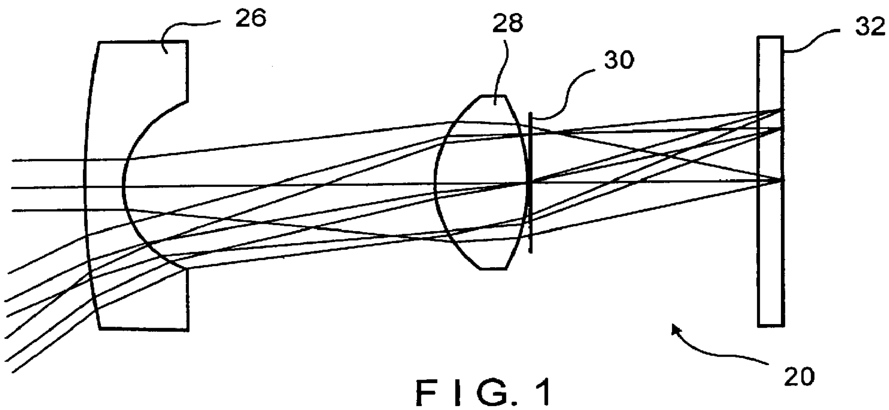


FIG. 1

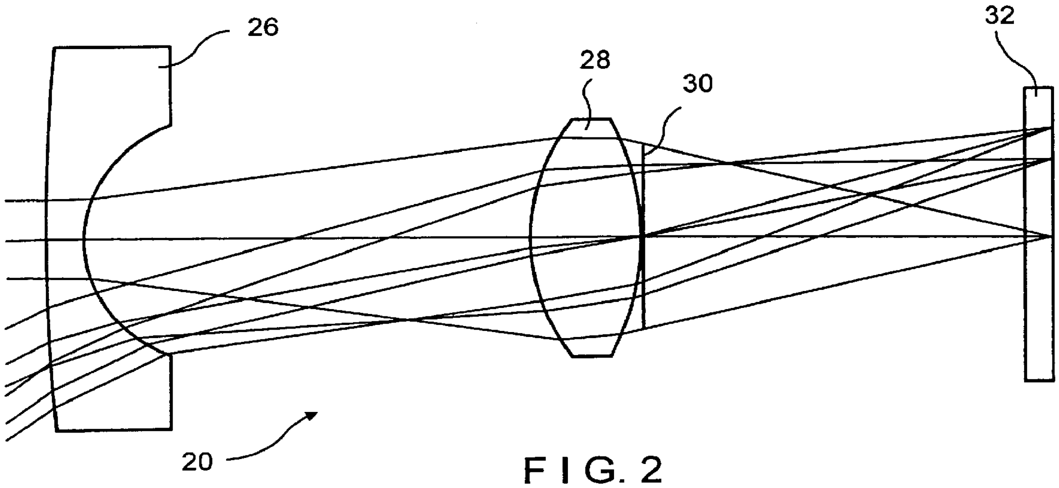


FIG. 2

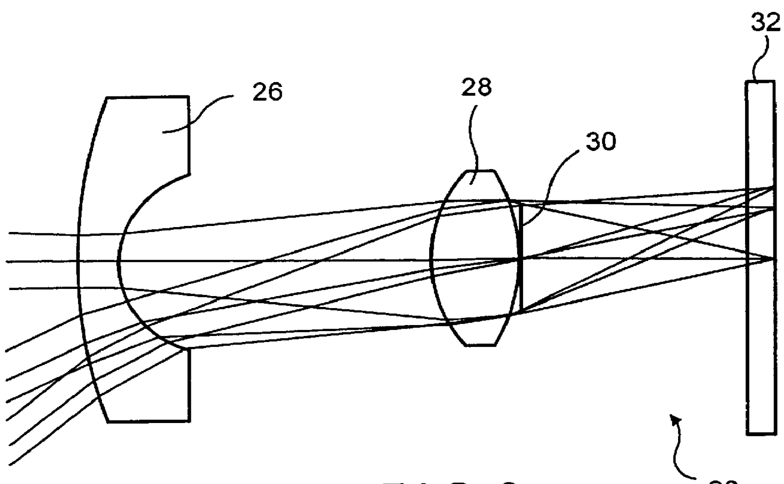
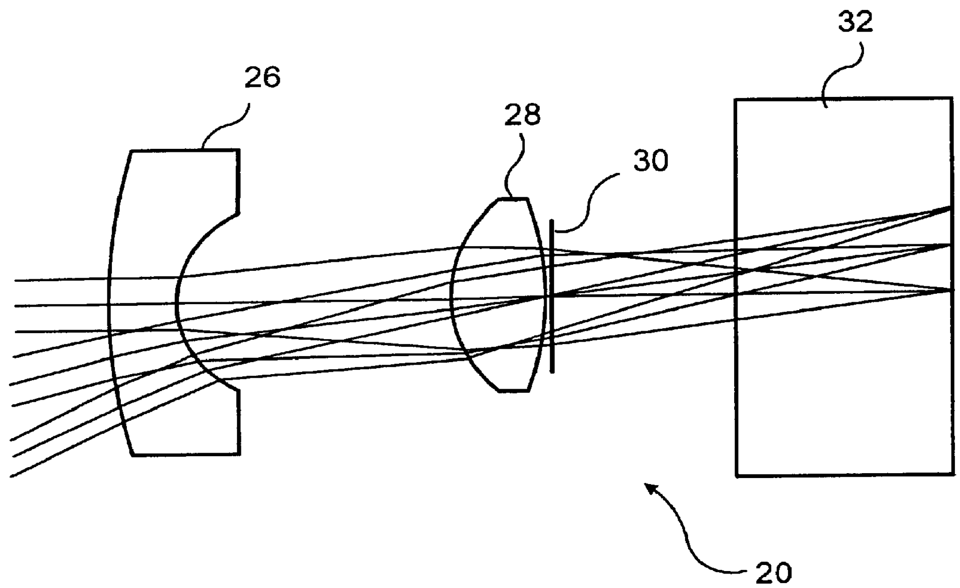


FIG. 3



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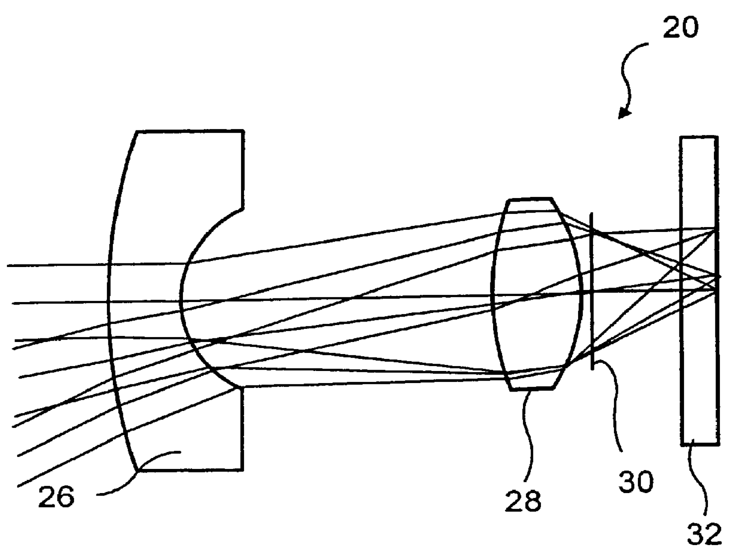
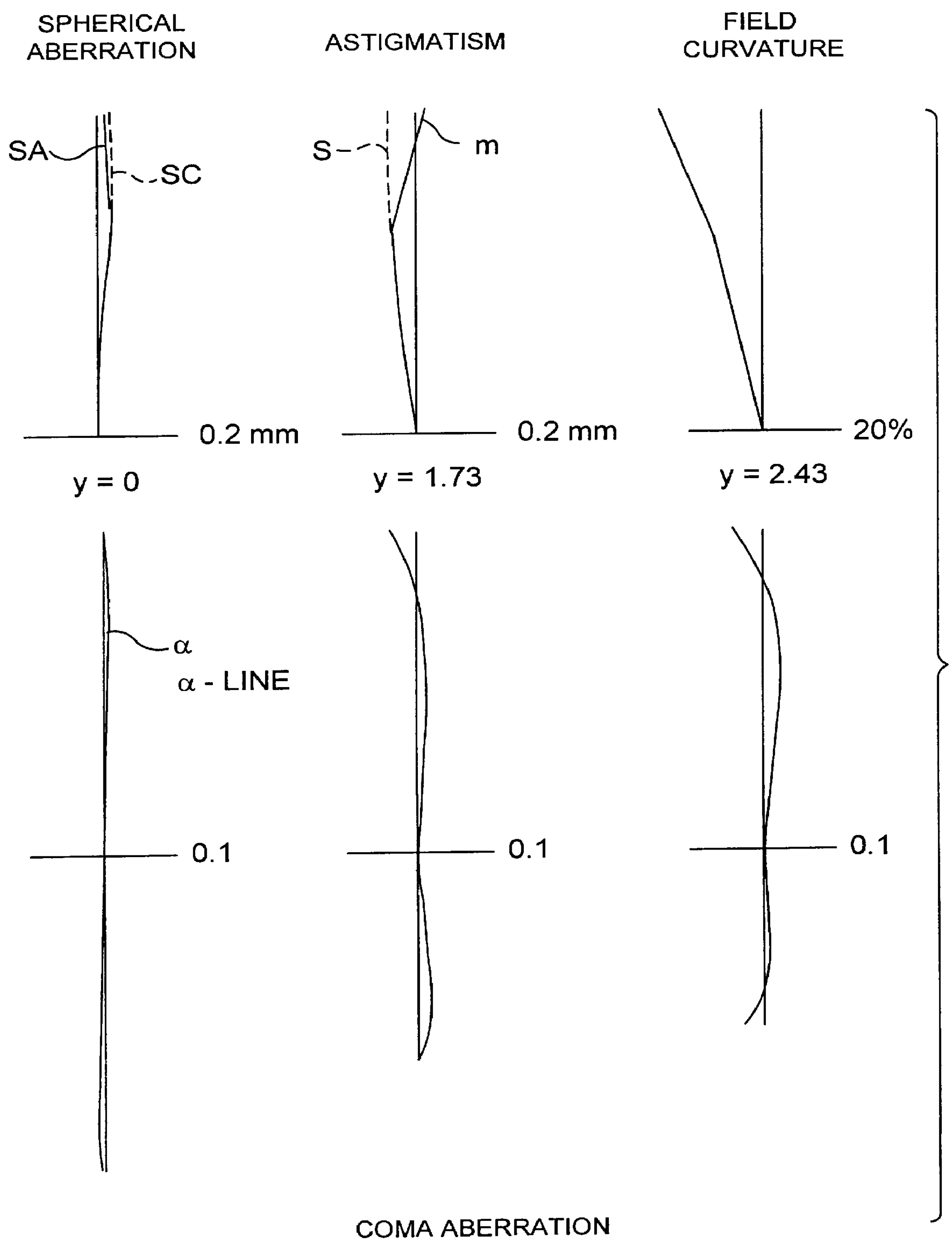
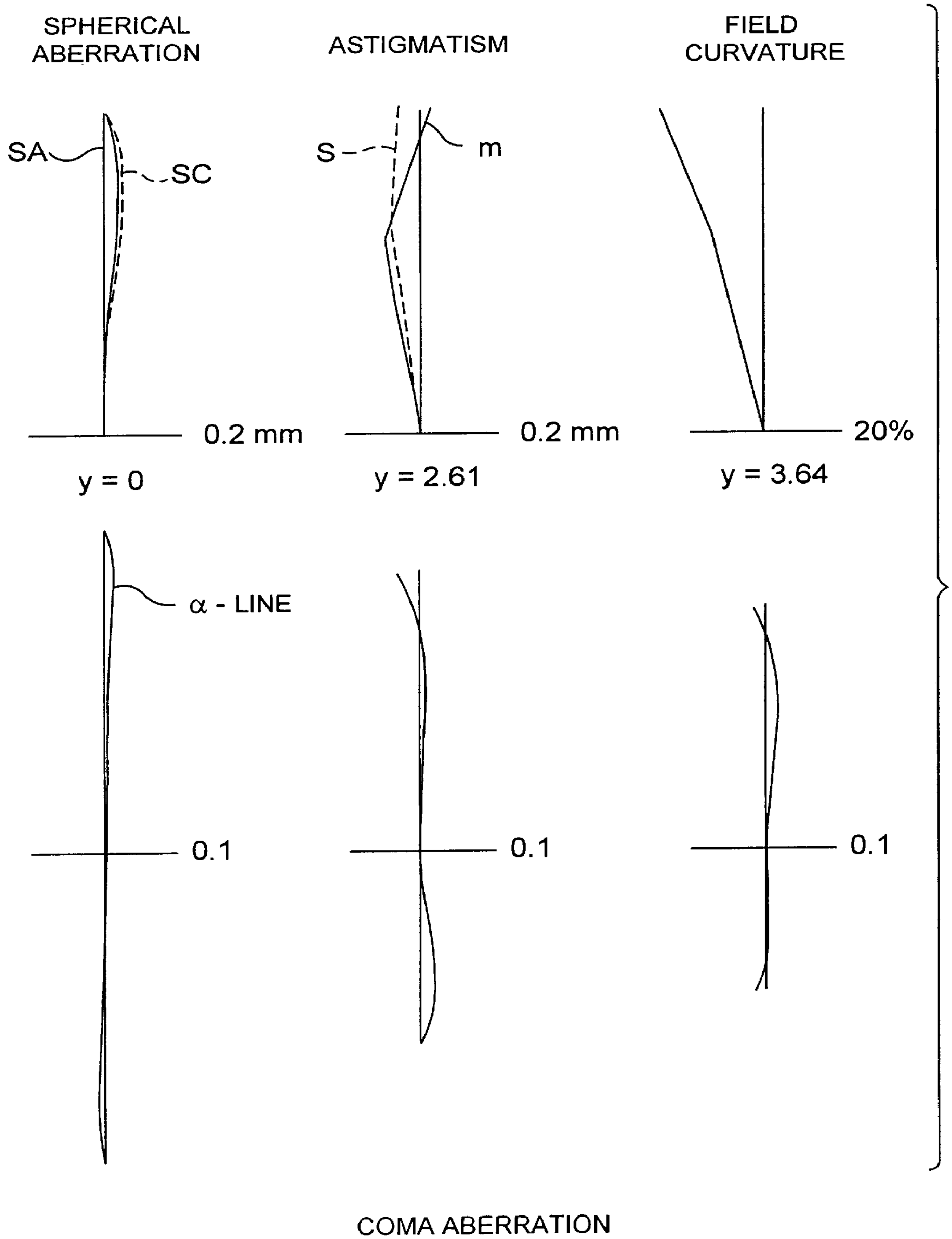


F I G. 5


SPHERICAL ABERRATION
ASTIGMATISM
FIELD CURVATURE
SA
SC
S
m
0.2 mm
0.2 mm
20%
y = 0
y = 1.73
y = 2.43
α
α - LINE
0.1
0.1
0.1
COMA ABERRATION

F I G. 6


SPHERICAL ABERRATION
ASTIGMATISM
FIELD CURVATURE
SA
SC
S
m
0.2 mm
0.2 mm
20%
y = 0
y = 2.61
y = 3.64
α - LINE
0.1
0.1
0.1
COMA ABERRATION

F I G. 7

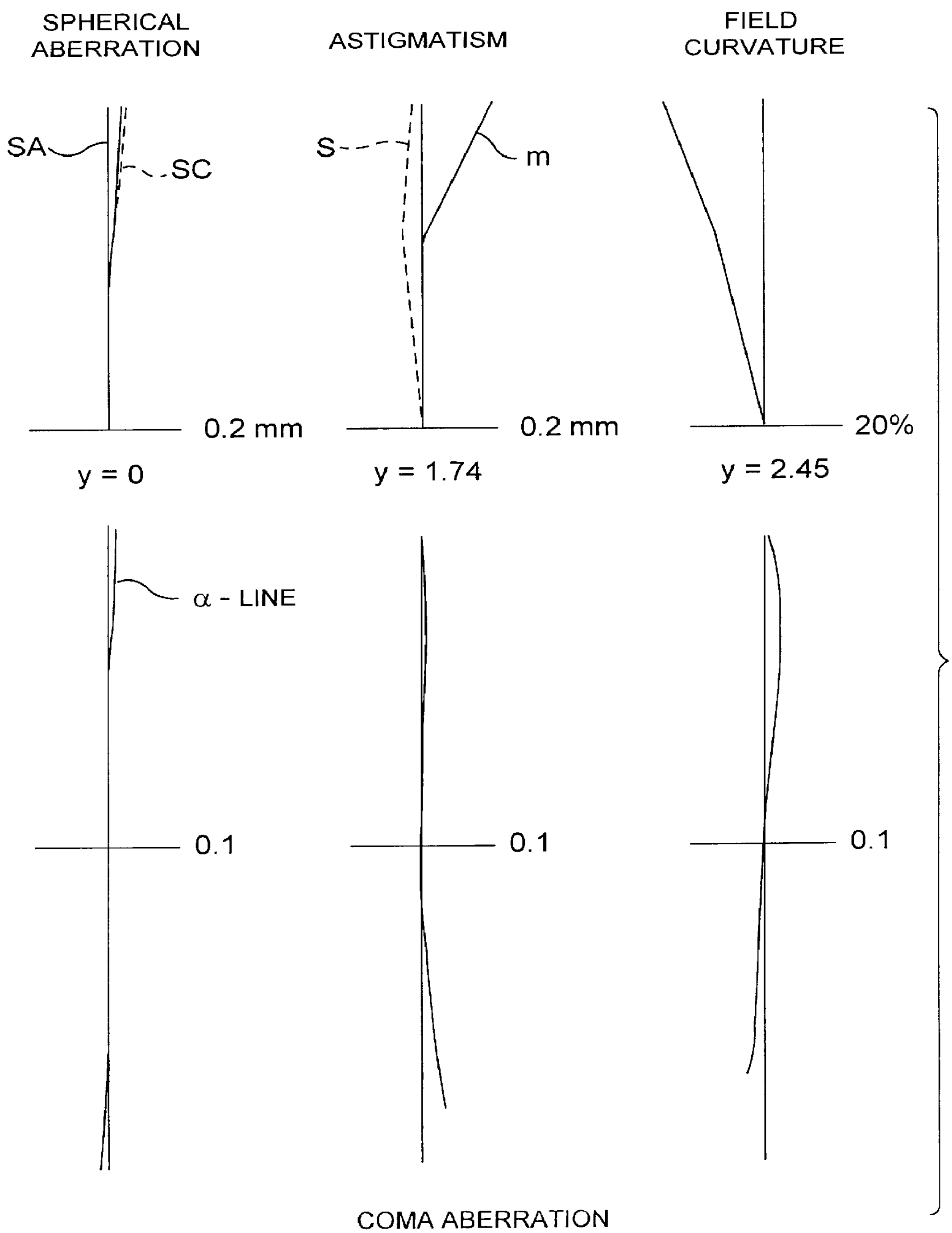
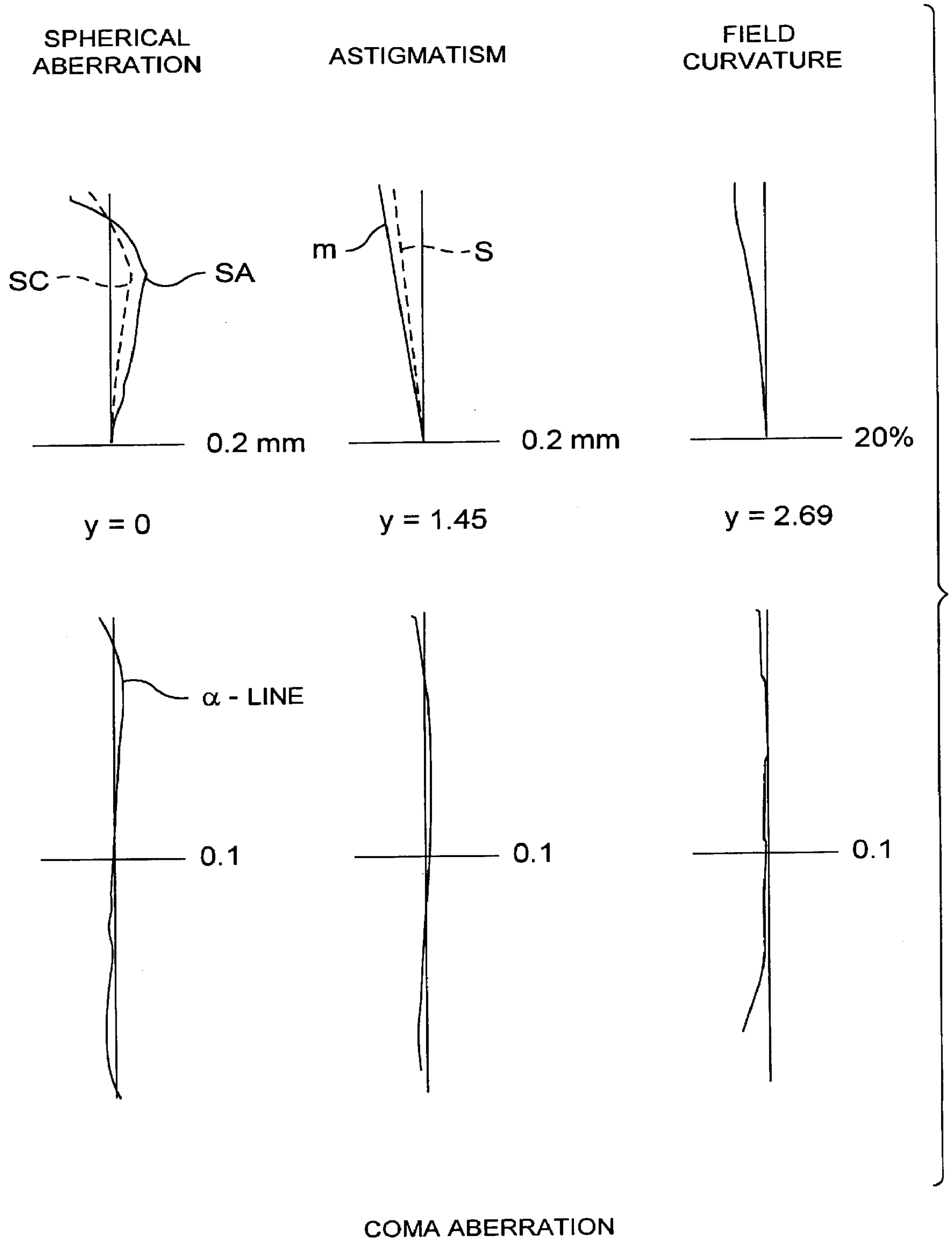
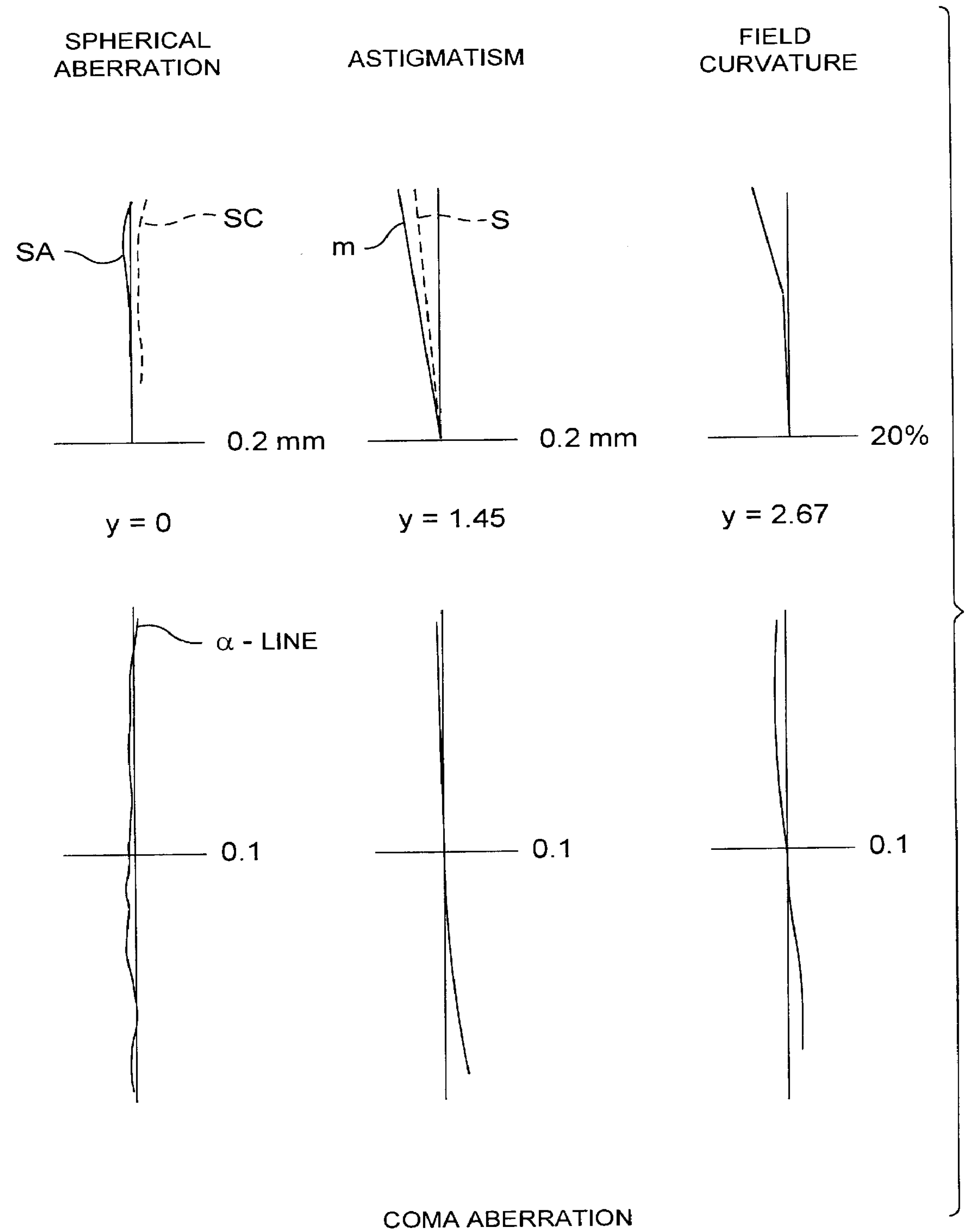

SPHERICAL ABERRATION
ASTIGMATISM
FIELD CURVATURE
SA
SC
S
m
0.2 mm
0.2 mm
20%
y = 0
y = 1.74
y = 2.45
α - LINE
0.1
0.1
0.1
COMA ABERRATION

FIG. 8


SPHERICAL ABERRATION
ASTIGMATISM
FIELD CURVATURE
SC
SA
m
S
0.2 mm
0.2 mm
20%
y = 0
y = 1.45
y = 2.69
α - LINE
0.1
0.1
0.1
COMA ABERRATION

F I G. 9


SPHERICAL ABERRATION
ASTIGMATISM
FIELD CURVATURE
SA
SC
m
S
0.2 mm
0.2 mm
20%
y = 0
y = 1.45
y = 2.67
α - LINE
0.1
0.1
0.1
COMA ABERRATION

F I G. 10

WIDE-ANGLE LENS

This is a continuation-in-part of application Ser. No. 08/590,725, filed Jan. 24, 1996, now abandoned, which in turn, was a continuation of application Ser. No. 08/251,623, filed May 31, 1994, now abandoned, which, in turn, was continuation of application Ser. No. 07/738,854, filed Jul. 31, 1991, now abandoned.

BACKGROUND OF THE INVENTION

1. Field of the Invention

The invention relates to a wide-angle lens. More particularly, the invention relates to a wide angle lens having particular application to CCD-type cameras.

2. Background Prior Art

Lately, small-sized wide-angle lenses have become increasingly used in ½- and ⅓-inch CCD cameras which have recently been put into use.

Five-element wide-angle lenses are a common known type of such small-sized lenses.

However, such wide-angle lenses have practical limitations in size, weight and cost because they employ as many as five lens elements.

OBJECT OF THE INVENTION

The present invention was designed to solve the problems mentioned above. Its primary object, therefore, is to provide a novel wide-angle lens which can easily be decreased in size and weight and manufactured at a low cost.

For a better understanding of the present invention, reference is made to the following description and accompanying drawings while the scope of the invention will be pointed out in the appended claims.

BRIEF DESCRIPTION OF THE DRAWINGS

FIGS. **1** to **5** show the lens construction of corresponding embodiments **1** to **5**.

FIGS. **6** to **10** show aberrations of embodiments **1** to **5**, respectively.

DESCRIPTION OF INVENTION AND PREFERRED EMBODIMENTS

The wide-angle lens system **20** according to the invention comprises a first lens element and a second lens element which are located on object and image (picture) sides, respectively. In the drawings, a first lens element is designated as **26** and a second lens element is designated as **28**. The first lens element **26** is a meniscus type having a negative refractive power and the second lens element **28** is a two sided convex type having a positive refractive power, one or more of lens surfaces of lens elements **26**, **28** being made aspherical.

The wide-angel lens system **20** can be used in ½- and ⅓-inch CCD cameras, for example.

The quantity of the component lens element of the wide-angle lens system **20** according to the present invention is thereby reduced to two. In order to secure high performance with the small quantity of lens elements, however, they are made aspherical.

In order to make its performances more effective, the wide-angle lens according to the invention is made to satisfy the following requirements.

$$|f_1|<D \quad (1)$$

wherein (f_1) is the focal length of the first lens element **26** and D is the distance between the principal points of the first and second lens elements **26**, **28**.

When satisfying requirement (1), the wide-angle lens system **20** permits its back-focus to be made two times longer despite its short focal length.

$$-1.5<r_2/\{(n_1-1)f_1\}<-0.5 \quad (2)$$

wherein (r_2) is the curvature radius of the image-side surface of the first lens element **26** and (n_1) is the refractive index of the material from which the first lens element **26** was constructed.

When satisfying requirement (2), the wide-angle lens system **20** permits astigmatism to become positively large or negatively large above the upper limit of requirement (2) or below its lower limit respectively.

$$-10<K_4<-1 \quad (3)$$

wherein K_4 is the conical reflection constant when the image-side surface of the second lens element **28** is aspherical.

When satisfying requirement (3), the wide-angle lens system **20** permits spherical aberration to be well corrected. Namely, spherical aberration becomes negatively large or positively large above the upper limit of requirement (3) or below its lower limit respectively.

$$-2<f_1/f_2<-1 \quad (4)$$

wherein (f_2) is the focal length of the second lens element **28**.

When satisfying requirement (4), the wide-angle lens system **20** permits field curvature to be well corrected. Namely, field curvature becomes positive or negative above the upper limit of requirement (4) or below its lower limit respectively When not satisfying requirement (4), its lowers performance of the lens system **20**.

The wide-angle lens system **20** according to the invention permits achromatism even when its first and second lens elements **26**, **28** are made from the same material.

When the first and second lens elements **26**, **28** are made from acryl (PMMA), the wide-angle lens system **20** permits material and manufacturing costs to be reduced further.

The invention will be more fully understood by describing five embodiments as follows.

It is assumed that the first lens surface counted from the object side (including lens surface, diaphragm and CCD cover glass) has a curvature radius r_i (i=1–7) and a distance d_i (i=1–5) is given between the (i)-th and (i+1)-th surfaces on the optical axis. Formula j=1, 2 represent the first and second lens elements respectively, j=3 the above mentioned cover glass, (n_j) refractive index of the material of the lens elements and cover glass j=1–3.

Aspherical surface of the lens elements of the wide-angle lens is obtained by revolving curve:

$$X=\left[CY^2/\{1+\sqrt{1-(K+1)C^2Y^2}\}\right]+A_4Y^4+A_6Y^6$$

about the optical axis (X) with optically-axial coordinate and the coordinate orthogonal therewith given symbols X and Y respectively, optically-axial curvature C, conical reflection constant K, A_4, A_6 quarternary and hexanary aspherical coefficients, and its configuration is specified by giving conical reflectin constant K ans aspherical coefficients A_4, A_6.

Embodiment 1

f=3.3 mm, F/No=1.8

Picture size: ⅓ inch (diagonal distance: 5.5 mm)				
i	r_i	d_i	j	n_j
1	40.00	1.00	1	1.491
2	3.16	8.50		
3	4.38	2.50	2	1.491
4	−5.03	0.00		
5	(Diaphragm)	6.22		
6	∞	0.70	3	1.5168
7	∞			

Aspherical surface: r_4

K=−4.16934

$A_4=2.19540\times10^{-3}$, $A_6=2.19540\times10^{-3}$

$f_1=-7.04$, $f_2=5.22$, D=8.68, $r_2/\{(n_1-1)f_1\}=-0.91$

$f_1/f_2=-1.35$

The first and second lens elements **26, 28** were made from PMMA (acryl). The configuration of the lens and associated light paths according to the first embodiment are illustrated in FIG. **1** and the aberrations of the first embodiment are illustrated in FIG. **6**. The coma aberration shown therein is obtained in connection with (d)- line.

Embodiment 2

f=5.0 mm, F/No=1.8

Picture size: ½ inch (diagonal distance: 8.0 mm)				
i	r_i	d_i	j	n_j
1	100.00	1.00	1	1.491
2	4.32	12.00		
3	7.32	3.00	2	1.491
4	−7.05	0.00		
5	(Diaphragm)	10.58		
6	∞	0.70	3	1.5168
7	∞			

Aspherical surface: r_4

K=−2.70060

$A_4=6.15920\times10^{-4}$, $A_6=4.25890\times10^{-6}$

$f_1=-9.21$, $f_2=7.84$, D=13.16, $r_2/\{(n_1-1f_1\}=-0.95$

$f_1/f_2=-1.17$

The first and second lens elements **26, 28** were made from PMMA (acryl). The configuration of the lens and associated light paths according to the second embodiment are illustrated in FIG. **2** and the aberrations of the second embodiment are illustrated in FIG. **7**. The coma aberration shown therein is obtained in connection with (d)- line.

Embodiment 3

f=3.3 mm, F/No=1.8

Picture size: ⅓ inch (diagonal distance: 5.5 mm)				
i	r_i	d_i	j	n_j
1	20.00	1.00	1	1.5168
2	3.11	8.50		
3	5.16	2.50	2	1.5168
4	−4.64	0.00		
5	(Diaphragm)	6.15		
6	∞	0.80	3	1.5168
7	∞			

Aspherical surface: r_3

K=−1.76816

$A_4=2.20288\times10^{-5}$, $A_6=-6.86197\times10^{-7}$

Aspherical surface: r_4

K=−2.83668

$A_4=-6.15852\times10^{-6}$, $A_6=2.98626\times10^{-7}$

$f_1=-7.28$, $f_2=5.18$, D=9.33, $r_2/\{(n_1-1)f_1\}=-0.83$

$f_1/f_2=-1.41$

The first and second lens elements **26, 28** and cover glass **32** were made from the same material (BK7). The configuration of the lens and associated light paths according to the third embodiment are illustrated in FIG. **3** and the aberrations of the third embodiment are illustrated in FIG. **8**. The coma aberration shown therein is obtained in connection with (d)- line.

Embodiment 4

f=5.0 mm, F/No=3.5

Picture size: ⅓ inch (diagonal distance: 5.5 mm)				
i	r_i	d_i	j	n_j
1	16.500	1.500	1	1.49091
2	2.663	6.000		
3	5.050	2.000	2	1.49091
4	−5.328	0.200		
5	(Diaphragm)	5.875		
6	∞	4.600	3	1.51680
7	∞			

Aspherical surface: r_3

K=−2.27678

$A_4=0$, $A_6=$

Aspherical surface: r_4

K=−9.5

$A_4=0$, $A_6=0$

$f_1=-6.708$, $f_2=5.639$, D=6.900, $r_2/\{(n_1-1)f_1\}=-0.809$

$f_1/f_2=-1.190$

The first and second lens elements **26, 28** were made from PMMA (acryl). The configuration of the lens and associated light paths according to the fourth embodiment are illustrated in FIG. **4** and the aberrations of the fourth embodiment are illustrated in FIG. **9**. The coma aberration shown therein is obtained in connection with (d) - line.

Embodiment 5

f=5.0 mm, F/No=2.5

Picture size: ⅓ inch (diagonal distance: 5.5 mm)				
i	r_i	d_i	j	n_j
1	21.000	1.500	1	1.49091
2	2.805	6.800		
3	8.403	2.000	2	1.49091
4	−4.382	0.00		
5	(Diaphragm)	9.386		
6	∞	0.800	3	1.51680
7	∞			

Aspherical surface: r_3

K=−5.54774

$A_4=0$, $A_6=0$

Aspherical surface: r_4

K=−1.2

$A_4=0$, $A_6=0$

$f_1=-6.779$, $f_2=6.095$, D=7.900, $r_2/\{(n_1-1)f_1\}=-0.843$

$f_1/f_2=-1.112$

The first and second lens elements **26**, **28** were made from PMMA (acryl). The configuration of the lens and associated light paths according to the fifth embodiment are illustrated in FIG. **5** and the aberrations of the fifth embodiment are illustrated in FIG. **10**. The coma aberration shown therein is obtained in connection with (d) - line.

FIGS. **1** through **5** show the layout of the lens elements of the wide-angle lens system of the Embodiments 1 through 5 and light paths therein. In FIGS. **1** through **5** numeral **26** is a first lens element, **28** a second lens element, **30** a diaphragm and **32** a cover glass.

As is clear from the drawings, all the embodiments show good performances.

In the aberration diagrams, consideration is given to the presence of the cover glass.

While the foregoing description and drawings represent the preferred embodiments of the present invention, it will be obvious to those skilled in the art that various changes and modifications may be made therein without departing from the true spirit and scope of the present invention.

What is claimed is:

1. A wide angle lens system comprising:

a first lens element and a second lens element which are located on the object side and image side respectively, said first lens element being of a meniscus type having a negative refractive power and said second lens element being of a two-sided convex type having a positive refractive power, at least one surface of said lens elements being aspherical, said wide angle lens system having no more than two lens elements and wherein

$|f_1|<D$;

[$-1.5<r_2/\{(n_1-1)f_1\}<-0.5$; and

$-2<f_1/f_2\leqq\_1$]

$-1.5<r_2/\{(n_1-1)f_1\}-0.5$; and

$-2<f_1/f_2<-1$

where (f_1) is the focal length of the first lens element and D is the distance between a back principal point of the first lens element and a front principal point of the second lens element, where (r_2) is the curvature radius of the image-side surface of the first lens element, where (n_1) is the refractive index of the material of the first lens element, and where (f_2) is the focal length of the second lens element.

2. The wide angle lens system of claim **1**, wherein

$-10<K_4<-1$

where (K_4) is the conical reflection constant when the image-side surface of the second lens element is aspherical.

3. The wide angle lens system of claim **2**, wherein said lens elements are made of plastic.

4. The wide angle lens system of claim **3**, wherein said lens elements are made from acryl.

5. The wide angle lens system of claim **1**, wherein said lens elements are made of plastic.

6. The wide angle lens system of claim **5**, wherein said lens elements are made from acryl.

7. The wide angle lens system of claim **5**, including a diaphragm and a cover glass for a CCD layer on the image side, said diaphragm being between said second lens element and said cover glass.

8. The wide angle lens system of claim **1**, including a diaphragm and a cover glass for a CCD layer on the image side, said diaphragm being between said second lens element and said cover glass.

9. The wide angle lens system of claim **8**, wherein said first and second lens elements are constructed of the same material as said cover glass.

10. In a camera having a wide angle lens system, a diaphragm and a plane surface for forming an image, the improvement comprising:

that said wide angle lens system comprises:

a first lens element and a second lens element which are located on the object side and image side respectively, said first lens element being of a meniscus type having a negative refractive power and said second lens element being of a two-sided convex type having a positive refractive power, at least one surface of said lens elements being aspherical, said wide angle lens system having no more than two lens elements and wherein

$|f_1|<D$;

$-1.5<r_2/\{(n_1-1)f_1\}<-0.5$; and

$-2<f_1/f_2<-1$

where (f_1) is the focal length of the first lens element and D is the distance between a back principal point of the first lens element and a front principal point of the second lens element, where (r_2) is the curvature radius of the image-side surface of the first lens element, where (n_1) is the refractive index of the material of the first lens element, and where (f_2) is the focal length of the second lens element.

11. The camera of claim **1** wherein said camera is of the CCD type and wherein a cover glass for CCD elements is arranged on the image side, said diaphragm being disposed between said second element and said cover glass.

12. The camera of claim **11** wherein said first and second elements are constructed of the same material as said cover glass.

13. The camera of claim **1** wherein said first and second elements are made of plastic.

14. The camera of claim **10** wherein

$-10<K_4<-1$

where K_4 is a conical reflection constant when the image-side surface of said second lens element is aspherical.

15. In a camera having a wide angle lens system, a diaphragm and a plane surface for forming an image, the improvement comprising:

that said wide angle lens system has a first lens element and a second lens element which are located on an object side and image side respectively, said first lens element being of a meniscus type having a negative refractive power and said second lens element being of a two-sided convex type having a positive refractive power, at least one surface of said lens elements being aspherical wherein

$$-1.5<r_2/\{(n_1-1)f_1\}<-0.5$$

wherein (r_2) is the curvature radius of the image side surface of the first lens element, (f_1) is the focal length of the first lens element and (n_1) is the refractive index of the material of the first lens element.

* * * * *

EXHIBIT 6a

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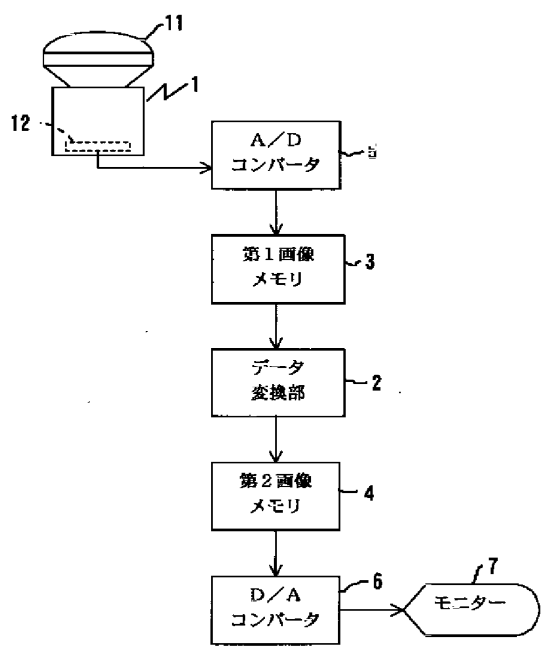
最終頁に続く

(54)【発明の名称】　画像データ変換装置

(57)【要約】

【課題】　魚眼レンズにより得られた全周囲の撮影データを、歪みを修正しつつ、一つの画像としてつなぎ目なく表示できるように変換する。

【解決手段】魚眼レンズによる撮影により得られる円形画像データの一部分の領域に対して、前記円形画像の中心を原点とする平面直交座標系における前記領域上の点（ｇ（Θ）・ｃｏｓψ，ｇ（Θ）・ｓｉｎψ）（Θは０＜Θ＜π／２を満たすパラメータ、ｇ（Θ）はｇ（０）＝０を満たし、前記Θの範囲で単調増加する関数、ψは前記平面直交座標系の原点と前記円形画像上の点とを結んだ線分が前記平面直交座標系における一座標軸となす角）をＲを定数とする円柱座標系上の点（Ｒ，ψ，Ｒ／ｔａｎΘ）へ変換する。



【特許請求の範囲】

【請求項１】魚眼レンズによる撮影により得られる円形画像データの一部分の領域に対して、

前記円形画像の中心を原点とする平面直交座標系における前記領域上の点（ｇ（Θ）・ｃｏｓψ，ｇ（Θ）・ｓｉｎψ）　（Θは0＜Θ＜π／２　を満たすパラメータ、ｇ（Θ）はｇ（０）＝０を満たし、前記Θの範囲で単調増加する関数、ψは前記平面直交座標系の原点と前記円形画像上の点とを結んだ線分が前記平面直交座標系における一座標軸となす角）をＲを定数とする円柱座標系上の点（Ｒ，ψ，Ｒ／ｔａｎΘ）へ変換する画像データ変換装置。

【請求項２】前記魚眼レンズがｈ＝ｇ（θ）（ｈは像高、θは画角）の特性を有するものである請求項１に記載の画像データ変換装置。

【請求項３】前記関数ｇ（θ）がｇ（θ）＝２ｆ・ｔａｎ（θ／２）（ｆは焦点距離）である請求項２に記載の画像データ変換装置。

【請求項４】前記関数ｇ（θ）がｇ（θ）＝ｆ・θ（ｆは焦点距離）である請求項２に記載の画像データ変換装置。

【請求項５】コンピュータに請求項１から４のいずれかに記載の画像データ変換装置としての動作を実行させるプログラムを記録した前記コンピュータに読み取り可能な記録媒体。

【請求項６】前記魚眼レンズと、

前記魚眼レンズより得られる像を前記画像データへ変換する変換手段と、

請求項１から４のいずれかに記載の画像データ変換装置と、

この画像データ変換装置により変換された前記円柱座標面上の画像データを平面に展開して表示する表示手段とより構成される撮像システム。

【請求項７】魚眼レンズによる撮影により得られる円形画像データの一部分の領域に対して、

前記円形画像の中心を原点とする平面直交座標系における前記領域上の点（ｇ（Θ）・ｃｏｓψ，ｇ（Θ）・ｓｉｎψ）　（Θは0＜Θ＜π／２　を満たすパラメータ、ｇ（Θ）はｇ（０）＝０を満たし、前記Θの範囲で単調増加する関数、ψは前記平面直交座標系の原点と前記円形画像上の点とを結んだ線分が前記平面直交座標系における一座標軸となす角）をＲを定数とする円柱座標系上の点（Ｒ，ψ，Ｒ／ｔａｎΘ）へ変換する画像データ変換方法。

【発明の詳細な説明】

【０００１】

【発明の属する技術分野】本発明は、画像データ変換装置に関し、詳しくは、魚眼レンズによる撮影により得られる円形の画像データを、歪みを修正しつつ広範囲に渡る表示を行えるような平面画像データへと変換する装置に関する。

【０００２】

【従来の技術】従来、店舗内の監視カメラや交通管制用のカメラ等では、周囲の状況を監視するために、前方の限られた視野を持つカメラをモータ等の駆動装置で旋回させることが一般的に行われている。しかし、このような視野の限られたカメラを回転させるようにすると、回転駆動部が必要になるので装置が複雑となり、また、特定の対象を捕らえようとする際にカメラを回転させる必要があり、対象が動いているようなときは回転速度の制約から対象を捕らえることができないようなことも生じる。また、同時に複数の方向を撮影することができず、常に監視範囲に関して死角が生じるので、監視等の機能としては十分とは言えない。

【０００３】このような問題を解決する技術として、特公表平６−５０１５８５号公報に、魚眼レンズにより前方の全方位を撮影して得られる円形の画像データを、平面画像に変換するものが提示されている。この技術を以下に簡単に説明する。魚眼レンズにより得られる円形の画像データは全方位の像を含むことができるが外周へ行くほど像が歪む。この歪みは円形画像データを半球面上に変換するとほぼ解消することができるが、半球面に変換した画像データでは平面的なモニターに表示することができない。そこで、上記技術ではさらに半球面に変換された画像データの一部を平面に投影することで平面に変換して表示を可能としている。このような方法を用いることにより、回転駆動機構が不要となって装置を簡易化でき、表示する方向の切り替えもデータ処理時間の制約だけとなるので格段に速く行うことができる。

【０００４】

【発明の解決しようとする課題】しかし、このように魚眼レンズで撮影した円形画像データを直接平面画像データに変換するようにしても、歪みを十分に修正したまま半球面のすべてを一つの平面に投影することはできないので、得られる画像は特定の方向に関するものだけとなる。従って、魚眼レンズにより全周囲の撮影をしているにもかかわらず表示画面においては死角が生じることとなる。また、死角をなくす方法として同時に複数の方向に関して平面画像への変換を行いこれらを同時に表示することが考えられるが、この場合は画像同時のつなぎ目が連続にならず、また、複数の異なる画像変換を行う必要が生じる。

【０００５】本発明はこのような問題を解決するためになされたものであり、魚眼レンズにより得られた全周囲の撮影データを、歪みを修正しつつ、一つの画像としてつなぎ目なく表示できるように変換することを目的とする。

【０００６】

【課題を解決するための手段】上記課題を解決するために、本発明に係る画像データ変換装置は、魚眼レンズに

よる撮影により得られる円形画像データの一部分の領域に対して、前記円形画像の中心を原点とする平面直交座標系における前記領域上の点（ｇ（Θ）・ｃｏｓψ，ｇ（Θ）・ｓｉｎψ）　（Θは０＜Θ＜π／２　を満たすパラメータ、ｇ（Θ）はｇ（０）＝０を満たし、前記Θの範囲で単調増加する関数、ψは前記平面直交座標系の原点と前記円形画像上の点とを結んだ線分が前記平面直交座標系における一座標軸となす角）をＲを定数とする円柱座標系上の点（Ｒ，ψ，Ｒ／ｔａｎΘ）へ変換する。なお、本発明にいう魚眼レンズには、視野角が略１８０度を有する一般的に魚眼レンズと呼ばれるもののみならず、それよりも小さな視野角を有する一般的に広角レンズと呼ばれるものも含まれる。

【０００７】なお、変換は結果として上記関係を満たす変換が行われれば足り変換の過程を問題としない。即ち、上記式を直接用いる必要は必ずしもなく、変換元の画素と変換先の画素の対応を示すテーブルを用いて変換するような場合も含まれる。また、前記平面直交座標系および円柱座標系は互いに独立であり、座標の方向は任意に定めることができる。また、Ｒを定数とする円柱座標系は円筒面となるが、ここでは、これを展開して平面として上記のような変換を行う場合も含まれる。

【０００８】このようにすると、まず、ψを固定して点（ｇ（Θ）・ｃｏｓψ，ｇ（Θ）・ｓｉｎψ）が上記円形画像データの一部分の領域に入る範囲でΘを小さい値から大きい値へと増加させていくと、円形画像データにおける中心から半径方向へ向かう線分が、Ｒを定数とする円柱座標系即ち半径Ｒの円筒面において上方から下方に向かう線分として変換される。このような変換がさらにψについて上記点が前記円形画像データの一部分の領域に入るように最大３６０度の範囲で行われるので、魚眼レンズが撮影した魚眼レンズを中心とする全周囲の画像情報を含む円形画像データの一部が、歪みを補正される形でなめらかに円筒面へ変換されることとなる。円筒面に変換された画像は円筒面を展開することにより容易に平面画像にできるので、魚眼レンズにより得られた全周囲の撮影データを歪みを修正しつつ一画像としてつなぎ目なく表示できる。

【０００９】また、前記魚眼レンズをｈ＝ｇ（θ）（ｈは像高、θは画角）の特性を有するものとすると、Θの増加にともなう上記ｇ（Θ）の増加量は、像高ｈの増加量と同じとなる。従って、即ちΘを変化させることは画角θを変化させることに他ならない。このようにした場合、円形画像を歪みのない仮想的な半球面へと変換し、さらに、中心軸がこの半球面の中心軸と一致するように配置した前記円筒面に対して半球面の中心点から半径方向へ向かう投射光により、変換した半球面画像を投射した画像が得られるようになる。従って、魚眼レンズの側方の全周に渡る撮影領域、即ち円形画像の外周側の画像に関しては、ほぼ歪みのない画像へ変換されることになる。

【００１０】また、前記魚眼レンズの特性を示す関数ｇ（θ）をｇ（θ）＝２ｆ・ｔａｎ（θ／２）（ｆは焦点距離）とすると、円形画像データの外周側の画像のデータ量が多くなるので、魚眼レンズの側方の全周に渡る撮影領域の円筒面への変換時における再現性を向上させることができる。

【００１１】さらに、前記前記魚眼レンズの特性を示す関数ｇ（θ）をｇ（θ）＝ｆ・θ（ｆは焦点距離）とすると、この特性は最も一般的に使用される魚眼レンズの特性であるので、量産された安価な魚眼レンズを使用することができ装置のコストダウンを図ることが可能となる。

【００１２】上記の画像データ変換装置は、コンピュータに上記画像データ変換装置としての動作を実行させるプログラムを組み込むことでも実現することができ、このプログラムは前記コンピュータに読み取り可能な記録媒体に記録することができる。

【００１３】さらに、上記課題を解決するために、本発明に係る撮像システムは、前記魚眼レンズと、前記魚眼レンズより得られる像を前記画像データへ変換する変換手段と、請求項１から４のいずれかに記載の画像データ変換装置と、この画像データ変換装置により変換された前記円柱座標面上の画像データを、当該円柱座標面を展開して平面として表示する表示手段とより構成される。

【００１４】このような構成により、この撮像システムは前述のように画像データ変換装置により歪みを修正されてつなぎ目無く変換された円筒面上の画像を展開して平面として表示するので、一画面で魚眼レンズが撮影した周囲の様子をすべて示すことが可能となる。なお、展開した平面には、展開した平面を適当に加工する場合も含み、例えば、展開した平面を所定位置で切断して、各切断部分を適宜配列して表示するような場合も含む。

【００１５】また、上記課題を解決するために、本発明に係る画像データ変換方法は、魚眼レンズによる撮影により得られる円形画像データの一部分の領域に対して、前記円形画像の中心を原点とする平面直交座標系における前記領域上の点（ｇ（Θ）・ｃｏｓψ，ｇ（Θ）・ｓｉｎψ）　（Θは０＜Θ＜π／２　を満たすパラメータ、ｇ（Θ）はｇ（０）＝０を満たし、前記Θの範囲で単調増加する関数、ψは前記平面直交座標系の原点と前記円形画像上の点とを結んだ線分が前記平面直交座標系における一座標軸となす角）をＲを定数とする円柱座標系上の点（Ｒ，ψ，Ｒ／ｔａｎΘ）へ変換するものである。この画像データ変換方法もやはり、魚眼レンズが撮影した魚眼レンズを中心とする全周囲の画像情報を含む円形画像データの一部が、歪みを補正される形でなめらかに円筒面へ変換されるので、魚眼レンズにより得られた全周囲の撮影データを歪みを修正しつつ、つなぎ目なく表示するようにできる。

【0016】
【発明の実施の形態】以下に本発明の実施の形態について図面を参照して説明する。図1に本発明の実施の形態に係る撮像システムの構成を示すブロック図を示す。この撮像システムは、カメラ部1、データ変換部2、第1画像メモリ3、第2画像メモリ4、A／Dコンバータ5、D／Aコンバータ6、モニター7より構成される。
【0017】カメラ部1はレンズとして魚眼レンズ11を用いてあり、少なくともレンズの光軸方向に対して画角90度以上での撮影が可能である。ここでは、魚眼レンズとして、

h＝2f・tan（θ／2）　　　①

の特性を有するものを用いることとする。このような特性のレンズを用いると画角θの増加に対する像高hの増加量が、一般的なh＝f・θのレンズに比べて大きくなるので画角θの大きな範囲つまり魚眼レンズで得られる円形画像の周辺部での情報量を多くすることができる。このような特性を有する魚眼レンズ11により得られる円形画像はCCD12により各画素のRGBごとに電気信号に変換されてA／Dコンバータ5へと出力される。ここではCCDとして例えば、1280×1024画素のものを用いるものとする。
【0018】A／Dコンバータ5はCCD12から送られるアナログ信号をデジタル信号へと変換して第1画像メモリ3へと出力する。第1画像メモリ3はRAMにより構成され、送られた円形画像を表すデジタル信号に基づき各画素ごとのRGB値を記録する。データ変換部2は本発明に係る画像データ変換装置に相当し、後述のような演算を行う演算回路により構成される。データ変換部2は第1画像メモリ3に記録された円形の画像データを後に詳述するような変換により円筒の画像データへと変換して第2画像メモリ4へと出力する。
【0019】第2画像メモリ4はやはりRAMにより構成され、出力された画像データの画素ごとのRGB値を後述するような円筒面を展開した平面として記録する。また、円筒面を展開した画像は横方向に長いので、後述するような表示データが得られるように第2画像メモリ4は画像データ記録する際に展開した画像を半分に分けて上下に所定間隔を置いた画像となるように記録する。D／Aコンバータ6は第2画像メモリ4に記録されたデジタル値の画像データを読み出しアナログ信号へと変換して、画像信号としてモニター7の走査線順に送出する。モニター7はD／Aコンバータ6より送られる画像信号に基づき第2画像メモリ4に記録されている画像を表示する。
【0020】なお、本撮像システムはカメラ部1を除いた部分は一般的なコンピュータに上記機能および下記動作を実現させるようなプログラムを組み込むことによって実現可能であり、プログラムはこのコンピュータにより読み取り可能なフロッピーディスクのような記録媒体に記録が可能である。また、このプログラムはインターネット等の通信手段からも当該コンピュータに組み込むことができる。
【0021】ここで、データ変換部2の変換方法について詳述する。データ変換部2は円形面上の画像データを円筒面上へと変換する。円形面上の点と円筒上の点との対応関係を図2および図3を用いて説明する。図2は魚眼レンズ11により撮影される全周面を仮想的に想定した半球面O上の任意の点P0 と変換する面である円筒面Cの点P2 との関係を示す図である。図2では、半球面Oはxyz座標系において、底円（半球面の縁を構成する円）が原点を中心としてxy平面上に位置している。z軸は魚眼レンズ11の光軸方向と一致する。また、円筒面Cはz軸を中心軸とする半径Rの円筒である。即ち、円筒面CはRを定数とするrψz円柱座標系における曲面として表すことができる。また、ここでは、円筒面C上の点をrψz円柱座標系上の点として（R、ψ、z）で表す。但し、ψは、xy平面に降ろした垂線とxy平面との交点と原点とでできる線分がx軸となす角である。そして、原点から半球面O上の任意の点P0を結ぶ線分を延長した直線が円筒面Cと交わる点がP2 となる。なお、原点から点P0とを結ぶ線分とz軸とのなす角が点P0に関する画角θとなる。
【0022】図3は上述の撮影される全周面を仮想的に想定した半球面O上の任意の点P0が、魚眼レンズ11より映される撮影面F上の点P1 の位置を示している。図3において撮影面F上の円形領域が魚眼レンズ11を通して光りが照射されるCCD12上の領域であり、この部分が変換される画像データが表示される円形面Sを形成する。図3では、XY座標系において原点をこの円形面Sの中心にとっている。なお、X軸およびY軸の方向は図2のxyz座標系のx軸およびy軸の方向と逆になるようにしてある。これは、カメラ部1で撮影した画像は上下左右が反転するので、P0 も上下左右が反転した位置に映ることになるため、これに対応させるためである。もっとも、円筒面は任意であるので、実際の変換においては座標の取り方も自由である。そして、P1 の位置は、原点から像高hの距離でかつ原点とP1 を結んだ線分とX軸とがなす角がψとなる位置となる。hは上記① 式により表され、画角θにより定まる。
【0023】データ変換部2は図3に示すP1 を図2に示すP2 へと変換するものである。以下に、具体的な計算について説明する。まず、パラメータをθ、ψとする場合を考える。この場合XY平面上におけるP1 の座標は（h・cosψ，h・sinψ）であり、上記式① よりhを消去すると（2f・tan（θ／2）・cosψ，2f・tan（θ／2）・sinψ）と表される。一方、P2 の座標はRは定数であり、zは図2よりz＝

Ｒ／ｔａｎθの関係があるので、（Ｒ，ψ，Ｒ／ｔａｎθ）と表される。従って、パラメータθ、ψを動かして、ＸＹ平面上における円形画像上のＰ1 を特定でき、これに対するｒψｚ円柱座標系上の点、即ち円筒面Ｃ上の点も特定できるので、上記Ｐ1 、Ｐ2 を示す式に従って画像データを変換することができる。但し、θ＝０の場合はＰ2 のｚ座標が無限大となってしまうので、現実にはθの値はある値以上のものを使用することになる。本実施の形態ではθとしてπ／４≦θ＜π／２の範囲を使用している。

【００２４】ところで、実際の変換においてはパラメータとして、撮影されたＣＣＤ１２上の各画素位置もしくは変換される円筒面Ｃ上の変換後の各画素位置を直接表すものを用いる方が計算が容易である。そこで、円筒面Ｃ上の変換後の各画素位置を直接表すパラメータとしてｚとψを用いることを考える。この場合円筒面Ｃ上の点Ｐ2 をパラメータｚ、ψで表すと、（Ｒ、ψ、ｚ）となる。変換される円筒面Ｃは展開されてモニター７に表示されることになり、各画素は縦方向および横方向に画素ピッチｄの等間隔で並ぶことになる。図４に展開した円筒面Ｃと円形面Ｓとの関係を表す図を示す。円筒面Ｃの縦方向はパラメータｚと一致するので、パラメータｚに関しては画素ピッチｄずつ変化させれば円筒面Ｃの縦方向の画素位置に合致する。展開した円筒面の横方向のψの変化量にともなう変化量はＲ・ψと表すことができるので、円筒面Ｃの画素ピッチｄに対応するパラメータψの変化量をΔψとすると、Δψ＝ｄ／Ｒと表すことができる。従って、パラメータψに関してはｄ／Ｒずつ変化させると円筒面Ｃの横方向の画素位置に合致することになる。なお、図において円形面Ｓのハッチングされている範囲は、π／４≦θ＜π／２に対応する円形面Ｓの範囲であり、円筒面Ｃに変換される範囲を示している。

【００２５】一方、円形画像上の点Ｐ1 をパラメータｚ、ψで表すことを考える。まず、上記① 式を三角関数の倍角の公式を用いて変形すると、

ｈ＝２ｆ・ｔａｎ（θ／２）＝２ｆ・｛ｓｉｎθ／（１＋ｃｏｓθ）｝ ①'

となる。図２より $\mathrm{sin}\theta=R/(R^2+z^2)^{1/2}$、$\mathrm{cos}\theta=z/(R^2+z^2)^{1/2}$ であるので、これらを①'式に代入して整理すると、$h=2f\cdot R/\{(R^2+z^2)^{1/2}+z)\}$ となるので、結果としてＰ1は、$(2f\cdot R\cdot \mathrm{cos}\psi/\{(R^2+z^2)^{1/2}+z)\},\ 2f\cdot R\cdot \mathrm{sin}\psi/\{(R^2+z^2)^{1/2}+z)\})$ となる。従って、上述のようにｚをｄずつ、ψをｄ／Ｒずつ変化させて、この式より円筒面Ｃ上の各画素位置に変換される円形面Ｓ上の画素位置を求めることができる。この場合、計算で得られる画素位置と実際のＣＣＤ１２が撮影した画素位置とは完全には合致しないので、最も近い画素を抽出するようにする。具体的には、例えば得られたＸ座標値およびＹ座標値をＣＣＤ１２の画素ピッチｄs で割り、その値を例えば小数点以下を切り捨てることで得られる整数値を画素の番号として抽出することができる。なお、この場合、ＣＣＤ１２の各画素は、ＸＹ座標における原点を（０，０）としてＸＹ座標の各象限に応じてそれぞれ正負が定まるものとする。

【００２６】以上のような方法を用いてデータ変換部２は、変換後の円筒面Ｃ上の各画素に対応する円形面Ｓ画素位置を算出して、その画素位置における画素データを各円筒面Ｃ上の画素データとして変換していく。この結果図４に示すように円形面Ｓ上の画素データは円筒面Ｃ上の各画素データとして変換されていくことになる。なお、円形画像の各画素が円筒面のどの画素位置へ変換されるかは一義的に決まるので、演算を行わずにデータ変換部２に円形画像の画素と円筒面上の画素位置との対応を示すテーブルを設けておき、これに基づいてデータ変換を行うようにすることもできる。

【００２７】続いて、以上のような構成を有する撮像システムの動作について説明する。なお、カメラ部１は、室内において天井中央から下方に向けて取り付けられているものとする。また、変換する円筒面のｚの範囲を０＜ｚ≦Ｒとする。言い換えると、θの範囲をπ／２＞θ≧π／４に設定するものとする。図５に撮像システムの動作を表すフローチャートを示す。まず、室内の全景がカメラ部１により魚眼レンズ１１を通して円形画像として映される。この円形画像はＣＣＤ１２により電気信号に変換され、さらに、Ａ／Ｄコンバータ５により画素ごとにデジタル値に変換される。そして、これらのデータは第１画像メモリ３に記録される（ｓ１０１）。また、パラメータψ、ｚの初期値としてそれぞれ０を入れておく（ｓ１０２）。

【００２８】次に、データ変換部２によりパラメータψi をｄ／Ｒずつｉ＝１～ｎ（ｎ＝２πＲ／ｄ）まで増加させ、また、パラメータｚj をｄずつｊ＝１～ｍ（ｍ＝Ｒ／ｄ）まで増加させる。そして、それぞれの値ごとに、

$$Xi=[2f\cdot R\cdot \mathrm{cos}\psi i/\{(R^2+zj^2)^{1/2}+zj\}\cdot ds]$$

$$Yj=[2f\cdot R\cdot \mathrm{sin}\psi i/\{(R^2+zj^2)^{1/2}+zj\}\cdot ds]$$

が計算され、この結果に基づき第１画像メモリ３に記録されている（Xi ，Yj）番目の画素データが抽出され、円筒面における（ｉ，ｊ）番目の画素の画素データとして第２画像メモリ４へと記録される（ｓ１０３～ｓ１０８）。なお、第２画像メモリ４では、図６に示すような画像がモニター７に映し出されるように、円筒面上の画素（ｉ，ｊ）のｉ＝１～n／２、ｊ＝１～mの部分と、ｉ＝（n／２）＋１～n、ｊ＝１～mの部分とは２分され、後者は前者の下方に所定間隔を置いたところへ

位置するように配置された画像となるように記録される。なお、図６に示されている角度を示すテキストデータは予め第２画像メモリ４に記録されている。

【００２９】第２画像メモリ４に記録された画像データはD／Aコンバータ６によって画像信号としてモニター７へ出力され（ｓ１０９）、モニター７により表示される（ｓ１１０）。上述のように画像データは２分されて上下に配置されるように形成されているるので、図６に示す画面が表示されることになる。このように本実施の形態に係る撮像システムでは魚眼レンズで撮影した周囲３６０度の映像をすべてつなぎ目無く表示することができ、レンズ周囲の状況を死角無く完全に監視することができる。

【００３０】ところで、上記実施の形態では、上記式①で表される特性を持つ魚眼レンズを用いたが、魚眼レンズの特性は式① で表されるものでなくてもよい。つまり、魚眼レンズの特性をｈ＝ｇ（θ）として一般化するとP2は上記のままで、P1 は（ｇ（θ）・ｃｏｓψ，ｇ（θ）・ｓｉｎψ）と表すことができるので、パラメータをθ、ψとする場合は、これを用いれば足りる。さらに、上記のようにパラメータをｚ、ψとする場合は、図２よりθ＝Ｔａｎ$^{-1}$（Ｒ／ｚ）と表すことができるので、P2は上記のままでP1 は（Ｇ（Ｔａｎ$^{-1}$（Ｒ／ｚ））・ｃｏｓψ，Ｇ（Ｔａｎ$^{-1}$（Ｒ／ｚ））・ｓｉｎψ）と表すことができるので、上記と同様にｚ、ψの値を変えながら対応するＰ2、Ｐ1 の画素位置を求めることが可能である。

【００３１】例えば、魚眼レンズとして一般的によく用いられるｈ＝ｆ・θの特性をもつものを使用する場合は、パラメータをθ，ψとすると、P1 は（ｆ・θ・ｃｏｓψ，ｆ・θ・ｓｉｎψ）となり、パラメータをｚ，ψとすると、P1 は（ｆ・Ｇ（Ｔａｎ$^{-1}$（Ｒ／ｚ）・ｃｏｓψ，ｆ・Ｇ（Ｔａｎ$^{-1}$（Ｒ／ｚ）・ｓｉｎψ）として上記と同様な変換を行えば足りる。なお、Ｔａｎ$^{-1}$（Ｒ／ｚ）は公知の回帰計算により求めることができる。

【００３２】さらに、上記実施の形態において魚眼レンズ１１としてｈ＝ｆ・θの特性をもつ魚眼レンズに置き換え、他の構成部分はそのままのものを用いることも可能である。これは、上記式① の特性をもつ魚眼レンズで得られる円形画像とｈ＝ｆ・θの特性をもつ魚眼レンズ円形画像とでは、半径方向の像の伸縮率が異なるが画素同士の隣接関係は変わらないので、得られる画像はｚ方向に多少の伸縮の違いがでるだけで監視用の画像としての役割を果たすことはできるからである。

【００３３】このことをさらに一般化すると、０＜Θ＜π／２の範囲で単調増加関数となるｇ（Θ）を用いて、P1 を（ｇ（Θ）・ｃｏｓψ，ｇ（Θ）・ｓｉｎψ）とすれば、種々の魚眼レンズに対して、ｚ方向に伸縮率が異なるだけの画像が表示されることになる。そして、関数ｇ（Θ）として、使用する魚眼レンズの特性に応じて最もｚ方向の歪みが少なくなるようなものを用いることで、より監視用の画像として見やすいものを得ることも可能となる。

【００３４】それから、上記実施の形態における撮像システムは魚眼レンズ１１が撮影した周囲３６０度すべての画像を変換して表示するようにしたが、例えば、カメラ部１を天井の壁際に設置したような場合は壁方向を除いた１８０度部分を変換して表示すれば足り、カメラ部１をコーナー部分に設置したような場合はコーナーを挟む壁方向を除いた９０度部分を変換して表示すれば足りる。このように、状況に応じて、変換する範囲は任意に決めることができる。

【００３５】また、上記実施の形態における撮像システムでは、０≦θ＜π／４の範囲は表示されてないが、この範囲はもとの円形画像における歪みが少ないので、モニター７に円形画像のまま変換せずに上記円筒面Cの画像と合わせて表示するようにしてもよい。

【図面の簡単な説明】

【図１】実施の形態に係る撮像システムの構成を示すブロック図である。

【図２】魚眼レンズにより撮影された全周面を仮想的に想定した半球面上の点と変換する円筒面上の点との関係を示す図である。

【図３】魚眼レンズにより撮影された全周面を仮想的に想定した半球面上の点に対応する撮影面上の点を示す図である。

【図４】展開した円筒面を示す図である。

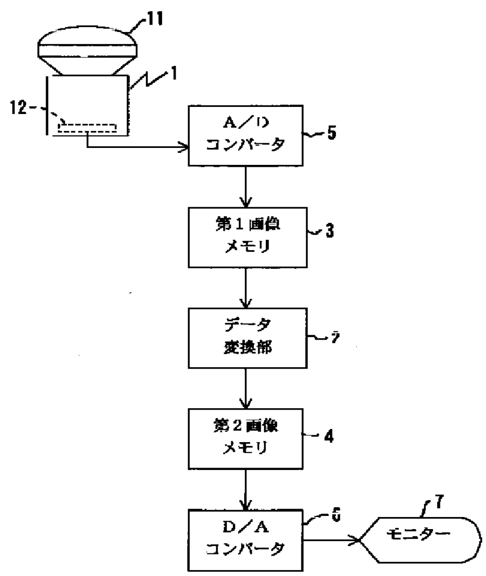
【図５】撮像システムの動作を示すフローチャートである。

【図６】モニターによる表示画面を示す図である。

【符号の説明】

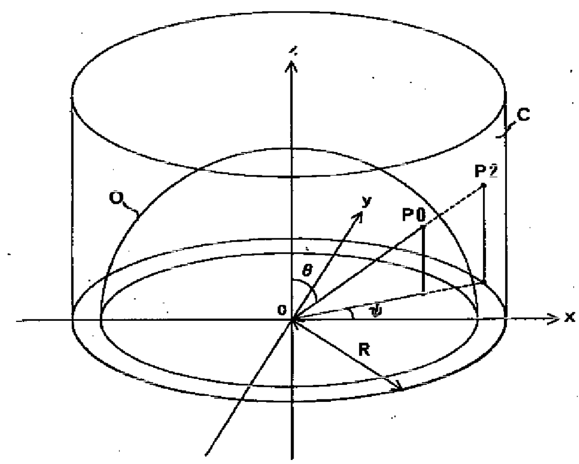
１　カメラ部
２　データ変換部
３　第１画像メモリ
４　第２画像メモリ
５　A／Dコンバータ
６　D／Aコンバータ
７　モニター
１１　魚眼レンズ
１２　ＣＣＤ

【図1】



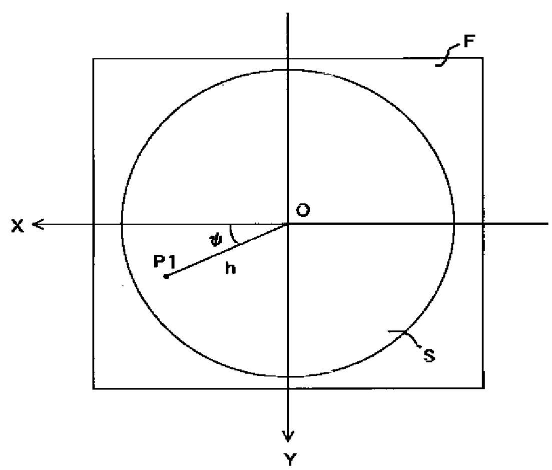
11
1
12
A／D
コンバータ
5
第１画像
メモリ
3
データ
変換部
第２画像
メモリ
4
D／A
コンバータ
6
モニター
7

【図2】



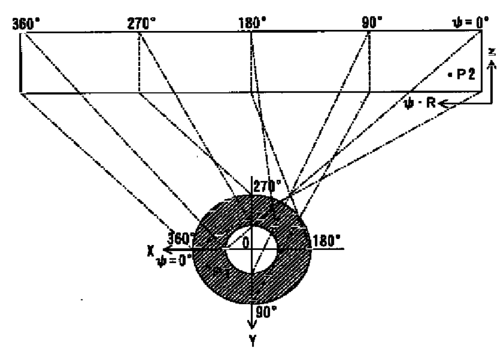
z
C
P2
O
y
P0
θ
o
ψ
x
R

【図3】



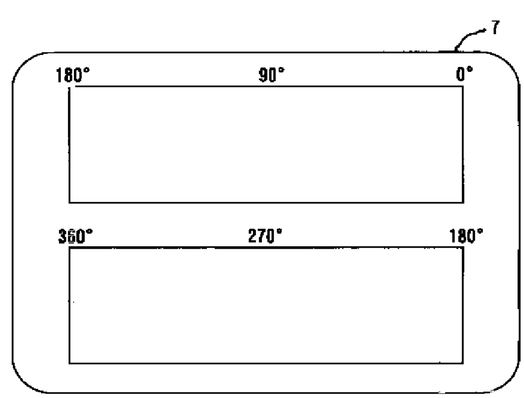
F
X
O
ψ
P1
h
S
Y

【図4】



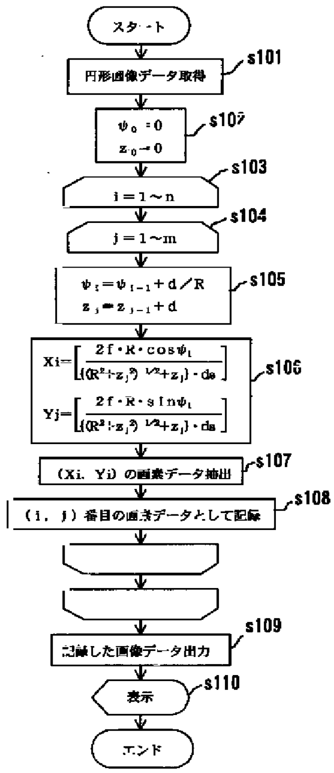
360°
270°
180°
90°
ψ=0°
z
P2
ψ·R
270°
360°
0
180°
X
ψ=0°
90°
Y

【図6】



7
180°
90°
0°
360°
270°
180°

【図5】



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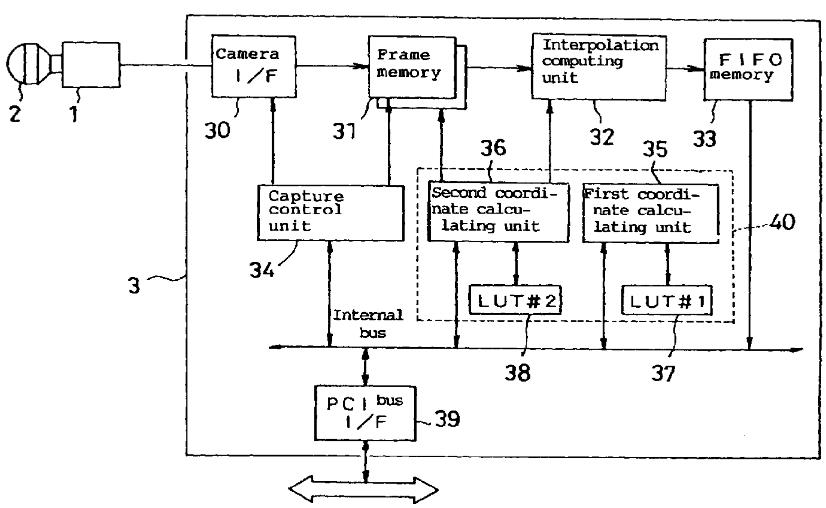
(54) **Arithmetic unit for image transformation**

(57) An arithmetic unit for image transformation is disclosed for transforming a fisheye image obtained by using a fisheye lens (2) into a plane image for display, comprising: a first coordinate calculating unit (35) for obtaining first projection coordinates derived by projecting coordinates on the plane image onto a fisheye image face as an imaginary object face; and a second coordinate calculating unit (36) for obtaining second projection coordinates derived by projecting the first projection coordinates obtained by the first coordinate calculating unit (35) onto the fisheye image face.

FIG. 4



EP 1 028 389 A2

Description

BACKGROUND OF THE INVENTION

1. Field of the Invention

[0001] The present invention relates to an arithmetic unit for image transformation and a monitoring system. More particularly, the invention relates to an arithmetic unit for image transformation for transforming an image obtained by using a fisheye lens into a plane image for display and a monitoring system having the arithmetic unit.

2. Description of the Related Art

[0002] An arithmetic unit for image transformation is used in, for example, a monitoring system using a monitoring camera. The operator monitors the state in a space (for example, shop) in which the monitoring camera is installed, by watching images from the monitoring camera displayed on a monitor provided for the monitoring system. When a lens attached to the camera is an ordinary standard lens, the space can be monitored only within the range of the angle of view of the standard lens. In order to monitor the entire space in which the camera is installed, it is necessary to provide a mechanism for properly changing the orientation of the camera. In case of providing such a mechanism, the cost increases and the camera has to be remote controlled. It consequently becomes hard for the operator to handle it.

[0003] There is an idea such that a fisheye lens having the wide angle of view is attached to the camera and monitoring is performed by using the fisheye lens. An image produced by the fisheye lens is, however, distorted as compared with an image obtained by using the standard lens and is very hard for the operator to watch it. A technique for transforming an image produced by the fisheye lens into a plane image is disclosed as a camera orientation system in WO92/21208.

[0004] The system transforms a circular image obtained by using the fisheye lens into an image produced by a normal image pickup lens (for example, standard lens) by an arithmetic process and a plane image seen from an arbitrary view point can be obtained. In this case, when a high speed arithmetic unit is used, plane image data can be obtained at real time rates only by software. In most of the cases, it takes long time for a communicating process, operation as a human interface, and the like in a terminal device connected to a network. It is therefore preferable to realize a part in which the same process is repeated in an image transforming process, by hardware.

[0005] Since the projecting method (stereoscopic projection, equidistant projection, orthogonal projection, or the like) of projecting a fisheye lens image onto an image pickup device (such as CCD) provided for the camera is determined at the time of designing, by executing arithmetic computations according to mathematical expressions by hardware, the image can be transformed to a plane image.

[0006] As disclosed in WO92/21208, however, when calculations upon transformation are expressed by mathematical equations and executed according to the mathematical equations by hardware, it is necessary to realize many calculations of not only addition, subtraction, multiplication, and division, but also square root, trigonometric function, and the like by the hardware. The unit consequently cannot help becoming expensive inevitably.

[0007] The invention has been achieved in consideration of the actual condition of the conventional technique and it is an object of the invention to provide an arithmetic unit for image transformation capable of providing inexpensive hardware for transforming a fisheye image obtained by using a fisheye lens into a plane image for display.

SUMMARY OF THE INVENTION

[0008] In order to achieve the object, an arithmetic unit for image transformation according to the invention, for transforming a fisheye image obtained by using a fisheye lens into a plane image for display, comprises:

> a first coordinate calculating unit for obtaining first projection coordinates on a fisheye image face as an imaginary object face derived by projecting coordinates on the plane image; and
> a second coordinate calculating unit for obtaining second projection coordinates derived by projecting the first projection coordinates obtained by the first coordinate calculating unit onto the fisheye image face.

[0009] The action of the configuration is as follows:

> Step 1. The first projection coordinates on the fisheye image face as an imaginary object face obtained by projecting coordinates on the plane image are derived by the first coordinate calculating unit; and
> Step 2. The second projection coordinates obtained by projecting the first coordinates onto the fisheye image face are derived.

[0010] That is, when an image is transformed, the coordinate calculations are not performed by mathematical equations at once but are executed by stages. Consequently, the calculating unit can be constructed by combining simple arithmetic circuits and the hardware part in the arithmetic unit for image transformation can be realized at low cost.

[0011] As a preferred embodiment of the invention, a logic circuit for arithmetic operation has a pipelined architecture in each of the first and second coordinate calculating units.

[0012] By making the logic circuit have the pipelined architecture, the coordinate transformation can be sequentially performed by stages and the circuit configuration can be partially simplified. As a result, the hardware part in the arithmetic unit for image transformation can be realized at low cost.

[0013] As another preferred embodiment of the invention, the logic circuit for arithmetic operation is limited to calculations of addition, subtraction, multiplication, and square root, and division and other function calculations are handled by referring to a lookup table.

[0014] In case of executing the calculations according to the equations by the hardware, it is necessary to realize many arithmetic operations such as addition, subtraction, multiplication, and division, and in addition, square root, trigonometric function, and the like by hardware. It is consequently necessary to use a large-scale circuit part. Especially, depending on the projecting method of the fisheye lens, there may be a case such that approximation occurs by trigonometric function or infinite polynomial. The logic circuit for arithmetic operation is consequently limited to addition, subtraction, multiplication, and square root. With respect to a part expressed by division or other function, a lookup table is referred to. Consequently, the hardware can be simplified and it can contribute to reduce the cost of the arithmetic unit for image transformation.

[0015] According to further another preferred embodiment of the invention, the second coordinate calculating unit is used to obtain the second projection coordinates by multiplying the first projection coordinates by a predetermined coefficient and the predetermined coefficient is obtained from the lookup table.

[0016] When the projecting method of the fisheye lens differs, the coefficient becomes different. Only by changing data in the lookup table, the invention can deal with a different projecting method and it is unnecessary to replace the hardware part. The cost of the hardware part in the arithmetic unit for image transformation can be therefore reduced also with respect to the point.

[0017] A monitoring system according to the invention is characterized by comprising the arithmetic unit for image transformation. According to the arithmetic unit for image transformation, the arithmetic unit can be constructed by combining simple arithmetic circuits and the cost of the hardware part in the arithmetic unit for image transformation can be reduced, so that an inexpensive monitoring system can be provided.

BRIEF DESCRIPTION OF THE DRAWINGS

[0018]

Fig. 1 is a diagram showing setting of a coordinate system;

Fig. 2 is a diagram for explaining a correction coefficient k_1;

Fig. 3 is a diagram for explaining a procedure of transforming coordinates by hardware; and

Fig. 4 is a block diagram of circuits mounted on a PCI bus substrate.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

[0019] A preferred embodiment of an arithmetic unit for image transformation according to the invention will be described in detail with reference to the drawings.

〈Positional relation of coordinate system〉

[0020] Referring to Fig. 1, the positional relation of coordinates to be transformed will be described. The coordinate system will be set as follows. As a space for showing the position of an object, an (X, Y, Z) coordinate space in which the position of a fisheye lens is the origin and the direction of the optical axis is the Z axis is set. The azimuth (φ) and the zenithal angle (θ) are set as parameters indicating the position of the object seen from the origin.

[0021] Since the position on an image pickup device (such as CCD), of an object whose image is obtained through the fisheye lens is determined at an angle seen through the fisheye lens, it is assumed that the object is positioned on the surface of a hemisphere of radius of 1. The hemispherical face is called an imaginary object face.

[0022] A plane image to be obtained is shown by an (u, v) coordinate system in Fig. 1. It is assumed that the center (origin) of the (u, v) coordinate system is in the position apart from the origin of the (X, Y, Z) coordinate system by distance 1 and is in contact with the hemispherical face as the imaginary object face. The plane expressed by the (u, v) coordinate system is made correspond to pixels of a display image on a monitor. The angle between the u axis of the coordinate system and the (X, Y) plane, that is, the angle formed by an intersecting line of a plane which passes the origin of the (u, v) coordinate system and is in parallel with the (X, Y) plane and the (u, v) plane and the u axis is set as (α).

[0023] A plane image (fisheye image) obtained through the fisheye lens is expressed by a (p, q) coordinate system as shown in Fig. 1. It is assumed that the (p, q) coordinate system is parallel to the (X, Y) plane and has the origin on the Z axis. In a position on an image pickup face (for example, position of a pixel on a CCD image pickup device), the image circle diameter differs according to the size of the image pickup device and the focal distance of the fisheye lens. Consequently, it is assumed that a fisheye image is projected in a circle of radius 1 of an image of an object positioning at 90 degrees (Z = 0) from the front of the lens. At the time of actually use, magnification adjustment is performed.

[0024] An image is transformed as follows. The projecting position on the image pickup face (p, q coordinates) of a point (u, v coordinates) on a plane image is obtained by arithmetic operation. By referring to luminance information at the point, data of the plane image to be obtained can be generated. Information of the view points (φ, θ, α) and the scale factor (zoom ratio) as the size of the plane image is information inputted by the operator through a keyboard, pointing device, or the like and is obtained and set in advance as data for calculation by a higher-order arithmetic processing unit.

[0025] Necessary parameters are, as shown in Figs. 1 and 2, (X_0, Y_0, Z_0) indicative of the center (origin) of a plane image and change amounts ∂ux, ∂vx, ∂uy, ∂vy, ∂uz, ∂vz in the respective axes of the (X, Y, Z) coordinates when a point is moved in the respective directions on the (u, v) coordinate system by an amount of one pixel (corresponding to one pixel on the monitor screen).

[0026] The parameters can be easily obtained from the information of the angle information (φ, θ, α) of the view point and the magnification of the image.

〈Calculating procedure for image transformation〉

[0027] A calculating procedure for image transformation will now be described with reference to Fig. 3. The calculating procedure is performed by, broadly, two steps of first and second steps.

Step 1

[0028] First, the coordinates of a point P' (first projection coordinates) on the hemispherical face as an imaginary object face, which is a projection of a point P on a plane image (the u, v coordinates) are obtained.

[0029] When it is assumed that the (X, Y, Z) coordinates of the point P are (X_1, Y_1, Z_1) and the (u, v) coordinates are (u_1, v_1), the following are given.

$$X_1 = X_0 + u_1 \cdot \partial ux + v_1 \cdot \partial vx$$

$$Y_1 = Y_0 + u_1 \cdot \partial uy + v_1 \cdot \partial vy$$

$$Z_1 = Z_0 + u_1 \cdot \partial uz + v_1 \cdot \partial vz$$

[0030] As clearly shown in Fig. 2, the point P' is on the line connecting O and P. When a coefficient is set to k_1, the following relation is satisfied.

$$(X_2, Y_2, Z_2) = k_1 \cdot (X_1, Y_1, Z_1)$$

[0031] The distance between the origin of the (X, Y, Z) coordinate system and the point P' expressed by the coordinates (X_2, Y_2, Z_2) is 1. The distance between the origin (X_0, Y_0, Z_0) of the (u, v) coordinate system and the point P' expressed by the coordinates (X_2, Y_2, Z_2) is 1. The distance L from the origin of the (u, v) coordinate system to the point P is obtained as follows.

$$L = (u^2 + v^2)^{0.5}$$

[0032] When the distance L is determined, k_1 is constant. Consequently, a table of k_1 with respect to the distance L is formed as a lookup table and multiplication by k_1 obtained from the lookup table is executed, thereby enabling (X_2, Y_2, Z_2) to be obtained as follows (refer to Fig. 3).

$$X_2 = k_1 \cdot X_1$$

$$Y_2 = k_1 \cdot Y_1$$

$$Z_2 = k_1 \cdot Z_1$$

In this manner, the first projection coordinates on the hemispherical face are determined.

Step 2

[0033] As a second step of the calculation, a procedure of obtaining second projection coordinates w(p_1, q_1) on a fisheye image face from the first projection coordinates (X_2, Y_2, Z_2) determined (refer to Fig. 1 with respect to w) will be explained.

[0034] As described above, since the point P' is on the surface of the hemisphere of radius of 1, the zenithal angle (θ_1) is unconditionally determined from the value of Z_2 (refer to Fig. 1 with respect to θ_1). The following equation (1) is therefore derived.

$$\theta_1 = \cos^{-1}(Z_2) \qquad (1)$$

[0035] Since the azimuth of the point w on the image pickup face and that of the point P' on the hemispherical face are the same, the following equation (2) is satisfied.

$$(p_1, q_1) = k_2 \cdot (X_2, Y_2) \qquad (2)$$

[0036] Since the height (h) from the origin on the fisheye image face (origin of the p, q coordinate system) to the point w is expressed as a function of θ_1 according to the fisheye image projecting method, the following equation (3) is satisfied.

$$h = F(\theta_1) \qquad (3)$$

[0037] Some examples of specific functions of $F(\theta_1)$ according to the projecting method will be shown. When it is assumed that the focal distance of the fisheye lens is f, the following relations are established.

equidistant projection: $h = f \cdot \theta$

stereoscopic projection: $h = 2f \cdot \tan(\theta/2)$

[0038] When the equation (1) is substituted for the equation (3), the following equation (4) is given. h can be expressed as a function determined by Z_2.

$$h = F(\cos^{-1}(Z_2)) \quad (4)$$

[0039] With respect to the distance r from the origin of the (X, Y, Z) coordinate system to the point Q obtained by projecting the point P' onto the (X, Y) plane, since the point P' is a point on the surface of the hemisphere of radius of 1, the following equation (5) is satisfied.

$$r = (1 - {Z_2}^2)^{0.5} \quad (5)$$

[0040] The following equation (6) is therefore given from the equations (4) and (5).

$$k_2 = h/r$$
$$= F(\cos^{-1}(Z_2))/(1 - {Z_2}^2)^{0.5} \quad (6)$$

[0041] That is, the coefficient k_2 of the equation (2) can be derived as a function of Z_2. With respect to the coefficient k_2, a lookup table for obtaining the coefficient k_2 from the value of Z_2 in accordance with the equation (3) is generated. By using the value, second projection coordinates (p_1, q_1) on the image pickup face are obtained as follows.

$$p_1 = k_2 \cdot X_2$$

$$q_1 = k_2 \cdot Y_2$$

[0042] As described above, in the first step for image transformation, calculation is limited to addition, subtraction, multiplication, and square root, and the other functions are obtained from the lookup table. The calculation in the second step is limited to multiplication and the other calculation of functions and the like is handled by referring to the lookup table. By executing the calculations in accordance with the steps, a simple arithmetic circuit (logic circuit such as an adder) can have a pipelined architecture. The circuit scale of the part of the complicated function calculation is suppressed by using the lookup table. Further, by changing the table for obtaining k_2 in the second step, a fisheye lens of a different projecting method can be dealt with easily, moreover, by the same arithmetic circuit.

〈Example of circuit configuration〉

[0043] A specific circuit block configuration will now be described with reference to Fig. 4. The configuration relates to an example of a substrate which is configured for a computer system having a PCI (Peripheral Component Interconnect) bus.

[0044] A fisheye lens 2 is attached to a CCD camera 1 and image information obtained by the CCD camera 1 is sent to a PCI bus substrate 3 and subjected to processes for image transformation. The PCI bus substrate 3 comprises: a camera interface 30 for obtaining fisheye image data from a CCD provided for the CCD camera 1; a frame memory 31 for storing fisheye image data of one frame; an interpolation computing unit 32 for executing an interpolating computation on the basis of the calculation result of an operation part 40; an FIFO memory 33; a capture control unit 34 for controlling capture of the fisheye image data to the frame memory 31; the operation part 40 (part surrounded by a broken line) having the configuration which characterizes the invention; and a PCI bus interface 39 for sending plane image data obtained by the coordinate transformation.

[0045] The operation part 40 comprises a first coordinate calculating unit 35, a second coordinate calculating unit 36, a first lookup table 37 connected to the first coordinate calculating unit 35, and a second lookup table 38 connected to the second coordinate calculating unit 36. Further description will be given in relation to the coordinate transforming procedure. The first coordinate calculating unit 35 is a part of executing the calculation of the first step shown in Fig. 3 and can obtain the first projection coordinates (X_2, Y_2, Z_2) on the hemispherical face from the (u, v) coordinates in the plane image. The first lookup table 37 is a table for obtaining the correction coefficient k_1 from the distance L.

[0046] The second coordinate calculating unit 36 is a part of executing the calculation of the second step in Fig. 3 and can obtain the second projection coordinates (p_1, q_1) on the fisheye image face from the first projection coordinates (X_2, Y_2, Z_2) derived by the first coordinate calculating unit 35. The second lookup table 38 is a table for obtaining the correction coefficient k_2.

〈Description of circuit operation〉

[0047] The operation of the circuit shown in Fig. 4 will now be described.

[0048] Fisheye image data obtained by the CCD camera 1 is written into the frame memory 31 via the camera interface 30. Since the coordinates (p, q) on the image pickup face corresponding to the coordinates (u, v) on the display screen are obtained in the operation part 40, image data corresponding to the coordinates (p, q) sequentially designated by the operation part 40 is read from the frame memory 31 and is sent to the interpolation computing unit 32.

[0049] Strictly, the position of a pixel on the fisheye image does not coincide with a pixel on the plane image to be displayed on the monitor. Plural data of pixels nearby is consequently read from the frame memory 31 and interpolation is performed by obtaining a weighted mean of the data, thereby enabling a natural plane image to be obtained.

[0050] The interpolated image data is subjected to speed adjustment by the FIFO memory and resultant data is transferred to a memory on the host computer side via the PCI bus interface 39. In case of the example of the configuration of Fig. 4, since the processes such as coordinate calculation and interpolating calculation can be executed by a middle-scale FPGA (or gate array), the hardware can be constructed relatively cheap.

Claims

1. An arithmetic unit for image transformation for transforming a fisheye image obtained by using a fisheye lens (2) into a plane image for display, characterized by comprising:

   - a first coordinate calculating unit (35) for obtaining first projection coordinates derived by projecting coordinates on the plane image onto a fisheye image face as an imaginary object face; and
   - a second coordinate calculating unit (36) for obtaining second projection coordinates derived by projecting the first projection coordinates obtained by the first coordinate calculating unit (35) onto the fisheye image face.

2. The arithmetic unit according to claim 1, characterized in that a logic circuit for arithmetic operation has a pipelined architecture in each of the first and second coordinate calculating units (35, 36).

3. The arithmetic unit according to claim 2, characterized in that the logic circuit for arithmetic operation is limited to calculations of addition, subtraction, multiplication, and square root, and division and other function calculations are handled by referring to a lookup table (37, 38).

4. The arithmetic unit according to claim 3, characterized in that the second coordinate calculating unit (36) is used to obtain the second projection coordinates by multiplying the first projection coordinates by a predetermined coefficient (k1) and the predetermined coefficient (k1) is obtained from a lookup table (38).

5. A monitoring system comprising

   - a CCD camera (1) to which a fisheye lens (2) is attached and
   - a Peripheral Component Interconnect (PCI) bus substrate (3) having an arithmetic unit for image transformation for transforming a fisheye image obtained by using the fisheye lens (2) into a plane image for display,
   characterized in that the arithmetic unit for image transformation comprises:
   - a first coordinate calculating unit (35) for obtaining first projection coordinates derived by projecting coordinates on the plane image onto a fisheye image face as an imaginary object face; and
   - a second coordinate calculating unit (36) for obtaining second projection coordinates derived by projecting the first projection coordinates obtained by the first coordinate calculating unit (35) onto the fisheye image face.

6. The monitoring system according to claim 5, characterized in that a logic circuit for arithmetic operation has a pipelined architecture in each of the first and second coordinate calculating units (35, 36).

7. The monitoring system according to claim 6, characterized in that the logic circuit for arithmetic operation is limited to calculations of addition, subtraction, multiplication, and square root, and division and other function calculations are performed by referring to a lookup table (37, 38).

8. The monitoring system according to claim 7, characterized in that the second coordinate calculating unit (36) is used to obtain the second projection coordinates by multiplying the first projection coordinates by a predetermined coefficient (k1) and the predetermined coefficient (k1) is obtained from a lookup table (38).

FIG.1

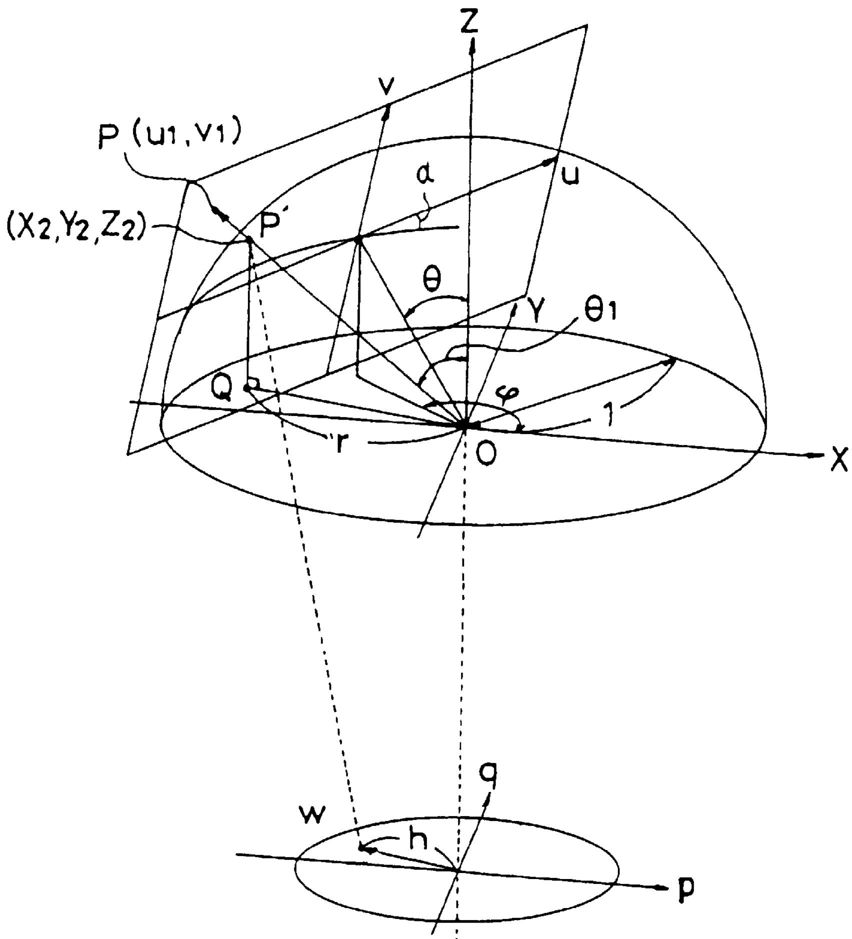


FIG. 2

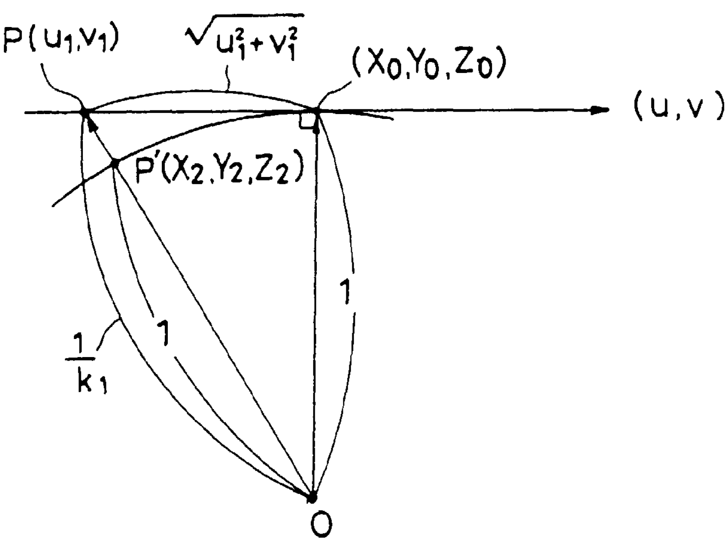
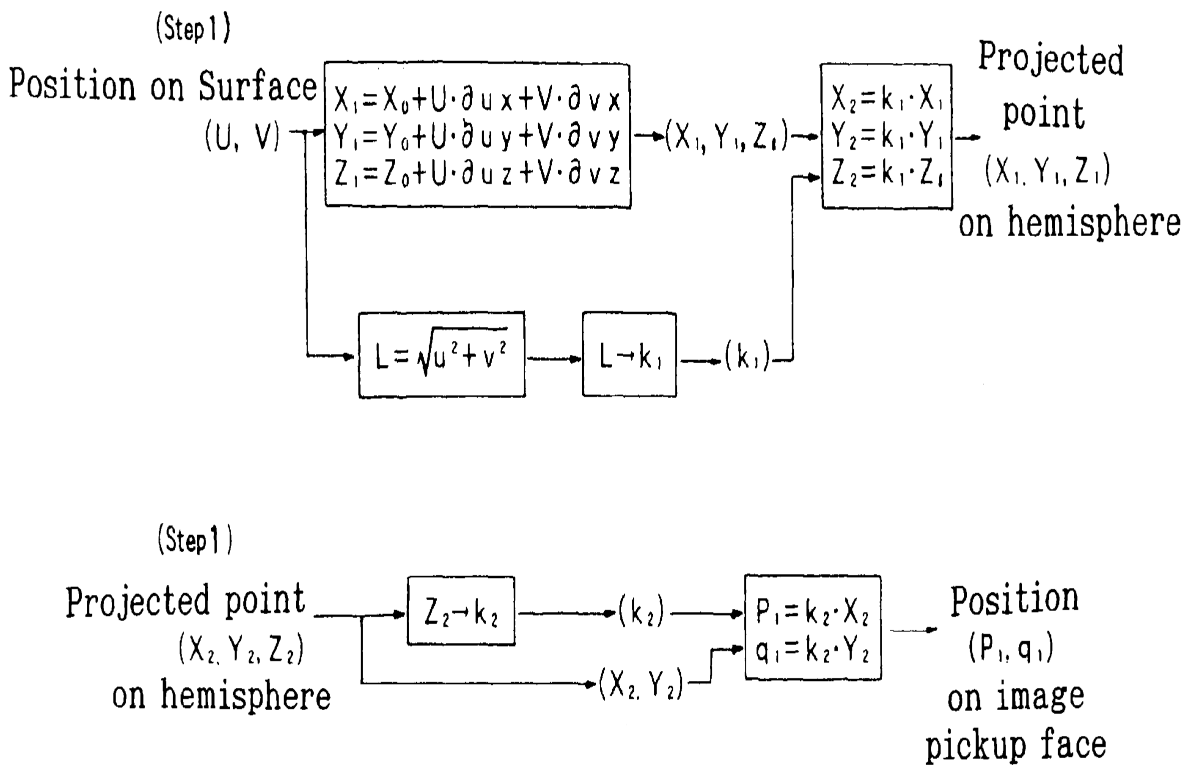


FIG. 3



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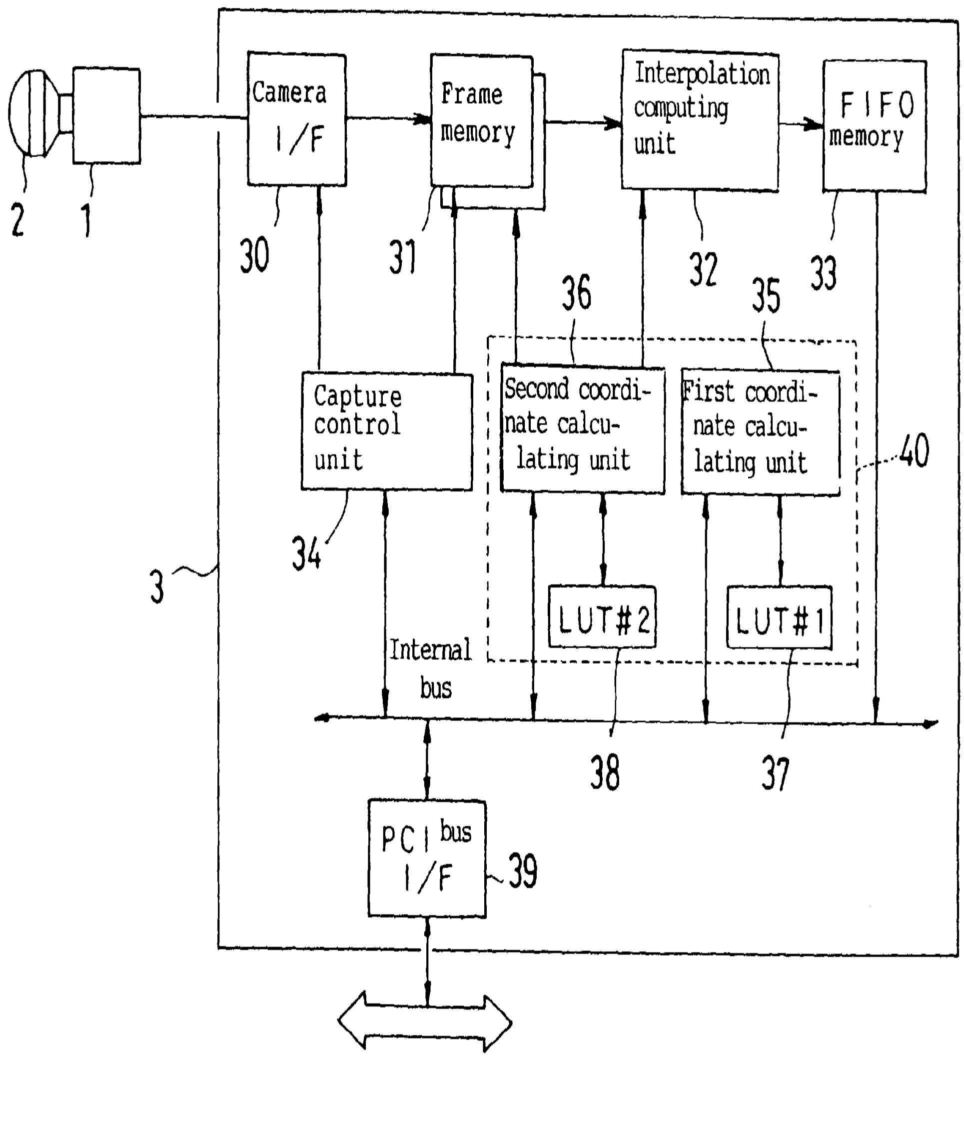
EP 1 028 389 A2

FIG. 4



Camera I/F
Frame memory
Interpolation computing unit
FIFO memory
Capture control unit
Second coordinate calculating unit
First coordinate calculating unit
LUT#2
LUT#1
Internal bus
PCI bus I/F
2
1
30
31
32
33
36
35
34
40
3
38
37
39

EXHIBIT 4

United States Patent [19]

Fisher et al.

[11] **3,953,111**

[45] **Apr. 27, 1976**

[54] **NON-LINEAR LENS**

[75] Inventors: **Ralph W. Fisher**, St. Charles; **George Licis**, Manchester; **Wayne W. Schurter**, Bridgeton, all of Mo.

[73] Assignee: **McDonnell Douglas Corporation**, St. Louis, Mo.

[22] Filed: **Nov. 4, 1974**

[21] Appl. No.: **520,487**

[52] **U.S. Cl.** **350/189**; 350/181
[51] **Int. Cl.²** **B29D 13/18**; G02B 13/08
[58] **Field of Search** 350/189, 192, 198, 175, 350/181

[56] **References Cited**

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Primary Examiner—John K. Corbin
Assistant Examiner—Conrad Clark
Attorney, Agent, or Firm—Graveley, Lieder & Woodruff

[57] **ABSTRACT**

A non-linear lens possesses distortion characteristics which are such that objects along the optical axis of the lens occupy disproportionately large areas of the image cast by the lens, whereas objects near the periphery of the field of view occupy a disproportionately small area of the image. The distortion characteristics approximate the formula $H=\sin^{1/3}\theta$ where H is height measured from the optical axis and θ is the angle measured from the optical axis. The image cast by the lens falls on the vidicon of a television camera where it is scanned and transmitted to a projector. Since the lens enlarges objects in the vicinity of the optical axis, those objects are transmitted with much greater detail than objects in the peripheral region of the view. The transmitted image is reproduced at a projector and the reproduced image is rectified through another lens having identical distortion characteristics. This lens casts the rectified image on a spherical screen. The final image which appears on the screen possesses a high degree of acuity in the region of the optical axis and substantially less acuity in peripheral regions. The resolution throughout the entire field of the reproduced image corresponds quite closely to the resolution characteristics of the human eye.

10 Claims, 7 Drawing Figures

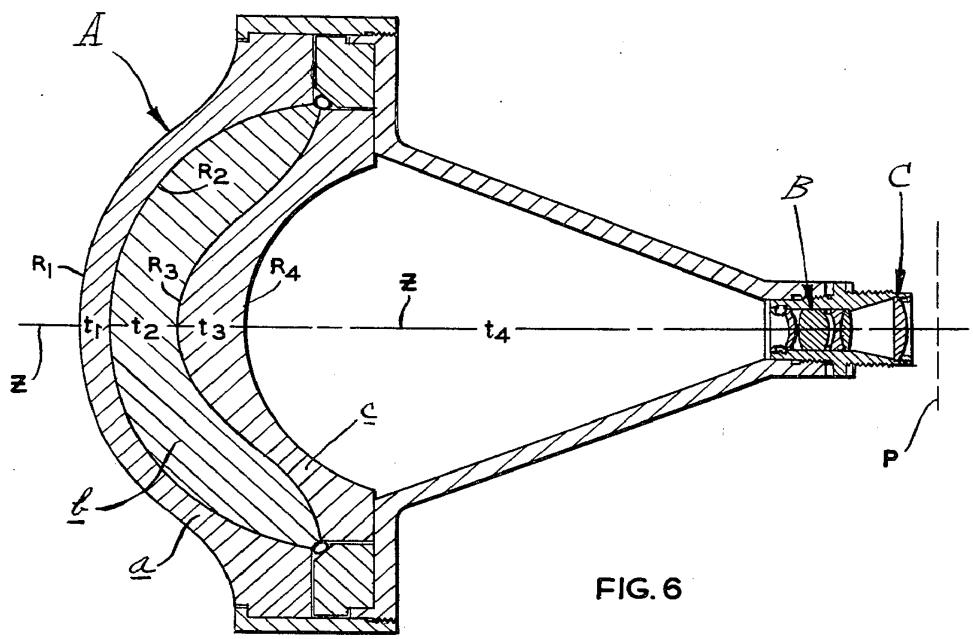

FIG. 6

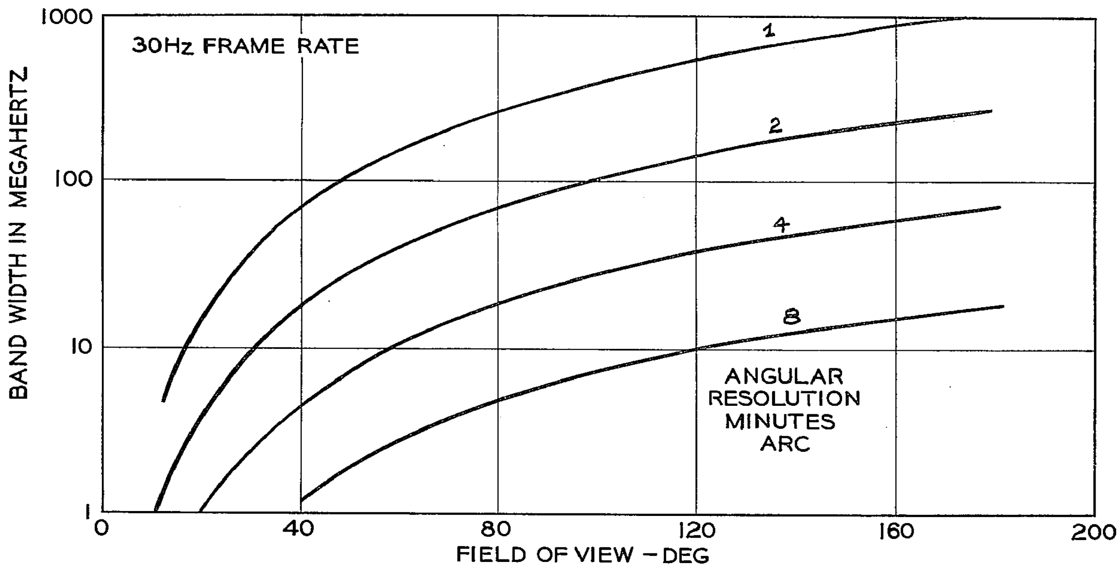

FIG. 1

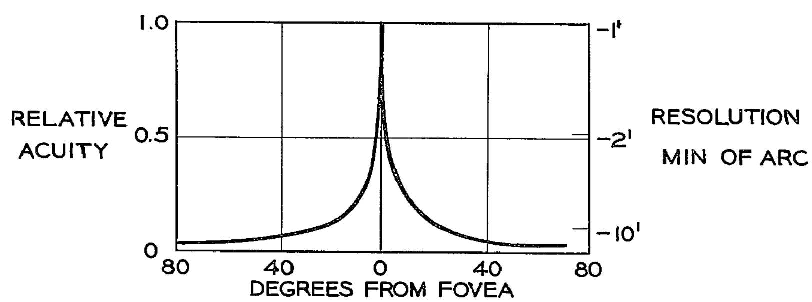

FIG. 2

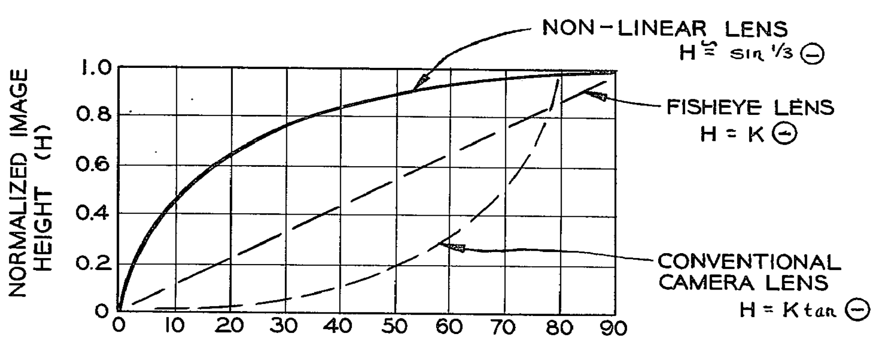

FIG. 3

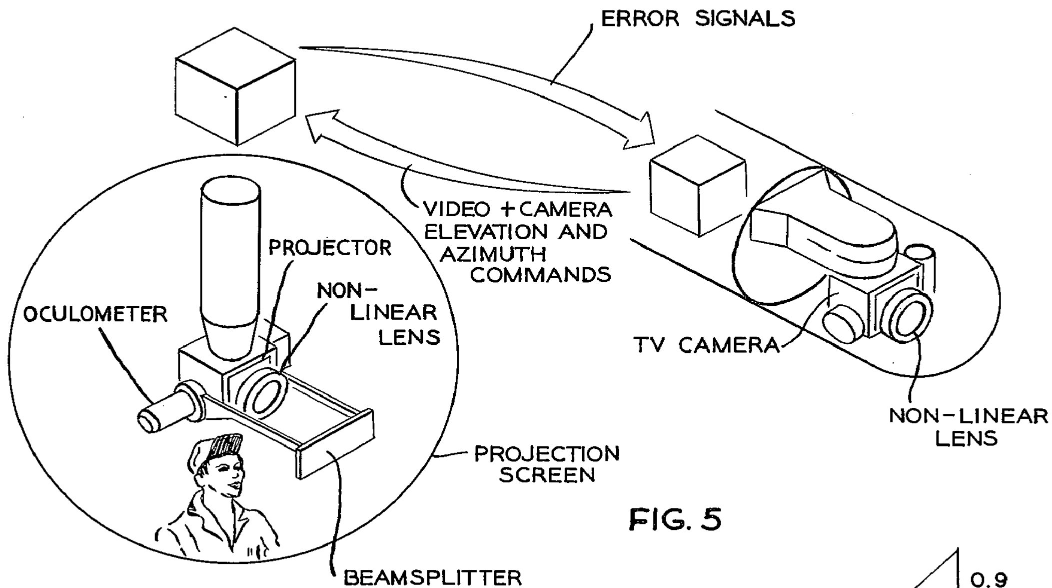
ERROR SIGNALS
VIDEO + CAMERA ELEVATION AND AZIMUTH COMMANDS
PROJECTOR
NON-LINEAR LENS
OCULOMETER
TV CAMERA
NON-LINEAR LENS
PROJECTION SCREEN
BEAMSPLITTER

FIG. 5

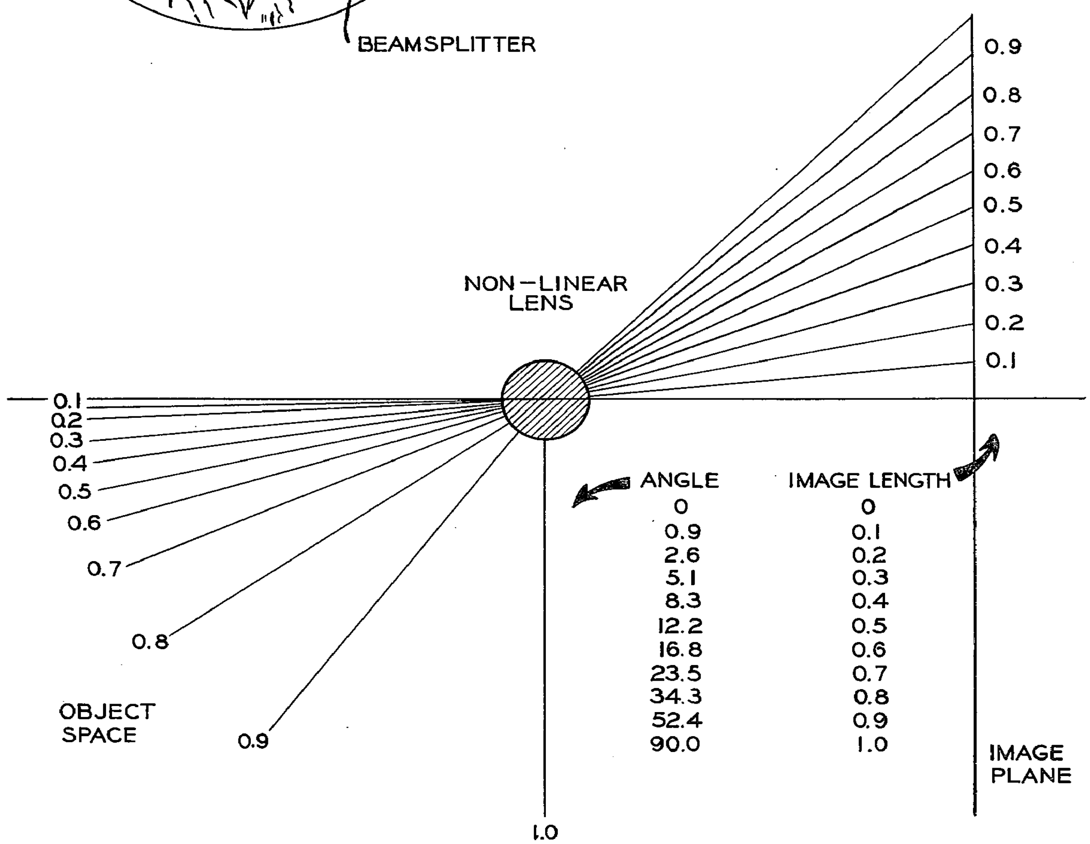
NON-LINEAR LENS
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
OBJECT SPACE
1.0
ANGLE
0
0.9
2.6
5.1
8.3
12.2
16.8
23.5
34.3
52.4
90.0
IMAGE LENGTH
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1.0
IMAGE PLANE

FIG. 4

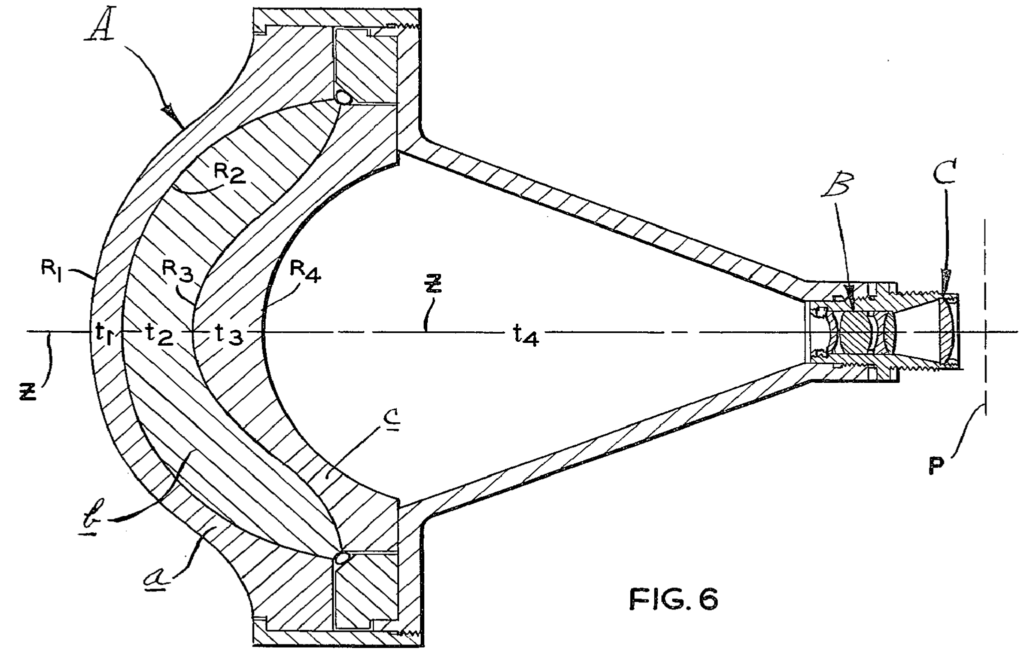
A
R2
B
C
R1
R3
R4
Z
t1
t2
t3
t4
Z
c
P
b
a

FIG. 6

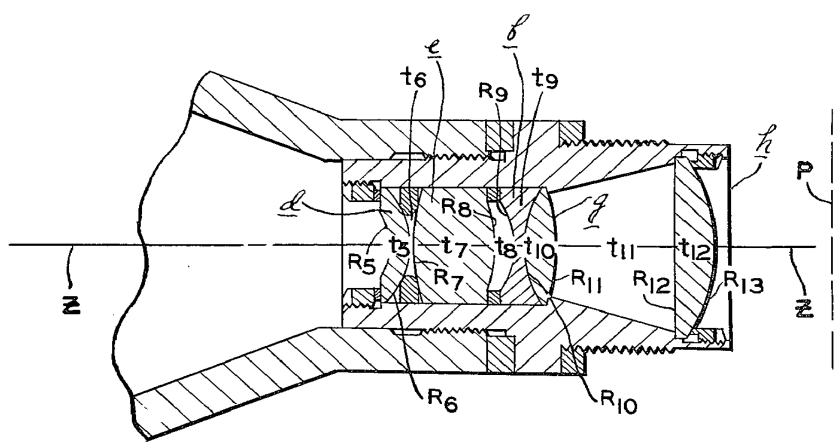
e
f
t6
R9
t9
h
P
d
R8
g
t5
t7
t8
t10
t11
t12
R5
R7
R11
R12
R13
Z
Z
R6
R10

FIG. 7

NON-LINEAR LENS

The Government has rights in this invention pursuant to Contract Number N00014-73-C-0154 awarded by the Department of the Navy.

BACKGROUND OF THE INVENTION

The present invention relates in general to lenses and more particularly to a lens having non-linear distortion characteristics.

The typical remote viewing system utilizes a television camera at the remote location, some type of projector at the observer location, and a television transmitting system linking the two. These viewing systems fall far short of duplicating the visual characteristis of the human eye in that they have extremely limited fields of view or else poor resolution in a large field of view.

In particular, for any fixed angular resolution (measured in minutes of arc) and frame rate (usually 30 Hz or frames/sec.) a definite relationship exists between field of view and bandwidth for transmitting that field of view. For example, commercial television, which utilizes a 525 line raster traced 30 times per second, operates on a bandwidth of 3.93 MHz. To match the resolution of the human eye, which is one minute of arc along its foveal or optical axis, the field of view for commercial television must be restricted to less than 10° (see FIG. 1). On the other hand, if the field of view is increased to about 180°, which is the field of view for the human eye, the bandwidth must be increased to 1000 Mhz to maintain one minute of arc resolution over the entire field. This demands a raster of 10,000 lines and is far in excess of the capabilities of current television systems.

Indeed, the most advanced television currently available utilizes an 875 line system and requires a bandwidth of 10.9 Mhz. This provides a field of view of about 20° with one minute arc resolution throughout the entire field, which is far less than the 180° field of view possessed by the human eye.

From the foregoing, it is clear that present television viewing systems present a dilemma. If the field of view is sufficient to encompass all possible locations of interest, resolution is so low that detection or clear observation is impossible. On the other hand, if the resolution is adequate to insure that the objects will be seen clearly, the field of view is quite limited and many objects of interest are located outside of the field of view.

In a sense the human eye provides a solution for the foregoing dilemma. The human eye possesses high optical acuity along and in the vicinity of its foveal or optical axis, but the acuity diminishes outwardly therefrom. In other words, the eye distinguishes fine detail directly in front of it, but not to the sides. This characteristic is not derived from the shape of the eye lens, but instead results from the fact that most of the optical fibers for the eye are concentrated in the vicinity of the optical axis. Hence, only along the optical axis does the eye possess one minute of arc resolution. The resolution becomes progressively less toward the periphery of the field of vision (see FIG. 2). Nevertheless, the resolution in the peripheral area is sufficient to detect the presence of many objects in that area as well as much movement in that area. Of course, when the eye detects anything of interest in the peripheral areas, the head or eye is immediately moved to bring the foveal axis to the thing of interest and thereby provide a clearer image of it.

SUMMARY OF THE INVENTION

One of the principal objects of the present invention is to provide a lens having non-linear distortion characteristics which are such that objects located along and near the optical axis of the lens occupy a disproportionately large area of the image produced by the lens. Another object is to provide a lens of the type stated which closely approximates the resolution characteristics of the human eye over a wide field of view. A further object is to provide a lens of the type stated which is ideally suited for use in remote viewing systems in that it provides a wide field of view with maximum acuity along the optical axis. These and other objects and advantages will become apparent hereinafter.

The present invention is embodied in a lens which distorts a field of view such that objects in the vicinity of the optical axis occupy a disproportionately large area of the image cast by the lens and objects in the peripheral region of the field of view occupy a disproportionately small area of the image. The invention also consists in the parts and in the arrangements and combinations of parts hereinafter described and claimed.

DESCRIPTION OF THE DRAWINGS

In the accompanying drawings which form part of the specification and wherein like numerals and letters refer to like parts wherever they occur:

FIG. 1 is a graph showing the relationship between field of view, angular resolution, and bandwidth for transmitting a picture of a remote location by television;

FIG. 2 is a graph showing relative acuity of the human eye throughout the field of view for the eye;

FIG. 3 is a graph showing the distortion characteristics of the lens of the present invention in terms of normalized image height and field of view and comparing such distortion characteristics with the distortion characteristics of a fisheye lens and a conventional camera lens;

FIG. 4 is a graphic representation of the non-linear distortion characteristics and showing how equal increments on the image plane correspond to unequal increments in the field of view;

FIG. 5 is a schematic perspective view of the remote viewing system in which the non-linear lens may be utilized;

FIG. 6 is a sectional view of the non-linear lens; and

FIG. 7 is an enlarged sectional view of the second and third lens groupings for the non-linear lens.

DETAILED DESCRIPTION

The lens of the present invention (FIGS. 6 and 7) provides non-linear image distortion characteristics over an extremely wide field of view which approaches 160°. This is in contrast to so-called fisheye lenses which provide linear distortion characteristics. In paticular, with a linear or fisheye lens the image height is directly proportional to the field angle (FIG. 3). The relationship is defined by the formula $H=K\,\theta$ where H is the image height from the optical axis, K is a constant, and θ is the angle measured from the optical axis. Thus, with a linear lens an object occupying twice the angle as another object, when measured from the optical axis, will cast an image twice as high as the other object. On the other hand, with a non-linear lens of the present invention the image height is equal to a variable function of the field angle (FIG. 3). The relationship is approximated by the formula $H = \sin^{1/3}\theta$. Thus, objects centered along the optical axis of the non-linear lens L cast a much larger image than objects located near the periphery of the field of view with the size diminishing as the angle from the optical axis increases. The result of the distortion is that objects along the optical axis occupy a disproportionately large share of the image cast by the lens when compared with other objects closer to the periphery of the field of view for the lens. In effect, the center of the non-linear lens is a telephoto lens, while the periphery of the lens amounts to a wide angle lens with the annular region between the center and periphery varying from telephoto to wide angle. Naturally, the image produced is quite distorted. The typical camera lens is represented by the formula $H = K \tan\theta$ (FIG. 3) and is non-linear, but in a sense opposite from that of the lens of the present invention.

The non-linear transfer characteristics of the lens may be illustrated by breaking the image into equal angular increments (FIG. 4) and comparing each image increment with the corresponding increment it represents in the actual field of view. Clearly, equal angular increments on the image side of the lens represent unequal increments on the object side of the lens. More specifically, near the optical axis relatively small arcs on the object side are converted to large arcs on the image side, thus enlarging the image. At about 25° from the optical axis arcs on the object side equal the arcs on the image side and this portion of the lens may be considered linear. Objects from about 25° to 80° (lens periphery) occupy arcs much larger than they cast on the image side with the variance in arcs becoming greater as the object approaches the periphery of the field. Hence, objects within 25° of the optical axis for the lens are magnified with the magnification being substantial along the lens axis, whereas objects in the annular region located beyond 25° are reduced in size, with the reduction becoming progressively greater as the maximum field angle for the lens is approached.

To appreciate the lens requires an understanding of the remote viewing system in which it is utilized. That viewing system basically comprises (FIG. 5) a television camera at the remote location, a projector at the observer location, and a transmission system linking the camera and projector in both directions. Both the camera and projector are fitted with non-linear lenses having identical distortion characteristics. However, the projector lens is mounted just the reverse of the camera lens so that it rectifies the distortion created by the camera lens. The camera is supported on a gimballed mount and is therefore capable of swinging both vertical and horizontal angles with respect to fixed coordinates at the remote location. A suitable servo mechanism bridges the gimballed mount to control the position of the camera. The projector is likewise supported on a gimballed mount which permits it to swing both vertical and horizontal angles with respect to fixed coordinates at the observer location. Another servo mechanism bridges the gimballed mount of the projector, and this servo is slaved to the camera through the transmission system such that a change in elevation or azimuth of the camera with respect to its fixed coordinates results in a corresponding change in elevation and azimuth of the projector with respect to its fixed coordinates.

The projector projects the transmitted image through its non-linear lens which casts the image upon a spherical screen surrounding the projector. The observer views the screen from the position of the projector.

Positioned on the projector is an oculometer which views the observer's eye through a transparent beamsplitter, and in effect tracks the observer's eye, producing error signals whenever the foveal axis of the eye deviates from the optical axis of the projector lens. In other words, error signals are produced when the foveal axis of the eye and the optical axis of the projector lens intersect the screen at different locations. These signals are converted into elevation and azimuth commands which are transmitted to the servo system for the camera through the transmission system. The commands cause the camera to change elevation and azimuth, and the movement is such that the corresponding movement of the projector reduces the error and brings the foveal axis of the camera back toward coincidence with the optical axis of the lens, at least at the screen. Thus, the oculometer controls the position of the camera and the camera controls the position of the projector, so in effect the camera and projector are both slaved to the observer's eye through the oculometer. The oculometer and servo mechanisms for the camera and projector should all respond fast enough to bring the optical axis of the projector lens into coincidence with, or at least within 2 percent of, the foveal axis for the eye within 0.2 seconds. This is about as rapidly as the eye can fixate and perceive when changing from one object of interest to another, so the lag in the projector is barely discernible, if at all. A suitable oculometer is marketed by Honeywell Inc., Radiation Center, Boston, Mass.

Referring again to the television camera at the remote location, the camera lens casts the distorted image of all objects in the field of view on the vidicon of the camera, and this vidicon is scanned in the usual manner, that is with a beam which traces a raster pattern at uniform velocity. The conventional commercial television system of 525 lines per scan and 30 scans per second may be employed. This requires a bandwidth of 3.93 MHz (FIG. 1). The beam in effect picks the image off of the camera vidicon. Since the objects along the optical axis are magnified and occupy a disproportionately large area of the vidicon, they are picked off the vidicon in great detail. On the other hand, objects in the peripheral region of the field of view are reduced in size and occupy relatively little area on the vidicon. Hence, they are picked off of the vidicon with substantially less detail. The picture is transmitted accordingly. The magnification along and near the optical axis is great enough to enable the beam to extract one minute of arc detail, which is all an eye with 20—20 vision can perceive along its foveal axis. The beam extracts greater angles of arc detail away from the optical axis and hence poorer resolution is available in this area. In this regard, it will be recalled that to extract one minute arc detail over a full 180° requires a 10,000 line vidicon or in other words a bandwidth of 1000 MHz which is far in excess of present television capabilities.

The distorted image cast upon the vidicon of the camera is reproduced by the light valve of the projector and this image likewise has at least one minute of arc resolution along the optical axis with the resolution diminishing toward the periphery of the image so that only much larger angles of arc are discernible beyond the optical axis. The image so produced is rectified by the projector lens which casts it upon the spherical screen. The resulting screen image constitutes a faithful reproduction of the scene which lies within the field of view for the camera lens. The projector lens in no way affects the resolution of the image it transmits and as a result the image appearing on the screen shows detail as close as one minute of arc at the optical axis for the lens and the area immediately surrounding it, but in the remaining area such detail is not available. In other words, the resolution in the other areas is somewhat less. Hence, the projected image is very sharp and clear on the screen at the optical axis, that is directly in front of the projector, and then turns somewhat fuzzy or blurred in the surrounding area particularly at the maximum angle of 80° from the optical axis.

The variance in clarity or in resolution of the final image cast upon the screen closely resembles the optical characteristics of the eye (FIG. 2). In this connection, it will be recalled that most of the optical sensing elements for the human eye are concentrated along the foveal axis.

As previously mentioned, the oculometer tracks the eye position and causes the camera to change position in response to eye movement while the projector undergoes corresponding movement as a result of being slaved to the camera. Consequently, the foveal or optical axis of the eye is always directed at the center of the projected image, that is the portion along the optical axis for the projector lens. This is the portion having the one minute of arc resolution. Since the resolution of the eye falls off with the angle from the foveal axis, little is lost by having the resolution of the projected image diminish with the angle from the optical axis. The resolution in the surrounding area of the picture is still good enough to permit the eye, as a result of the built-in peripheral vision, to detect movement and objects of interest, and if whatever is detected appears interesting enough, the viewer will turn his eye toward it. This, of course, causes the camera and projector to change position so that the formerly blurred area of the image to which the eye is turned lies along the optical axis of the camera and projector lenses and is projected with high resolution.

The non-linear lens (FIGS. 6 and 7) has three lens sets or groupings A, B and C. Its aperture ratio is 5.6 and it forms a 0.358 F diameter image where F is the focal length along the optical axis Z. The first lens grouping A is considerably larger than the other grouping B and C and is contained in the large end of a tapered lens housing. The other lens groupings B and C are contained within a subhousing which fits into the small end of the tapered main housing. The first lens grouping is a triplet and provides the mapping function, that is the unique distortion which is essentially defined by the formula $H = \sin^{1/3}\theta$. The second grouping B, which has four elements, contains the aperture stop and forms an image of the scene as distorted by the first grouping A. The third grouping C is a single element which functions as a field flatener, that is it makes the image cast by the second grouping B planar.

The first lens grouping A (FIG. 6) consists of three lens elements *a*, *b*, and *c* with no air gaps between adjacent elements. The outside lens element *a* has a non-spherical surface R_1 exposed outwardly and a spherical surface R_2 presented inwardly against a matching surface R_2 on the intermediate element *b*. The opposite surface R_3 of the intermediate element *b* is non-spherical and abuts a matching surface R_3 on the inside element *c*. The inside element *c* also has a spherical surface R_4 which faces the tapered interior of the housing 2 and is presented toward the second lens grouping B. Along the optical axis Z for the lens, the element *a* has a thickness t_1, the element *b* a thickness t_2, and the element *c* a thickness t_3. Index matching oil couples the matching surfaces R_2 of the lens elements *a* and *b* and the matching surfaces R_3 of the lens elements *b* and *c*. The outside and inside lens elements *a* and *c* are formed from type SK16 glass, whereas the intermediate lens element is formed from type F2 glass. The index of refraction for SK16 glass is 1.62041 and for F2 glass is 1.62004. The Abbe number for SK16 is 60.27 and for F2 is 36.25.

Turning now to the second lens grouping B, it consists of four lens elements, namely, a convex-concave lens element *d*, a double convex lens element *e*, a double concave lens element *f*, and a double convex lens element *g*, all arranged in that order from the first lens grouping A. The innermost lens element *d* has spherical surfaces R_5 and R_6 and a thickness t_5, along the optical axis Z. The next lens element *e* has spherical surfaces R_7 and R_8 and a thickness t_7 along the optical axis Z. Next, is the double concave lens element *f* having spherical surfaces R_9 and R_{10} and a thickness t_{10} along the optical axis Z. The surface R_{10} of the element *f* corresponds to and is against a matching surface R_{10} on the lens element *g* which has another spherical surface R_{11} presented toward the third lens grouping C. The surfaces R_6 and R_7 of the lens elements *d* and *e*, respectively, are separated by an air gap t_6 measured along the axis Z of the lens, while the surfaces R_8 and R_9 of the lens elements *e* and *f*, respectively, are separated by an air gap t_8 measured along the optical axis Z. The matching surfaces R_{10} of the lens element *f* and *g* are cemented. The lens elements *d* and *f* are formed from type F2 glass, while the lens elements *e* and *g* are formed from type SK16 glass.

The third lens grouping C contains a single lens element *h* having a non-spherical and non-planar surface R_{12} which is presented toward the second lens group B and a spherical surface R_{13} exposed outwardly. The lens element *h* has a thickness t_{12} along the optical axis Z and is made from the type SK16 glass.

The first and second lens groupings A and B are separated by an air gap t_4 which is measured from the surface R_4 to the surface R_5 along the axis Z of the lens. The second and third lens groupings B and C are separated by an air gap t_{11} which is the distance between the surfaces R_{11} and R_{12} measured along the optical axis Z.

The distorted image formed by the non-linear lens exists in an image plane *p* located beyond the third lens grouping C. The vidicon of the television camera should be at this plane *p*.

The surfaces R_2, R_4, R_5, R_6, R_7, R_8, R_9, R_{10}, R_{11} and R_{13} are all spherical and have their centers of curvature along the optical axis Z of the lens. The surfaces R_1, R_3, and R_{12}, while being curved, are not spherical. The radii of curvature for the surfaces R_1 through R_{13} follow:

	R_1	: 1.37F	(at optical axis only)
1.4F	$< R_2$	< 1.5 F	
	R_3	: 0.729F	(at optical axis only)
1.091F	$< R_4$	< 1.092F	
0.2373F	$< -R_5$	< 0.2376F	
0.272F	$< -R_6$	< 0.273F	
0.3936F	$< R_7$	< 0.3940F	
0.334F	$< -R_8$	< 0.335F	
0.2268F	$< -R_9$	< 0.2271F	

-continued

0.280F	$< R_{10}$	$< 0.285F$	
0.571F	$< -R_{11}$	$< 0.572F$	
	$-R_{12}$	: 0.314F	(at optical axis only)
0.4168F	$< -R_{13}$	$< 0.4173F$	

where F is the focal length of the lens along its optical axis Z. Note, that since the surfaces R_1, R_3 and R_{13} are not spherical, the radii of curvature listed above for those surfaces represents only radii along the optical axis Z of the lens.

The thicknesses of the various lens elements measured along the optical axis Z follow:

$0.199F < t_1 < 0.202F$
$0.399F < t_2 < 0.402F$
$0.399F < t_3 < 0.402F$
$0.047F < t_5 < 0.049F$
$0.186F < t_7 < 0.189F$
$0.019F < t_9 < 0.022F$
$0.06F < t_{10} < 0.07F$
$0.08F < t_{12} < 0.09F$

The thicknesses of the air gaps measured along the optical axis Z follow:

$3.248F < t_4 < 3.251F$
$0.0004F < t_6 < 0.0014F$
$0.266F < t_{11} < 0.267F$
$0.037F < t_8 < 0.041F$

As previously noted, the surfaces R_1, R_3, and R_{13} are neither spherical nor planar. Furthermore, not one of them fits any single known mathematical formula. They are defined in terms of splines, that is each surface is broken up into increments or intervals which are defined separately. The surfaces R_1, R_3 and R_{13} are considered spline surfaces and are defined by the following cubic spline equation:

$$S(\rho)=M_{i-1}\frac{(\rho_i-\rho)^3}{6\,h_i}+M_i\frac{(\rho-\rho_{i-1})^3}{6\,h_i}+\left(X_{i-1}-\frac{M_{i-1}h_i^2}{6}\right)\frac{(\rho_i-\rho)}{h_i}+\left(X_i-\frac{M_ih_i^2}{6}\right)(\rho-\rho_{i-1})$$

where

ρ_{i-1} = The value of the spline surface height at the start of the ith interval.

ρ_i = The value of the spline surface height at the end of the ith interval.

X_{i-1} = The value of the spline surface sag at the start of the ith interval.

X_i = The value of the spline surface sag at the end of the ith interval.

$h_i = \rho_i - \rho_{i-1}$ = The length of the ith interval.

M_{i-1} = The value of the slope derivative at the start of the ith interval.

M_i = The value of the slope derivative at the end of the ith interval.

ρ = The spline surface height (independent variable)

$S(\rho)$ = The spline surface sag as a function of height (dependent variable)

The slope of a spline surface element at a particular height (ρ) is given by

$$\text{Slope} = d\ S(\rho)/d\rho$$

The values of spline surface sag (X), spline surface height (ρ), and slope derivative (M) for various spline intervals **0**, **1**, **2**, etc. follow:

	Surface R_1	Surface R_3	Surface R_{12}
X(0)	0.0000000	0.0000000	0.0000000
X(1)	0.2108668	0.1795877	−0.0029324
X(2)	0.8554116	0.7202623	−0.0041130
X(3)	1.7838662	1.4361922	−0.0004761
X(4)	1.9775600	1.6027882	0.0065340
X(5)	—	—	0.0100000
X(6)	—	—	0.0100000
ρ(0)	0.0000000	0.0000000	0.0000000
ρ(1)	1.0780200	0.7222734	0.0825000
ρ(2)	2.1560400	1.4444546	0.1650000
ρ(3)	3.2340801	2.1668202	0.2475000
ρ(4)	3.6360801	2.4760010	0.3300000
ρ(5)	—	—	0.4010000
ρ(6)	—	—	0.5000000
M(0)	0.3644990	0.6859612	−1.5916510
M(1)	0.3596961	0.6935749	0.5983017
M(2)	0.4358774	0.6937277	0.7436587
M(3)	−0.6375478	−1.4543979	0.6856855
M(4)	−2.1376087	−0.6921574	−0.5200549
M(5)	—	—	0.0000000
M(6)	—	—	0.0000000

What is claimed is:

1. A non-linear lens comprising first lens means for distorting a scene in the field of view for the lens such that objects in the vicinity of the optical axis are given substantially greater prominence than objects in the peripheral region of the field of view, and second lens means for forming a real image of the scene as distorted by the first lens means, whereby objects in the vicinity of the optical axis will occupy a disproportionately large area of the real image and objects in peripheral regions of the scene will occupy a disproportionately small area of the real image.

2. A lens according to claim **1** wherein the field of view is at least approximately 160°.

3. A non-linear lens according to claim **1** and further characterized by third lens means for causing the real image formed by the second lens means to lie in a plane.

4. A non-linear lens according to claim **1** wherein the distortion in the real image approximates the formula

$$H=\sin^{1/3}\theta$$

where H is the distance in the image measured from the optical axis and θ is the angle measured from the optical axis.

5. A non-linear lens according to claim **1** wherein the first lens means comprises a plurality of individual lens elements and the second lens means includes a plurality of different lens elements.

6. A non-linear lens comprising a first lens grouping for distorting a scene in the field of view for the lens such that objects in the vicinity of the optical axis are given greater prominence than objects in the peripheral region of the field of view, the first lens grouping including first, second, and third lens elements, the first lens element having surfaces R_1 and R_2, the second lens element having surfaces R_2 and R_3, and the third lens element having surfaces R_3 and R_4, the surface R_2 of the first lens element matching the surface R_2 of the second lens element and being substantially in contact therewith, the surface R_3 of the second lens element matching the surface R_3 of the third lens element and being substantially in contact therewith, the surfaces R_1 and R_3 being curved at the optical axis and being non-spherical beyond the optical axis, the surfaces R_2 and R_4 being spherical substantially throughout, the radii of the surfaces along the optical axis being substantially as follows:

	R_1:		1.37	F
1.4F	$<R_2$	<	1.5	F
	R_3:		0.729	F
1.091F	$<R_4$	<	1.092	F

where F is the focal length of the lens along the optical axis of the lens; and a second lens grouping for forming a real image of the scene as distorted by the first grouping, whereby objects in the vicinity of the optical axis will occupy a disproportionately large area of the real image and objects in peripheral regions of the scene will occupy a disproportionately small area of the real image.

7. A lens according to claim **6** wherein the first, second, and third lens elements have thicknesses t_1, t_2 and t_3, respectively, along the optical axis of the lens and the thicknesses are as follows:

$0.199F<t_1<0.202F$

$0.399F<t_2<0.402F$

$0.399F<t_3<0.402F$.

8. A non-linear lens according to claim **6** wherein the non-spherical surfaces R_1 and R_3 are defined by the cubic spline equation

$$S(\rho)=M_{i-1}\frac{(\rho_i-\rho)^3}{6h_i}+M_i\frac{(\rho-\rho_{i-1})^3}{6h_i}+\left(X_{i-1}-\frac{M_{i-1}h_i^2}{6}\right)\frac{(\rho_i-\rho)}{h_i}+\left(X_i-\frac{M_ih_i^2}{6}\right)(\rho-\rho_{i-1})$$

where

i-1 = The value of the spline surface height at the start of the ith interval.

i = The value of the spline surface height at the end of the ith interval.

X_{i-1} = The value of the spline surface sag at the start of the ith interval.

X_i = The value of the spline surface sag at the end of the ith interval.

$h_i=\rho_i-\rho_{i-1}$ = The length of the ith interval.

M_{i-1} = The value of the slope derivative at the start of the ith interval.

M_i = The value of the slope derivative at the end of the ith interval.

ρ = The spline surface height (independent variable)

$S(\rho)$ = The spline surface sag as a function of height (dependent variable); and wherein the value for X at spline intervals **0**, **1**, **2**, etc. is

	Surface R_1	Surface R_3
X(0)	0.0000000	0.0000000
X(1)	0.2108668	0.1795877
X(2)	0.8554116	0.7202623
X(3)	1.7838662	1.4361922
X(4)	1.9775600	1.6027882;

wherein the value for ρ at spline intervals **0**, **1**, **2**, etc. is

ρ(0)	0.0000000	0.0000000
ρ(1)	1.0780200	0.7222734
ρ(2)	2.1560400	1.4444546
ρ(3)	3.2340801	2.1668202
ρ(4)	3.6360801	2.4760010;

and wherein the value for M at spline intervals **0**, **1**, **2**, etc. is

M(0)	0.3644990	0.6859612
M(1)	0.3596961	0.6935749
M(2)	0.4358774	0.6937277
M(3)	−0.6375478	−1.4543979
M(4)	−2.1376087	−0.6921574.

9. A non-linear lens according to claim **6** wherein the second lens grouping comprises a convex-concave first lens element, a double convex second lens element, a double concave third lens element, and a double convex fourth lens element, arranged in that order from the first lens grouping, the first lens element having a thickness t_5 along the optical axis and spherical surfaces R_5 and R_6, the second lens element having a thickness t_7 and spherical surfaces R_7 and R_8, the third lens element having a thickness **t9** and spherical surfaces R_9 and R_{10}, and the fourth lens element having a thickness t_{10} and spherical surfaces R_{10} and R_{11}, the surface R_{10} of the third lens element matching the surface R_{10} of the fourth lens element and being substantially in contact therewith, the surfaces R_6 and R_7 being separated by a distance t_6 along the optical axis and the surfaces R_8 and R_9 being separated by a distance t_8 along the optical axis; wherein the radii of curvature for the surfaces are:

$1.091F<R_4<1.092F$

$0.2373F<R_5<0.2376F$

$0.272F<R_6<0.273F$

$0.3936F<R_7<0.3940F$

$0.334F<R_8<0.335F$

$0.2268F<R_9<0.2271F$

$0.280F<R_{10}<0.285F$

$0.571F<R_{11}<0.572F$;

wherein the thicknesses of the lens elements along the optical axis are

$0.047F<t_5<0.049F$

$0.186F<t_7<0.189F$

$0.019F<t_9<0.022F$

$0.06F<t_{10}<0.07F$

$0.08F<t_{12}<0.09F$;

and wherein the spaces separating the lens elements are:

$0.0004F < t_6 < 0.0014F$

$0.037F < t_8 < 0.041F$

10. A non-linear lens according to claim **9** wherein the surface R_4 in the first lens grouping and the surface R_5 in the second lens grouping are separated by a distance t_4 which is greater than 3.248F and less than 3.251F.

* * * * *

EXHIBIT 3

US005686957A

United States Patent [19]

Baker

[11] **Patent Number: 5,686,957**

[45] **Date of Patent: Nov. 11, 1997**

[54] **TELECONFERENCING IMAGING SYSTEM WITH AUTOMATIC CAMERA STEERING**

[75] Inventor: **Robert G. Baker**, Delray Beach, Fla.

[73] Assignee: **International Business Machines Corporation**, Armonk, N.Y.

[21] Appl. No.: **496,742**

[22] Filed: **Jun. 30, 1995**

Related U.S. Application Data

[63] Continuation-in-part of Ser. No. 281,331, Jul. 27, 1994, Pat. No. 5,508,734.

[51] **Int. Cl.**^{6} **H04N 7/18**

[52] **U.S. Cl.** **348/36**; 348/15; 348/53; 348/214; 348/580

[58] **Field of Search** 348/15, 214, 36, 348/53, 580; H04N 7/18

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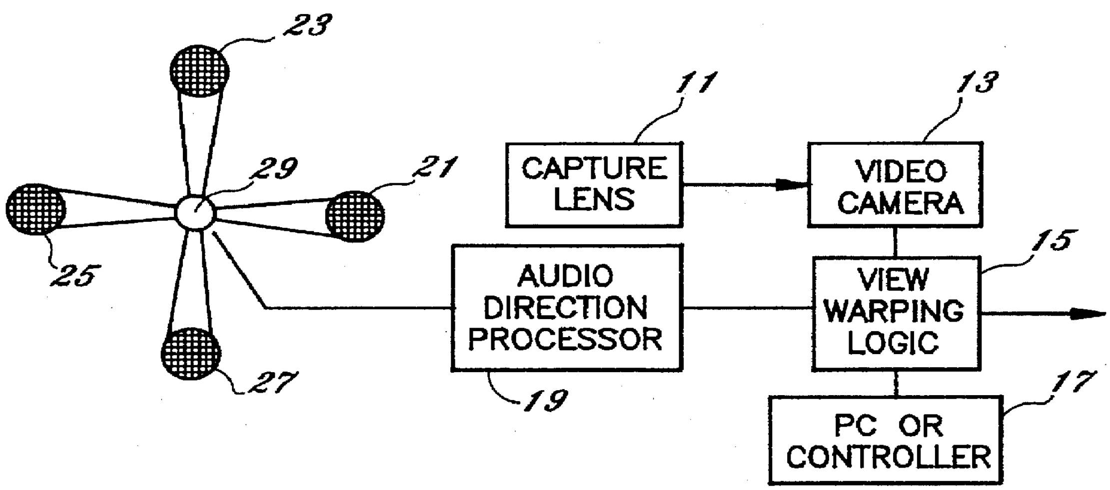
Primary Examiner—Howard W. Britton

Attorney, Agent, or Firm—Richard A. Tomlin; John C. Black; Malin, Haley, DiMaggio & Crosby, P.A.

[57] **ABSTRACT**

An automatic, voice-directional video camera image steering system specifically for use for teleconferencing that electronically selects segmented images from a selected panoramic video scene typically around a conference table so that the participant in the conference currently speaking will be the selected segmented image in the proper viewing aspect ratio, eliminating the need for manual camera movement or automated mechanical camera movement. The system includes an audio detection circuit from an array of microphones that can instantaneously determine the direction of a particular speaker and provide directional signals to a video camera and lens system that provides a panoramic display that can electronically select portions of that image and, through warping techniques, remove any distortion from the most significant portions of the image which lie from the horizon up to approximately 30 degrees in a hemispheric viewing area.

14 Claims, 7 Drawing Sheets



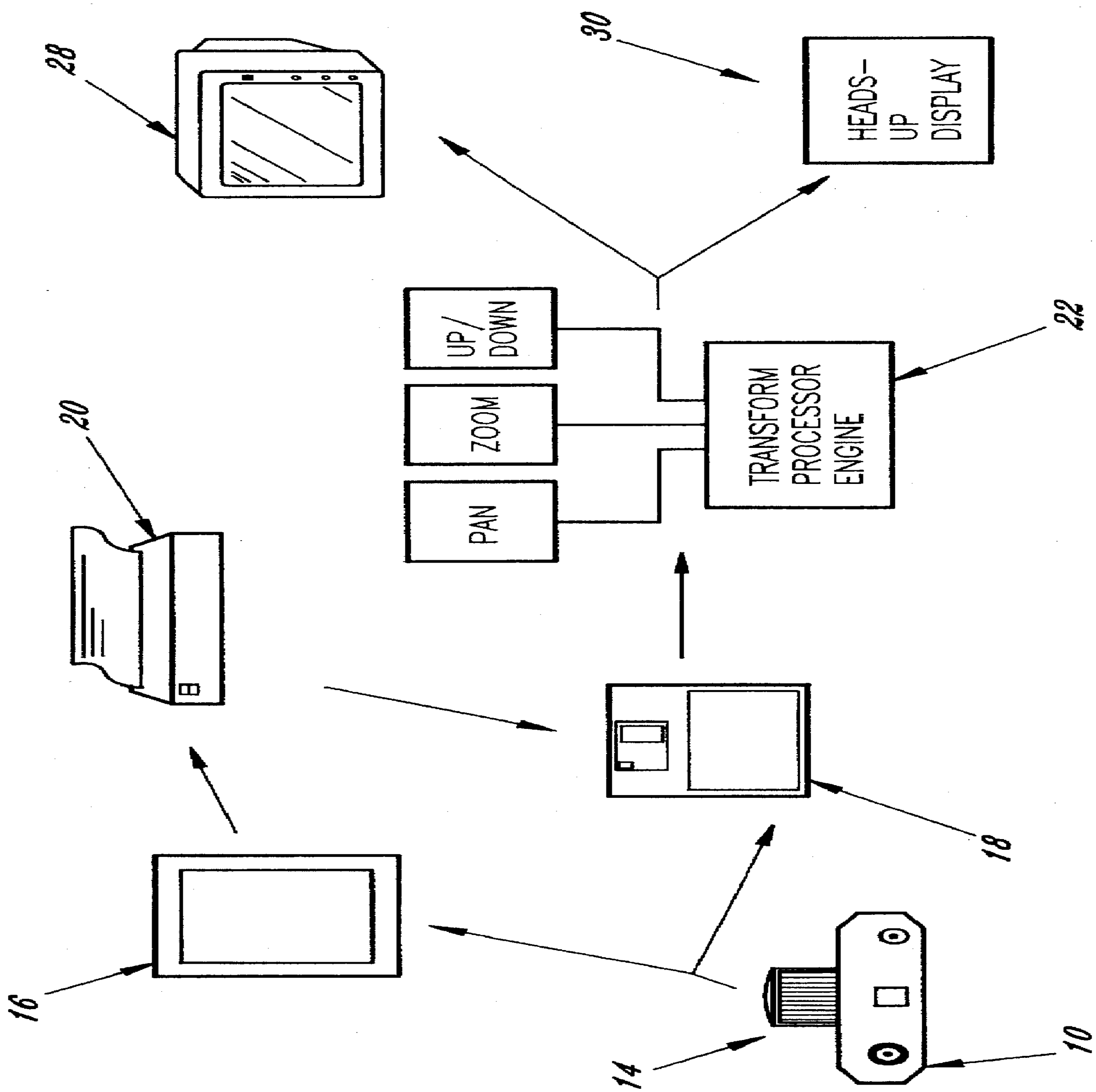

28
30
HEADS-
UP
DISPLAY
UP/
DOWN
ZOOM
PAN
TRANSFORM
PROCESSOR
ENGINE
22
20
18
16
14
10

Fig. 1

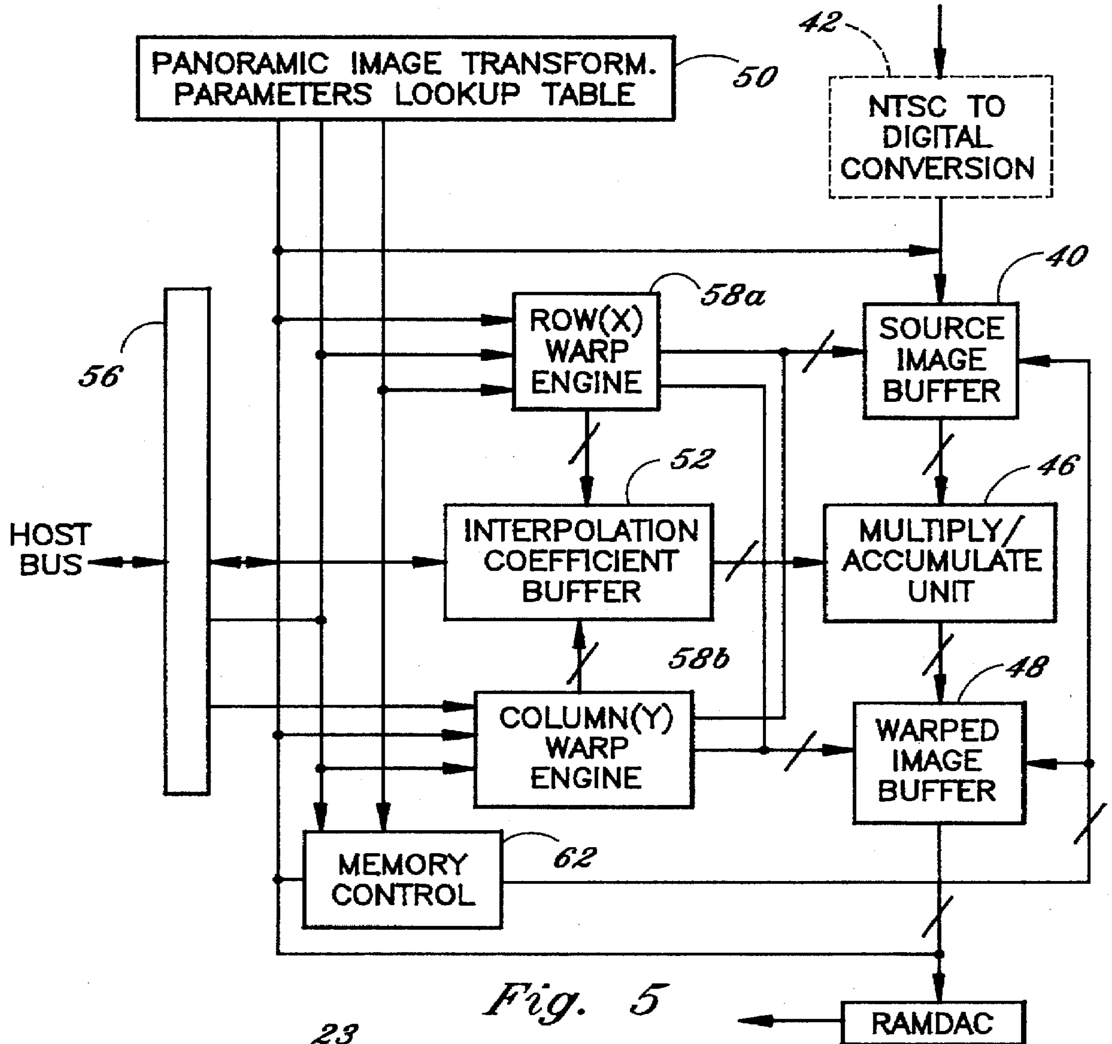

PANORAMIC IMAGE TRANSFORM. PARAMETERS LOOKUP TABLE
50
42
NTSC TO DIGITAL CONVERSION
40
58a
56
ROW(X) WARP ENGINE
SOURCE IMAGE BUFFER
52
46
HOST BUS
INTERPOLATION COEFFICIENT BUFFER
MULTIPLY/ ACCUMULATE UNIT
58b
48
COLUMN(Y) WARP ENGINE
WARPED IMAGE BUFFER
MEMORY CONTROL
62
RAMDAC

Fig. 5

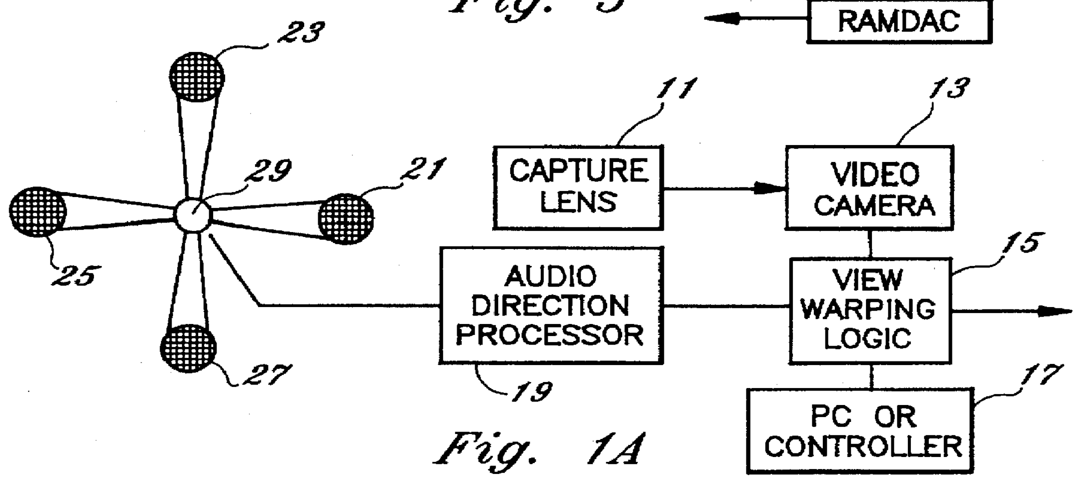

23
11
13
29
21
CAPTURE LENS
VIDEO CAMERA
15
25
AUDIO DIRECTION PROCESSOR
VIEW WARPING LOGIC
27
19
17
PC OR CONTROLLER

Fig. 1A

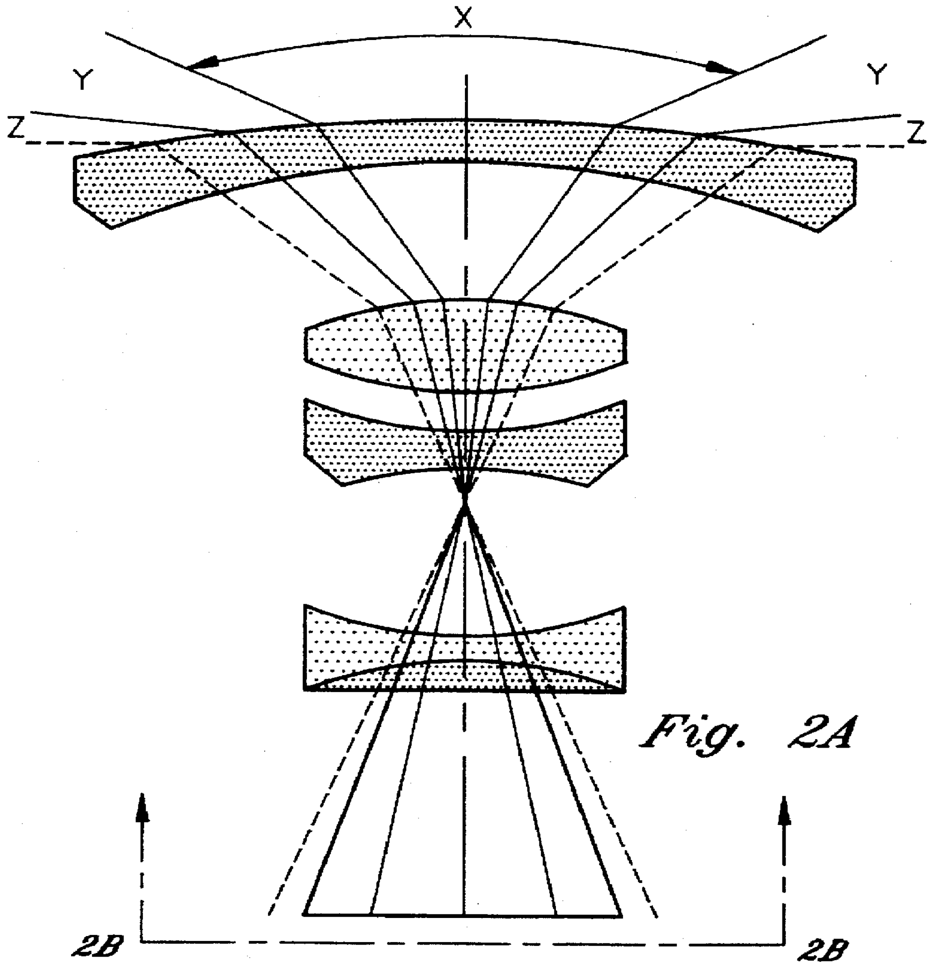


Fig. 2A

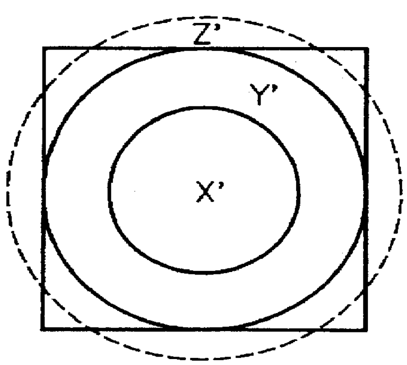


Fig. 2B

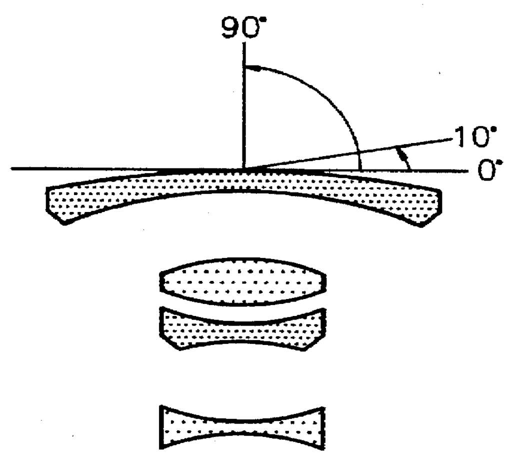


Fig. 2C

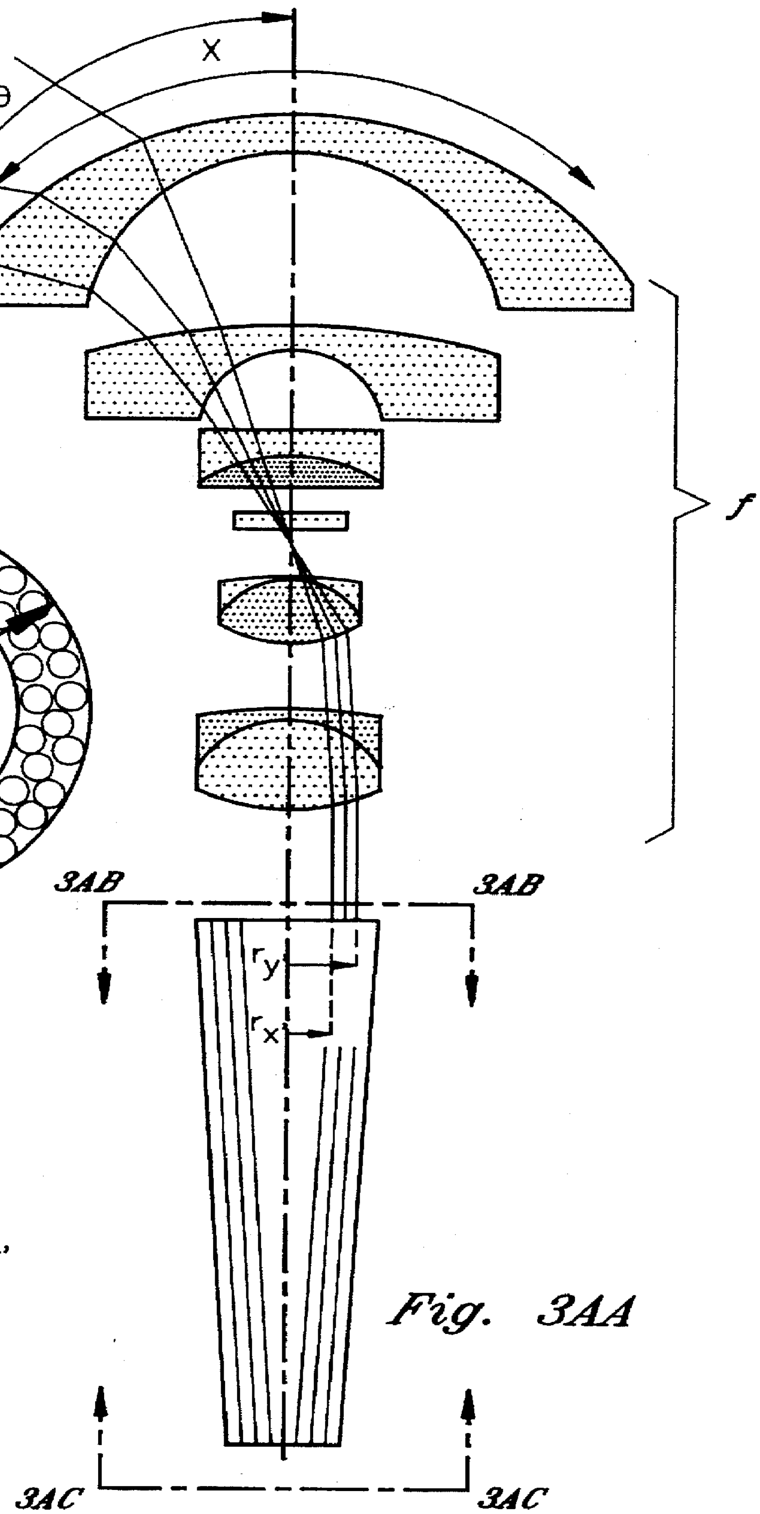


Fig. 3AA

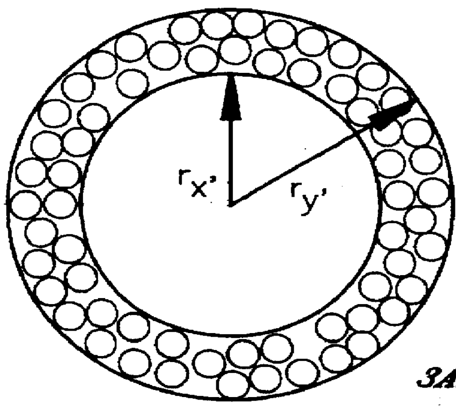


Fig. 3AB

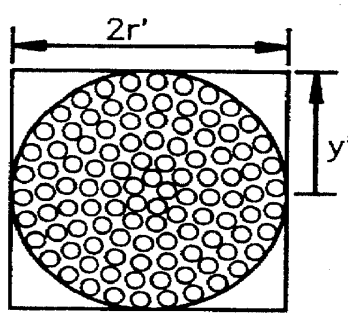


Fig. 3AC

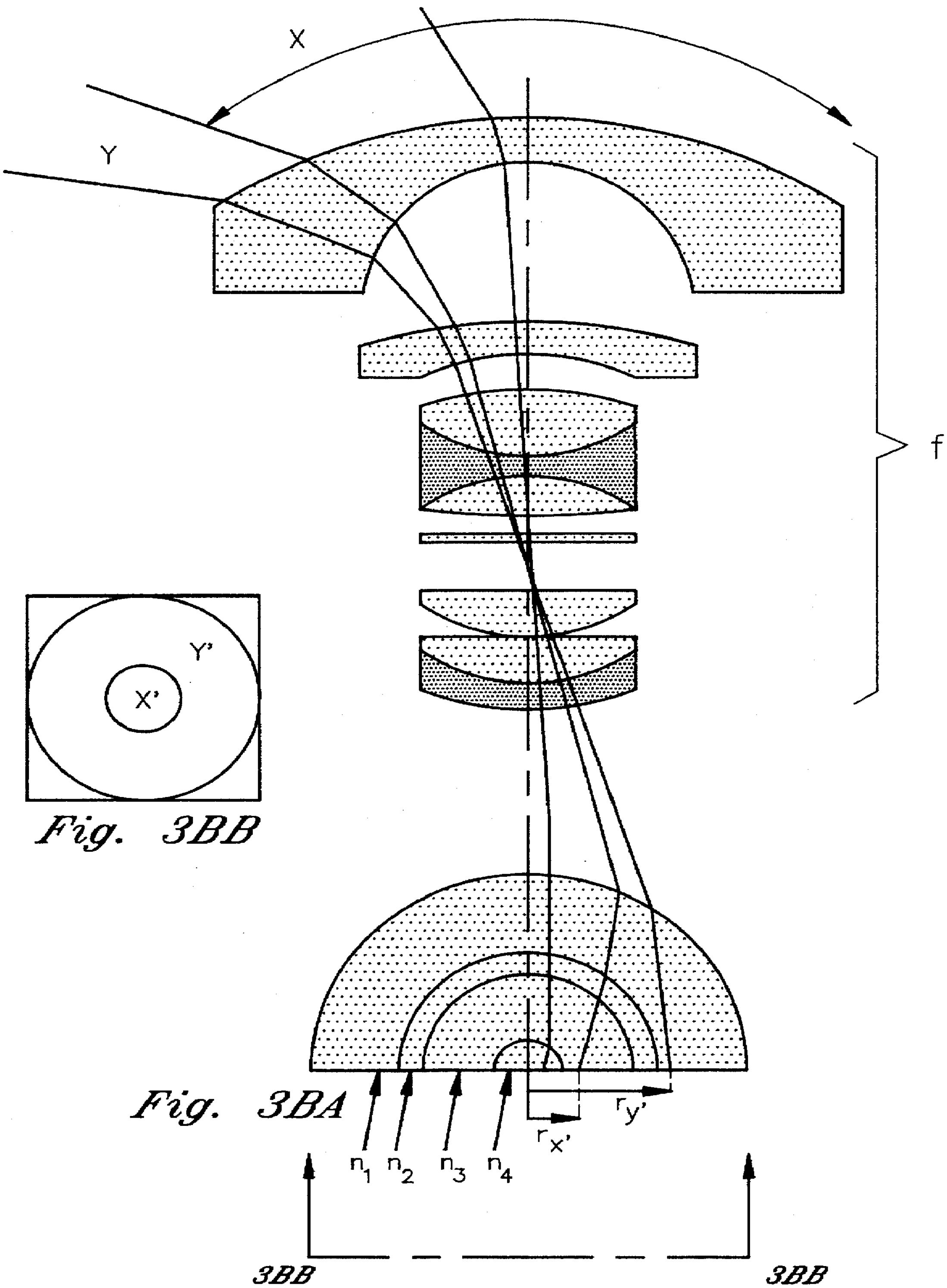


Fig. 3BB

Fig. 3BA

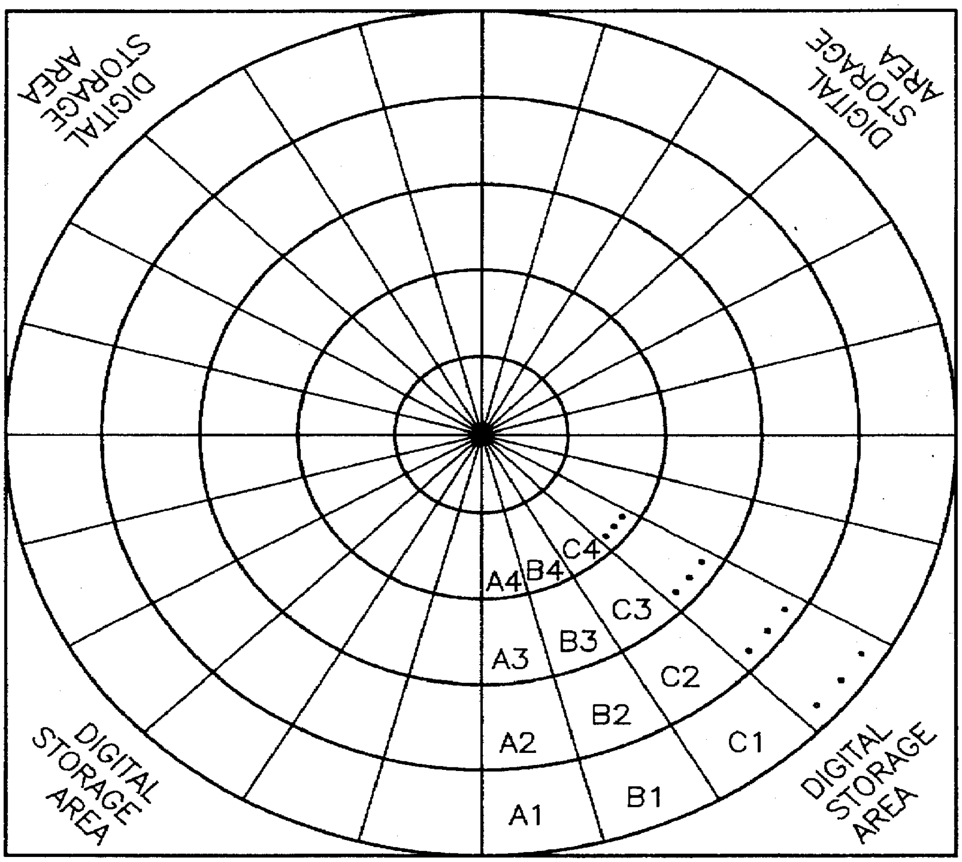

DIGITAL STORAGE AREA
DIGITAL STORAGE AREA
DIGITAL STORAGE AREA
DIGITAL STORAGE AREA
A1
A2
A3
A4
B1
B2
B3
B4
C1
C2
C3
C4

Fig. 4

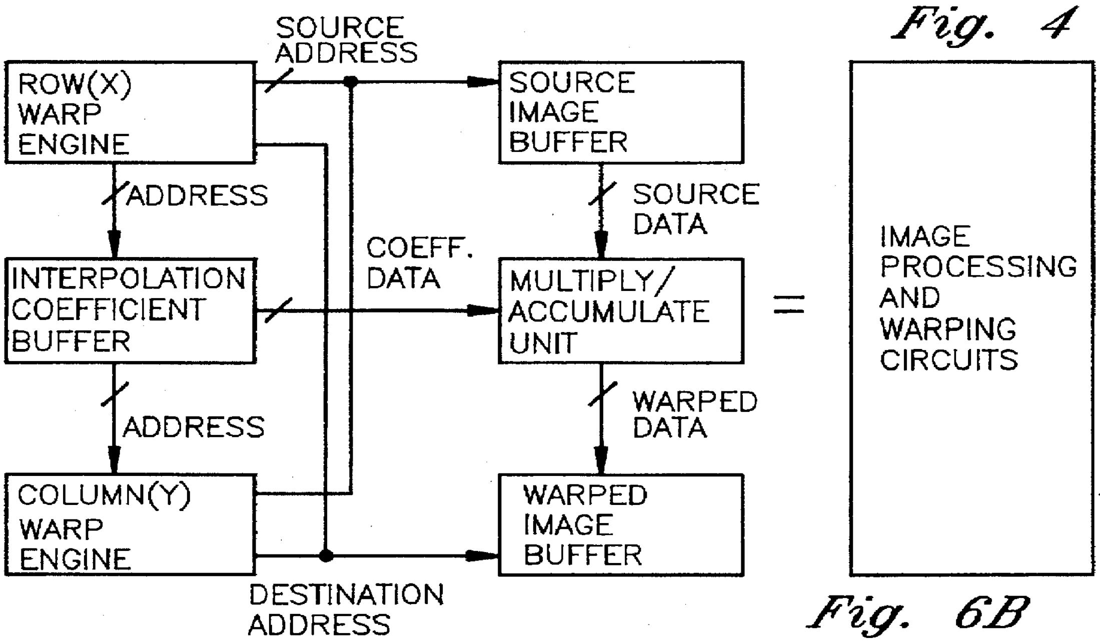

ROW(X) WARP ENGINE
SOURCE ADDRESS
SOURCE IMAGE BUFFER
ADDRESS
SOURCE DATA
INTERPOLATION COEFFICIENT BUFFER
COEFF. DATA
MULTIPLY/ ACCUMULATE UNIT
=
IMAGE PROCESSING AND WARPING CIRCUITS
ADDRESS
WARPED DATA
COLUMN(Y) WARP ENGINE
WARPED IMAGE BUFFER
DESTINATION ADDRESS

Fig. 6B

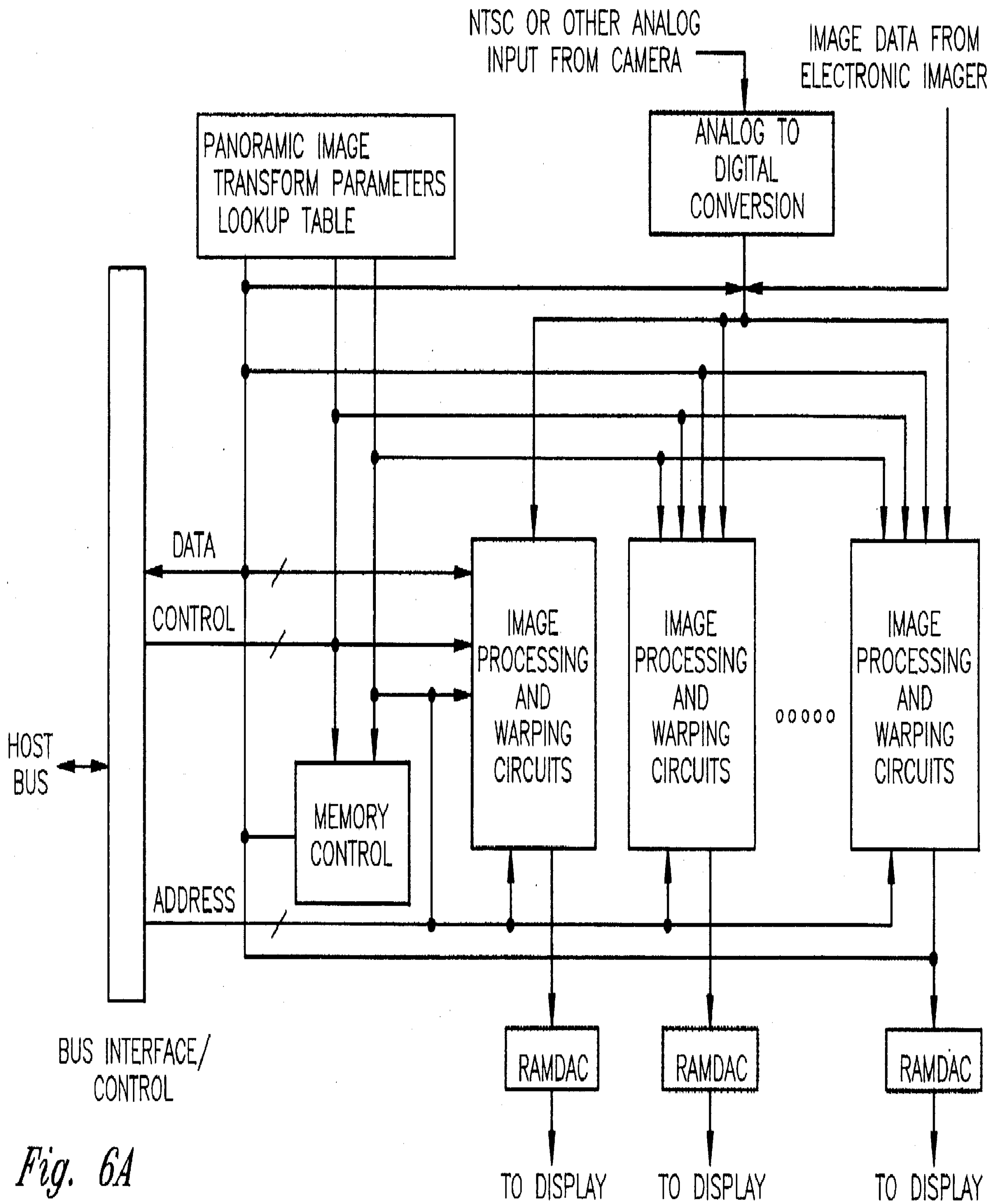

NTSC OR OTHER ANALOG INPUT FROM CAMERA
IMAGE DATA FROM ELECTRONIC IMAGER
PANORAMIC IMAGE TRANSFORM PARAMETERS LOOKUP TABLE
ANALOG TO DIGITAL CONVERSION
DATA
CONTROL
IMAGE PROCESSING AND WARPING CIRCUITS
IMAGE PROCESSING AND WARPING CIRCUITS
ooooo
IMAGE PROCESSING AND WARPING CIRCUITS
HOST BUS
MEMORY CONTROL
ADDRESS
BUS INTERFACE/ CONTROL
RAMDAC
RAMDAC
RAMDAC
TO DISPLAY
TO DISPLAY
TO DISPLAY

Fig. 6A

TELECONFERENCING IMAGING SYSTEM WITH AUTOMATIC CAMERA STEERING

This application is a continuation-in-part of U.S. patent application Ser. No. 281,331 filed Jul. 27, 1994 U.S. Pat. No. 5,508,734.

BACKGROUND OF THE INVENTION

1. Field of the Invention

This invention relates to a video conferencing system that has automatic, voice-directional camera image steering, and specifically to a teleconferencing system that employs automatic video image selection of the current participant speaking electronically selected from a panoramic video scene.

2. Description of the Prior Art

Teleconferencing provides for the exchange of video and audio information between remotely separated participants. Typically, a first group of participants is arranged around a conference table or seated strategically in a conference room and telecommunicating with a second group of participants similarly situated at a remote location. One or more video cameras at each location creates video images of the participants through manual manipulation of each video camera, normally directed at the participant speaking at the moment. Microphones at each location provide for sound transmission signals. The video image and audio voice signals are then transmitted to the remote location. The video image is projected onto a large screen or other type of video display which also would include audio outputs for providing the sounds.

Manual manipulation of each video camera at each conference site is required to change the direction of each camera to different participants as speakers change, unless a large overall view of all the participants is maintained. Such a process is labor intensive. Also image content and perspective, dependent on the location of the video camera relative to the participants, contributes to the quality of the final visual display available to the participants watching the display screen. The quality of the image and the scene content all contribute to the overall effectiveness of the telecommunication process. In particular, in a setting such as a conference table in a conference room, a hemispheric or panoramic viewpoint would be much more efficient for video image capture of surrounding selected participants. With a hemispheric scene, certain efficiencies are gained by eliminating large areas that are unused scene content while concentrating on a band of hemispheric areas populated by the teleconferencing participants. Therefore, it is believed that hemispheric or panoramic electronic imaging would be greatly beneficial to a teleconferencing environment, especially when controlled with audio directional processors. The selected video image is taken from a desired segment of a hemispherical view in the correct video aspect ratio. A centralized panoramic image capture system which already has a distorted picture of the hemisphere bounded by the plane of the table upward selects a portion of the scene and warps the image to correspond to a normal aspect ratio view of the person speaking. The signal can be converted to whatever display format is desired for transmission to a remote location. The present invention has incorporated, in one automated system, audio beam steering and electronically selectable subviews of a much larger panoramic scene. The video/subviews can be converted to an NTSC display format for transmission to a remote location for video display.

The collection, storage, and display of large areas of visual information can be an expensive and difficult process to achieve accurately. With the recent increased emphasis on multimedia applications, various methods and apparatuses have been developed to manage visual data. A unique class of multimedia data sets is that of hemispheric visual data. Known multimedia methods and apparatuses attempt to combine various multimedia imaging data, such as still and motion (or video) images, with audio content using storage media such as photographic film, computer diskettes, compact discs (CDs), and interactive CDs. These are used in traditional multimedia applications in various fields, such as entertainment and education. Teleconferencing is an application where automated electronic selection of scene content would result in greatly improved usability. Non-multimedia applications also exist that would employ hemispheric visual data, such as in security, surveillance, unmanned exploration, and fire and police situations. However, as will be described below, the known methods and apparatuses have certain limitations in capturing and manipulating valuable information and hemispheric scenes in a rapid (i.e., real-time) and cost effective manner.

One well known multimedia technique is used at theme parks, wherein visual information from a scene is displayed on a screen or collection of screens that covers almost 360 degrees field of view. Such a technique unfortunately results in the consumption of vast quantities of film collected from multiple cameras, requires specially designed carriages to carry and support the cameras during filming of the scene, and necessitates synchronization of shots during capture and display. The technique is also limited in that the visual image cannot be obtained with a single camera nor manipulated for display, e.g., pan, tilt, zoom, etc., after initial acquisition. Hence, this technique, while providing entertainment, is unable to fulfill critical technical requirements of many functional applications.

Other known techniques for capturing and storing visual information about a large field of view (FOV) are described in U.S. Pat. Nos. 4,125,862; 4,442,453; and 5,185,667. In U.S. Pat. No. 4,125,862, a system is disclosed that converts signal information from a scene into digital form, stores the data of the digitized scene serially in two-dimensional format, and reads out the data by repetitive scan in a direction orthogonally related to the direction in which the data was stored. U.S. Pat. No. 4,442,453 discloses a system in which a landscape is photographed and stored on firm. The film is then developed, with display accomplished by scanning with electro-optical sensors at "near real-time" rates. These techniques, however, do not provide instant visual image display, do not cover the field of view required for desired applications (hemispheric or 180 degrees field-of-view), do not generate visual image data in the format provided by the techniques of this invention, and are also not easily manipulated for further display, e.g., pan, tilt, etc.

The technique disclosed in U.S. Pat. No. 5,185,667 overcomes some of the above-identified drawbacks in that it is able to capture a near-hemispheric field of view, correct the image using high speed circuitry to form a normal image, and electronically manipulate and display the image at real-time rates.

For many hemispheric visual applications, however, even U.S. Pat. No. 5,185,667 has limitations in obtaining sufficient information of critical and useful details. This is particularly true when the camera is oriented with the central axis of the lens perpendicular to the plane bounding the hemisphere of acquisition (i.e. lens pointing straight up). In such applications, the majority of critical detail in a scene is contained in areas of the field along the horizon and little or no useful details are contained in central areas of the field located closer to the axis of the lens (the horizon being defined as the plane parallel to the image or camera plane and perpendicular to the optical axis of the imaging system). For example, in surveillance, the imaging system is aimed upward and the majority of the critical detail in the scene includes people, buildings, trees, etc., most of which are located within only a few degrees along the horizon (i.e., this is the peripheral content). Also, in this example, although the sky makes up the larger central arc of the view, it contains little or no useful information requiring higher relative resolution.

To obtain sufficient detail on the critical objects in the scene, the technique should differentiate between the relevant visual information along the horizon and the remaining visual information in the scene in order to provide greater resolution in areas of higher importance. U.S. Pat. No. 5,185,667 does not differentiate between this relevant visual information contained along the horizon and the remaining visual information in this scene. Thus, it fails to yield a sufficient quality representation of the critical detail of the scene for projected applications.

Instead, techniques described above concentrate on obtaining, storing, and displaying the entire visual information in the scene, even when portions of this information are not necessary or useful. To obtain the near-hemispheric visual information, such techniques require specific lens types to map image information in the field of view to an image plane (where either a photographic film or electronic detector or imager is placed). Known examples of U.S. Pat. No. 5,185,667 and U.S. Pat. No. 4,442,453 respectively use a fish-eye lens and a general wide-angle lens. As these lenses map information of a large field without differentiation between the central and peripheral areas, information from the periphery will be less fully represented in the image plane than from the central area of acquisition.

In U.S. Pat. No. 4,170,400, Bach et al. describes a wide-angle optical system employing a fiber optic bundle that has differing geometric shapes at the imaging ends. Although this is useful in itself for collecting and repositioning image data, bending of light is a natural characteristic of optical fibers and not exclusive to that patent. Further, U.S. Pat. No. 4,170,400 employs a portion of a spherical mirror to gather optical information, rendering a very reduced subset of the periphery in the final imaging result. This configuration is significantly different from the multi-element lens combination described in the present invention.

Imperfections in the image representation of any field inherently result from the nature of creating an image with any spherical glass (or plastic) medium such as a lens. The magnitude of these imperfections increases proportionally to the distance a point in the field is from the axis perpendicular to the optical imaging system. As the angle between the optical axis and a point in the field increases, aberrations of the corresponding image increase proportional to this angle cubed. Hence, aberrations are more highly exaggerated in the peripheral areas with respect to more central areas of a hemispheric image.

Although the lens types above achieve a view of a large field, the valuable content from the peripheral areas lacks in potential image quality (resolution) mapping because the imaging device and system does not differentiate between these areas and the central areas of less valuable detail. Often, the difference between the imaging capabilities between the two areas is compensated for by using only the central portion of a lens to capture the scene ("stopping the lens down"). This works in effect to reduce the image quality of both areas such that the difference in error is a lesser percentage of the smallest area even the central area can resolve. Simultaneously, this compensation technique further degrades the performance of the lens by limiting the amount of light which is allowed to enter the lens, and thus reducing the overall intensity of the image.

More typically, the peripheral content imaged by a conventional lens is so degraded in comparison with the central area that the lens allows for only a minimal area of the periphery to be recorded by the film or electronic imager. As a result of these "off-axis" aberrations inherent to large field, the relevant information of the horizon in the scene can be underutilized or worse yet, lost.

Another limitation in U.S. Pat. No. 5,185,667 is its organization for recording only views already corrected for perspective. The nature of that methodology is that the specific view of interest must be selected and transformed prior to the recording process. The result is that no additional selection of views can be accomplished after the storage process, reducing system flexibility from the user's perspective.

Hence, there is a demand in the industry for single camera imaging systems that efficiently capture, store, and display valuable visual information within a hemispheric field of view containing particularly peripheral content, and that allow electronic manipulation and selective display of the image post-acquisition while minimizing distortion effects.

Such a system finds advantageous application in a teleconferencing environment in accordance with the present invention.

Limited control of video cameras is disclosed in the prior art. U.S. Pat. No. 4,980,761 issued to Natori, Sep. 25, 1990 describes an image processing system that rotates a camera for a teleconference system. A control unit outputs a drive signal based on an audio signal to control the movement of the image until the image controlling unit receives an operational completion signal. In this case, the rotational movement of the camera, moving the video image from one participant to another participant, alleviates having to view the camera movement. Once the camera stops skewing, the picture will then provide the proper aspect ratio. A plurality of microphones are provided to each attendant. A sound control unit then determines with a speaker detection unit which participant is speaking. U.S. Pat. No. 4,965,819 shows a video conferencing system for courtroom and other applications in which case each system includes a local module that includes a loud speaker, a video camera, a video monitoring unit and a microphone for each local conferee. U.S. Pat. No. 5,206,721 issued to Ashida, Apr. 27, 1993, shows a television conference system that allows for automatically mechanically moving and directing a camera towards a speaking participant. In this system a microphone is provided for each participant and is recognized by the control system. Image slew is corrected to avoid camera image motion. A review of these systems thus shows that the automation provided is very expensive and in every case requires individualized equipment for each participant.

Limited audio direction finding for multiple microphone arrays is known in the prior art. For example, a self steering digital microphone array defined by W. Kellerman of Bell Labs at ICASSP in 1991 created a teleconference in which a unique steering algorithm was used to determine direction of sound taking into account the acoustical environment in which the system was located. Also a two stage algorithm for determining talker location from linear microphone array data was developed by H. Silverman and S. Kirkman at Brown University and disclosed in April, 1992. The filtered cross correlation of the system is introduced as the locating algorithm.

A "telepresence" concept from BellCorp briefly described in IEEE Network Magazine in March, 1992 suggests a spherical camera for use in the teleconference system. However, the entire image is sent in composite form for the remote users to select from at the other end. The present invention is quite different and includes automated pointing and control including incorporation in one automated system of both audio beam steering and selectable subviews of a much larger panoramic scene.

SUMMARY OF THE INVENTION

The present invention comprises a video conferencing, voice-directional video imaging system for automatic electronic video image manipulation of a selected, directional signal of a hemispheric conference scene transmitted to a remote conference site. The system employs three separate subsystems for voicedirected, electronic image manipulation suitable for automated teleconferencing imaging in a desirable video aspect ratio.

The audio beam, voice pickup and directing subsystem includes a plurality of microphones strategically positioned near a predetermined central location, such as on a conference table. The microphone array is arranged to receive and transmit the voices of participants, while simultaneously determining the direction of a participant speaking relative to the second subsystem, which is a hemispheric imaging system used with a video camera. The third subsystem is a personal computer or controller circuits in conjunction with the hemispheric imaging system which ultimately provides automatic image selection of the participant speaking that is ultimately transmitted as a video signal to the remote video display at the remote teleconference location.

The hemispheric electronic image manipulator subsystem includes a video camera having a capture lens in accordance with the invention that allows for useful electronic manipulation of a segmented portion of a hemispheric scene. In a conference table setting, as viewed from the center of the conference table, participants are arranged around the table in the lower segment of the hemisphere, with the plane of the table top forming the base of the hemisphere. The electronic image is warped to provide a desired subview in proper aspect ratio in the audio selected direction.

The present invention provides a new and useful voice-directional visual imaging system that emphasizes the peripheral content of a hemispheric field of view using a single video camera. The invention allows user-selected portions of a hemispheric scene to be electronically manipulated, transmitted, and displayed remotely from the video camera in real-time and in a cost-effective manner.

The visual imaging system of the present invention involves a video image having a lens with enhanced peripheral content imaging capabilities. The lens provides an enhanced view of the valuable information in the scene's periphery by imaging the field of view to the image plane such that the ratio of the size of the smallest detail contained within the periphery of the scene to the size of the smallest resolving pixel of an image device is increased. For this to be accomplished, the peripheral content must map to a larger percentage of a given image detector area and, simultaneously, the mapped image of the central area of the scene must be minimized by the lens so that it does not interfere with the peripheral content now covering a wider annulus in the image plane. Information in the image plane is then detected by the video camera. The detected information of the entire hemispheric scene is then stored as a single image in memory using traditional methods.

When a portion of the scene is to be displayed, the image information relating to the relevant portion of the scene is instantaneously retrieved from memory. A transform processor subsystem electronically manipulates the scene for display as a perspective-correct image on a display device, such as a teleconference display screen or monitor, as if the particular portion of the scene had been viewed directly with the video camera pointed in that direction. The transform processor subsystem compensates for the distortion or difference in magnification between the central and peripheral areas of the scene caused by the lens by applying appropriate correction criteria to bring the selected portion of the scene into standard viewing format. The transform processor subsystem can also more fully compensate for any aberrations of the enhanced peripheral image because of the image's improved resolution as it covers a larger portion of the image device (increased number of pixels used to detect and measure the smallest detail in the periphery image). More pixels equates to more measurement data, hence more accurate data collection.

The stored image can also be manipulated by the transform processor subsystem to display an operator-selected portion of the image through particular movements, such as pan, zoom, up/down, tilt, rotation, etc.

By emphasizing the peripheral content of a scene, the visual imaging system can use a single camera to capture the relevant visual information within a panoramic field of view existing along the horizon, while being able to conventionally store and easily display the scene, or portions thereof, in real-time. Using a single optical system and camera is not only cost-effective, but keeps all hemispheric visual data automatically time-synchronized.

In the present invention, at a conference table view point, with participants seated around a conference table, hemispheric scene content is ideally suited for segmented subviews of participants, especially when directionally electronically manipulated by voice actuation. The video image should be of the current speaker.

One advantage of the present invention is that the unique visual imaging system lens can capture information from a hemispheric scene by emphasizing the peripheral portion of the hemispheric field of view and thus provide greater resolution with existing imaging devices for the relevant visual information in the scene. As an example, if an ordinary fisheye lens focuses the lowest 15 degrees up from the horizon on ten percent of the imager at the imaging plane and the peripheral-enhancing lens focuses that same 15 degrees on fifty percent of the imager, there is a five-fold increase in resolution using the same imaging device. Depending on the application and exact formulation of the lens equations, there will be at least a five times increase in resolving power by this lens/imager combination.

The third subsystem of the present invention comprises a control apparatus such as a personal computer or other collection of electronic circuits, connected to the imagery system to allow flexible operation delivering options and defaults, including an override of the automated video image manipulation. A minimal control program is the software of the host controller to provide the options that may be necessary for individual teleconferences. An example would be to delay switching time segments between speakers, or perhaps the use of alternate cameras that may include a dual display.

In operation, at a particular teleconferencing site, participants will be arranged at a conference table or in a conference room with an array of microphones, each of which will pick up the normal speaking voice of each participant. The array of microphones is directly connected to an audio direction processor. The hemispheric lens system in conjunction with the video camera is attached to view warping logic as explained above and to the controller, or a personal computer. The video and audio signals are then transmitted through a transmission medium in an NTSC or other format to the remote teleconferencing site for remote display.

Sound from the participant speaking that is processed in the audio direction processor determines the direction of the participant speaking relative to the panoramic video camera and lens. Once the particular speaker direction is determined, the panoramic image of a specific hemispherical region of interest, such as the participant's face, is processed to provide a normal video aspect ratio view for the remote participants using the system.

It is a principal object and advantage of this invention to provide a video conferencing system that automatically directs a video image to the participant that is speaking while providing a hemispherical video imaging subview that can be electronically manipulated in the direction of the speaker selected from a panoramic scene.

It is another principal advantage of this invention to provide an automatic teleconferencing system that saves transmission time, reduces coincident cost by eliminating or reducing manual operation of a video camera, and does not detract from the concentration of the subject during the conference.

And yet another advantage of this invention is to provide an automatic video camera with electronic image manipulation for video conferencing equipment that has no moving mechanical parts or physical mechanisms which improves the reliability of the system and reduces maintenance costs and service costs.

In accordance with these and other objects which will become apparent hereinafter, the instant invention will now be described with particular reference to the accompanying drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. **1** is a schematic illustration of the visual imaging system organization and components of the parent application.

FIG. **1A** is a schematic illustration of the automated video conferencing system organization and components.

FIGS. **2A**, **2B**, and **2C** show a cross sectional diagram indicating the field input and output rays and the resulting relative field coverage a lens typically provides in the image plane for detection by an imager device.

FIGS. **3AA**, **3AB**, and **3AC** show a cross sectional diagram indicating the field input and output rays and the resulting field coverage that optical system Example I, constructed according to the principles of the present invention, provides in the image plane for detection by an imaging device or substrate.

FIGS. **3BA**, **3BB** show a cross sectional diagram indicating the field input and output rays and the resulting field coverage that optical system Example II of this present invention provides in the image plane for detection by an imaging device or substrate.

FIG. **4** is a schematic representation of the mapping locations on the imaging device.

FIG. **5** is a schematic block diagram of the panoramic transform processor subsystem for use with the teleconferencing system of the present invention.

FIGS. **6A** and **6B** are a schematic diagram showing how multiple transform processor subsystems can be tied into the same distorted image to provide multiple different view perspectives to different users from the same source image as described in the parent application.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

The invention will be defined initially with a brief description of the principles thereof.

Principles of the Present Invention

As described in the parent U.S. patent application, the imaging invention stems from the realization by the inventors that in many of the technical hemispheric field applications, where the image detector is parallel to the plane of the horizon, much of the relevant visual information in the scene (e.g., trees, mountains, people, etc.) is found only in a small angle with respect to the horizon. Although the length of the arc from the horizon containing the relevant information varies depending upon the particular application, the inventors have determined that in many situations, almost all the relevant visual information is contained within about 10 to 45 degrees with respect to the horizon. This determination is especially true with respect to the teleconference environment which is normally centered around a conference table or conference room.

To maximize data collection and resolution for analysis and/or display of the relevant visual information located in this portion of the hemispheric scene, it is desirable to maximize the dedication of the available image detection area to this peripheral field portion. To accommodate this, it is necessary that the "central" portion of the scene (from 45 to 90 degrees with respect to the horizon) cover only the remaining areas of the imager plane so as not to interfere with light from the periphery.

In many cases, since the "central" area contains less detailed information, such as a solid white ceiling or a clear or lightly clouded sky, it is allowable to maximize completely the dedication of the available image detection area to the peripheral field portion by reducing the portion of the imager device representing the "central" area to near zero. Of course, in certain instances, it is desirable to analyze this less detailed information, but this portion of the scene can be minimized to some extent without significant degradation of such visual information. As will be described herein in more detail, the present invention provides two manners (Example I and Example II) for capturing, storing, and selectively displaying the critical visual information in a scene for many important applications.

System Organization and Components

Referring now to the drawings, and initially to FIG. **1**, the visual imaging system of the parent invention includes a still image or moving picture camera **10**, having a lens, indicated generally at **14**, designed to capture and enhance the peripheral content of a hemispheric scene. The captured scene can be stored onto an assortment of media, e.g., photographic film **16**, electronic storage **18**, or other conventional storage means. Electronic storage **18** is preferred because of the ease of electronic manipulation thereof. Additionally, photographic film **16** requires an image scanner **20** or other capture-and-conversion method to change the image into electronic format before electronic manipulation can be performed. A video camera **11** in FIG. **1A** is used for the teleconferencing system to capture the image.

The stored electronic image data is then selectively accessed by a transform processor engine **22** and can be electronically manipulated according to user-defined criteria, such as pan, up/down, zoom, etc. The transform processor **22** corrects the image for display on a conventional display device **28** such as a video monitor or a video projection display system in a normal viewer format or on head-mounted displays **30**, in which integrated orientation-sensing devices can be used to manipulate the user controls.

Referring to FIG. **1A**, the audio directive component of the teleconferencing system for the present invention is comprised of four microphones spaced apart which would be arranged concentrically about the lens and camera on a conference room table so that all of the participants in the conference will have audio access to the microphones for transmission of sound. The primary purpose of the invention is to provide automated camera steering of the video camera **11** scenes based on which particular participant is currently speaking. Therefore, the audio energy from a particular participant speaking will be the basis for directing the video camera imaging as discussed below. The microphones **21**, **23**, **25**, and **27** are connected to a speaker detection circuit **29**. The audio generated signals from the microphones are transferred to a mixer and sampling circuit in audio direction processor **19**. In one particular embodiment, each microphone input would be sampled to determine which has the largest amplitude of signals or which one has signals, to determine the specific direction for steering the video camera. Once the audio detection circuits and sampling circuits have determined which microphone is the microphone being used by the current speaker, this signal information is conveyed to the audio direction processor **19** which is correlated between the location of a particular microphone in use and the video imaging system providing the segmented image discussed below. Thus, using the microphone array and audio circuitry, a signal can be arrived at from the audio direction processor to the imaging system to give relevance of which direction or which segment of the panoramic image should be selected as a function of the current participant speaking. Determining the direction of the source of acoustical waves from an array of sensors such as an array microphone is known. Audio speaker detection circuitry is disclosed in U.S. Pat. No. 5,206,721 cited above. Additional discussion on the broad concepts can be found in *Array Signal Processing: Concepts and Techniques*, authored by Don H. Johnson and Dan E. Dudgeon, chapter 4, Beamforming, published by PTR Prentice-Hall, 1993, and *Multidimensional Digital Signal Processing*, authored by Dan E. Dudgeon and Russell M. Mersereau, chapter 6, Processing Signals Carried by Propagating Waves, published by Prentice-Hall, Inc., 1984. In the present system, the number of participants can substantially exceed the number of microphones. The video imaging system, which will ultimately provide images of the participant speaking for the teleconferencing, then receives the audio direction processor signal as an input to select the specific imaging segment as described below.

I. Image Acquisition

A. Camera

As described in the parent application, the camera **10** for the visual imaging system is an optical device that is capable of receiving a focused image from a lens and transforming that image into an electronic signal or into hard copy storage such as photographic film. Various types of cameras for wide-angle viewing are known to those in the art, such as 35 mm cameras, 8 mm cameras, NTSC, RS170, and HDTV-type cameras. The present invention is designed to be compatible with most commercially available two-dimensional cameras, with scaling of the lens geometries. It also has the technological capability to be applied to three-dimensional cameras. The camera can be mounted and supported in a conventional manner.

FIG. **1A** shows a teleconferencing system in accordance with the present invention, including an NSTC video camera **11** using the capture lens **13**, view-warping logic **15**, and PC or master controller **17**, which receives input from four microphones **21**, **23**, **25**, and **27** disposed apart around a central audio connector **29**, the output of which is connected to the audio direction processor **19**. By detecting the differences in audio signal amplitude obtained from each microphone, the audio direction processor can determine the closest microphone to the current participant speaking. It is also possible, by normal audio beam steering techniques, to select points between microphones, such that the number of participants can far exceed the number of microphones. The video camera **11** lens viewing angle segment based as a panoramic view can then be electronically changed through the view-warping logic and the PC or master controller **17** to automatically shift the segmented scene content in the direction of the person speaking at the time. Note that the video camera **11** will be physically located in a central area, preferably in the center of the conference table, whereby a panoramic view of the participants at the conference table or in a conference room can be obtained so that the relative bearing from a central camera location to a particular participant can be established relative to the panoramic scene desired and the particular amount of scene content to accurately represent and provide the proper video aspect ratio of a particular speaker while that person is speaking.

B. Lens With Enhanced Peripheral Content

The fundamental principle behind the enhanced peripheral content lens is the selective magnification of the periphery and the focusing of more of that content on the imaging plane. This recognizes the current limitations of imaging devices and film with regard to resolution. As such, the more of the peripheral content that can be focused on the imaging plane surface, the more points of data that can be resolved with a given density of imaging device or material. Therefore, for this new class of selective magnification lenses, the surface area of the imaging plane reserved for peripheral content will be large relative to the central content and roughly similar for all lenses in this class, regardless of whether the lens is designed for 1–10 degree peripheral emphasis or 1–45 degree peripheral emphasis. However, it should be noted that the lens with 1–10 degree emphasis will have much better resolution for the same objects than the lens with 1–45 degree emphasis.

The lens **13** in FIG. **1A** for video camera **11** provides a collection of data for enhanced digital processing of the peripheral portion of a given field of view. The lens uniquely achieves this by filling the greater available area of an imager device with the peripheral areas rather than the central areas of the captured scene.

A periphery-enhancing optical system suitable for achieving the goals of the present invention can be configured in various ways to present an image of the field free of detrimental values of critical aberrations. Two examples or embodiments are preferred. Example I in FIGS. **3AA–3AC**,m preferably is a multi-medium system comprising a wide-angle multi-element optical lens and a fiber optic imager device. Example II preferably is a combination system comprised of multiple refractive optical elements, one of which is of gradient index material, hemispherical in shape. The inventors define that other configurations relying on binary optics could also be utilized to accomplish similar results.

The system of Example I is best suited for applications where the capture of the minimal information contained in the central area is irrelevant. A coordinated fiber bundle array, either rigid or flexible, carefully aligned and assembled by methods known to those skilled in the art, is used to capture a peripheral annulus of the wide field image provided by the multi-element wide field lens. (REF. Journal of the Optical Society of America, 1964; lens designs presented by Miyamota. Also see U.S. Pat. No. 4,256,373 by M. Horimoto for additional wide-field lenses.) The multi-element wide field lens therefore, although covering the same field as standard wide field lenses, is required to provide a larger image of the entire field. This can be accomplished by those skilled in the art by scaling a standard lens to a larger focal length until the desired image size is reached. (REF. Chapter 5.4, "Scaling a Design" of Modern Lens Design, Warren J. Smith, McGraw-Hill inc., copyright 1992.)

The fibers, arranged in a specific mechanical manner, deliver the information in a geometrically annular shape from the peripheral image area to either the rectangular or circular shape of a specific imaging device. Specific configurations can be devised for desired peripheral coverage (up to 10 degrees through 45 degrees) and matched to required image detector plane geometry. (REF. Sect. 13, Fiber Optics, Handbook of Optics, McGraw-Hill Inc., 1978.) Referring to FIGS. 3AA–3AC for a desired angle θ (theta), a standard wide-field lens design is scaled in "f," the length of the square camera imaging device (2r') is met. In the "Camera/Imager Interface" portion of the figure, the equation for fiber bundle radius r' as related to the imager is:

$$\text{Area at imager}=(pi)r^2_y-(pi)r^2_x=(pi)\ (r^2_y-r^2_x)$$

$$\text{Imager length}=2r',\ \text{where}\ r'=\text{square root}\ [r^2_y-r^2_x]$$

A configuration in the form of Example I achieves an image in which the peripheral portion (0–45 degrees with respect to the horizon) of the field of view preferably encompasses between approximately 90% to 100% of the entire usable area of the imager device, rather than the 35% or less that is typical with commercially available wide-angle, fish-eye, or other conventional lenses. A configuration in the form of Example II achieves an image in which the peripheral portion preferably encompasses between 50% to 70% of the usable area of the imaging device surface.

The system of Example II is best suited for applications where all information contained in the field of view is relevant, although to differing degrees. The combination system of Example II relies on the principal use of a Bravais System where a hemispherical lens or a combination of lenslets magnify an object to an image, wherein the object and image lie in the same plane. In this case, the hemispherical lens is made of gradient index material such that points impinging the image plane incur different factors of magnification depending on what index of refraction and what portion of the hemispherical curve or lenslets they pass through. This concept is used in combination with a multi-element refractive lens that is designed to capture a wide field of view and also compensate for the color aberration induced by insertion of the hemispherical lens. This color compensation can be designed by those skilled in the art by using a computer optimization routine. (REF. Mercado et al. and U.S. Pat. No. 5,210,646 on "Color Corrected Optical Systems and Method of Selecting Optical Materials Thereof." Also see Chapter 9 of the Users Manual for "Three Color Optimization" using Kidger Optics Optical Design Program v.4.71, copyright Kidger Optics 1983–1989.) By use of the hemispherical gradient index unit with a wide field multi-element lens, the portion of the camera dedicated to the periphery is increased, thereby increasing the relative resolution of information detectable by the imaging device sensing elements. With the gradient index hemisphere, index values decrease from the center, such that:

$$n_1<n_2<n_3<n_4$$

The operation of the optical systems is schematically illustrated in FIGS. 2A–2C and 3BA–3BB. The arc X represents the field of view of the "center" portion of the "peripheral" field. The areas X' and Y' represent the subtended peripheral angles of incidence. Arc Z and area Z' represent areas outside the normal imaging range of the lens. (No actual demarcation lines would exist in actual use; this is merely for exemplary purposes.)

FIGS. 2A–2C represents a typical wide-angle type lens, while FIGS. 3BA–3BB represents a lens constructed according to the principles of the present invention. As should be apparent from comparing FIGS. 2A–2C and 3BA–3BB, a typical wide-angle type lens has a fairly significant portion of the imaging surface dedicated to the central field of the lens; while the lens constructed according to the present invention has a fairly significant portion of the imaging surface dedicated to the peripheral field, and consequently less of the surface dedicated to the central field.

The portion of the imaging surface used for the peripheral portion of the scene (as compared with the central portion of the scene) can vary depending upon the particular prescription of lens specified, which is selected to capture items of interest for a given application. For example, if the imaging system is used to capture a panorama of an outdoor scene, the relevant visual information may be contained within 10 degrees of the horizon. The lens of the present invention can thus be designed to enhance only the field of view within 10 degrees of the horizon. On the other hand, if the imaging system is being used to capture a room scene within a building, the relevant visual information may include objects on walls and thus be contained within about 45 degrees from the horizon. A peripheral enhancing lens can thus also be designed to enhance the field of view up to 45 degrees from the horizon. Of course, the enhanced portion of the field of view depends upon the needs of the particular application, with the enhanced portion preferably falling somewhere between these two extremes. In any case, the principles of the present invention can be applied to these types of situations with equal success, with any appropriate corrections being made with the image transform processors, as will be described herein in more detail.

As illustrated in FIGS. 3AA–3AC, a preferred form of the Example I form of optical system comprises a standard wide field lens and a coordinated fiber array. The focal length of the wide field lens is scaled in order to match the peripheral field of view desired. The coordinated fiber array consists of an annular input face that collects the image projected from the standard wide field lens. The fiber bundle array then redirects the information from the peripheral view to its output end by total internal reflection. Fibers capable of 3 micron accuracy, covering the area of the annual region, are coordinated into a rectangular or circular shape at their output, depending on the geometry of the corresponding imaging device. The size of output is also matched to the camera imaging device used.

Of course, these system configurations and parameters are only exemplary in nature and other configurations and parameters of the present invention could be used to provide enhanced peripheral imaging capabilities, as should be apparent to those skilled in the art.

C. Imager Device

With the present invention, a video camera **11** receives the optical image from the lens and fiber optic array.

It should be apparent from the above discussion that when the imager device is used with a lens constructed according to the principles of the present invention, the imager device will collect more information along the horizon than it will from the central area of the hemispheric scene. With only a given limited resolution of either film emulsions or CCD pixel density, the lens focuses more useful information at the imaging plane. The peripheral portion of the scene will therefore have a higher relative resolution in the resultant transformed image than the central portion. Thus, the details of any objects along the horizon will be more highly accentuated. Further, any distortion (e.g., spherical aberration) that occurs in the peripheral region of the lens will be imaged onto a larger surface area and can thus be more easily and fully compensated for. Also, as imaging device resolution improvements are made over time, peripheral enhancing lenses and configurations will continue to yield improved visual renditions.

The image mapped onto the imager device can be described by a series of concentric circles, as schematically illustrated in FIG. **4**. As an example, each circle on the imager device can be described by radii of arbitrary units, e.g., **2**, **5**, **9**, **14**, etc. The radii of the circles depends on the magnification of the different regions of the hemisphere, with the blocks in the outer circles having a greater area as the magnification of the peripheral region increases. In an arbitrarily selected illustration case, each concentric circle represents 18 degrees field of view from the horizontal plane, with the outer circumference of the outermost circle being level with the horizon. The inventors have determined that the arc subtending the two outer circles (i.e., 36 degrees from the horizon) contains the relevant information in many hemispheric scenes for many applications (although again, this value can be varied depending upon the particular application).

Calculating the total circular area of the entire image circle yields 1257 units squared. The are of the three inner circles is 254 units squared. Therefore, the two outer circles contain about 80% of the usable area on the imaging device. Note that the image blocks corresponding to the horizon are spread across more area on the imager device than those in the central area of the image. Thus, the image blocks of the imager device are dominated by objects along the horizon, and those are the area of interest. This correlates to greater resolution for the peripheral areas of the scene.

The panoramic image provided by the imager is ideally suited for teleconferencing. For example, with the image lens apparatus mounted in the center of a conference table, from the plane of the table, a hemispheric view is presented. If the participants of the conference are seated around the table and the microphone array located conveniently on the table, the important image information, i.e. the participants, are found with the imager along a 10 to 30 degree or 45 degree segment of the horizon, by far the bulk of the images of interest. Therefore, using the present invention with audio detection to determine the direction of the current speaker, the desired image segments can be electronically manipulated between speakers automatically controlled by the direction of the current speaker's voice from the array disposed at or near the center of the conference table. Camera steering and image segment selection among participants speaking is undetectable by the participants, providing for minimal distractions and maximum concentration by the participants of the conference.

II. Image Storage

The image received on the imager device is passed on to the system components for storage and/or transmission to a remote teleconferencing site. For photographic processes, a storage device might be film; while for electronic processes, the storage device might be electronic storage in the form of random access memories, a conventional diskette or hard file, or video recording tape. The entire display of the scene (along with any secondary documentation) can be stored as a single image on the storage device.

As should be apparent from the configuration of the imager device in FIG. **4**, the image is stored or transmitted in a "warped" form. The warped image is caused not only by the wide-angle nature of the lens (i.e. the "keystoning" effect), but also by the enhanced peripheral field of view of the lens (i.e., magnification along the periphery). The underlying concept is that a partial slice of the scene can be reproduced with the proper aspect ratio for the human visual system (i.e., as a perspective corrected view).

Looking at FIG. **5**, the stored image will be loaded into the source image buffer **40** if it has been stored in electronic form on the host system, an example of which would be a personal computer or controller. Alternatively, the image can be brought in for processing without going through storage for real-time teleconferencing transmission. As one option, an analog signal from a video camera **11** (FIG. **1A**) can connect into an NTSC-to-digital converter **42**. This converts the image from analog information into a digital bit map (i.e., into "pixels"). The source image is then loaded into the source image frame buffer **40**. However, as indicated previously, any type of camera can be used to provide the electronic input to buffer **40**. The buffer preferably operates with sufficient speed so that real-time viewing is possible.

III. Image Retrieval/Display

Referring to FIG. **1A**, the video camera **11** image can be selectively accessed and transformed for display at the source location or at a remote teleconference location. In order to recreate a proper display of the scene in two dimensions for perspective-correct viewing, processor logic in transform processor engine **22** is utilized (see FIG. **1**). The transform processors may be made of collections of small-scale, medium-scale, large-scale, or very-large-scale integrated (VLSI) circuits, examples of which are image re-sampling sequencers, commercially available from Raytheon Semiconductors (formerly TRW LSI Products, Inc., LaJolla, Calif.), which are marketed under the mark/designation TMC2301 and TMC2302.

In FIG. **5**, the re-sampling sequencers control the address sequencing of the pixels in the source image buffer **40** through a multiply-accumulate unit **46**, and from there into the warped image buffer **48**. The sequencers control the filtering or remapping of two-dimensional images from a set of Cartesian coordinates (x,y) as defined within each sector "unit" (A1, B1, etc.) onto a newly transformed set of coordinates (u,v). The "fish-eye" type of transformations described in U.S. Pat. No. 5,185,667 are based on non-constant second-order derivatives. A different set of second-order derivatives employed for the transforms associated with the sequencers can also handle three-dimensional images by re-sampling them from a set of Cartesian coordinates (x,y,z) into a new, transformed set (u,v,w). Typically, these sequencers can support nearest-neighbor, bilinear interpolation or convolution re-sampling, and can operate at speeds allowing real-time operation. Alternate electronic solutions can be constructed using VLSI or application-specific integrated circuits.

Re-mapped pixel locations (i.e., interpolation "kernels") of more than one pixel in the bit map requires an external interpolation coefficient look-up table 50 and the multiply/accumulate unit **46** as shown in FIG. **5**. A table "walk" is typically performed on each source pixel, thus providing a smoother image by summing the products of the original lens image data with the appropriate interpolation coefficients. By capturing the hemispheric lens image data into source image buffer **40**, the warp engine can be programmed to perform a perspective correction, much like an inverse keystoning effect. The re-mapping of the pixel locations is matched to the differential magnification of the particular periphery-enhancing lens used.

Direct access to the interpolation coefficient look-up table **50** and to the transformation parameters is also often desirable to allow dynamic modification of the interpolation algorithm. Thus, a local interpolation coefficient buffer **52** to update the varying transform parameters is included to allow for real-time still and motion image transformations.

The row and column warping engines **58***a*, **58***b* of the transform processor **22** supply addresses to the source image buffer **40**. The addresses are determined by the interpolation algorithm chosen. The multiply-accumulate unit **46** takes the pixels supplied by the source image buffer **40** under warping engine control and multiplies the pixels together using combinational logic with weighting factors dependent on the algorithm. Compensation for aberration (e.g., spherical aberration) can also be made at this point. Finally, the composed interpolated pixels are sent to the warped image buffer **48**. The address location within the warped image buffer is again determined by the warping. The algorithm parameters from lookup table **50** are input to the registers of the row and column warping engines **58***a*, **58***b*, as well as into the interpolation coefficient buffer **52**.

The memory controller/clock circuitry **62** provides refresh control to the source and warped image buffers **40**, **48**. In addition, all clock sources are synchronized through this circuitry. The bus interface and control circuitry **56** also provide an interface to the host system bus (i.e., for MCA, ISA, etc.) and the re-mapping circuitry. This interface logic serves to load control information into the re-mapping circuitry and to provide a path to transport warped images to the system display buffer (not shown; part of host system), or store images to disk via the system bus prior to warping. An optional random access memory digital-to-analog converter (RAMDAC) **66** provides support for a local display connection if desired.

One feature of the transform processors is the valid source address flag within the transform processor engine. This allows the user to construct abutting sub-images in the (x,y) plane without danger of edge interference. Thus, edge detection of the unused areas outside the circular image of FIG. **4** can alert the system to ignore these values.

The image capture function can also be accomplished with motion video devices. All types of image data are input to the source image buffer **40** for processing as desired. The NTSC digitizer **42**, for example, can provide real-time data from an NTSC video camera **11** used for teleconferencing. Any similar device that converts an image to the appropriate digital format for input to the source image buffer can be employed as optional element **42** in FIG. **5**. Prerecorded distorted images generated through this invention's optical system can also be input through optional conversion block **42** to allow dynamic manipulation of previously recorded image data.

The image transformation performed on the captured digitized image from modified hemispheric coordinates to planar coordinates for display is one of a multitude of possible image transformations, any of which can be invoked in real-time for smooth merging of effects. These transformations include, but are not limited to pans, up/downs, zooms, tiles, rotations, scaling, cropping, and image shear, which can be controlled using human or computer input. Image filtering can be performed as well as edge detection in associated processes during the course of manipulation. These services can be applied to any system image loaded into the source image buffer, thus providing a host of added features beyond the simple application of the hemispheric lens and display system.

The advantage of the image transformation logic becomes apparent when describing particular applications. A security camera application can be implemented to view an entire panorama such that the security monitor will display full-motion rate images in real-time. Source image coordinates for still images can also be sequenced, allowing perceived animation or full-motion renditions by simply reloading new source image coordinates into the warping engines as frames are drawn from memory. Details from other stored images can be utilized to give the effect of full motion panning of the horizon within the captured image by the lens.

Finally, the transform processor subsystem can produce multiple different outputs simultaneously from individual stored or currently converted images. Referring to FIGS. **6A** and **6B**, with the main transform processor circuits collected into a simplified single block as shown in the lower drawing, multiple outputs are generated from a single image source, either motion or still, with individual effects for each scene as desired, allowing several scenes on different display devices or several windows on a single display. This is accomplished by incorporating several image processing subsystems within one overall system.

In all cases, by having greater resolution of the peripheral image of a scene, the details of any objects along the horizon will be enhanced. Further, aberrations occurring around the periphery of the lens (i.e., spherical aberrations) can be more fully and completely compensated for, as the aberrations are spread across a greater area on the imager device.

As described above, the present invention provides a visual imaging system that efficiently captures, stores, and displays visual information about an enhanced hemispheric field of view existing particularly along the horizon, and that allows electronic manipulation and selective display thereof even after acquisition and storage, while minimizing distortion. The present invention provides an automatic, audio directed video camera steering of segmented images selected from a hemispherical view ideally suited for teleconferencing.

The principles, embodiments, and modes of operation of the present invention have been described in the foregoing specification. The invention that is intended to be protected herein should not, however, be construed to the particular form described as it is to be regarded as illustrative rather than restrictive. Variations and changes may be made by those skilled in the art without department from the spirit of the present invention. Accordingly, the foregoing detailed description should be exemplary in nature and not limiting as to the scope and spirit of the invention as set forth in the appended claims.

What is claimed is:

1. An automatic audio controlled video camera steering system for electronic imaging and manipulation of a hemispheric field of view, comprising:

at least two microphones;

audio detection circuitry connected to said microphones for determining which of said microphones is receiving audio energy;

means for generating a signal representing the direction of the received audio energy based on signals from the microphones;

a video camera for receiving optical images of the field of view and for producing video image output signals;

an optical system associated with said video camera for producing the optical images from a hemispheric field of view for optical conveyance to said video camera, said optical system having a configuration that emphasizes the peripheral content of the panoramic field of view (when the central lens axis is oriented vertically) as compared to the central content of a hemispheric field of view, this being accomplished through differential magnification;

an imager device associated with said camera for receiving the optical images from said lens and for providing digitized output signals;

input image memory for receiving the digitized output signals from said imager device and for storing the digitized output signals;

an image transform processor or set of circuits for selectively accessing and processing the digitized output signals from said input image memory according to user defined criteria;

output image memory for receiving the processed signals from the image transform processor, and

means connected to said output image memory from said hemispheric field of view for selecting a particular segmentized image from the hemispheric field of view representative of the direction from the camera of the microphone array determined to be receiving sound wave energy;

an output display connected to said output image memory for displaying the signals in said output image memory according to the user defined criteria.

2. The system as in claim 1, wherein said optical system has a configuration that images the peripheral portion of the hemispheric scene onto at least 50% -90% of the usable surface area of the imaging device, when used in an electronic image capture apparatus.

3. The system as in claim 2, wherein said optical system includes a color aberrated wide field lens and a gradient index hemispheric lens.

4. The system as in claim 2, wherein said optical system has a configuration which emphasizes the field of view from 1 to 45 degrees up from the horizon in a hemispherical captured image, the lens representing one of many configurations that may selectively emphasize some subset of the aforesaid 1 to 45 degrees covered.

5. The system as in claim 4, wherein said optical system includes a wide field multi-element lens and a coordinated fiber array geometrically fabricated with an annular input end and a rectangular output end.

6. The system as in claim 4, wherein said optical system includes a wide field multi-element lens and a coordinated fiber array geometrically fabricated with an annular input end and a circular output end.

7. A teleconferencing system for electronic manipulation of a hemispheric scene, comprising:

a plurality of microphones;

means connected to the output of said microphones for determining the amplitude levels of audio signals from the microphones;

means for detecting and comparing the audio signals from said microphones to determine the direction of a particular speaker;

means for providing an output signal representing the direction of a speaker at a given time;

a camera imaging system for receiving optical images of the field of view and for producing output video signals corresponding to the optical images;

an optical system associated with said camera imaging system for producing the optical images from a field of view for optical conveyance to said camera imaging system;

an imager device associated with said camera for receiving the optical images from said lens and for providing digitized output signals;

input image memory for receiving the digitized output signals from said imaging device and for storing the digitized output signals;

an image transform processor for selectively accessing and processing the digitized output signals from said input image memory according to user-defined criteria;

means connected to said image transform processor from said microphone direction means to provide the image segment of a hemispheric scene to be selected representing the direction of the speaker based on the audio signals from that array of microphones;

output image memory for receiving the processed signals from the image transform processor means;

an output display device connected to said output image memory for displaying the signals in said output image memory according to user-defined criteria;

wherein the improvement comprises said optical systems having a configuration that emphasizes the peripheral content of field of view of a hemispheric scene as compared to the central content, such that said imager device receives magnified optical images of the peripheral portion of the hemispheric field of view.

8. A teleconferencing method for electronically capturing, storing, and manipulating a hemispheric field of view, having a plurality of individual human speakers, comprising the steps of:

providing a plurality of microphones connected to a microphone audio detection circuit that can provide an output signal that determines which microphone is in use at a given point in time, indicative of the direction of the human speaker;

providing an optical system having a configuration that enhances the peripheral portion of the field of view in the direction of the human speaker;

capturing the hemispheric field of view with the periphery-enhancing optical system and imaging the field of view onto an imager device by enhancing the peripheral field of view;

storing the captured image as a single image;

selectively accessing a portion of the stored image according to user-defined criteria;

transforming the stored image so that the stored image can be displayed as a perspective-correct image;

selecting from a portion of the field of view a specific image segment representative of the direction of the speaker;

displaying the perspective-correct image in a user-defined format.

9. The method as in claim **8**, wherein said transforming step comprises manipulating the peripheral-enhanced image into a perspective-correct image.

10. The method as in claim **8**, wherein said periphery-enhancing optical system selectively magnifies visual content within an arc of between 10 and 45 degrees up from the horizon in a hemispheric field of view onto the imager device.

11. The method as in claim **8**, wherein the storage step comprises storing the captured image in electronic storage.

12. A method for electronically manipulating a hemispheric scene having an enhanced peripheral field of view stored as an image on a video camera, comprising the steps of:

providing a plurality of microphones connected to an audio detection circuit that determines the direction of a given speaker;

converting the image on a video camera into electronic output signals;

selectively accessing a portion of the output signals according to user-defined criteria;

transforming the accessed portion of the output signals by manipulating the peripheral-enhanced field of view so that the stored image can be displayed as a perspective-correct image in a direction based on audio signals from said audio detection circuit;

selecting a particular image segment as a function of speaker direction for display;

displaying the perspective-correct image in the user-defined format.

13. A videoconferencing imaging system having automatic camera steering comprising:

plurality of microphones disposed in a common plane strategically positioned relative to each other and relative to conference participants to be captured on video for remote video and audio transmission of each participant's image and spoken word;

microphone output circuit connected to each of said microphones;

audio detection processor having an input connected to said microphone output circuit;

conference platform for arranging participants in individual locations about said conference platform;

video camera including a hemispheric lens mounted strategically in a predetermined location on said conference platform capable of presenting a hemispheric view to said video camera from said platform;

video image view warping logic circuit connected to the output of said video camera and said output of said audio direction processor, said video image view warping logic circuit having a video output of specific regions of interest based on said hemispheric lens image and having an audio output;

a computer processor or other controller circuits having input connected to said view warping logic circuit for controlling the desired specific region of interest as a function of audio directed processor input related to the participant speaking to create a normal aspect ratio view based on the participants using the system; and

video and audio transmission medium connected to the output of said view warping logic circuit for transmitting said audio and video signals to said remote video conference.

14. A videoconferencing image system having automatic camera steering as in claim **13**, including:

said video image view warping logic circuit including a source image buffer connected to the input from the video camera lens;

a row (X) warp engine having an output connected to said source image buffer;

column (Y) warp engine, said row warp engine and said column warp engine connected to panoramic image transformation parameter look up table and said computer control output;

interpolation coefficient buffer connected to the output of said row (X) warp engine and said column (Y) warp engine;

multiply accumulation unit connected to the output of said source image buffer and said interpolation coefficient buffer for receiving coefficient data;

memory control device connected to the output of said panoramic image transformation parameter look up table and said computer controller;

warped image buffer connected to the output of said column (Y) warp engine and said memory control and having a warp data output connected to said transmission medium whereby the selection of a normal aspect ratio view containing specific regions of interest selected by the determination of the participant speaking is based on the participant's direction, as determined by the audio direction processor.

* * * * *

EXHIBIT 2

US006128145A

United States Patent [19]

Nagaoka

[11] **Patent Number: 6,128,145**

[45] **Date of Patent: Oct. 3, 2000**

[54] **IMAGE PICK-UP DEVICE, IMAGE DISPLAY DEVICE AND INFORMATION RECORDING MEDIUM COMPRISING A FISHEYE LENS**

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[73] Assignees: **FIT Corporation**, Nagano-Pref.; **Rios Corporation**; **Advanet, Inc.**, both of Okayama-Pref., all of Japan

[21] Appl. No.: **09/300,972**

[22] Filed: **Apr. 28, 1999**

[30] **Foreign Application Priority Data**

Nov. 25, 1998 [JP] Japan 10-350751

[51] **Int. Cl.**[7] **G02B 13/04**

[52] **U.S. Cl.** **359/749**; 359/672

[58] **Field of Search** 359/749, 750–753, 359/680–682, 672–675

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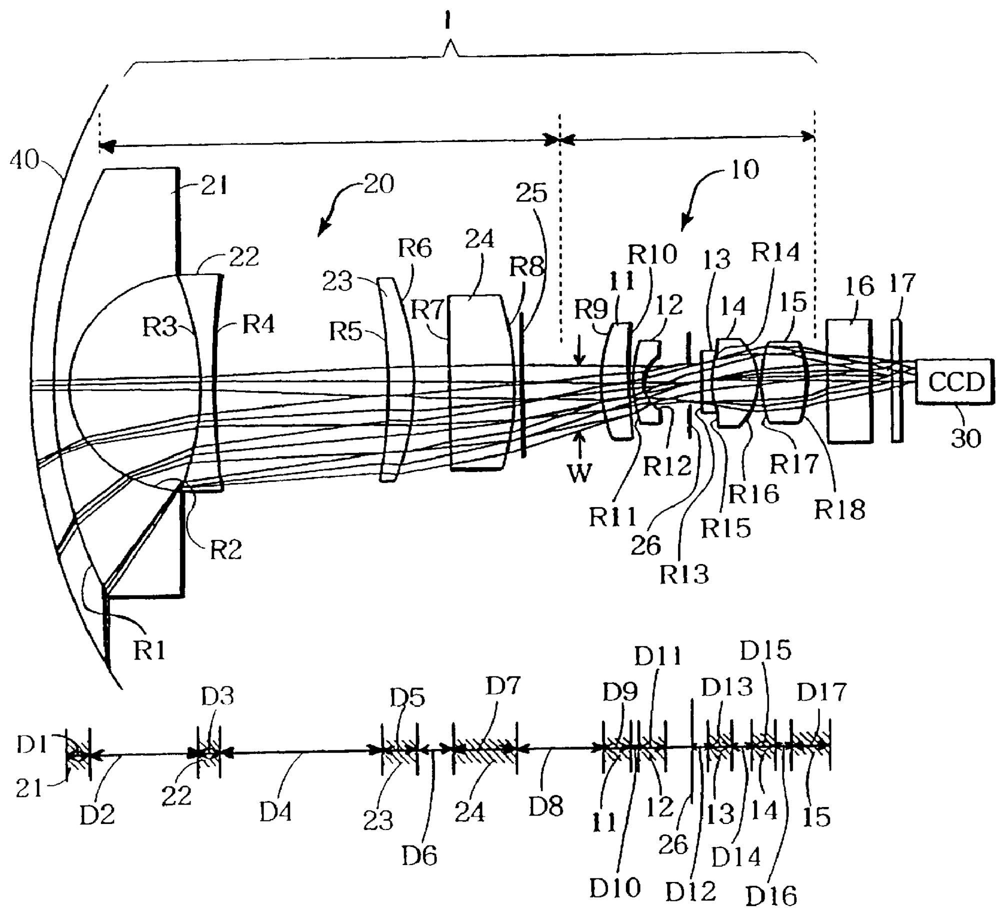
Primary Examiner—Georgia Epps
Assistant Examiner—Jordan M. Schwartz
Attorney, Agent, or Firm—McAulay Nissen Goldberg & Kiel, LLP

[57] **ABSTRACT**

An image is picked up by a camera comprising a fisheye lens having a relationship of $h=n\cdot f\cdot \tan(\theta/m)$, wherein h is the height of an image of a subject at a certain point, f is the focal distance of the fisheye lens, θ is a field angle, m has a value of $1.6\leqq m\leqq 3$, and n has a value of $m-0.4\leqq n\leqq m+0.4$, and the image data of which is output from the camera, is converted into a plane image by an image data processing unit, and this converted image is then output to a monitor unit. Preferably, n and m both equal 2.

14 Claims, 9 Drawing Sheets



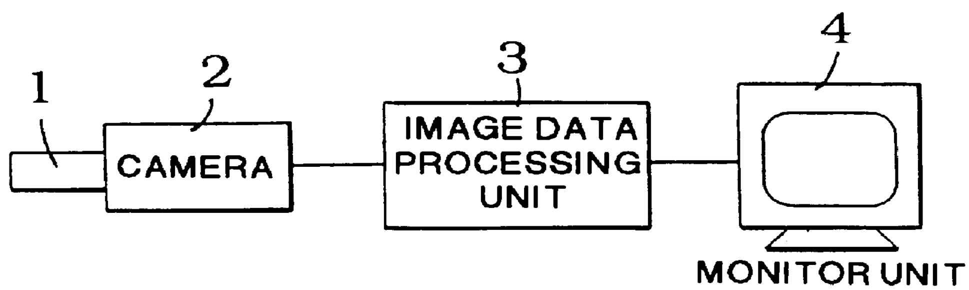
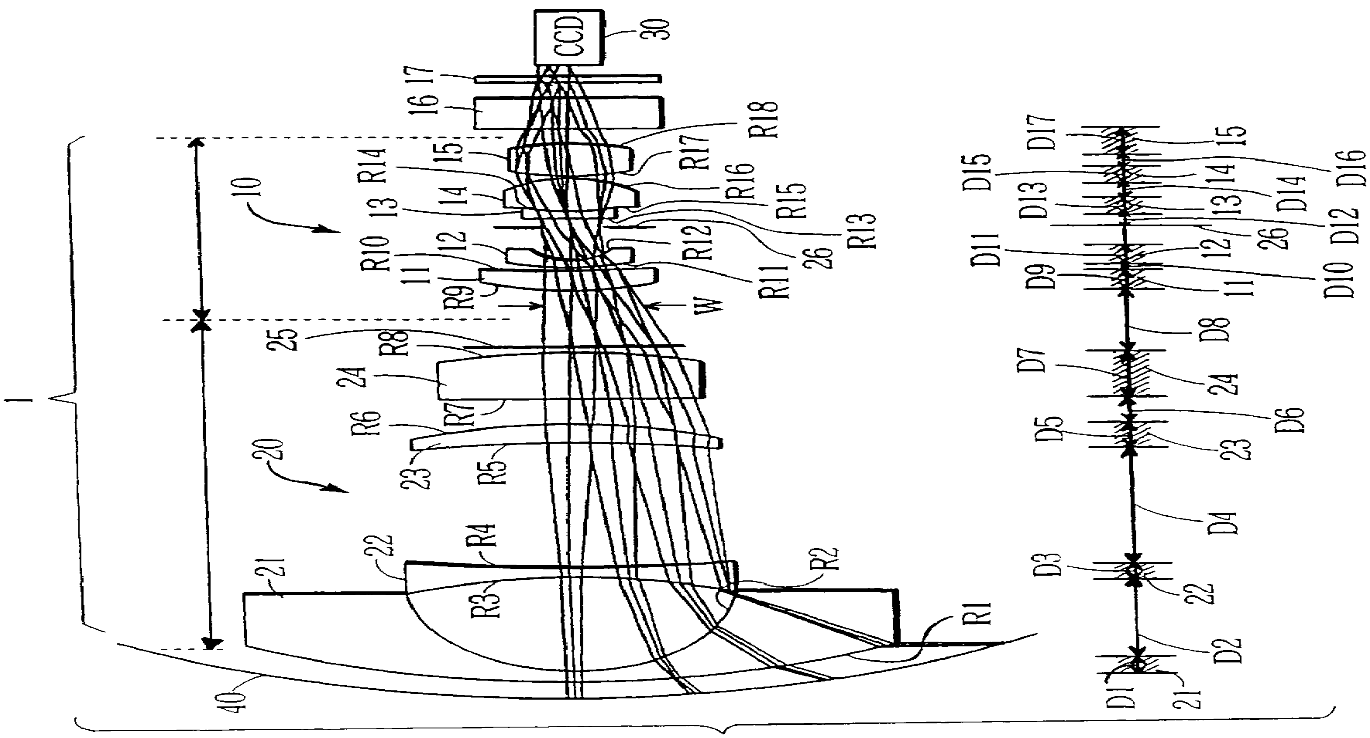


FIG. 1


1
10
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24
25
11
12
13
14
15
16
17
26
30
40
CCD
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R1
R2
R3
R4
R5
R6
R7
R8
R9
R10
R11
R12
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R15
R16
R17
R18
D1
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D14
D15
D16
D17

FIG.2

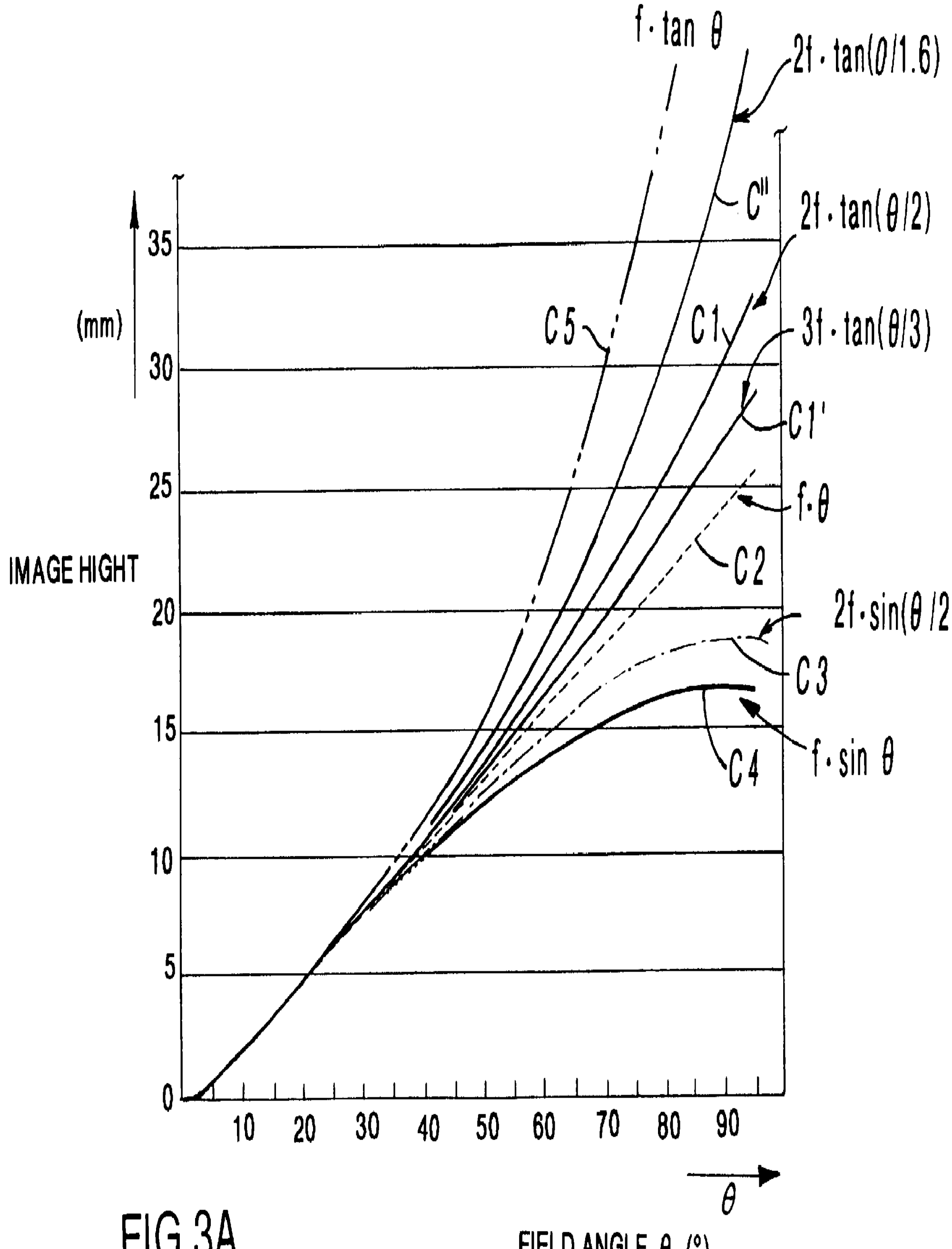

f · tan θ
2f · tan(θ/1.6)
C''
2f · tan(θ/2)
C5
C1
3f · tan(θ/3)
C1'
f·θ
C2
2f·sin(θ/2)
C3
f · sin θ
C4
(mm)
IMAGE HIGHT
35
30
25
20
15
10
5
0
10
20
30
40
50
60
70
80
90
θ
FIELD ANGLE θ (°)

FIG.3A

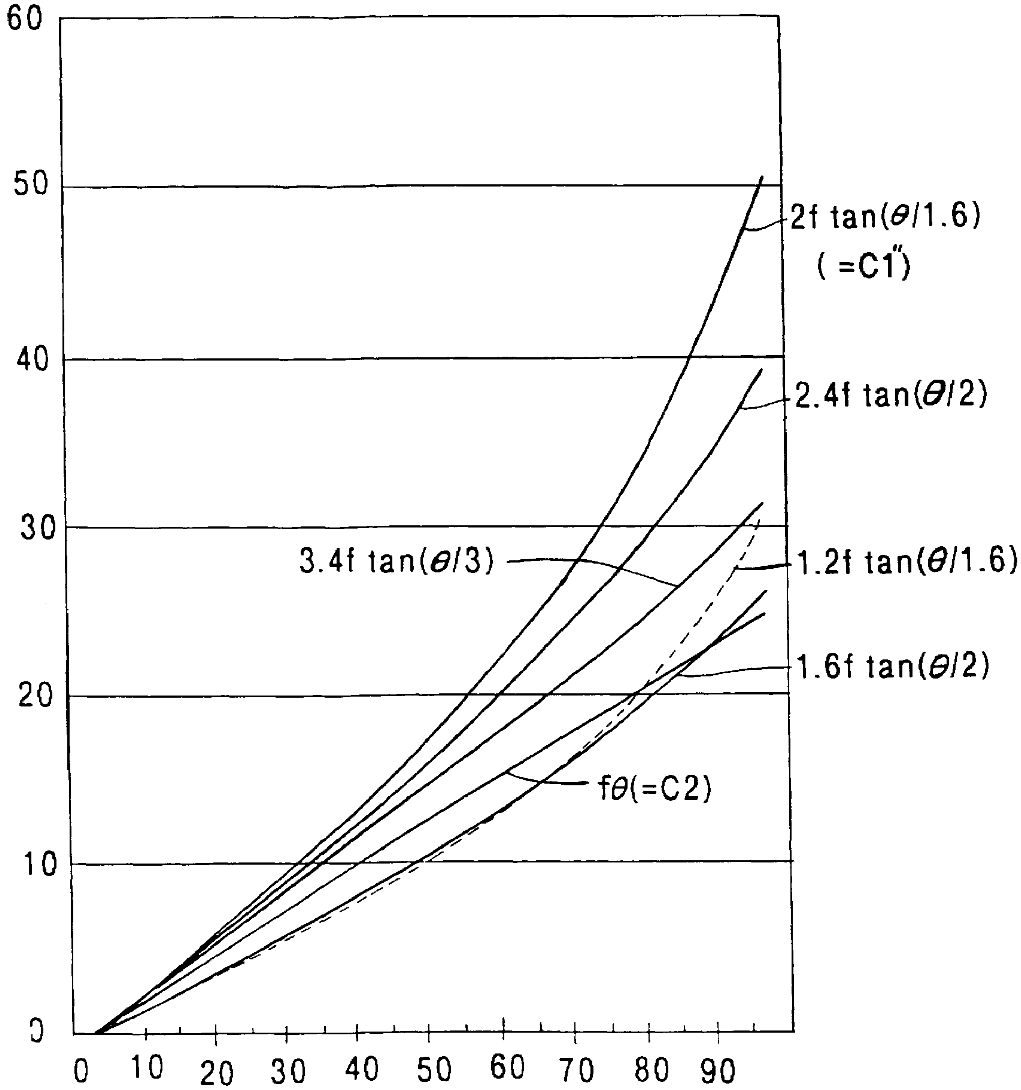

60
50
40
30
20
10
0
0
10
20
30
40
50
60
70
80
90
2f tan(θ/1.6)
(=C1″)
2.4f tan(θ/2)
3.4f tan(θ/3)
1.2f tan(θ/1.6)
1.6f tan(θ/2)
fθ(=C2)

FIG.3B

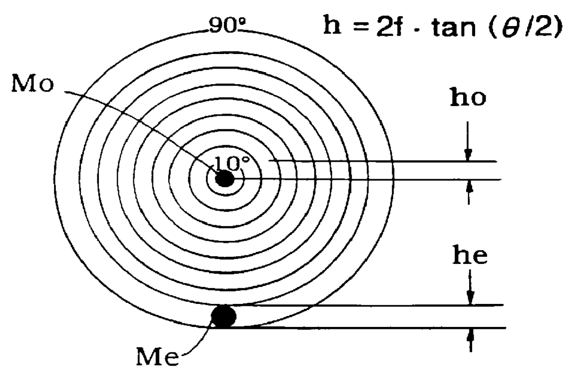


FIG.4A

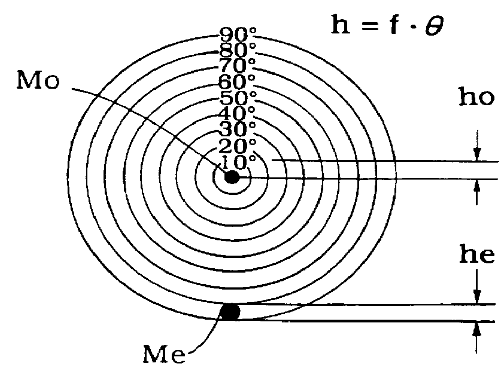


FIG.4B

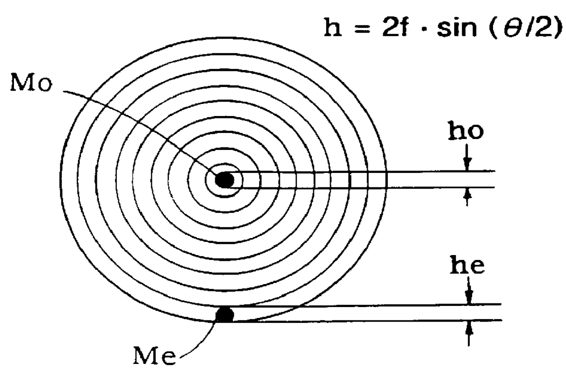


FIG.4C

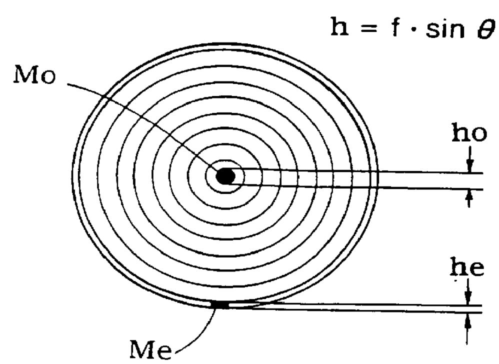


FIG.4D

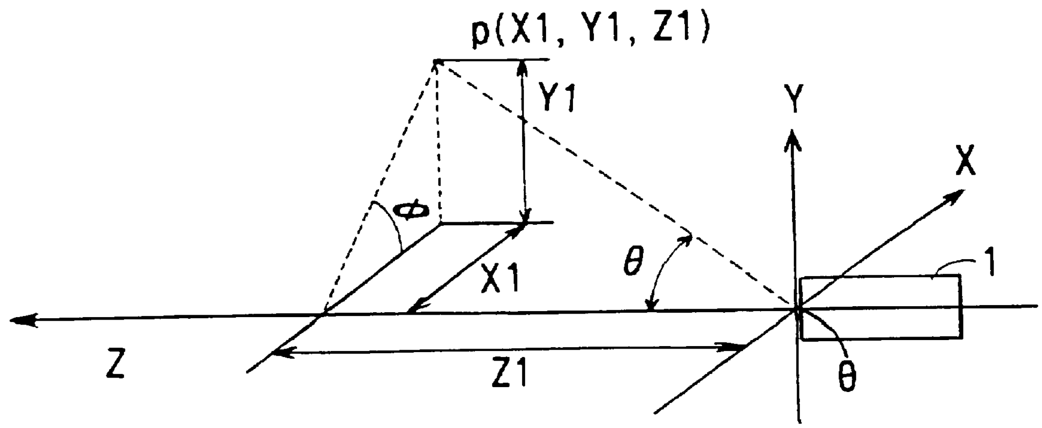


FIG.5

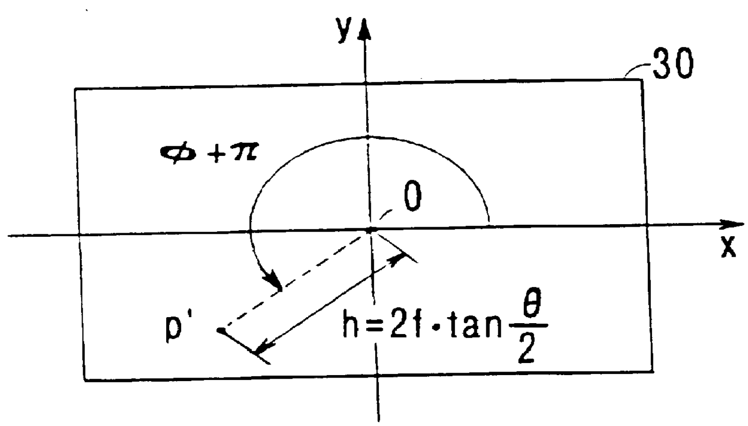


FIG.6

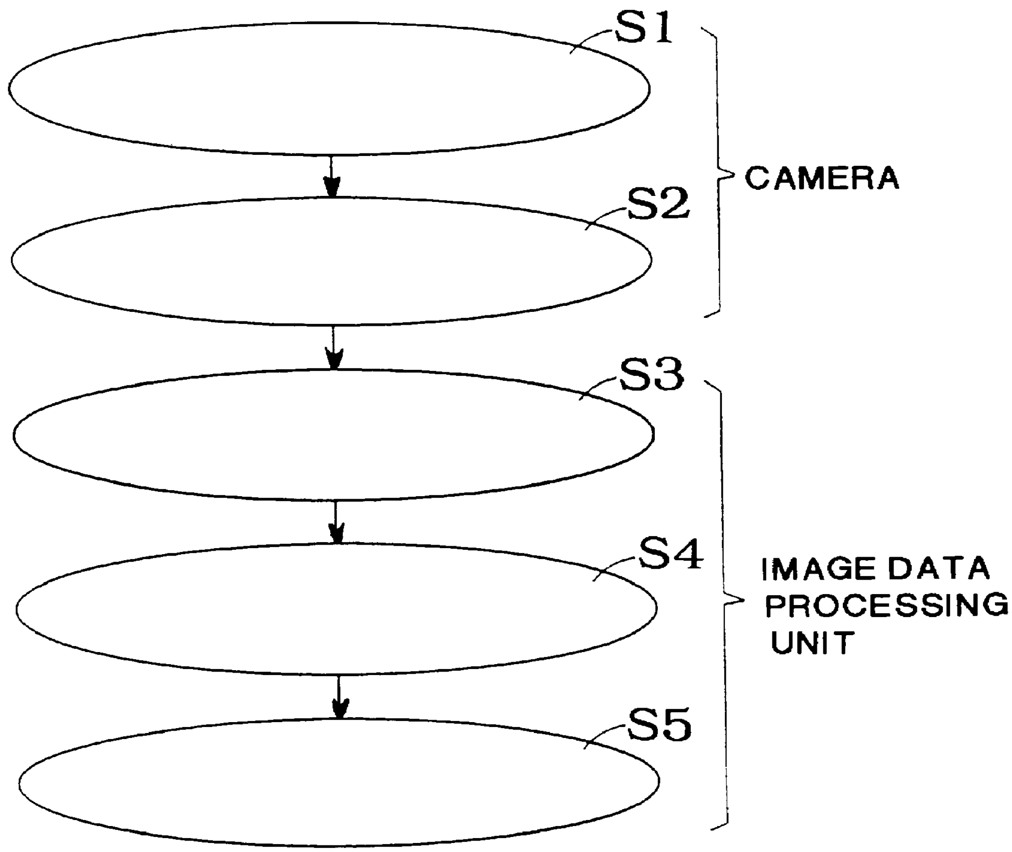


FIG.7

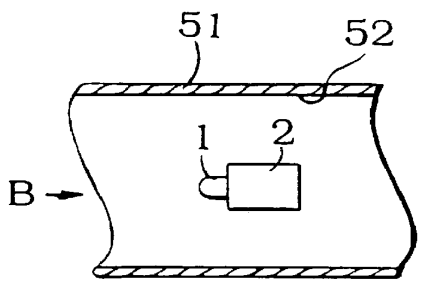


FIG.8A

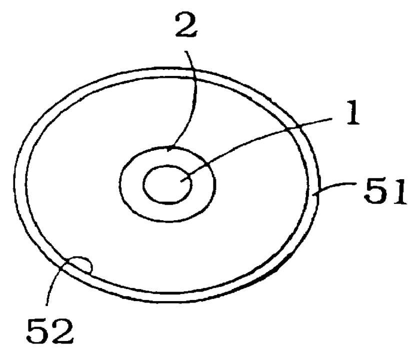


FIG.8B

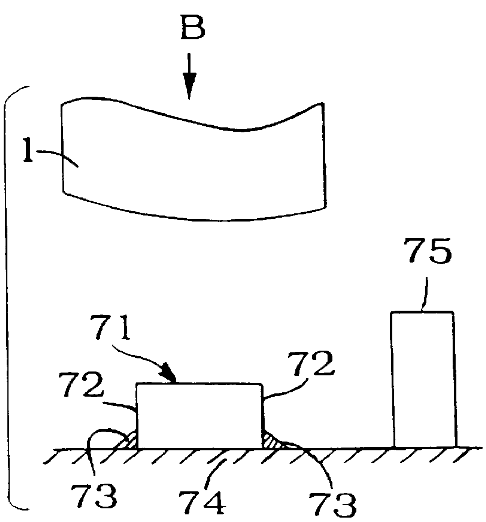


FIG.9A

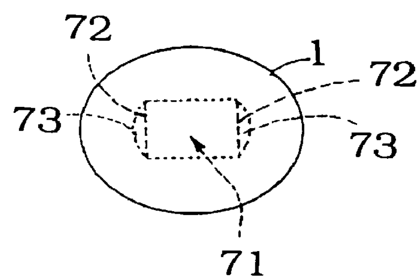


FIG.9B

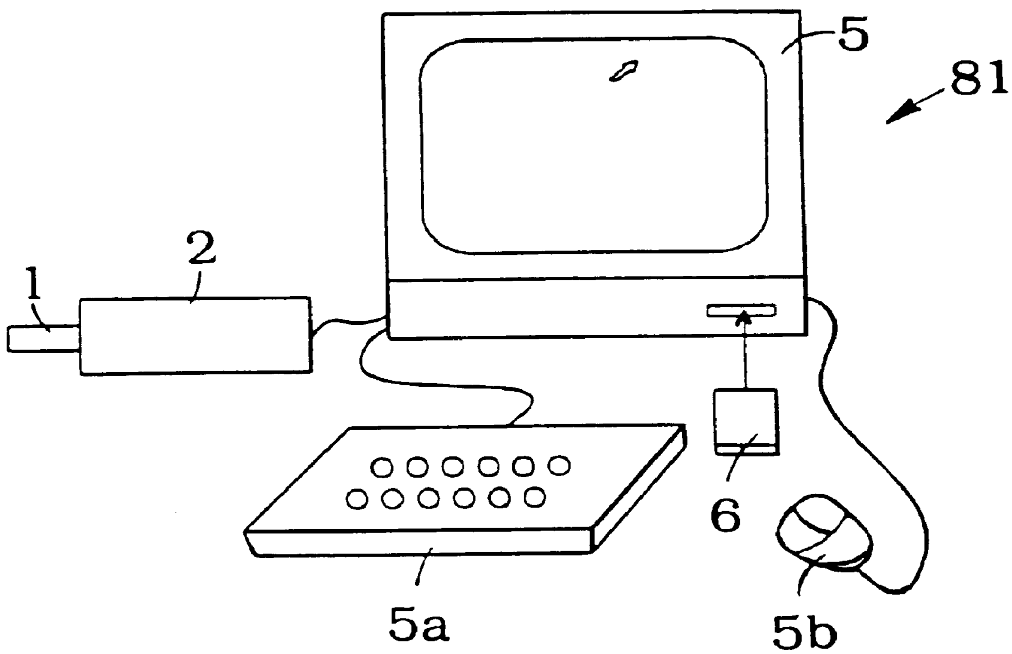


FIG.10

IMAGE PICK-UP DEVICE, IMAGE DISPLAY DEVICE AND INFORMATION RECORDING MEDIUM COMPRISING A FISHEYE LENS

BACKGROUND OF THE INVENTION

The present invention relates to an image pick-up device comprising a fisheye lens, an image display device and an information recording medium, all of which can obtain a high-quality converted image when an image picked up by the fisheye lens is converted into a plane image.

A monitoring system using a camera which enables product examination at a plant or construction work at a construction site to be monitored from a remote place has recently been developed. In this monitoring system, depending on what is monitored, capability of monitoring a wide range at a limited number of cameras is desired. To realize this, the development of a monitoring system comprising a fisheye lens which can pick up an image of all the directions of the field of view around the optical axis at a field angle of at least 90° in each direction with respect to the optical axis is under way.

Use of this fisheye lens makes it possible to obtain an image of all the space with a single camera. That is, the space is regarded as a single sphere, a camera is installed at the center of the sphere, an image of half of the sphere is picked up by the fisheye lens, the camera is turned at an angle of 180° from that position, an image of the other half of the sphere in the opposite direction is picked up, and the two images are combined together to obtain an image of all the directions of the field of view in the space of 360°, that is, the sphere. This image is converted into a plane image.

As the monitoring system comprising a fisheye lens of the prior art, there is a system disclosed by Japanese Patent Application Laid-open No. Hei6-501585 (to be referred to as "prior art" hereinafter), for example. Although this prior art makes it possible to pick up an image of all the directions of the field of view, the lens used in the prior art is a fisheye lens having a relationship of $h=f\cdot\theta$ (wherein h is the height of an image of a subject at a certain point obtained by the fisheye lens, f is the focal distance of the fisheye lens and θ is a field angle). This is obvious from the fact that Nikon's 8-mm f/2.8 lens is used as the fisheye lens in the above Japanese Patent Application Laid-open No. Hei6-501585. Conventional fisheye lenses generally have a relationship of $h=f\cdot\theta$ and Nikon's 8-mm f/2.8 fisheye lens has the above relationship of $h=f\cdot\theta$.

The method of picking up an image by a fisheye lens having this relationship of $h=f\cdot\theta$ and converting the image into a plane image is called "equidistant projection". Since an image picked up by a fisheye lens having the above characteristics has a small volume of image data on its peripheral portion (field angle of around 90° with respect to the optical axis of the fisheye lens), when the image is converted into a plane image, there are many missing portions of image data on the peripheral portion of the image and the missing portions must be interpolated. In addition, the image picked up by the fisheye lens having the above characteristics involves such a problem that the peripheral portion of the image is distorted.

An object of the present invention is to provide an image pick-up device comprising a fisheye lens, an image display device and an information recording medium, which minimize missing portions of image data by extracting a large volume of image data at a field angle of around 90° with respect to the optical axis of the fisheye lens to reduce interpolating of the missing portions and can obtain a natural plane image when images of all the directions of the field of view around the optical axis are picked up at a field angle of at least 90° with respect to the optical axis and are converted into plane images.

Various other objects, advantages and features of the present invention will become readily apparent to those of ordinary skill in the art, and the novel features will be particularly pointed out in the appended claims.

SUMMARY OF THE INVENTION

To attain the above object, according to a first aspect of the present invention, there is provided an image pick-up device comprising a fisheye lens for picking up an image of all the directions of the field of view around the optical axis of the fisheye lens at a field angle of at least 90° in each direction with respect to the optical axis, wherein the fisheye lens has a relationship of $h=nf\cdot\tan(\theta/m)$ (wherein h is the height of an image of a subject at a certain point obtained by the fisheye lens, f is the focal distance of the fisheye lens, $1.6\leqq m\leqq 3$, $m-0.4\leqq n\leqq m+0.4$, and θ is a field angle).

According to a second aspect of the present invention, the fisheye lens is constructed by a master lens provided on an existing image pick-up device and by an attachment lens to be attached to the master lens.

Further, according to a third aspect of the present invention, there is provided an image display device comprising an image data processing unit for converting an image obtained by the image pick-up device of the first or second aspect of the present invention into a plane image and a display unit for displaying the converted plane image.

According to a fourth aspect of the present invention, there is provided an information recording medium that records a program having at least the step of converting an image obtained by a fisheye lens having a relationship of $h=nf\cdot\tan(\theta/m)$ (wherein h is the height of an image of a subject at a certain point, f is the focal distance of the fisheye lens, θ is a field angle, $1.6\leqq m<3$. and $m-0.4\leqq n\leqq m+0.4$) into a plane image, the step of displaying a predetermined portion of the converted plane image on a display unit and the step of changing continuously the predetermined portion with instruction means.

One of the fisheye lens used in the present invention has the relationship of $h=2f\cdot\tan(\theta/2)$. Compared with an ordinary fisheye lens having a relationship of $h=f\cdot\theta$, an image at a peripheral portion (field angle of around 90° with respect to the optical axis of the fisheye lens) is enlarged and missing portions of image data on the peripheral portion can be minimized with the fisheye lens in accordance with the present invention. With this, when a picked-up image is to be converted into a plane image, the interpolating of image data can be reduced, thereby making it possible to obtain a more natural plane image.

The fisheye lens according to the present invention may be constructed by attaching an attachment lens to a master lens provided on an existing camera so that the fisheye lens can be attached to almost all the existing cameras. In addition, only the attachment lens is newly produced, thereby making it possible to reduce costs.

Further, the image display device for displaying a plane image converted from an image picked up by the image pick-up device having the above fisheye lens on a display unit makes the displayed image easy to be seen, thereby improving the value of the device. When the information recording medium recording the above steps is read by a computer and the program is executed, a more natural plane image can be displayed on the display unit and the displayed portion can be freely shifted within the range of the image picked up by the image pick-up device.

BRIEF DESCRIPTION OF THE DRAWINGS

The following detailed description, given by way of example and not intended to limit the present invention solely thereto, will best be appreciated in conjunction with the accompanying drawings, wherein like reference numerals denote like elements and parts, in which:

FIG. **1** is a schematic structural diagram of an image processing system using an image pick-up device comprising a fisheye lens according to the present invention;

FIG. **2** are a structural diagram of the fisheye lens shown in FIG. **1** and a corresponding diagram schematically showing lens intervals (lens intervals and lens thicknesses);

FIG. **3**(A) is a diagram showing the relationship between field angle θ and image height h with respect to fisheye lenses having relationships of h=f·θ, h=2f·sin (θ/2), h=f·sin θ, h=f·tan θ, h=3f·tan (θ/3), h=2f·(tan θ/1.6) and one of the fisheye lenses of the present invention having a relationship of h=2f·tan(θ/2);

FIG. **3**(B) is a diagram showing the relationship between field angle θ and image height h with respect to fisheye lenses having relationships of h=2f·tan(θ/1.6), h=2.4f·tan(θ/2), h=3.4f·tan(θ/3), h=1.2f·tan(θ/1.6), h=1.6f·tan(θ/2) and h=f·θ.

FIGS. **4**(A) to **4**(D) are views illustrating, in concentric circles each centering around the optical axis of each fisheye lens shown in FIG. **3**, changes of image heights when the field angle is changed in 10° with respect to the optical axis of each fisheye lens;

FIG. **5** is a diagram for explaining a method of polar-coordinate converting a hemispherical image obtained by a fisheye lens;

FIG. **6** is a diagram for explaining a method of obtaining the position of an image formation point on the surface of CCD image pick-up elements in the polar coordinate conversion of FIG. **5**;

FIG. **7** is a flow chart for explaining the steps of processing an image using the image processing system of FIG. **1**;

FIGS. **8**(A) and **8**(B) are diagrams showing another application example of the image pick-up device of the present invention, wherein FIG. **8**(A) is a schematic diagram showing the side thereof and FIG. **8**(B) is a diagram when seen from a direction indicated by an arrow B in FIG. **8**(A);

FIGS. **9**(A) and **9**(B) are diagrams showing still another application example of the image pick-up device of the present invention, wherein FIG. **9**(A) is a schematic diagram showing the side thereof and FIG. **9**(B) is a diagram when seen from a direction indicated by an arrow B in FIG. **9**(A); and

FIG. **10** is a diagram showing another example of an image processing system utilizing the image pick-up device comprising a fisheye lens of the present invention.

DETAILED DESCRIPTION OF CERTAIN PREFERRED EMBODIMENTS

Preferred embodiments of the present invention will be described hereinafter with reference to FIGS. **1** to **10**.

FIG. **1** schematically shows an image processing system utilizing an image pick-up device comprising a fisheye lens of the present invention. This image processing system comprises a camera (such as a video camera) **2** that is an image pick-up device equipped with a fisheye lens **1**, an image data processing unit **3** for processing image data from the camera **2**, and a monitor unit **4** for displaying an image processed by the image data processing unit **3**. The image data processing unit **3** has a CPU, memory means and the like and performs various processing using image data output from the camera **2**. In the case of the present invention, the image data processing unit **3** also converts an image picked up by the fisheye lens **1** into a plane image.

As shown in FIG. **2**, the fisheye lens **1** used in this embodiment roughly consists of a lens unit (called master lens unit) **10** provided on the camera **2** and a lens unit (called attachment lens unit) **20** that can be attached to and detached from the master lens unit **10**. The fisheye lens **1** of the present invention functions as a fisheye lens when the attachment lens unit **20** is attached to the master lens unit **10**.

The attachment lens unit **20** consists of a first lens **21**, a second lens **22**, a third lens **23**, a fourth lens **24** and a plate **25**. The master lens unit **10** consists of a fifth lens **11**, a sixth lens **12**, a seventh lens **13**, an eighth lens **14**, a ninth lens **15** and a diaphragm **26** interposed between the sixth lens **12** and the seventh lens **13**.

The curvature R (diameter of the curved surface of the lens) of each lens and interval D (lens thickness or lens interval) in this embodiment are as follows. That is, beginning with the curvature R**1** of the left curved surface of the first lens **21** on the leftmost side of FIG. **2**, in turn, the curvatures R**1** and R**2** of the first lens **21** are 40.0 mm and 9.0 mm, the curvatures R**3** and R**4** of the second lens **22** are −26.0 mm and 80.0 mm, the curvatures R**5** and R**6** of the third lens **23** are −36.0 mm and −20.0 mm, and the curvatures R**7** and R**8** of the fourth lens **24** are −81.0 mm and −27.0 mm, respectively.

Further, the curvatures R**9** and R**10** of the fifth lens **11** are 14.0 mm and 68.0 mm, the curvatures R**11** and R**12** of the sixth lens **12** are 9.0 mm and 3.0 mm, the curvatures R**13** and R**14** of the seventh lens **13** are 0.0 mm and −8.0 mm, the curvatures R**15** and R**16** of the eighth lens **14** are 10.0 mm and −6.0 mm, and the curvatures R**17** and R**18** of the ninth lens **15** are 11.0 mm and −9.0 mm, respectively.

Meanwhile, the thickness D**1** of the first lens **21** on the leftmost side of FIG. **2** is 1.2 mm, the interval D**2** between the first lens **21** and the second lens **22** is 10.00 mm, and the thickness D**3** of the second lens **22** is 1.2 mm. The interval D**4** between the second lens **22** and the third lens **23** is 14.0 mm, the thickness D**5** of the third lens **23** is 2.0 mm, the interval D**6** between the third lens **23** and the fourth lens **24** is 3.0 mm, and the thickness D**7** of the fourth lens **24** is 5.0 mm.

Further, the interval D**8** between the fourth lens **24** and the fifth lens **11** is 7.0 mm, the thickness D**9** of the fifth lens **11** is 2.0 mm, the interval D**10** between the fifth lens **11** and the sixth lens **12** is 0.3 mm, and the thickness D**11** of the sixth lens **12** is 0.8 mm The seventh lens **13**, the eighth lens **14** and the ninth lens **15** can be moved in the direction of the optical axis to change magnification, and the intervals between adjacent lenses to be described hereinafter are maximum values thereof. The interval D**12** between the diaphragm **26** and the seventh lens **13** is 4.0 mm, the thickness D**13** of the seventh lens **13** is 1.0 mm, the interval D**14** of the seventh lens **13** and the eighth lens **14** is 1.0 mm, and the thickness D**15** of the eighth lens **14** is 4.0 mm.

The interval D**16** between the eighth lens **14** and the ninth lens **15** is 2.0 mm, and the thickness D**17** of the ninth lens is 4.0 mm. Parallel plates **16** and **17** are arranged on the right side in FIG. **2** of the ninth lens **15**.

In this arrangement, light incident upon the first lens **21** passes through the first to fourth lenses **21** to **24**, further through the fifth to ninth lenses **11** to **15** and is input into CCD image pick-up elements **30** in the camera **2**. In this attachment lens unit **20**, parallel rays input into the first lens **21** are output from the fourth lens **24** as parallel rays. Therefore, this attachment lens unit **20** can be attached to almost all the cameras. The width of the parallel pencil of rays output from the fourth lens **24** of the attachment lens unit **20** (shown by "w" in the figure) is set to ½ or less the effective diameter of the master lens **10** of the camera to which the attachment lens unit **20** is attached. In FIG. **2**, the spherical surface **40** at the front of the first lens **21** represents a virtual subject surface of the picked up image.

As described above, the present invention is characterized in that a desired fisheye lens **1** constructed by the master lens unit **10** and the attachment lens unit **20** and has a relationship of $h=2f\cdot\tan(\theta/2)$ (wherein h is the height of an image of a subject at a certain position, f is the focal distance of the fisheye lens and θ is a field angle). It is noted that although the preferred embodiment of the present invention has the above-indicated relationship, the present invention also embodies fisheye lenses having the relationship of $h=n\cdot f\cdot\tan(\theta/m)$, where m has the value of $1.6\leqq m\leqq 3$, and n has the value of $m-0.4\leqq n\leqq m+0.4$. Also, the present invention contemplates such a relationship when m equals n. Also, the relationship $h=1.2\ f\cdot\tan(\theta/m)$, $m\geqq 1.6$ also is embodied by the present invention. However, for purposes of discussion herein, m and n both equal to 2.

The fisheye lens that has been generally used in the prior art has a relationship of $h=f\cdot\theta$ as described above. These functions are used to map a spherical image as a polar-coordinate converted image. The relationship, other than that, may be $h=2f\cdot\sin(\theta/2)$, $h=2f=\cdot\sin\theta$ or $h=f\cdot\tan\theta$.

FIG. **3**(A) is a diagram showing relationships between field angle θ and image height h when fisheye lenses having relationships of $h=2f\cdot\tan(\theta/2)$, $h=f\cdot\theta$, $h=f\cdot\sin(\theta/2)$, $h=f\cdot\sin\theta$ and $h=f\cdot\tan\theta$, etc. are used. Here, θ=90° shows a field angle with respect to the optical axis (the field angle of the optical axis is 0°).

In FIG. **3**(A), a curve C**1** shows the relationship between field angle θ and image height h when the fisheye lens of the present invention having the relationship of $h=2f\cdot\tan(\theta/2)$ is used, and a curve C**2** shows the relationship between field angle θ and image height h when a fisheye lens having the relationship of $h=f\cdot\theta$ is used. A curve C**3** shows the relationship between field angle θ and image height h when a fisheye lens having the relationship of $h=2f\cdot\sin(\theta/2)$ is used, a curve C**4** shows the relationship between field angle θ and image height h when a fisheye lens having the relationship of $h=2f\cdot\sin\theta$ is used, and a curve C**5** shows the relationship between field angle θ and image height h when a fisheye lens having the relationship of $h=f\cdot\tan\theta$ is used. A curve C1' shows the relationship of $h=3f\cdot\tan(\theta/3)$ and a curve C" shows the relationship of $h=2f\cdot\tan(\theta/1.6)$.

FIG. **3**(B), is a diagram showing the relationship between field angle θ and image height when fisheye lenses having relationships of $h=2f\cdot\tan(\theta/1.6)$, $h=2.4f\cdot\tan(\theta/2)$, $h=3.4f\cdot\tan(\theta/3)$, $h=1.2f\cdot\tan(\theta/1.6)$, $h=1.6f\cdot\tan(\theta/2)$ and $h=f\cdot\theta$. All of these fisheye lenses, except $h=f\cdot\theta$, are embodied by the present invention.

As is evident from FIG. **3**, an increase in image height h at a field angle θ of about 90° is largest when the fisheye lens having the relationship of $h=f\cdot\tan\theta$ is used and is second largest when the fisheye lens having the relationship of $h=2f\cdot\tan(\theta/2)$ is used. Changes in image height h with respect to changes in field angle θ become linear when the fisheye lens having the relationship of $h=f\cdot\theta$ is used and further an increase in image height h tends to be smaller as the field angle becomes closer to 90° when the fisheye lenses having the relationships of $h=2f\cdot\sin(\theta/2)$ and $h=f\cdot\sin\theta$ are used.

An increase in image height becomes larger toward the peripheral portion (field angle of 90°) when the fisheye lens having the relationship of $h=f\cdot\tan\theta$ is used and more image data can be obtained. However, at a field angle θ of 90°, tan θ becomes infinite. Since the fisheye lens is required to obtain an image of all the directions of the field of view around the optical axis at a field angle of at least 90° with respect to the optical axis, it can be said that the fisheye lens having the relationship of $h=f\cdot\tan\theta$ is not suitable.

Therefore, the fisheye lenses having relationships of $h=2f\cdot\tan(\theta/2)$, $h=f\cdot\theta$, $h=2f\cdot\sin(\theta/2)$ and $h=f\cdot\sin\theta$ may be used. FIGS. **4**(A) to **4**(D) show, in concentric circles each centering around the optical axis of each fisheye lens, image heights h when the field angle θ is changed in 10° with respect to the optical axis of each fisheye lens. FIG. **4**(A) shows the image height in the fisheye lens having the relationship of $h=2f\cdot\tan(\theta/2)$, FIG. **4**(B) shows the image height in the fisheye lens having the relationship of $h=f\cdot\theta$, FIG. **4**(C) shows the image height in the fisheye lens having the relationship of $h=2f\cdot\sin(\theta/2)$, and FIG. **4**(D) shows the image height in the fisheye lens having the relationship of $h=f\cdot\sin\theta$. In FIGS. **4**(A) to **4**(D), ho represents the height of an image Mo near the optical axis of each fisheye lens and he represents the height of an image Me at a field angle of around 90°.

As is understood from FIGS. **4**(A) to **4**(D), image height at a field angle of around 90° when the fisheye lens having the relationship of $h=2f\cdot\sin(\theta/2)$ or the fisheye lens having the relationship of $h=f\cdot\sin\theta$ is used is smaller than image height near the optical axis and only a small volume of image data can be obtained. The image height he of an image Me at a peripheral portion of the fisheye lens that has been generally used and has the relationship of $h=f\cdot\theta$ is the same as the image height ho of an image Mo near the optical axis and the image is distorted.

From these facts, it can be said that the fisheye lenses having relationships of $h=2f\cdot\sin(\theta/2)$ and $h=f\cdot\sin\theta$ are not preferred in view that how large volume of data can be obtained at a field angle of 90° or therearound. Even with the fisheye lens that has been generally used and has the relationship of $h=f\cdot\theta$ is not satisfactory.

In contrast to that, the image height he of the image Me at a peripheral portion of the fisheye lens **1** having the relationship of $h=2f\cdot\tan(\theta/2)$ in accordance with the present invention is enlarged and larger than the image height ho of the image Mo near the optical axis, a larger volume of image data can be obtained in comparison with the conventional fisheye lens, and the obtained image is not distorted.

When a single spherical image obtained by combining two hemispherical images of all the directions of the field of view around the optical axis of the fisheye lens **1**, which are picked up at a field angle of 90° with respect to the optical axis is converted into a plane image by the image data processing unit **3**, it is necessary to interpolate missing image data on the peripheral portion (field angle of around 90° with respect to the optical axis) of the image. According to the present invention, since an image at the peripheral portion is enlarged and a large volume of data on the peripheral portion can be extracted, the volume of image data to be interpolated can be greatly reduced, when compared with the conventional system.

An image of all the directions of the field of view around the optical axis is picked up at a field angle of at least 90°

with respect to the optical axis and is polar-coordinate converted into a plane image in the following manner.

An X, Y and Z coordinate system as shown in FIG. **5** is imagined in subject space. At this point, the optical axis of the fisheye lens **1** is made Z axis. The coordinates of a certain point p are represented as (X1, Y1, Z1) and the elevation angle of the point p from the origin O of the coordinates with respect to the XZ plane is represented by θ. The elevation angle of the point p from the position of Z1 on the Z axis with respect to the XZ plane is represented by ø.

When an x and y coordinate system having the optical axis (Z axis) as an origin o is imagined on the surface of CCD image pick-up elements **30** as shown in FIG. **6** and the focal distance of the fisheye lens **1** is represented by f, the image formation point (p') for the point p is located as shown in FIG. **6**. In FIG. **6**, π is added to ø because an image formed at the point p' is inverted vertically and horizontally with respect to the image of the subject surface (point p). The optical axis in FIG. **6** is present in a direction perpendicular to the paper from the origin o of the x and y coordinates.

The position of the point p' is expressed as polar coordinates with a length (h) between the origin o and the point p' and an angle ø+π formed by op' and the x axis. When the polar coordinates are expressed on the x and y rectangular coordinates, the position (x1, y1) on the x and y rectangular coordinates are expressed as follows.

$$x1=h\cdot\cos(\varnothing+\pi) \quad (1)$$

$$y1=h\cdot\sin(\varnothing+\pi) \quad (2)$$

In addition, the image height h of the point p' is represented by h=2f·tan(θ/2), hence, when h=2f·tan(θ/2) is substituted into the above expressions (1) and (2), the coordinates (x1, y1) of the image formation point p' on the surface of the CCD image pick-up elements **30** are as follows.

$$x1=2f\cdot\tan(\theta/2)\cdot\cos(\varnothing+\pi) \quad (3)$$

$$y=2f\cdot\tan(\theta/2)\cdot\sin(\varnothing+\pi) \quad (4)$$

As a result, they are expressed as follows.

$$x=-2f\cdot\tan(\theta/2)\cdot\cos\varnothing \quad (5)$$

$$y=-2f\cdot\tan(\theta/2)\cdot\sin\varnothing \quad (6)$$

In the above expressions, θ and ø are defined as follows.

$$\theta=\tan^{-1}(\sqrt{X1^2+Y1^2}/Z1)$$

$$\varnothing=\tan^{-1}(Y1/X1)$$

Thus, the position of the point p' on the surface of CCD image pick-up elements **30** can be obtained for the point p on the surface of the subject.

Thereafter, a description is subsequently given, with reference to FIG. **7**, of steps required when the sphere (all directions) is photographed by the camera **2** comprising the fisheye lens **1** and an image thereof is displayed on the monitor unit **4** that is the display unit.

First, a hemisphere in one direction is photographed by the camera **2** comprising the fisheye lens **1** (step S**1**). Thereby, an image of the hemisphere is formed on the surface of the CCD image pick-up elements **30** as a polar-coordinate converted image. Thereafter, the camera **2** is turned at an angle of 180° to photograph the other hemisphere in the opposite direction (step S**2**). Thereby, an image of the other hemisphere is formed on the surface of the CCD image pick-up elements **30** as a polar-coordinate converted image.

The above two images are then combined together and the combined image is converted into a plane image by the image data processing unit **3** (step S**3**). At this point, an area corresponding to a connection portion between these hemispheres must be corrected. Since the polar-coordinate converted image obtained by the fisheye lens **1** has a large volume of information on a peripheral portion, the processing of combining these images is easy. Thereafter, a predetermined portion of the thus obtained plane image is extracted and displayed on the monitor unit **4** (step S**4**).

A user shifts the screen with instruction means such as a mouse when the user likes to change the displayed predetermined portion. This shifting can be made continuously in any direction of 360° around the portion displayed on the monitor unit **4** (step S**5**).

The above steps are for picking up an image of a sphere in all the directions of 360°. When only a single hemisphere is photographed, the same steps are taken. However, step S**2** is unnecessary and the processing of combining two images in step S**3** is also unnecessary.

In the present invention, since the volume of information on the peripheral portion of an image obtained by the fisheye lens **1** is large, that is, an image at the peripheral portion is enlarged, it is convenient when the present invention is used for the examination of a product. For example, when the inner surface **52** of a cylindrical body **51** is photographed at the condition that the optical axis of the fisheye lens **1** of the present invention is aligned with the central axis of the cylindrical body **51** as shown in FIGS. **8**(A) and **8**(B), a peripheral portion of an image can be extracted as an image having a larger volume of information than a central portion in the present invention. Therefore, it is easy to find that a scratch has been generated in the inner surface **52**. Consequently, this can be used for the examination of a pipe-like body such as a water pipe or gas pipe and further for the monitoring of a crack that has been generated in the wall surface of a tunnel or the like.

It can also be used for the examination of the connection condition of a small part such as an IC. That is, when a part **71** is fixed to a substrate **74** by a solder **73** on its both sides **72** and **72** shown in FIGS. **9**(A) and **9**(B), the soldering state of the part must be checked from its side direction in the prior art. However, when another part **75** is existent in a side direction, the solder **73** on the part **75** side cannot be seen through a camera, thereby making automatic examination difficult. On the other hand, even when the fisheye lens **1** is installed right over the part **71** as shown in FIG. **9**(A), the side direction of the part **71** can be sufficiently photographed by the camera **2** comprising the fisheye lens **1** of the present invention, thereby enabling automatic examination with the camera **2**.

Although each foregoing embodiment is an example of a preferred embodiment of the invention, it is to be understood that the invention is not limited thereto and that various changes and modifications may be made in the invention without departing from the spirit and scope thereof. For example, the fisheye lens may be constructed by the attachment lens unit **20** alone without the master lens **10**, or contrariwise may be constructed by an integrated unit of the master lens unit **10** and the attachment lens unit **20**. Also, the construction and numerical values of the fisheye lens **1** shown in the above embodiment are just examples and a fisheye lens having other construction and numerical values may be used.

Further, as the system comprising the fisheye lens **1** of the present invention, an image processing system **81** shown in FIG. **10** may be used. This image processing system **81** is mainly constructed with a camera **2** equipped with a fisheye lens **1** and an image data processing unit/monitor **5** connected to the camera **2** by a cable. The image data processing unit/monitor **5** is a personal computer equipped with a monitor, and a key board **5***a* and a mouse **5***b* are connected to the computer as instruction means.

Also, this image data processing unit/monitor **5** has a hard disk (not shown) in that the contents of an information recording medium (floppy disk) **6** recording a program for executing the steps S3, **S4** and S5 shown in FIG. **7** are to be installed. By installing this program in the image data processing unit/monitor **5**, the image data processing unit/monitor **5** carries out the same function as the image data processing unit **3** which has been described in the foregoing.

Image pick-up data may be transferred from the camera **2** to the image data processing unit/monitor **5** by a memory card such as a flash card or wireless communication such as infrared communication, besides a cable. Further, the program may be installed not from the floppy disk **6** but other recording medium such as a CD-ROM, or transferred from other storage unit over a network. When the program is transferred over a network, the storage unit of a transmitter or the hard disk (storage unit) of the image data processing unit/monitor **5** serves as the information recording medium of the present invention.

As having been described above, in the image pick-up device comprising the fisheye lens according to the first aspect of the present invention, the fisheye lens has the relationship of $h=nf\cdot\tan(\theta/m)$ (wherein h is an image height, f is a focal distance, and θ is a field angle). With this, compared with the ordinary fisheye lens having the relationship of $h=f\cdot\theta$ (wherein h is an image height, f is a focal distance, and θ is a field angle), an image at a peripheral portion (field angle of around 90° with respect to the optical axis of the fisheye lens) is enlarged and the volume of information is large, thereby making it possible to minimize the missing portions of image data on the peripheral portion. When the picked-up image is to be converted into a plane image, interpolating of image data can be thereby minimized and a more natural plane image can be obtained.

Also, according to the second aspect of the present invention, by attaching the attachment lens different from the master lens provided on the existing image pick-up device (camera) to the master lens, the fisheye lens is constructed by this master lens and the attachment lens. Therefore, the fisheye lens can be attached to almost all the existing image pick-up devices (cameras) and further, only the attachment lens is newly produced, thereby reducing costs.

Further, according to the third aspect of the present invention, the image display device can convert a spherical image into a plane image with ease and can display a more natural plane image. In addition, according to the fourth aspect of the present invention, when the program recorded in the information recording medium is read and executed by a computer, a more natural plane image can be formed.

Therefore, it is intended that the appended claims be interpreted as including the embodiments described herein, the alternatives mentioned above, and all equivalents thereto.

What is claimed is:

1. An image pick-up device, comprising:

a fisheye lens for picking up an image of all directions of a field of view around an optical axis of said fisheye lens at a field angle of at least 90° in each direction with respect to the optical axis,

the fisheye lens having a relationship of $h=n\cdot f\cdot\tan(\theta/m)$, h being a height of an image of a subject at a predetermined point obtained by the fisheye lens, f being a focal distance of the fisheye lens, θ being a field angle, m having a value of $1.6\leqq m<3$, and n having a value of $m-0.4<n\leqq m+0.4$.

2. The image pick-up device of claim **1**, wherein m and n are substantially equal.

3. The image pick-up device of claim **1**, wherein m and n both substantially equal 2.

4. The image pick-up device of claim **1**, wherein m and n both equal 2 such that the fisheye lens has a relationship of $h=2f\cdot\tan(\theta)/2)$.

5. The image pick-up device of claim **1**, wherein the fisheye lens is constructed by a master lens provided on an existing image pick-up device and an attachment lens to be attached to the master lens.

6. An image display device, comprising:

an image data processing unit for converting an image obtained by the image pick-up device of claim **1** into a plane image; and

a display unit for displaying the converted plane image.

7. The image display device of claim **6**, wherein said image data processing unit receives the image picked up by said fisheye lens.

8. The image display device of claim **6**, wherein m and n are substantially equal.

9. The image display device of claim **6**, wherein m and n both substantially equal 2.

10. The image display device of claim **6**, wherein m and n both equal 2 such that the fisheye lens has a relationship of $h=2f\cdot\tan(\theta/2)$.

11. An information recording medium having recorded thereon a program including at least the steps of:

converting into a plane image an image obtained by a fisheye lens for picking up an image of all directions of a field of view around an optical axis of said fisheye lens at a field angle of at least 90° in each direction with respect to the optical axis, said fisheye lens having a relationship of $h=n\cdot f\cdot\tan(\theta/m)$, h being a height of an image of a subject at a predetermined point obtained by the fisheye lens, f being a focal distance of the fisheye lens, θ being a field angle, m having a value of $1.6\leqq m\leqq 3$, and n having a value of $m-0.4\leqq n\leqq m+0.4$;

displaying a predetermined portion of the converted plane image on a display unit; and

changing continuously the predetermined portion with instruction means.

12. The information recording medium of claim **11**, wherein m and n are substantially equal.

13. The information recording medium of claim **11**, wherein m and n both substantially equal 2.

14. The information recording medium of claim **11**, wherein m and n both equal 2 such that the fisheye lens has a relationship of $h=2f\cdot\tan(\theta/2)$.

* * * * *

APPENDIX H

Appendix H

Claim Analysis Chart of U.S. Patent No. 6,844,990 B2 ("the '990 patent")

Detailed Explanation of Pertinency of Baker, Shiota, and Enami

The '990 Patent	Prior Art
15. The method according to claim 10, further comprising:	Baker and Shiota disclose the elements of claim 10, as described in Appendix F.
determining the color of image points of a display window, by projecting the image points of the display window onto the initial image by means of the non-linear distribution function, and	Enami discloses determining the color of image points of a display window, by projecting the image points of the display window onto the initial image by means of the non-linear distribution function. (Enami translation at paras. [0058], [0084]-[0085]). Enami discloses allocating to each image point of the display window the color of an image point that is the closest on the initial image. (Enami translation at paras [0072]-[0074]). Enami discloses a coordinate of a point of the fisheye lens image img corresponding to a coordinate of each point arranged on a raster in the image frame frm is specified, and a color information signal of the point having the coordinate is made to correspond to a color information signal of a point having a coordinate of the display frame frm, and thus it is possible to perform a correction process of transforming the fisheye lens image img to an original image. (Enami translation at para. [0058]).
allocating to each image point of the display window the color of an image point that is the closest on the initial image.	Enami discloses: "Here, the point (x", y") on the coordinates of the fisheye lens image obtained through the above-described operation is indicated by (u, v). In order to smoothly interpolate this coordinate point (u, v), the following interpolation process is performed. Color information signal components of three colors of a picture signal are indicated by Y, U, and V, those components of the point (u, v) are indicated by Yu, v, Uu, v, and Vu, v, values which become an integer by omitting decimal points of the coordinate components u and v of the point (u, v) are indicated by u0 and v0, and a value of the color information signal Y in a point having the coordinate (u0, v0) is indicated by Yu0v0. Similarly, the same content is indicated by Uu0v0 and Vu0v0 for the color information signals U and V. In addition, values obtained by rounding up decimal points of the coordinate components u and v are respectively indicated by u1 and v1, and values of the color information signals Y, U and V having a coordinate corresponding thereto are respectively indicated by Yu1v1, Uu1v1, and Vu1v1. Further, decimal parts of the coordinate components u and v are respectively indicated by du and dv."

	(Enami translation at para. [0072]).
16. The method according to claim 15, wherein the projection of the image points of the display window onto the initial image comprises: projecting the image points of the display window onto a sphere or a sphere portion,	Enami discloses mapping from a three-dimensional coordinate point (x,y,z) to a point P (x",y") of the fisheye lens image on the two-dimensional coordinates which is first performed by transforming the point (x,y,z) into a point (r,•,•) expressed in polar coordinates. This transform can be performed using a polar coordinate transform expression of Equation (5). (Enami translation at para. [0066]). Shiota discloses "transforming a fisheye image obtained using a fisheye lens (2) into a plane image for display comprising: a first coordinate calculating unit (35) for obtaining first projection coordinates derived by projecting coordinates on the plane image onto a fisheye face as an imaginary object face." (Shiota at Abstract).
determining the angle in relation to the center of the sphere or the sphere portion of each projected image point, and	Enami discloses this transform can be performed using a polar coordinate transform expression of Equation (5). (Enami translation at para. [0067]). Shiota discloses "Necessary parameters are, as shown in Figs. 1 and 2, (X0, Y0, Z0) indicative of the center (origin) of a plane image and change amounts •ux, •vx, •uy, •vy, •uz, •vz in the respective axes of the (X, Y, Z) coordinates when a point is moved in the respective directions on the (u, v) coordinate system by an amount of one pixel (corresponding to one pixel on the monitor screen). (Shiota at para. [0025]). "The parameters can be easily obtained from the information of the angle information (•, •, •) of the view point and the magnification of the image." (Shiota at para. [0026]). Since point P' "is on the surface of the hemisphere of radius of 1, the zenithal angle (•1) is unconditionally determined…" (Shiota at para. [0034]).
projecting onto the initial image each image point projected onto the sphere or the sphere portion,	Enami discloses a fisheye lens of an equal area mapping formula which is expressed by Equation (3-2), and this equation is assigned to Equation (2) so as to obtain an expression of Equation (6). The expression of Equation (5) is simplified as in an expression of Equation (7) using a relation of x2 + y2 + z2 = x'2 + y'2 + z'2 = r2, Equation (5), and further a basic expression of a trigonometric function. (Enami translation at paras. [0068], [0070]).

	Shiota discloses "First, the coordinates of a point P' (first projection coordinates) on the hemispherical face as an imaginary object face, which is a projection of a point P on a plane image (the u, v coordinates) are obtained." (Shiota at para. [0028]).
the projection being performed by means of the non-linear distribution function considering the field angle that each point to be projected has in relation to the center of the sphere or the sphere portion.	Enami discloses that the projection is performed by means of the non-linear distribution function considering the field angle that each point to be projected has in relation to the center of the sphere or the sphere portion. The field angle is defined according to the horizontal and vertical extents in the image area while the center is defined to be the image center position. Further, a fisheye lens of an equal area mapping formula is expressed by an expression of Equation (3-2), and this equation is assigned to Equation (2) so as to obtain an expression of Equation (6). (Enami translation at para. [0068]). Shiota discloses as a second step of the calculation, "a procedure of obtaining second projection coordinates w(p1, q1,) on a fisheye image face from the first projection coordinates (X2, Y2, Z2) determined (refer to FIG. 1 with respect to w) will be explained." (Shiota at para. [0033]). An example of a specific function of F(• 1) according to the projecting method is the stereographic projection, which has the non-linear distribution function: 2f•tan(•/2). (Shiota at para. [0037]).

APPENDIX G

Appendix G

Claim Analysis Chart of U.S. Patent No. 6,844,990 B2 ("the '990 patent")

Detailed Explanation of Pertinency of Nagaoka, Shiota, and Enami

The '990 Patent	Prior Art
15. The method according to claim 10, further comprising:	Nagaoka and Shiota disclose the elements of claim 10, as described in Appendix D.
determining the color of image points of a display window, by projecting the image points of the display window onto the initial image by means of the non-linear distribution function, and	Enami discloses determining the color of image points of a display window, by projecting the image points of the display window onto the initial image by means of the non-linear distribution function. (Enami translation at paras. [0058], [0084]-[0085]). Enami discloses allocating to each image point of the display window the color of an image point that is the closest on the initial image. (Enami translation at paras [0072]-[0074]). Enami discloses a coordinate of a point of the fisheye lens image img corresponding to a coordinate of each point arranged on a raster in the image frame frm is specified, and a color information signal of the point having the coordinate is made to correspond to a color information signal of a point having a coordinate of the display frame frm, and thus it is possible to perform a correction process of transforming the fisheye lens image img to an original image. (Enami translation at para. [0058]).
allocating to each image point of the display window the color of an image point that is the closest on the initial image.	Enami discloses: "Here, the point (x", y") on the coordinates of the fisheye lens image obtained through the above-described operation is indicated by (u, v). In order to smoothly interpolate this coordinate point (u, v), the following interpolation process is performed. Color information signal components of three colors of a picture signal are indicated by Y, U, and V, those components of the point (u, v) are indicated by Yu, v, Uu, v, and Vu, v, values which become an integer by omitting decimal points of the coordinate components u and v of the point (u, v) are indicated by u0 and v0, and a value of the color information signal Y in a point having the coordinate (u0, v0) is indicated by Yu0v0. Similarly, the same content is indicated by Uu0v0 and Vu0v0 for the color information signals U and V. In addition, values obtained by rounding up decimal points of the coordinate components u and v are respectively indicated by u1 and v1, and values of the color information signals Y, U and V having a coordinate corresponding thereto are respectively indicated by Yu1v1, Uu1v1, and Vu1v1. Further, decimal parts of the coordinate components u and v are respectively indicated by du and dv."

	(Enami translation at para. [0072]).
16. The method according to claim 15, wherein the projection of the image points of the display window onto the initial image comprises: projecting the image points of the display window onto a sphere or a sphere portion,	Enami discloses mapping from a three-dimensional coordinate point (x,y,z) to a point P (x",y") of the fisheye lens image on the two-dimensional coordinates which is first performed by transforming the point (x,y,z) into a point (r,•,•) expressed in polar coordinates. This transform can be performed using a polar coordinate transform expression of Equation (5). (Enami translation at para. [0066]). Shiota discloses "transforming a fisheye image obtained using a fisheye lens (2) into a plane image for display comprising: a first coordinate calculating unit (35) for obtaining first projection coordinates derived by projecting coordinates on the plane image onto a fisheye face as an imaginary object face." (Shiota at Abstract).
determining the angle in relation to the center of the sphere or the sphere portion of each projected image point, and	Enami discloses this transform can be performed using a polar coordinate transform expression of Equation (5). (Enami translation at para. [0067]). Shiota discloses "Necessary parameters are, as shown in Figs. 1 and 2, (X0, Y0, Z0) indicative of the center (origin) of a plane image and change amounts •ux, •vx, •uy, •vy, •uz, •vz in the respective axes of the (X, Y, Z) coordinates when a point is moved in the respective directions on the (u, v) coordinate system by an amount of one pixel (corresponding to one pixel on the monitor screen). (Shiota at para. [0025]). "The parameters can be easily obtained from the information of the angle information (• , •, •) of the view point and the magnification of the image." (Shiota at para. [0026]). Since point P' "is on the surface of the hemisphere of radius of 1, the zenithal angle (•1) is unconditionally determined…" (Shiota at para. [0034]).
projecting onto the initial image each image point projected onto the sphere or the sphere portion,	Enami discloses a fisheye lens of an equal area mapping formula which is expressed by Equation (3-2), and this equation is assigned to Equation (2) so as to obtain an expression of Equation (6). The expression of Equation (5) is simplified as in an expression of Equation (7) using a relation of x2 + y2 + z2 = x'2 + y'2 + z'2 = r2, Equation (5), and further a basic expression of a trigonometric function. (Enami translation at paras. [0068], [0070]).

	Shiota discloses "First, the coordinates of a point P' (first projection coordinates) on the hemispherical face as an imaginary object face, which is a projection of a point P on a plane image (the u, v coordinates) are obtained." (Shiota at para. [0028]).
the projection being performed by means of the non-linear distribution function considering the field angle that each point to be projected has in relation to the center of the sphere or the sphere portion.	Enami discloses that the projection is performed by means of the non-linear distribution function considering the field angle that each point to be projected has in relation to the center of the sphere or the sphere portion. The field angle is defined according to the horizontal and vertical extents in the image area while the center is defined to be the image center position. Further, a fisheye lens of an equal area mapping formula is expressed by an expression of Equation (3-2), and this equation is assigned to Equation (2) so as to obtain an expression of Equation (6). (Enami translation at para. [0068]). Shiota discloses as a second step of the calculation, "a procedure of obtaining second projection coordinates w(p1, q1,) on a fisheye image face from the first projection coordinates (X2, Y2, Z2) determined (refer to FIG. 1 with respect to w) will be explained." (Shiota at para. [0033]). An example of a specific function of F(•1) according to the projecting method is the stereographic projection, which has the non-linear distribution function: 2f•tan(•/2). (Shiota at para. [0037]).

APPENDIX F

Appendix F

Claim Analysis Chart of U.S. Patent No. 6,844,990 B2 ("the '990 patent")

Detailed Explanation of Pertinency of Baker and Shiota

The '990 Patent	Prior Art
10. A method for displaying an initial panoramic image obtained in accordance with the method according to claim 1, the method for displaying comprising:	Baker discloses the elements of claim 1, as described in Appendix B.
correcting the non-linearity of the initial image, performed by means of a reciprocal function of the non-linear distribution function of the objective lens or by means of the non-linear distribution function.	Baker discloses a "transform processor 22" which "corrects the image for display on a conventional display device 28" by "compensate[ing] for the distortion or difference in magnification between the central and peripheral areas of the scene caused by the lens by applying appropriate correction criteria to bring the selected portion of the scene into standard viewing format." (Baker at col. 6, lns. 5-24; col. 9, lns. 5-13). Baker does not disclose details on the specific corrections applied by the transform processor 22. Shiota discloses correcting the non-linearity of an initial image performed by using a non-linear distribution function. (Shiota at paras. [0030]-[0032]). "An image is transformed as follows. The projecting position on the image pickup face (p, q coordinates) of a point (u, v coordinates) on a plane image is obtained by arithmetic operation." (Shiota at para. [0024]). In one embodiment, a non-linear distribution function (h=2f·tan(/2)) is used to compute the coefficient k2. k2 = h/r, where h is defined by the lens function and r is the distance from the origin. (Shiota at paras. [0037]-[0042]). The coefficient k2 is used to obtain the image points that will be displayed. (Shiota at paras. [0031]-[0035]). As the coefficient k2 used to correct the image is computed using the non-linear distribution function, Shiota discloses "correcting the non-linearity of the initial image, performed … by means of the non-linear distribution function."
11. The method according to claim 10, wherein the step of correcting comprises a step of transforming the initial image into a corrected digital image comprising a number of image points higher than the number of pixels that the image sensor comprises.	Shiota discloses a stereoscopic projection having a relationship h=2f·tan(/2), which produces an image having an expanded portion. (Shiota at para. [0037]). Shiota further discloses that the position of a pixel on the fisheye image will not necessarily map to a pixel on the plane image and hence nearby pixels would be used for interpolation. (Shiota at

	para. [0049]). Because Shiota has an expanded portion, one of ordinary skill in the art would have known that the number of image points in a corrected digital image would be larger than the number of points in the initial image. Considering a region in the initial image that is to be expanded, each initial image point will represent the projection of multiple spatial points according to the lens system. Hence, during the expansion process, the image points will be mapped to one or more points in the corrected digital image. Shiota discloses this step of transforming the initial image into a corrected digital image where the number of image points is higher than the number of pixels of the image sensor.

APPENDIX E

Appendix E

Claim Analysis Chart of U.S. Patent No. 6,844,990 B2 ("the '990 patent")

Detailed Explanation of Pertinency of Nagaoka and Matsui

The '990 Patent	Prior Art
10. A method for displaying an initial panoramic image obtained in accordance with the method according to claim 1, the method for displaying comprising:	Nagaoka discloses the elements of claim 1, as described in Appendix A.
correcting the non-linearity of the initial image, performed by means of a reciprocal function of the non-linear distribution function of the objective lens or by means of the non-linear distribution function.	Nagaoka discloses that the obtained image is "converted into a plane image by the image data processing unit 3" (Nagaoka at col. 8, lns. 2-3), but does not disclose the specific correction applied by the image data processing unit. Matsui discloses correcting the non-linearity of an initial image, performed by the non-linear distribution function. (Matsui translation at paras. [0025], [0030]-[0031]. Matsui discloses a data image conversion device, in which image data obtained with a fish-eye lens is corrected to remove distortion so that it may be displayed. (Matsui translation at para. [0001]). Matsui discloses that this correction can be performed using the non-linear lens distribution function h = 2f·tan(/2) = 2f·{sin /(1 + cos)}, or more generally using the formula h = g( ). (Shiota at paras. [0025], [0030]). Matsui further discloses the calculation of pixel positions on the circular surface from the pixel positions actually captured by the CCD utilizing the non-linear distribution function h = 2f·tan(/2). (Shiota at para. [0025]). A data converter 2, that calculates the circular surface S pixel position corresponding to each pixel on the post-conversion cylindrical surface C, then converts the pixel data of the pixel positions as respective pixel data on the cylindrical surface C. "As a result, as shown in Fig. 4, the pixel data on the circular surface S is converted as respective pixel data on the cylindrical surface C." (Matsui translation at para. [0026]). "The data converter 2 converts P1 shown in Fig. 3 into P2 shown in Fig. 2." (Matsui translation at para. [0023]). Matsui therefore discloses "correcting the non-linearity of the initial image, performed … by means of the non-linear distribution function."

APPENDIX D

Appendix D

Claim Analysis Chart of U.S. Patent No. 6,844,990 B2 ("the '990 patent")

Detailed Explanation of Pertinency of Nagaoka and Shiota

The '990 Patent	Prior Art
10. A method for displaying an initial panoramic image obtained in accordance with the method according to claim 1, the method for displaying comprising:	Nagaoka discloses the elements of claim 1, as described in Appendix A.
correcting the non-linearity of the initial image, performed by means of a reciprocal function of the non-linear distribution function of the objective lens or by means of the non-linear distribution function.	Nagaoka discloses that the obtained image is "converted into a plane image by the image data processing unit 3" (Nagaoka at col. 8, lns. 2-3), but does not disclose the specific correction applied by the image data processing unit. Shiota discloses correcting the non-linearity of an initial image performed by using a non-linear distribution function. (Shiota at paras. [0030]-[0032]). "An image is transformed as follows. The projecting position on the image pickup face (p, q coordinates) of a point (u, v coordinates) on a plane image is obtained by arithmetic operation." (Shiota at para. [0024]). In one embodiment, a non-linear distribution function (h=2f·tan(/2)) is used to compute the coefficient k2. k2 = h/r, where h is defined by the lens function and r is the distance from the origin. (Shiota at paras. [0037]-[0042]). The coefficient k2 is used to obtain the image points that will be displayed. (Shiota at paras. [0031]-[0035]). As the coefficient k2 used to correct the image is computed using the non-linear distribution function, Shiota discloses "correcting the non-linearity of the initial image, performed … by means of the non-linear distribution function."
11. The method according to claim 10, wherein the step of correcting comprises a step of transforming the initial image into a corrected digital image comprising a number of image points higher than the number of pixels that the image sensor comprises.	Shiota discloses a stereoscopic projection having a relationship h=2f·tan(/2), which produces an image having an expanded portion. (Shiota at para. [0037]). Shiota further discloses that the position of a pixel on the fisheye image will not necessarily map to a pixel on the plane image and hence nearby pixels would be used for interpolation. (Shiota at para. [0049]). Because Shiota has an expanded portion, one of ordinary skill in the art would have known that the number of image points in a corrected digital image would be larger than the number of points in the initial image. Considering a region in the initial image that is to be

	expanded, each initial image point will represent the projection of multiple spatial points according to the lens system. Hence, during the expansion process, the image points will be mapped to one or more points in the corrected digital image. Shiota discloses this step of transforming the initial image into a corrected digital image where the number of image points is higher than the number of pixels of the image sensor.

APPENDIX J

Appendix J

Claim Analysis Chart of U.S. Patent No. 6,844,990 B2 ("the '990 patent")

Detailed Explanation of Pertinency of Baker and Inoue

The '990 Patent	Prior Art
25. The panoramic objective lens according to claim 22, comprising polymethacrylate lenses.	Baker discloses the elements of claim 22, as described in Appendix B. Inoue discloses making wide angle lenses from PMMA (Inoue at col. 2, lns. 42-44), which the '990 Patent equates to polymethacrylate ('990 Patent at col. 16, lns. 31-43).

APPENDIX I

Appendix I

Claim Analysis Chart of U.S. Patent No. 6,844,990 B2 ("the '990 patent")

Detailed Explanation of Pertinency of Nagaoka and Inoue

The '990 Patent	Prior Art
25. The panoramic objective lens according to claim 22, comprising polymethacrylate lenses.	Nagaoka discloses the elements of claim 22, as described in Appendix A. Inoue discloses making wide angle lenses from PMMA (Inoue at col. 2, lns. 42-44), which the '990 Patent equates to polymethacrylate ('990 Patent at col. 16, lns. 31-43).

APPENDIX C

Appendix C

Claim Analysis Chart of U.S. Patent No. 6,844,990 B2 ("the '990 patent")

Detailed Explanation of Pertinency of Fisher

The '990 Patent	Prior Art
1. A method for capturing a digital panoramic image,	Fig. 6 of Fisher depicts a non-linear panoramic objective lens. (Col. 5, lns. 44-45). Additionally, "[t]he distorted image formed by the non-linear lens exists in an image plane p located beyond the third lens grouping C. The vidicon of the television camera should be at this plane p." (Abstract; col. 6, lns. 51-54; col. 4, lns. 35-45).
by projecting a panorama onto an image sensor by means of a panoramic objective lens,	Fisher discloses projecting a panorama onto an image sensor by means of a panoramic objective lens. (Fig. 3; col. 3, lns. 48-49). Fisher also discloses "The image cast by the lens falls on the vidicon of a television camera where it is scanned and transmitted to a projector." (Abstract; col. 4, lns. 35-45).
the panoramic objective lens having an image point distribution function that is not linear relative to the field angle of object points of the panorama,	Fisher discloses "The present invention relates in general to lenses and more particularly to a lens having non-linear distortion characteristics." (Col. 1, lns. 9-11). "One of the principal objects of the present invention is to provide a lens having non-linear distortion characteristics." (Col. 2, lns. 6-8).
the distribution function having a maximum divergence of at least +/-10% compared to a linear distribution function,	Fig. 3 of Fisher shows a "NON-LINEAR LENS" where the image height is equal to a variable function of the field angle. Fig. 3 shows "the distortion characteristics of the lens of the present invention in terms of normalized image height and field of view and comparing such distortion characteristics with the distortion characteristics of a linear fisheye lens and a conventional camera lens." (Col. 2, lns. 38-43). The relationship is approximated by the formula $H=\sin^{1/3}$. (Col. 3, lns. 1-4). As shown in Fig. 3, Fisher discloses a non-linear lens having a distribution function whose maximum divergence is much greater than 10% compared to a linear distribution function (fisheye lens).

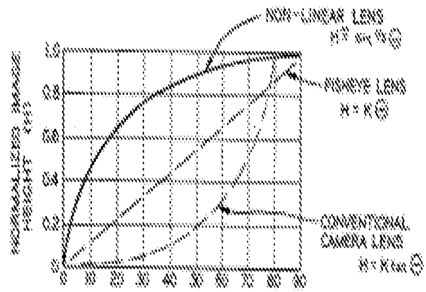
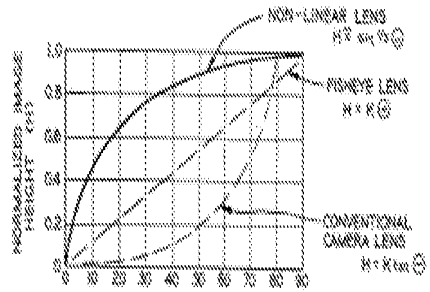
	 FIG. 3
such that the panoramic image obtained has at least one substantially expanded zone and at least one substantially compressed zone.	Fisher discloses: "The present invention is embodied in a lens which distorts a field of view such that objects in the vicinity of the optical axis occupy a disproportionately large area of the image cast by the lens and objects in the peripheral region of the field of view occupy a disproportionately small area of the image." (Col. 2, lns. 19-24). "[O]bjects centered along the optical axis of the non-linear lens L cast a much larger image than objects located near the periphery of the field of view with the size diminishing as the angle from the optical axis increases. The result of the distortion is that objects along the optical axis occupy a disproportionately large share of the image cast by the lens when compared with other objects closer to the periphery of the field of view for the lens." (Col. 3, lns. 4-12). Fig. 4 of Fisher further shows how equal increments on the image plane correspond to unequal increments in the field of view. (Col. 2, lns. 44-47).
2. The method according to claim 1, wherein the objective lens has a non-linear distribution function that is symmetrical relative to the optical axis of the objective lens, the position of an image point relative to the center of the image varying according to the field angle of the corresponding object point.	As shown in Fig. 6 of Fisher, the non-linear distribution function is symmetrical relative to the optical axis. As further shown in Fig. 4 of Fisher, the position of an image point varies according to the field angle of a corresponding object point.
3. The method according to claim 1, wherein the objective lens expands the center of the image and compresses the edges of the image.	Fisher discloses that the "present invention is embodied in a lens which distorts a field of view such that objects in the vicinity of the optical axis occupy a disproportionately large area of the image cast by the lens [*i.e.*, the image is expanded at the center] and objects in the peripheral region of the field of view occupy a disproportionately small area of the

	Image [*i.e.*, the image is compressed at the edges]." (Col. 2, lns. 19-24).
6. The method according to claim 1, wherein the objective lens comprises a set of lenses forming an apodizer.	As described in the '990 Patent, an "apodizer" is an optical system which provides a non-linear distribution of image points relative to the field angle of the object points. (Col. 16, lns. 1-4). As shown in Figs. 4 and 6 of Fisher, the lens system controls the angular distribution of the objective lens to obtain non-linearity, and therefore includes an "apodizer" as defined in the '990 Patent.
7. The method according to claim 6, wherein the set of lenses forming an apodizer comprises at least one aspherical lens.	Fisher discloses that the lens surfaces R1 and R3 shown in Fig. 6 are non-spherical (aspherical): "The first lens grouping A (FIG. 6) consists of three lens elements a, b, and c with no air gaps between adjacent elements. The outside lens element a has a non-spherical surface R1 exposed outwardly and a spherical surface R2 presented inwardly against a matching surface R2 on the intermediate element b. The opposite surface R3 of the intermediate element b is non-spherical and abuts a matching surface R3 on the inside element c." (Col. 5, ln. 61–col. 6, ln. 1).
17. A panoramic objective lens comprising:	Fig. 6 of Fisher depicts a non-linear panoramic objective lens. (Col. 5, lns. 44-45).
optical means for projecting a panorama into an image plane of the objective lens,	Fisher discloses projecting a panorama onto an image sensor by means of a panoramic objective lens. (Fig. 3; col. 3, lns. 48-49). Fisher also discloses "The image cast by the lens falls on the vidicon of a television camera where it is scanned and transmitted to a projector." (Abstract; col. 4, lns. 35-45).
the optical means having an image point distribution function that is not linear relative to the field angle of object points of the panorama,	Fisher discloses "The present invention relates in general to lenses and more particularly to a lens having non-linear distortion characteristics." (Col. 1, lns. 9-11). "One of the principal objects of the present invention is to provide a lens having non-linear distortion characteristics." (Col. 2, lns. 6-8).
the distribution function having a maximum divergence of at least .+-.10% compared to a linear distribution function,	Fig. 3 of Fisher shows a "NON-LINEAR LENS" where the image height is equal to a variable function of the field angle. Fig. 3 shows "the distortion characteristics of the lens of the present invention in terms of normalized image height and field of view and comparing such distortion characteristics with the distortion characteristics of a linear fisheye lens

	and a conventional camera lens." (Col. 2, lns. 38-43). The relationship is approximated by the formula H=sin$^{1/3}$. (Col. 3, lns. 1-4). As shown in Fig. 3, Fisher discloses a non-linear lens having a distribution function whose maximum divergence is much greater than 10% compared to a linear distribution function (fisheye lens).  FIG. 3
such that a panoramic image obtained by means of the objective lens comprises at least one substantially expanded zone and at least one substantially compressed zone.	Fisher discloses: "The present invention is embodied in a lens which distorts a field of view such that objects in the vicinity of the optical axis occupy a disproportionately large area of the image cast by the lens and objects in the peripheral region of the field of view occupy a disproportionately small area of the image." (Col. 2, lns. 19-24). "[O]bjects centered along the optical axis of the non-linear lens L cast a much larger image than objects located near the periphery of the field of view with the size diminishing as the angle from the optical axis increases. The result of the distortion is that objects along the optical axis occupy a disproportionately large share of the image cast by the lens when compared with other objects closer to the periphery of the field of view for the lens." (Col. 3, lns. 4-12). Fig. 4 of Fisher further shows how equal increments on the image plane correspond to unequal increments in the field of view. (Col. 2, lns. 44-47).
18. The panoramic objective lens according to claim 17, having a non-linear distribution function that is symmetrical relative to the optical axis of the objective lens, the position of an image point relative to the center of an image obtained varying according to the field angle of the corresponding object point.	As shown in Fig. 6 of Fisher, the non-linear distribution function is symmetrical relative to the optical axis. As further shown in Fig. 4 of Fisher, the position of an image point varies according to the field angle of a corresponding object point.

19. The panoramic objective lens according to claim 17, wherein the lens expands the center of an image and compresses the edges of the image.	Fisher discloses that the "present invention is embodied in a lens which distorts a field of view such that objects in the vicinity of the optical axis occupy a disproportionately large area of the image cast by the lens [*i.e.*, the image is expanded at the center] and objects in the peripheral region of the field of view occupy a disproportionately small area of the Image [*i.e.*, the image is compressed at the edges]." (Col. 2, lns. 19-24).
22. The panoramic objective lens according to claim 17, further comprising a set of lenses forming an apodizer.	As described in the '990 Patent, an "apodizer" is an optical system which provides a non-linear distribution of image points relative to the field angle of the object points. (Col. 16, lns. 1-4). As shown in Figs. 4 and 6 of Fisher, the lens system controls the angular distribution of the objective lens to obtain non-linearity, and therefore includes an "apodizer" as defined in the '990 Patent.
23. The panoramic objective lens according to claim 22, wherein the set of lenses forming an apodizer comprises at least one aspherical lens.	Fisher discloses that the lens surfaces R1 and R3 shown in Fig. 6 are non-spherical (aspherical): "The first lens grouping A (FIG. 6) consists of three lens elements a, b, and c with no air gaps between adjacent elements. The outside lens element a has a non-spherical surface R1 exposed outwardly and a spherical surface R2 presented inwardly against a matching surface R2 on the intermediate element b. The opposite surface R3 of the intermediate element b is non-spherical and abuts a matching surface R3 on the inside element c." (Col. 5, ln. 61–col. 6, ln. 1).

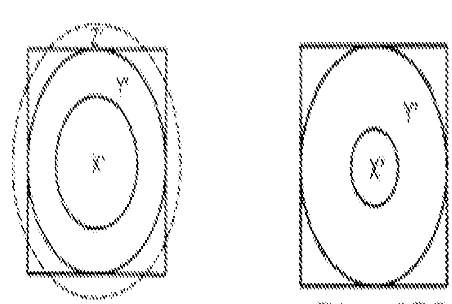
APPENDIX B

Appendix B

Claim Analysis Chart of U.S. Patent No. 6,844,990 B2 ("the '990 patent")

Detailed Explanation of Pertinency of Baker

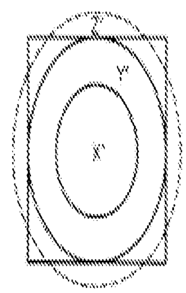
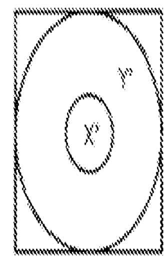
The '990 Patent	Prior Art
1. A method for capturing a digital panoramic image,	Baker discloses "the visual imaging system can use a single camera to capture the relevant visual information within a panoramic field of view existing along the horizon," (col. 6, lns. 29-32), and that the "captured scene can be stored onto an assortment of media, e.g., photographic film 16, electronic storage 18, or other conventional storage means." (Col. 2, lns. 35-39; col. 8, lns. 62-65; col. 10, lns. 55-57; col. 14, lns. 32-36).
by projecting a panorama onto an image sensor by means of a panoramic objective lens,	Baker discloses projecting a panorama onto an image sensor by means of a panoramic objective lens, and that a "CCD" may be used for digital storage. (Col. 13, lns. 14-17).
the panoramic objective lens having an image point distribution function that is not linear relative to the field angle of object points of the panorama,	Fig. 2A of Baker depicts a lens having a typical linear distribution function of image points, while Fig. 3BA of Baker depicts a lens having a non-linear distribution function of image points, relative to the field angle of the object points of the panorama. (Col. 12, lns. 23-25). Baker further discloses the "fundamental principle behind the enhanced peripheral content lens is the selective magnification of the periphery and the focusing of more of that content on the imaging plane." (Fig. 3BA; col. 10, lns. 38-41). Baker further discloses a non-linear "lens, indicated generally at 14, designed to capture and enhance the peripheral content of a hemispheric scene." (Col. 8, lns. 60-62). "To maximize data collection and resolution for analysis and/or display of the relevant visual information located in this portion of the hemispheric scene, it is desirable to maximize the dedication of the available image detection area to this peripheral field portion." (Col. 8, lns. 32-36).
the distribution function having a maximum divergence of at least +/-10% compared to a linear distribution function,	Baker discloses a panoramic objective lens with a distribution function having a maximum divergence of at least ±10% compared to a linear distribution function. "[I]f an ordinary fisheye lens focuses the lowest 15 degrees up from the horizon on ten percent of the imager at the imaging plane and the peripheral-enhancing lens focuses that same 15 degrees on fifty percent of the imager, there is a five-fold increase in resolution using the same imaging device. Depending on the application and exact formulation of the lens equations, there will be at least a five times

	increase in resolving power by this lens/imager combination." (Col. 6, lns. 48-56). Using a normalized height of 1 at 90°, one can calculate the height *h* at 75° for the circumstance in which 50% of the imager is occupied by the lowest 15°. That is, half of the area of the entire circular image is equal to the area of a circle with height *h* at 75°, or $(1)^2/2 = h^2$, which gives a height *h* of about 0.707. This is a divergence of greater than 10% compared to a linear distribution function, which would have a height *h* at 75° of about 0.833.
such that the panoramic image obtained has at least one substantially expanded zone and at least one substantially compressed zone.	Baker discloses "The lens uniquely achieves this by filling the greater available area of an imager device with the peripheral areas rather than the central areas of the captured scene." (Col. 10, lns. 57-60). "[T]he lens constructed according to the present invention has a fairly significant portion of the imaging surface dedicated to the peripheral field, and consequently less of the surface dedicated to the central field." (Col. 12, lns. 29-32). The panoramic image obtained from the linear objective lens is shown in Fig. 2B of Baker below, and the panoramic image obtained from the non-linear objective lens is shown in Fig 3BB of Baker below:  Fig. 2B Fig. 3BB Comparing the image in Fig. 2B (linear image) to the image in Fig. 3BB (non-linear image) shows how zone X' has been substantially compressed and zone Y' has been substantially expanded. Thus, the panoramic image obtained from the non-linear objective lens (Fig. 3BB) depicts a substantially expanded zone Y' and a substantially compressed zone X' compared to the panoramic image obtained from the linear objective lens (Fig. 2B). (Col. 12, lns. 29-32).

Appendix B

2. The method according to claim 1, wherein the objective lens has a non-linear distribution function that is symmetrical relative to the optical axis of the objective lens, the position of an image point relative to the center of the image varying according to the field angle of the corresponding object point.	Fig. 3BA of Baker shows that the distribution function of the lens depicted in Fig. 3BA is symmetrical with respect to the optical axis of the lens, as the height of an image point relative to the center of the image varies according to the field angle.
4. The method according to claim 1, wherein the objective lens expands the edges of the image and compresses the center of the image.	"The lens uniquely achieves this by filling the greater available area of an imager device with the peripheral areas rather than the central areas of the captured scene." (Col. 10, lns. 57-60). "The lens constructed according to the present invention has a fairly significant portion of the imaging surface dedicated to the peripheral field, and consequently less of the surface dedicated to the central field." (Col. 12, lns. 29-32). See also Fig. 3BB of Baker as compared to Fig. 2 thereof, which shows the expansion of the periphery of the image and compression of the center.
6. The method according to claim 1, wherein the objective lens comprises a set of lenses forming an apodizer.	As described in the '990 Patent, an "apodizer" is an optical system which provides a non-linear distribution of image points relative to the field angle of the object points. (Col. 16, lns. 1-4). The hemispherical lens elements at bottom of Fig. 3BA comprise an "apodizer," as defined in the '990 Patent, as they control the angular distribution of the panoramic objective lens to obtain the desired nonlinearity.
17. A panoramic objective lens comprising:	Baker discloses "the visual imaging system can use a single camera to capture the relevant visual information within a panoramic field of view existing along the horizon." (Col. 6, lns. 29-32).
optical means for projecting a panorama into an image plane of the objective lens,	Baker discloses projecting a panorama onto an image sensor by means of a panoramic objective lens, and that a "CCD" may be used for digital storage. (Col. 13, lns. 14-17).
the optical means having an image point distribution function that is not linear relative to the field angle of object points of the panorama,	Fig. 2A of Baker depicts a lens having a typical linear distribution function of image points, while Fig. 3BA of Baker depicts a lens having a non-linear distribution function of image points, relative to the field angle of the object points of the panorama. (Col. 12, lns. 23-25). Baker further discloses the "fundamental principle behind the enhanced peripheral content lens is the selective magnification of the periphery and

	the focusing of more of that content on the imaging plane." (Fig. 3BA; col. 10, lns. 38-41). Baker further discloses a non-linear "lens, indicated generally at 14, designed to capture and enhance the peripheral content of a hemispheric scene." (Col. 8, lns. 60-62). "To maximize data collection and resolution for analysis and/or display of the relevant visual information located in this portion of the hemispheric scene, it is desirable to maximize the dedication of the available image detection area to this peripheral field portion." (Col. 8, lns. 32-36).
the distribution function having a maximum divergence of at least .+-.10% compared to a linear distribution function,	Baker discloses a panoramic objective lens with a distribution function having a maximum divergence of at least ±10% compared to a linear distribution function. "[I]f an ordinary fisheye lens focuses the lowest 15 degrees up from the horizon on ten percent of the imager at the imaging plane and the peripheral-enhancing lens focuses that same 15 degrees on fifty percent of the imager, there is a five-fold increase in resolution using the same imaging device. Depending on the application and exact formulation of the lens equations, there will be at least a five times increase in resolving power by this lens/imager combination." (Col. 6, lns. 48-56). Using a normalized height of 1 at 90°, one can calculate the height *h* at 75° for the circumstance in which 50% of the imager is occupied by the lowest 15°. That is, half of the area of the entire circular image is equal to the area of a circle with height *h* at 75°, or $(1)^2/2 = h^2$, which gives a height *h* of about 0.707. This is a divergence of greater than 10% compared to a linear distribution function, which would have a height *h* at 75° of about 0.833.
such that a panoramic image obtained by means of the objective lens comprises at least one substantially expanded zone and at least one substantially compressed zone.	Baker discloses "The lens uniquely achieves this by filling the greater available area of an imager device with the peripheral areas rather than the central areas of the captured scene." (Col. 10, lns. 57-60). "[T]he lens constructed according to the present invention has a fairly significant portion of the imaging surface dedicated to the peripheral field, and consequently less of the surface dedicated to the central field." (Col. 12, lns. 29-32). The panoramic image obtained from the linear objective lens is shown in Fig. 2B of Baker below, and the panoramic image obtained from the non-linear objective lens is shown in Fig 3BB of Baker below:

	  Fig. 2B Fig. 3BB Comparing the image in Fig. 2B (linear image) to the image in Fig. 3BB (non-linear image) shows how zone X' has been substantially compressed and zone Y' has been substantially expanded. Thus, the panoramic image obtained from the non-linear objective lens (Fig. 3BB) depicts a substantially expanded zone Y' and a substantially compressed zone X' compared to the panoramic image obtained from the linear objective lens (Fig. 2B). (Col. 12, lns. 29-32).
18. The panoramic objective lens according to claim 17, having a non-linear distribution function that is symmetrical relative to the optical axis of the objective lens, the position of an image point relative to the center of an image obtained varying according to the field angle of the corresponding object point.	Fig. 3BA of Baker shows that the distribution function of the lens depicted in Fig. 3BA is symmetrical with respect to the optical axis of the lens, as the height of an image point relative to the center of the image varies according to the field angle.
20. The panoramic objective lens according to claim 17, wherein the lens expands the edges of an image and compresses the center of the image.	"The lens uniquely achieves this by filling the greater available area of an imager device with the peripheral areas rather than the central areas of the captured scene." (Col. 10, lns. 57-60). "The lens constructed according to the present invention has a fairly significant portion of the imaging surface dedicated to the peripheral field, and consequently less of the surface dedicated to the central field." (Col. 12, lns. 29-32). See also Fig. 3BB of Baker as compared to Fig. 2 thereof, which shows the expansion of the periphery of the image and compression of the center.
22. The panoramic objective lens according to claim 17, further comprising a set of lenses forming an apodizer.	As described in the '990 Patent, an "apodizer" is an optical system which provides a non-linear distribution of image points relative to the field angle of the object points. (Col. 16, lns. 1-4). The hemispherical lens

	elements at bottom of Fig. 3BA comprise an "apodizer," as defined in the '990 Patent, as they control the angular distribution of the panoramic objective lens to obtain the desired nonlinearity.

APPENDIX A

Appendix A

Claim Analysis Chart of U.S. Patent No. 6,844,990 B2 ("the '990 patent")

Detailed Explanation of Pertinency of Nagaoka

The '990 Patent	Prior Art
1. A method for capturing a digital panoramic image,	Nagaoka discloses a panoramic objective lens and a method for capturing a digital panoramic image: "…an image processing system utilizing an image pickup device comprising a fisheye lens..." (Col. 3, lns. 63-65). Nagaoka further discloses a panoramic objective lens: "an image of half of the sphere is picked up by the fisheye lens." (Col. 1, lns. 23-31). Digital image data can be stored, *e.g.,* on a flashcard. (Col. 9, lns. 18-21).
by projecting a panorama onto an image sensor by means of a panoramic objective lens,	Nagaoka discloses that the panorama is projected onto a CCD image sensor by a panoramic objective lens. (Fig. 2; col. 4, ln. 66-col. 5, ln. 2).
the panoramic objective lens having an image point distribution function that is not linear relative to the field angle of object points of the panorama,	Nagaoka discloses several panoramic (fisheye) lenses each having an image point distribution function that is not linear relative to the field angle of object points of the panorama. Specifically, Nagaoka discloses examples of such non-linear lenses have the functions h=1.2f·tan(/1.6) and h=1.6f·tan(/2). (Figs. 3A and 3B).
the distribution function having a maximum divergence of at least +/-10% compared to a linear distribution function,	Each of the above recited non-linear distribution functions lenses has a maximum divergence of at least ±10% compared to the linear distribution function. (Figs. 3A and 3B). Using a normalized image height (height = 1 at 90°), the function h=1.2f tan(/1.6) gives h of about 0.36 at 45°, which is about 18% divergence from the linear distribution function f (which would be 0.45 at 45°). Similarly, the function h=1.6f·tan(/2) gives a divergence at 45° of about 16%.
such that the panoramic image obtained has at least one substantially expanded zone and at least one substantially compressed zone.	The lenses having the functions h=1.2f·tan(/1.6) and h=1.6f·tan(/2) project a substantially expanded zone near the periphery (evidenced from Fig. 3B, which shows a slope for these two functions exceeding the slope of the linear distribution function (f) starting at about 60°) and a substantially compressed zone near the center (evidenced from Fig. 3B, which shows a slope for these two functions that is less than the slope of the linear distribution function (f) prior to about 60°).
2. The method according to claim 1, wherein the objective lens has a non-linear distribution function that is symmetrical relative to the optical axis of the objective lens, the position of an image point relative to	Fig. 2 of Nagaoka shows a lens having a non-linear distribution function that is symmetrical relative to the optical axis of the objective lens. In the lenses having functions h=1.2f·tan(/1.6) and h=1.6f·tan(/2) the non-linear distribution function is symmetrical relative to the optical axis and

the center of the image varying according to the field angle of the corresponding object point.	the positions of points relative to the center of the image are based on the field angle of the corresponding object point. See also Figs. 4A-4D, showing the intent to have symmetry about the optical axis (0°) and variance of position according to field angle.
4. The method according to claim 1, wherein the objective lens expands the edges of the image and compresses the center of the image.	As described above with respect to claim 1, Fig. 3B shows that the functions h=1.2f·tan(/1.6) and h=1.6f·tan(/2) have a shallower slope as compared to the linear distribution function closer the center of the image, and a steeper slope relative to the linear distribution function near the periphery, evidencing an expanded edge of the image and a compressed center.
6. The method according to claim 1, wherein the objective lens comprises a set of lenses forming an apodizer.	As described in the '990 Patent, an "apodizer" is an optical system which provides a non-linear distribution of image points relative to the field angle of the object points. (Col. 16, lns. 1-4). As shown in Fig. 2 of Nagaoka, the lens system controls the angular distribution of the panoramic objective lens to obtain a non-linear distribution function, and therefore includes an "apodizer" as defined in the '990 Patent.
17. A panoramic objective lens comprising:	Nagaoka discloses a panoramic objective lens and a method for capturing a digital panoramic image: "…an image processing system utilizing an image pickup device comprising a fisheye lens..." (Col. 3, lns. 63-65). Nagaoka further discloses a panoramic objective lens: "an image of half of the sphere is picked up by the fisheye lens." (Col. 1, lns. 23-31).
optical means for projecting a panorama into an image plane of the objective lens,	Nagaoka discloses that the panorama is projected onto a CCD image sensor by a panoramic objective lens. (Fig. 2; col. 4, ln. 66-col. 5, ln. 2).
the optical means having an image point distribution function that is not linear relative to the field angle of object points of the panorama,	Nagaoka discloses several panoramic (fisheye) lenses each having an image point distribution function that is not linear relative to the field angle of object points of the panorama. Specifically, Nagaoka discloses examples of such non-linear lenses have the functions h=1.2f·tan(/1.6) and h=1.6f·tan(/2). (Figs. 3A and 3B).
the distribution function having a maximum divergence of at least .+-.10% compared to a linear distribution function,	Each of the above recited non-linear distribution functions lenses has a maximum divergence of at least ±10% compared to the linear distribution function. (Figs. 3A and 3B). Using a normalized image height (height = 1 at 90°), the function h=1.2f tan(/1.6) gives h of about 0.36 at 45°, which is about 18% divergence from the linear distribution function f

Appendix A

	(which would be 0.45 at 45°). Similarly, the function h=1.6f·tan(/2) gives a divergence at 45° of about 16%.
such that a panoramic image obtained by means of the objective lens comprises at least one substantially expanded zone and at least one substantially compressed zone.	The lenses having the functions h=1.2f·tan(/1.6) and h=1.6f·tan(/2) project a substantially expanded zone near the periphery (evidenced from Fig. 3B, which shows a slope for these two functions exceeding the slope of the linear distribution function (f) starting at about 60°) and a substantially compressed zone near the center (evidenced from Fig. 3B, which shows a slope for these two functions that is less than the slope of the linear distribution function (f) prior to about 60°).
18. The panoramic objective lens according to claim 17, having a non-linear distribution function that is symmetrical relative to the optical axis of the objective lens, the position of an image point relative to the center of an image obtained varying according to the field angle of the corresponding object point.	Fig. 2 of Nagaoka shows a lens having a non-linear distribution function that is symmetrical relative to the optical axis of the objective lens. In the lenses having functions h=1.2f·tan(/1.6) and h=1.6f·tan(/2) the non-linear distribution function is symmetrical relative to the optical axis and the positions of points relative to the center of the image are based on the field angle of the corresponding object point. See also Figs. 4A-4D, showing the intent to have symmetry about the optical axis (0°) and variance of position according to field angle.
20. The panoramic objective lens according to claim 17, wherein the lens expands the edges of an image and compresses the center of the image.	As described above with respect to claim 1, Fig. 3B shows that the functions h=1.2f·tan(/1.6) and h=1.6f·tan(/2) have a shallower slope as compared to the linear distribution function closer the center of the image, and a steeper slope relative to the linear distribution function near the periphery, evidencing an expanded edge of the image and a compressed center.
22. The panoramic objective lens according to claim 17, further comprising a set of lenses forming an apodizer.	As described in the '990 Patent, an "apodizer" is an optical system which provides a non-linear distribution of image points relative to the field angle of the object points. (Col. 16, lns. 1-4). As shown in Fig. 2 of Nagaoka, the lens system controls the angular distribution of the panoramic objective lens to obtain a non-linear distribution function, and therefore includes an "apodizer" as defined in the '990 Patent.

EXHIBIT 7b

CERTIFICATION

I, Takayoshi Hongo, Toranomon East Bldg., No. 7-13, Nishi-Shimbashi 1-chome, Minato-ku, Tokyo, Japan, do hereby certify that I am conversant with the English and Japanese languages and am a competent translator thereof, and I further certify that to the best of my knowledge and belief the attached English translation is a true and accurate translation made by me of the Japanese Unexamined Patent Application Publication JP 11-261868 published on September 24, 1999.

Signed this on the 20th day of March, 2014

T. Hongo

Takayoshi Hongo

(19) Japan Patent Office (JP)

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(54) [Title of the Invention] FISHEYE LENS CAMERA APPARATUS, AND IMAGE DISTORTION CORRECTION METHOD AND IMAGE EXTRACTION METHOD THEREFOR

(57) [Abstract]

[Object] The present invention relates to a fisheye lens camera apparatus, and an image distortion correction method and an image extraction method therefor, in which an image deformation process of correcting distortion of a fisheye lens image is performed at high speed in a case where a fisheye lens camera is installed at any installation angle, and a moving figure such as a person's figure is detected and is extracted accurately so as to be displayed on a monitor television or the like with high accuracy.

[Solving Means] A configuration is provided in which an image captured by a fisheye lens 1-1 and a CCD imaging device 1-2 is stored in a picture memory 1-3, and an image correction processing unit 1-4 operates coordinate transform for correcting an installation angle of a fisheye lens camera and coordinate transform for correcting distortion of a fisheye lens image in combination with each other, and a fisheye lens image of equal area projection is transformed through mapping at high speed. In addition, a configuration is provided in which weighting corresponding to a region in the fisheye lens image is performed, a feature amount of a person's figure or the like is extracted, and a display area is extracted.

[Claims]

[Claim 1]

A fisheye lens camera apparatus comprising:

an image correction processing unit that corrects distortion of an image captured by a fisheye lens camera,

wherein the image correction processing unit operates coordinate transform for correcting an installation angle of the fisheye lens camera and coordinate transform for correcting distortion of a fisheye lens image in combination with each other.

[Claim 2]

The fisheye lens camera apparatus according to claim 1, wherein the image correction processing unit operates coordinate transform for correcting distortion of a fisheye lens image of equal area mapping.

[Claim 3]

A fisheye lens camera apparatus comprising:

an image correction processing unit that corrects distortion of an image captured by a fisheye lens camera,

wherein parameters for correcting distortion of a fisheye lens image, such as a central position of a displayed image, an aspect ratio of the fisheye lens image, and a radius of a fisheye lens image area, are extracted from the captured fisheye lens image itself, and distortion of the fisheye lens image is corrected using the parameters.

[Claim 4]

A fisheye lens camera apparatus which extracts a moving figure from an image captured by a fisheye lens camera, wherein regions are unified using a mutual positional relationship in a fisheye lens image so as to extract a region in which the figure varies.

[Claim 5]

A fisheye lens camera apparatus which extracts a moving figure from an image captured by a fisheye lens camera, wherein a fisheye lens image is transformed into a transversely long picture having a panorama form, a signal of an inter-frame difference of the picture or a signal in which an inter-frame difference and an in-frame difference are combined is extracted, a region is extracted using the signal, and regions of a plurality of moving figures are extracted together.

[Claim 6]

A fisheye lens camera apparatus which extracts a moving figure from an image captured by a fisheye lens camera, wherein an operation of extracting a feature amount of a signal of an inter-frame difference, a signal in which an inter-frame difference and an in-frame difference are combined, or the like is performed based on a picture of a fisheye lens image, and, in a region extraction process for a feature detection region, address transform between polar coordinates and orthogonal coordinates is performed and inside of the picture of the

fisheye lens image is scanned, so as to extract regions of a plurality of moving figures from a picture of a circular fisheye lens image.

[Claim 7]

A fisheye lens camera apparatus which extracts a moving figure from an image captured by a fisheye lens camera, wherein, in relation to regions of a plurality of persons' figures obtained from a picture of a fisheye lens image, a shape of each person's figure is normalized, color information in the shape of each figure is stored, and a picture for individually tracking a plurality of moving persons' figures is created based on the color information of each figure.

[Claim 8]

A fisheye lens camera apparatus which extracts a moving figure from an image captured by a fisheye lens camera, wherein a region is extracted based on a feature amount multiplied by weighting factors which are different depending on an extent of distortion of a central part and a peripheral part of the fisheye lens image.

[Claim 9]

The fisheye lens camera apparatus according to claim 8, wherein a non-extracted region is masked by further giving a different value thereto as the weighting factor so as to correspond to the region in a picture of the fisheye lens image, and the region is extracted.

[Claim 10]

An image distortion correction method for a fisheye lens camera, of correcting distortion of an image captured by the fisheye lens camera, comprising:

a step of operating coordinate transform for correcting an installation angle of the fisheye lens camera and coordinate transform for correcting distortion of a fisheye lens image in combination with each other.

[Claim 11]

The image distortion correction method for the fisheye lens camera, of correcting distortion of the image captured by the fisheye lens camera according to claim 10, wherein the step of operating coordinate transform includes a step of operating coordinate transform for correcting distortion of a fisheye lens image of equal area mapping.

[Claim 12]

An image distortion correction method for a fisheye lens camera, of correcting distortion of an image captured by the fisheye lens camera, comprising:

a step of extracting parameters for correcting distortion of a fisheye lens image, such as a central position of a displayed image, an aspect ratio of the fisheye lens image, and a radius of a fisheye lens image area, from a captured fisheye lens image itself, and correcting distortion of the fisheye lens image using the parameters.

[Claim 13]

An image extraction method for a fisheye lens camera, of extracting a moving figure from an image captured by the fisheye lens camera, comprising:

a step of unifying regions using a mutual positional relationship in a fisheye lens image so as to extract a region in which the figure varies.

[Claim 14]

An image extraction method for a fisheye lens camera, of extracting a moving figure from an image captured by the fisheye lens camera, comprising:

a step of transforming a fisheye lens image into a transversely long picture having a panorama form, extracting a signal of an inter-frame difference of the picture or a signal in which an inter-frame difference and an in-frame difference are combined, extracting a region using the signal, and extracting regions of a plurality of moving figures together.

[Claim 15]

An image extraction method for a fisheye lens camera, of extracting a moving figure from an image captured by the fisheye lens camera, comprising:

a step of performing an operation of extracting a feature amount of a signal of an inter-frame difference, a signal in which an inter-frame difference and an in-frame difference are combined, or the like based on a picture of a fisheye lens image, and performing address transform between polar coordinates and orthogonal coordinates and scanning inside of the picture of the fisheye lens image, in a region extraction process for a feature detection region, so as to extract regions of a plurality of moving figures from a picture of a circular fisheye lens image.

[Claim 16]

An image extraction method for a fisheye lens camera, of extracting a moving figure from an image captured by the fisheye lens camera, comprising:

a step of normalizing a shape of each person's figure, storing color information in the shape of each figure, and creating a picture for individually tracking a plurality of moving persons' figures based on the color information of each figure, in relation to regions of a plurality of persons' figures obtained from a picture of a fisheye lens image.

[Claim 17]

An image extraction method for a fisheye lens camera, of extracting a moving figure from an image captured by the fisheye lens camera, comprising:

a step of extracting a region based on a feature amount multiplied by weighting factors which are different depending on an extent of distortion of a central part and a peripheral part of the fisheye lens image.

[Claim 18]

The image extraction method for the fisheye lens camera according to claim 17, wherein the step of extracting a region includes a step of masking a non-extracted region by further giving a different value thereto as the weighting factor so as to correspond to the region in the picture of the fisheye lens image, and extracting the region.

[Detailed Description of the Invention]

[0001]

[Technical Field of the Invention]

The present invention relates to a fisheye lens camera apparatus, and an image distortion correction method and an image extraction method therefor, and particularly to a fisheye lens camera apparatus, and an image distortion correction method and an image extraction method therefor in a video conference system, a remote monitoring system, or the like which captures an image with a fisheye lens camera and cuts a part of the image so as to be displayed on a monitor television.

[0002]

A fisheye lens has an angle of view of about 180 degrees and projects an image of a wide range, but the image is distorted in a barrel form, and, particularly, the distortion is notable in a peripheral part thereof. The present invention is to use the fact that an imaging range of the fisheye lens is wide, and to cut an attentional part of an image in the image captured by a single fisheye lens camera so as to correct distortion of the image, thereby displaying the corrected image on a monitor television screen.

[0003]

In addition, the present invention is to detect a figure that has movements such as a person intruding in a picture which is taken through reflection by a fisheye lens camera, to automatically determine a monitor display region (cut region) of the figure so as to track the moving figure, and is to be appropriately used in a camera apparatus of a remote monitoring system or a video conference system.

[0004]

[Related Art]

Fig. 13 is a diagram illustrating a configuration of a fisheye lens camera apparatus in the related art, and a remote monitoring system and a video conference system using the same. Fig. 13(a) shows a configuration of the fisheye lens camera apparatus, Fig. 13(b) shows the remote monitoring system using the fisheye lens camera apparatus, and Fig. 13(c) shows the video conference system using the fisheye lens camera apparatus.

[0005]

In the same figures, the reference numeral 13-10 indicates the fisheye lens camera apparatus, the reference numeral 13-1 indicates a fisheye lens, the reference numeral 13-2 indicates a CCD imaging device, the reference numeral 13-3

indicates a picture memory (frame memory), the reference numeral 13-4 indicates an image correction processing circuit, and the reference numeral 13-5 indicates a corrected picture (NTSC) output circuit.

[0006]

The fisheye lens 13-1 optically projects an object at an angle of view of about 180 degrees, the CCD imaging device 13-2 generates an electrical image signal from the optical picture, and the picture memory (frame memory) 13-3 stores the image signal in the frame unit.

[0007]

The image correction processing circuit 13-4 corrects a distorted image of the fisheye lens so as to recover an original image with respect to a monitor display region, and the corrected picture (NTSC) output circuit 13-5 outputs the corrected image signal as a normal television picture signal of an NTSC format or the like.

[0008]

Since the fisheye lens has a wide angle of view, a remote monitoring system or a video conference system which obtains pictures of areas with a wide range can be constituted by a camera apparatus using the lens. As shown in Figs. 13(b) and 13(c), the system can be configured by the fisheye lens camera apparatus 13-10 in which an encoding device 13-20 is installed, or a fisheye lens camera apparatus 13-30 with an encoding device by transmitting a picture signal via a public network 13-40, and by displaying the image signal on a monitor television screen 13-60 or the like via a decoding device 13-50. However, since the fisheye lens has a wide angle of view, distortion of a picture is large, and thus the distortion is required to be corrected for display on the monitor television screen 13-60 or the like.

[0009]

Fig. 14 is an explanatory diagram of correction of distortion of a fisheye lens camera image in the related art. In the same figure, the reference numeral 14-1 indicates a virtual image frame, the reference numeral 14-2 indicates a virtual hemispherical face, and the reference numeral 14-3 indicates a fisheye lens imaging screen. In addition, it is assumed that the fisheye lens is located at the origin O of a three-dimensional space indicated by x, y and z axes, and the fisheye lens is located facing the z axis direction.

[0010]

In addition, if the virtual hemispherical face 14-3 is an orthographic projection formula lens, and a focal length thereof is f, the hemispherical face is a hemispherical face of a virtual hemisphere with a radius f, and a planar part thereof is located on the x-y plane, and a center thereof is located at the position of the origin O.

[0011]

The virtual image frame 14-1 is a frame on a virtual plane perpendicular to a direction of view vector DOV (Direction of View) from the position (origin) of the fisheye lens toward a object to be photographed and has a rim with a predetermined size, and a picture in this range is cut from a fisheye lens image and is displayed on the monitor television screen as described below. In other words, the frame has a rim with the same size as that of a rim of a display frame of the monitor television or the like.

[0012]

In addition, the image frame 14-1 includes two-dimensional coordinate axes (p,q) which have a point intersecting the direction of view vector DOV in the frame as an origin, and a point in the virtual image frame 14-1 is expressed by the coordinate components (p,q).

[0013]

A figure (fisheye lens image) projected by the fisheye lens is classified into several types depending on a projection formula of the lens, and, hereinafter, an orthographic projection formula fisheye lens will be described.

[0014]

It is assumed that a figure which is viewed through the virtual hemispherical face 14-2 from the position (the origin O) at which the fisheye lens is located is attached to the virtual hemispherical face 14-2 as it is. In addition, a figure in which the figure on the three-dimensional space attached to the hemispherical face 14-2 is vertically (from the z direction toward the origin) crushed and attached onto a plane of a two-dimensional space formed by the x axis and y axis of the figure is an image of the orthographic projection formula fisheye lens.

[0015]

Further, an image of the fisheye lens is actually formed at vertically and horizontally reversed positions, but a relative relationship of a distortion of the figure does not vary, and, thus, for simplification of description, it is assumed that an image is formed as described above.

[0016]

A plane of the two-dimensional space obtained by vertically crushing the figure on the hemispherical face 14-2 is the fisheye lens imaging screen 14-3, and an image inside the circle of the fisheye lens imaging screen 14-3 is an image captured by the fisheye lens. The outer rectangular rim is an outside line of the entire imaging screen obtained from the CCD imaging device.

[0017]

Since an image of the fisheye lens is distorted, if an image captured by the fisheye lens camera is to be displayed, a part thereof is required to be cut so as to be corrected to a normal image. Therefore, a frame corresponding to a

displayed frame is assumed as the virtual image frame 14-1.

[0018]

It is assumed that the direction of the z axis in which the fisheye lens is oriented is an upper direction of the vertical line, a vertex angle (zenith angle) formed by the direction of view vector DOV and the z axis is set to ϕ, and an azimuth angle formed with a reference axis (the x axis or the y axis) of the horizontal plane is set to θ. In addition, a focal length (a radius of the circle of the fisheye lens image) is set to f, a rotation angle of an image frame is set to ω, and a magnification ratio is set to m. The magnification ratio m is $m=D/f$ when a distance from the position (the origin O) of the fisheye lens to the origin in the image frame 14-1 is set to D.

[0019]

A correspondence relationship between a point (x,y) in the fisheye lens imaging plane 14-3 and a point (p,q) in the image frame 14-1 is expressed by a relation of Equation (1).

[0020]

[Equation 1]

$$\left.\begin{aligned} x &= \frac{R\{pA - qB + mR\sin\phi\sin\theta\}}{\sqrt{p^2+q^2+m^2R^2}} \\ y &= \frac{R\{pC - qD - mR\sin\phi\sin\theta\}}{\sqrt{p^2+q^2+m^2R^2}} \\ A &= (\cos\omega\cos\theta - \sin\omega\sin\theta\cos\phi) \\ B &= (\sin\omega\cos\theta + \cos\omega\sin\theta\cos\phi) \\ C &= (\cos\omega\sin\theta + \sin\omega\cos\theta\cos\phi) \\ D &= (\sin\omega\sin\theta - \cos\omega\cos\theta\cos\phi) \end{aligned}\right\} \cdots (1)$$

[0021]

A distortion of the fisheye lens image is corrected using the correspondence relationship of Equation (1) so as to recover an original image which can be displayed on the monitor television screen. In other words, first, the image frame 14-1 is localized, and a region (cut region) displayed on the monitor is determined. This localization operation is set by inputting a vertex angle ϕ, an azimuth angle θ, a rotation angle ϕ, and a magnification ratio m to the image correction processing circuit 13-4 from an external device.

[0022]

The image correction processing circuit 13-4 obtains the point (x,y) in the fisheye lens imaging plane 14-3 corresponding to the point (p,q) in the image frame 14-1 using the relation of Equation (1), reads a color information signal of the point from the picture memory (frame memory) 13-3, and writes the color information signal to an output picture memory (not shown) having an address corresponding to the point (p,q) in the image frame 14-1.

[0023]

The color information transmission operation between the picture memories is performed for all points (p,q) in the image frame 14-1 so as to sequentially send a color information signal to the corrected picture (NTSC) output circuit 13-5 from the output picture memory, and thus the corrected picture (NTSC) output circuit 13-5 can display an image of a real object target without distortion when viewed through the rim of the virtual image frame 14-1 from the origin O. (Refer to the specification of U.S. Patent No. 5,185,667, and the like.)

[0024]

[Problems to be Solved by the Invention]

The above-described distortion correction of a fisheye lens image is a correction when a targeted fisheye lens forms an orthographic projection figure, and an operation of coordination transform is more complex in a fisheye lens which forms a figure of the equal area mapping and is frequently used as an actual fisheye lens.

[0025]

In the operation of the distortion correction of a fisheye lens image, an operation of coordinate transform for each coordinate point of a displayed image frame is performed, and thus an operation amount is enormous, and if a resolution of an image increases, an operation amount further increases. Thus, an amount of the operation of coordinate transform is required to be as small as possible.

[0026]

In addition, since the above-described distortion correction of a fisheye lens image is performed on the premise that the fisheye lens camera is vertically located, for example, being installed on a desk so as to be directly oriented toward a ceiling, or being installed on a ceiling so as to be directly oriented toward a floor, the fisheye lens camera cannot be installed through free selection of an installation angle thereof. On the other hand, if the fisheye lens camera is installed on a wall sideways or is installed at a tilt angle at the corner of a ceiling, there are many cases where an imaging region such as a monitoring region is included in a more effective imaging area of a fisheye lens image.

[0027]

Further, a picture taken using the fisheye lens camera actually varies depending on characteristics of an individual fisheye lens camera. This difference in the characteristics of the fisheye lens camera is left as an image distortion in a converted image and is displayed even if image transform is performed using distortion correction of a fisheye lens image.

[0028]

In the related art, correction of horizontal deviation of a fisheye lens image in an imaging screen of the CCD image device or correction of an aspect ratio caused by a structure

of the CCD imaging device, which is a picture parameter of the fisheye lens camera, is required to be manually performed.

[0029]

In addition, in a tracking type remote monitoring system using the fisheye lens camera, detection of a person's figure or the like and determination of a monitor display region (cut region) are required to be automatically performed, but a method of merely determining a monitor display region (cut region) using a difference between frames of a fisheye lens image is limited to detection in a case where a moving object is only one, and, in a case where a plurality of objects move in the region, pictures for tracking the respective objects cannot be created.

[0030]

In addition, a fisheye lens image has a difference in brightness or in an extent of distortion between a central part and a peripheral part thereof, and thus has a disadvantage in that an image displayed on the monitor also becomes unnatural according to a variation in a cut region on tracking.

[0031]

An object of the present invention is to perform an image deformation process of distortion correction of a fisheye lens image at high speed in a case where a fisheye lens camera is installed at any installation angle, and to detect and extract a moving figure such as a person's figure captured by the fisheye lens camera with high accuracy, so as to be displayed on a monitor television or the like with high accuracy.

[0032]

[Means for Solving the Problems]

A fisheye lens camera apparatus of the present invention includes (1) an image correction processing unit that corrects distortion of an image captured by a fisheye lens camera, in which the image correction processing unit operates coordinate transform for correcting an installation angle of the fisheye lens camera and coordinate transform for correcting distortion of a fisheye lens image in combination with each other. In addition, (2) the image correction processing unit operates coordinate transform for correcting distortion of a fisheye lens image of equal area mapping.

[0033]

Further, (3) in a fisheye lens camera apparatus including an image correction processing unit that corrects distortion of an image captured by a fisheye lens camera, parameters for correcting distortion of a fisheye lens image, such as a central position of a displayed image, an aspect ratio of the fisheye lens image, and a radius of a fisheye lens image area, are extracted from the captured fisheye lens image itself, and distortion of the fisheye lens image is corrected using the parameters.

[0034]

In addition, (4) in a fisheye lens camera apparatus which extracts a moving figure from an image captured by a fisheye lens camera, regions are unified using a mutual positional relationship in a fisheye lens image so as to extract a region in which the figure varies.

[0035]

Further, (5) in a fisheye lens camera apparatus which extracts a moving figure from an image captured by a fisheye lens camera, a fisheye lens image is transformed into a transversely long picture having a panorama form, a signal of an inter-frame difference of the picture or a signal in which an inter-frame difference and an in-frame difference are combined is extracted, a region is extracted using the signal, and regions of a plurality of moving figures are extracted together.

[0036]

In addition, (6) in a fisheye lens camera apparatus which extracts a moving figure from an image captured by a fisheye lens camera, an operation of extracting a feature amount of a signal of an inter-frame difference, a signal in which an inter-frame difference and an in-frame difference are combined, or the like is performed based on a picture of a fisheye lens image, and, in a region extraction process for a feature detection region, address transform between polar coordinates and orthogonal coordinates is performed and inside of the picture of the fisheye lens image is scanned, so as to extract regions of a plurality of moving figures from a picture of a circular fisheye lens image.

[0037]

Further, (7) in a fisheye lens camera apparatus which extracts a moving figure from an image captured by a fisheye lens camera, in relation to regions of a plurality of persons' figures obtained from a picture of a fisheye lens image, a shape of each person's figure is normalized, color information in the shape of each figure is stored, and a picture for individually tracking a plurality of moving persons' figures is created based on the color information of each figure.

[0038]

In addition, (8) in a fisheye lens camera apparatus which extracts a moving figure from an image captured by a fisheye lens camera, a region is extracted based on a feature amount multiplied by weighting factors which are different depending on an extent of distortion of a central part and a peripheral part of the fisheye lens image. Further, (9) a non-extracted region is masked by further giving a different value thereto as the weighting factor so as to correspond to the region in a picture of the fisheye lens image, and the region is extracted.

[0039]

Further, an image distortion correction method for a

fisheye lens camera of the present invention, (10) of correcting distortion of an image captured by the fisheye lens camera, includes a step of operating coordinate transform for correcting an installation angle of the fisheye lens camera and coordinate transform for correcting distortion of a fisheye lens image in combination with each other. Further, (11) in the image distortion correction for a fisheye lens camera, the step of operating coordinate transform includes a step of operating coordinate transform for correcting distortion of a fisheye lens image of equal area mapping in correcting distortion of an image captured by the fisheye lens camera.

[0040]

In addition, an image distortion correction method for a fisheye lens camera, (12) of correcting distortion of an image captured by the fisheye lens camera, includes a step of extracting parameters for correcting distortion of a fisheye lens image, such as a central position of a displayed image, an aspect ratio of the fisheye lens image, and a radius of a fisheye lens image area, from a captured fisheye lens image itself, and correcting distortion of the fisheye lens image using the parameters, in correcting distortion of an image captured by the fisheye lens camera.

[0041]

Further, an image extraction method for a fisheye lens camera of the present invention, (13) of extracting a moving figure from an image captured by the fisheye lens camera, includes a step of unifying regions using a mutual positional relationship in a fisheye lens image so as to extract a region in which the figure varies.

[0042]

In addition, (14) an image extraction method of extracting a moving figure from an image captured by the fisheye lens camera, includes a step of transforming a fisheye lens image into a transversely long picture having a panorama form, extracting a signal of an inter-frame difference of the picture or a signal in which an inter-frame difference and an in-frame difference are combined, extracting a region using the signal, and extracting regions of a plurality of moving figures together.

[0043]

Further, (15) an image extraction method of extracting a moving figure from an image captured by the fisheye lens camera, includes a step of performing an operation of extracting a feature amount of a signal of an inter-frame difference, a signal in which an inter-frame difference and an in-frame difference are combined, or the like based on a picture of a fisheye lens image, and performing address transform between polar coordinates and orthogonal coordinates and scanning inside of the picture of the fisheye lens image, in a region extraction process for a feature

detection region, so as to extract regions of a plurality of moving figures from a picture of a circular fisheye lens image.

[0044]

In addition, (16) an image extraction method of extracting a moving figure from an image captured by the fisheye lens camera includes a step of normalizing a shape of each person's figure, storing color information in the shape of each figure, and creating a picture for individually tracking a plurality of moving persons' figures based on the color information of each figure, in relation to regions of a plurality of persons' figures obtained from a picture of a fisheye lens image.

[0045]

Further, (17) an image extraction method of extracting a moving figure from an image captured by the fisheye lens camera includes a step of extracting a region based on a feature amount multiplied by weighting factors which are different depending on an extent of distortion of a central part and a peripheral part of the fisheye lens image.

[0046]

In addition, (18) the step of extracting a region includes a step of masking a non-extracted region by further giving a different value thereto as the weighting factor so as to correspond to the region in a picture of the fisheye lens image, and extracting the region.

[0047]

[Embodiments of the Invention]

Fig. 1 is a diagram illustrating a configuration of a fisheye lens camera apparatus according to an embodiment of the present invention. In the same figure, the reference numeral 1-1 indicates a fisheye lens, the reference numeral 1-2 indicates a CCD imaging device, the reference numeral 1-3 indicates a picture memory (frame memory), the reference numeral 1-4 indicates an image correction processing unit, the reference numeral 1-41 indicates a camera installation angle correction unit, the reference numeral 1-42 indicates a pan/tilt angle rotation correction unit, the reference numeral 1-43 indicates a zoom correction unit, the reference numeral 1-44 indicates a picture interpolation creation unit, and the reference numeral 1-5 indicates a corrected picture (NTSC) output circuit.

[0048]

An image of a wide range is optically captured by the fisheye lens 1-1, an electrical image signal is generated from the optical image by the CCD imaging device 1-2, and the picture memory (frame memory) 1-3 stores the image signal in the frame unit.

[0049]

The image correction processing unit 1-4 performs a process of correcting an image distorted by the fisheye lens

so as to recover an original image, and the corrected picture (NTSC) output circuit 1-5 outputs a signal of the corrected image as a television picture signal of a normal NTSC format or the like. In addition, this signal may be encoded by an encoding device so as to be transmitted and to be displayed as a picture at a remote location.

[0050]

The camera installation angle correction unit 1-41 of the image correction processing unit 1-4 corrects an installation angle of the fisheye lens camera apparatus oriented in any direction; the pan/tilt angle rotation correction unit 1-42 controls a rotation angle of a pan/tilt angle of a picture display area (cut area); the zoom correction unit 1-43 controls a magnification ratio of a displayed picture; and the picture interpolation creation unit 1-44 interpolates an interval between coordinate points, and performs a process of correcting distortion of an image of a picture display area (cut area) so as to recover an original image.

[0051]

Fig. 2 is an explanatory diagram of a picture taken by the fisheye lens camera according to the embodiment of the present invention. Fig. 2(a) shows a fisheye lens image img in a case where the fisheye lens camera is oriented directly upward; Fig. 2(b) schematically shows a state in which the fisheye lens image img which is a display target is mapped onto a plane of an image frame frm; and Fig. 2(c) is a diagram in which the sphere of Fig. 2(b) is viewed in the y axis direction. In a case where the fisheye lens image img is an orthographic projection formula image, the fisheye lens image img of Fig. 2(a) is an image in which the sphere of Fig. 2(b) is viewed from the z axis direction.

[0052]

If the fisheye lens camera is assumed to be located upward (in the z axis direction) at the origin of the x axis, the y axis, and the z axis, first, a picture reflected by the fisheye lens camera can be analyzed assuming a state in which the picture is attached to inside of a sphere with a radius which is a distance R from the origin.

[0053]

As above, a distance to an object is disregarded, and the image img captured by the fisheye lens camera may be regarded as mapping of an image incident from a specific direction (r,θ,ϕ) to a point (x'',y'') expressed by a mapping transformation of Equation (2) in the two-dimensional x-y plane. In Equation (2), θ indicates an azimuth angle, ϕ indicates a vertex angle (zenith angle), and L indicates a distance (image height) from the origin O when an image incident at the vertex angle ϕ is formed on a fisheye lens image.

[0054]

[Equation 2]

$$\left.\begin{aligned} x'' &= L\cos\theta \\ y'' &= L\sin\theta \end{aligned}\right\} \cdots\cdots (2)$$

[0055]

In other words, the fisheye lens image img may be considered as mapping to two-dimensional (x'',y'') from a point of the three-dimensional coordinate (r,θ,ϕ). The distance (image height) L is different depending on a projection formula of the fisheye lens, and is expressed as in Equation (3-1) in a case of the above-described orthographic projection formula, expressed as in Equation (3-2) in a case of equal area projection, and expressed as in Equation (3-3) in a case of equal distance projection. In addition, f indicates a focal length of the lens.

[0056]

[Equation 3]

$$L = f\sin\phi \quad \cdots\cdots (3\text{-}1)$$

$$L = 2f\sin\frac{\phi}{2} \quad \cdots\cdots (3\text{-}2)$$

$$L = f\phi \quad \cdots\cdots (3\text{-}3)$$

[0057]

In Fig. 2(b), if an azimuth angle of the image frame frm displayed through distortion correction is indicated by θ, and a vertex angle thereof is indicated by ϕ, a pan/tilt operation of the displayed image corresponds to displaying a picture projected thereonto when this virtual image frame frm is rotated in the three-dimensional coordinates.

[0058]

In other words, a coordinate of a point of the fisheye lens image img corresponding to a coordinate of each point arranged on a raster in the image frame frm is specified, and a color information signal of the point having the coordinate is made to correspond to a color information signal of a point having a coordinate of the display frame frm, and thus it is possible to perform a correction process of transforming the fisheye lens image img to an original image. In a case where the camera is oriented directly upward or directly downward, a predetermined amount of the azimuth angle θ may be changed through a pan operation of the image frame frm, and a predetermined amount of the vertex angle ϕ may be changed through a tilt operation thereof, thereby performing mapping of a color information signal of a two-dimensional coordinate in a corresponding fisheye lens image img.

[0059]

Fig. 3 is an explanatory diagram of an image captured by the fisheye lens camera oriented in the transverse direction. The same figure shows a case where the fisheye lens camera is oriented in the x axis direction. In this case, the fisheye lens image img is formed on the vertical plane.

[0060]

Also in this case, an image without distortion can be

displayed through distortion correction as described above, but, if transform of the fisheye lens image as a picture right above is performed, a rotation direction is different from an actual direction of pan/tilt of the picture when the pan/tilt operation is performed. In other words, in a case of the picture right above, the tilt operation is performed by changing the angle ϕ with the z axis, but the tilt operation is not performed even by changing the angle ϕ when the fisheye lens camera is oriented in the transverse direction.

[0061]

For this reason, first, before the distortion correction is performed, an orientation of the fisheye lens camera, that is, a camera installation angle is corrected. This correction process is performed by the above-described camera installation angle correction unit 1-41.

[0062]

Fig. 4 is an explanatory diagram of correction of a fisheye lens camera image oriented in the transverse direction. As shown in Fig. 3, in a case where the fisheye lens camera is oriented in the direction of the x axis which is a transverse axis, the coordinate system is rotated toward the y axis by 90 degrees in advance such that the fisheye lens image plane img is rotated and moved to a position intersecting the z axis in the vertical direction, and thus it is possible to perform a process equivalent to a case of the above-described image right above for a pan/tilt operation. In other words, a tilt operation can be performed by changing the angle ϕ, and a pan operation can be performed by changing the angle θ.

[0063]

Although the example shown in Fig. 4 relates to a case where the fisheye lens camera is oriented in the transverse direction, in a case where, when the fisheye lens camera is oriented in any direction of upward, downward, transverse and tilt directions, a coordinate system having a vertical direction as a z' axis is set to (x', y', z'), a coordinate of a point on an image frame frm is indicated by (x', y', z'), an angle formed by a point (x', y', z') on the image frame frm and an orientation (z axis direction) of the fisheye lens camera is indicated by ϕ, an angle formed by the point (x', y', z') on the image frame frm and the x axis is indicated by θ, and an angle formed by the point (x', y', z') on the image frame frm and the y axis is indicated by ρ, rotation coordinate transform is performed using a rotation matrix expression of Equation (4) such that a pan/tilt operation direction can conform to that of an actual picture. Here, the matrices Rx, Rz and Ry of the rotation matrix expression of Equation (4) are matrices which respectively give rotation toward the x axis, the y axis, and the z axis, and the matrix Rx gives rotation corresponding to a camera angle.

[0064]

[Equation 4]

$$\left.\begin{aligned} \begin{bmatrix} x \\ y \\ z \end{bmatrix} &= Rz \cdot Ry \cdot Rx \cdot \begin{bmatrix} x' \\ y' \\ z' \end{bmatrix} \\ Rx &= \begin{bmatrix} \cos\theta & -\sin\theta & 0 \\ \sin\theta & \cos\theta & 0 \\ 0 & 0 & 1 \end{bmatrix} \\ Ry &= \begin{bmatrix} \cos\phi & 0 & -\sin\phi \\ 0 & 1 & 0 \\ \sin\phi & 0 & \cos\phi \end{bmatrix} \\ Rz &= \begin{bmatrix} 1 & 0 & 0 \\ 0 & \cos\rho & -\sin\rho \\ 0 & \sin\rho & \cos\rho \end{bmatrix} \end{aligned}\right\} \cdots (4)$$

[0065]

The rotation matrix expression of the above Equation (4) is calculated once in relation to the same azimuth angle and camera angle (vertex angle), and thus a coordinate after being rotated can be obtained as (x, y, z). Next, mapping of this point to a point (x", y") of the fisheye lens image on the two-dimensional coordinates is calculated such that a point on the image frame can be made to correspond to a point on the fisheye lens image. The increase in a calculation amount for an installation angle of the fisheye lens camera is caused by generating a rotation matrix only once, and is thus slight.

[0066]

The mapping from a three-dimensional coordinate point (x, y, z) to a point P (x", y") of the fisheye lens image on the two-dimensional coordinates is first performed by transforming the point (x, y, z) into a point (r, θ, ϕ) expressed in polar coordinates. This transform can be performed using a polar coordinate transform expression of Equation (5).

[0067]

[Equation 5]

$$\left.\begin{aligned} r &= \sqrt{x^2+y^2+z^2} \\ \theta &= \tan^{-1}(x/y) = \cos^{-1}(x/\sqrt{x^2+y^2}) \\ \phi &= \cos^{-1}(z/r) = \tan^{-1}(\sqrt{x^2+y^2}/z) \end{aligned}\right\} \cdots (5)$$

[0068]

Further, a fisheye lens of an equal area mapping formula is expressed by an expression of Equation (3-2), and this equation is assigned to Equation (2) so as to obtain an expression of Equation (6). The expression of Equation (6) is simplified as in an expression of Equation (7) using a relation of $x^2+y^2+z^2=x'^2+y'^2+z'^2=r^2$, Equation (5), and further a basic expression of a trigonometric function.

[0069]

[Equation 6]

$$\left.\begin{aligned} x'' &= 2f\sin\frac{\phi}{2}\cos\theta \\ y'' &= 2f\sin\frac{\phi}{2}\cos\theta \end{aligned}\right\} \cdots (6)$$

[0070]

[Equation 7]

$$\left.\begin{aligned} u &= \frac{\sqrt{2}fx\sqrt{r-z}}{\sqrt{r}\sqrt{x^2+y^2}} = \frac{\sqrt{2}fx\sqrt{r-z}}{\sqrt{r}\sqrt{r^2-z^2}} = \frac{\sqrt{2}fx}{\sqrt{r(r+z)}} \\ v &= \frac{fy\sqrt{r-z}}{\sqrt{r}\sqrt{x^2+y^2}} = \frac{fy\sqrt{r-z}}{\sqrt{r}\sqrt{r^2-z^2}} = \frac{\sqrt{2}fy}{\sqrt{r(r+z)}} \end{aligned}\right\} \cdots (7)$$

[0071]

In this way, in the correction of a fisheye lens camera installation angle, before an image transform process is performed, first, a coordinate (x',y',z') of the rectangular region of the image frame frm is transformed into a coordinate (x,y,z) through rotation coordinate transform, and, then, a point having the coordinate (x,y,z) is transformed into a point (x",y") on coordinates of the fisheye lens image. In addition, a component of the z axis corresponds to a zoom ratio, and two-dimensional-two-dimensional transform from (x,y) to (x",y") is basically performed. A coordinate transformation regarding the expression of Equation (7) is aimed at reducing the number of calculations by calculating coordinate transform according to a coordinate axis rotation and mapping transform according to characteristics of the fisheye lens at one time.

[0072]

Here, the point (x",y") on the coordinates of the fisheye lens image obtained through the above-described operation is indicated by (u,v). In order to smoothly interpolate this coordinate point (u,v), the following interpolation process is performed. Color information signal components of three colors of a picture signal are indicated by Y, U, and V, those components of the point (u,v) are indicated by Yu,v, Uu,v, and Vu,v, values which become an integer by omitting decimal points of the coordinate components u and v of the point (u,v) are indicated by u0 and v0, and a value of the color information signal Y in a point having the coordinate (u0,v0) is indicated by Yu0v0. Similarly, the same content is indicated by Uu0v0 and Vu0v0 for the color information signals U and V. In addition, values obtained by rounding up decimal points of the coordinate components u and v are respectively indicated by u1 and v1, and values of the color information signals Y, U and V having a coordinate corresponding thereto are respectively indicated by Yu1v1, Uu1v1, and Vu1v1. Further, decimal parts of the coordinate components u and v are respectively indicated by du and dv.

[0073]

An input picture signal is interpolated and is mapped using a linear transform expression of Equation (8), and thus a smooth image can be displayed.

[0074]

[Equation 8]

$$\left.\begin{aligned} Y_{u,v} &= (1-du)(1-dv)\cdot Yu0v0 + du(1-dv)\cdot Yu0v1 \\ &\quad + (1-du)dy\cdot Yu0v1 + dudyYu1v1 \\ U_{u,v} &= (1-du)(1-dv)\cdot Uu0v0 + du(1-dv)\cdot Uu0v1 \\ &\quad + (1-du)dy\cdot Uu0v1 + dudyUu1v1 \\ V_{u,v} &= (1-du)(1-dv)\cdot Vu0v0 + du(1-dv)\cdot Vu0v1 \\ &\quad + (1-du)dy\cdot Vu0v1 + dudyVu1v1 \end{aligned}\right\} \cdots (8)$$

[0075]

Next, a description will be made of a method of automatically extracting an image central position (Xbase, Ybase) and a value f corresponding to the focal length, which are parameters of the fisheye lens camera, from an imaging area of the fisheye lens camera. The above-described parameters are parameters used in distortion correction of a fisheye lens camera image.

[0076]

Fig. 5 is an explanatory diagram of extraction of parameters of the fisheye lens camera. In the same figure, the reference numeral 5-1 indicates an imaging area of the fisheye lens camera, and the reference numeral 5-2 indicates a fisheye lens image area. The circular fisheye lens image area 5-2 is observed in the imaging area 5-1 of the camera using a circular image fisheye lens. The fisheye lens image area 5-2 is observed at a predetermined position in the camera imaging area 5-1, and light does not reach the outer circumference of the fisheye lens image area 5-2, and thus the area has very low luminance.

[0077]

Therefore, a histogram regarding each of the horizontal and vertical directions is extracted with respect to the entire camera imaging area 5-1, so as to measure a position of the fisheye lens image area and a radius thereof.

[0078]

Appropriate threshold values Th and Tv are set for a horizontal direction histogram Hh(n) and a vertical direction histogram Hv(n), and histograms are measured from both ends of the imaging area screen so as to search for points which initially exceed the threshold values Tv and Th.

[0079]

Two points of the points are extracted for each of the horizontal and vertical directions, and points of a left end Xleft and a right end Xright of the fisheye lens image area can be detected from the horizontal histogram. In addition, points of an upper end Yup and a lower end Ydown of the fisheye lens image area can be detected from the vertical histogram.

[0080]

A radius Rh in the horizontal direction and a radius Rv in the vertical direction can be extracted using Equation (9) from the respective positions of the left end Xleft, the right end Xright, Yup, and the lower end Ydown of the fisheye lens image area. In addition, the image central position (Xbase, Ybase) can be extracted using Equation (10).

[0081]

[Equation 9]

$$\left.\begin{array}{l} Rh=(Xright-Xleft)/2 \\ Rv=(Ydown-Yup)/2 \end{array}\right\} \cdots\cdots (9)$$

[0082]

[Equation 10]

$$\left.\begin{array}{l} Xbase=(Xright+Xleft)/2 \\ Ybase=(Ydown+Yup)/2 \end{array}\right\} \cdots\cdots (10)$$

[0083]

Although the fisheye lens image area S-2 is basically circular, and thus the radius Rh in the horizontal direction and the radius Rv in the vertical direction are the same as each other as Rh=Rv, there may be a difference between the radius Rh in the horizontal direction and the radius Rv in the vertical direction due to a difference between aspect ratios in the vertical and horizontal directions of the imaging device such as a CCD in some cases.

[0084]

The radius R of the fisheye lens image area S-2 is originally a value defined based on the focal length f of the fisheye lens, and is expressed by Equation (11-1), for example, in an orthographic projection formula fisheye lens and is expressed by Equation (11-2) in an equal area projection formula fisheye lens.

[0085]

[Equation 11]

$$R=f \quad \cdots\cdots (11\text{-}1)$$

$$R=\sqrt{2}f \quad \cdots\cdots (11\text{-}2)$$

[0086]

Therefore, in the above-described calculation of the expression of Equation (6) for obtaining the point (x", y") on the coordinates of the fisheye lens image, in a case where there is a difference between the radius Rh in the horizontal direction and the radius Rv in the vertical direction, an identical value as a value of the focal length f is not used, but a value of f may be corrected by assigning a value of the radius Rh in the horizontal direction or the radius Rv in the vertical direction to a value of R of Equation (11-1) or Equation (11-3) for each direction, thereby performing distortion correction of the fisheye lens in consideration of a difference between the aspect ratios.

[0087]

Fig. 6 is a diagram illustrating a configuration of a moving figure detection device according to a first embodiment of the present invention. In the same figure, the reference numeral 6-1 indicates a fisheye lens camera, the reference numerals 6-2 and 6-3 indicate frame buffers, the reference numerals 6-4 and 6-5 indicate inter-frame difference calculation units, the reference numeral 6-6 indicates a region weighting table, and the reference numeral 6-7 indicates a region extraction unit.

[0088]

A signal of an image captured by the fisheye lens camera 6-1 is stored in the first frame buffer 6-2, and the image signal stored in the first frame buffer 6-2 is stored in the second frame buffer 6-3. An image signal one frame before is stored in the second frame buffer 6-3.

[0089]

In addition, based on an image signal output from the

first frame buffer 6-2 and an image signal output from the second frame buffer 6-3, the first inter-frame difference calculation unit 6-4 calculates a difference between frames thereof, and outputs an inter-frame difference signal having a great value related to a moving figure to the second inter-frame difference calculation unit 6-5.

[0090]

Based on the inter-frame difference signal output from the first inter-frame difference calculation unit 6-4 and a value corresponding to a region output from the region weighting table 6-6, the second inter-frame difference calculation unit 6-5 performs weighting corresponding to the region on the inter-frame difference signal, and outputs a resultant signal to the region extraction unit 6-7.

[0091]

The region extraction unit 6-7 detects a moving figure on the basis of the inter-frame difference signal having undergone the weighting corresponding to the region, so as to output a detection flag signal and also to extract a detected region, thereby outputting region information.

[0092]

Fig. 7 is a diagram illustrating a configuration of a moving figure detection device according to a second embodiment of the present invention. In the same figure, the reference numeral 7-1 indicates a fisheye lens camera, the reference numerals 7-2 and 7-3 indicate frame buffers, the reference numeral 7-4 indicates an inter-frame difference calculation unit, the reference numeral 7-5 indicates an in-frame difference calculation unit, the reference numeral 7-6 indicates a moving contour extraction unit, the reference numeral 7-7 indicates a region weighting table, the reference numeral 7-8 indicates a region extraction determining unit, and the reference numeral 7-9 indicates a region extraction unit.

[0093]

A signal of an image captured by the fisheye lens camera 7-1 is stored in the first frame buffer 7-2, and the image signal stored in the first frame buffer 7-2 is stored in the second frame buffer 7-3. An image signal one frame before is stored in the second frame buffer 7-3.

[0094]

In addition, based on an image signal output from the first frame buffer 7-2 and an image signal output from the second frame buffer 7-3, the inter-frame difference calculation unit 7-4 calculates a difference between frames thereof, and outputs an inter-frame difference signal having a great value related to a moving figure to the moving contour extraction unit 7-6.

[0095]

The in-frame difference calculation unit 7-5 calculates

a difference in a frame of an image signal which is output from the first frame buffer 7-2, and outputs an in-frame difference signal, which has a great value in a contour part of a figure, to the moving contour extraction unit 7-6.

[0096]

The moving contour extraction unit 7-6 linearly combines the inter-frame difference signal from the inter-frame difference calculation unit 7-4 with the in-frame difference signal from the in-frame difference calculation unit 7-5 so as to generate a signal of a moving figure of which a contour part is emphasized, and outputs the signal to the region extraction determining unit 7-8.

[0097]

Based on the signal of the moving figure of which the contour part is emphasized, output from the moving contour extraction unit 7-6, and a value corresponding to a region output from the region weighting table 7-7, the region extraction determining unit 7-8 performs weighting corresponding to the region on the signal of the moving figure, and outputs a resultant signal to the region extraction unit 7-9.

[0098]

The region extraction unit 7-9 detects the moving figure on the basis of the signal of the moving figure having undergone the weighting corresponding to the region, so as to output a detection flag signal and also to extract a detected region, thereby outputting region information.

[0039]

The moving figure detection devices according to the embodiments of the present invention shown in Figs. 6 and 7 perform weighting on a picture signal so as to correspond to a region when extracting the region of a moving figure, so as to reduce influence of detected parameter signals due to distortion of an image caused by the fisheye lens.

[0100]

In other words, typically, in a case of calculating an inter-frame difference $D_n(x,y)$ between a picture signal $F_n(x,y)$ of an n-th frame and a picture signal $P_{n-1}(x,y)$ of a (n-1)-th frame, the calculation is performed using Equation (12), but, in the present invention, the region weighting tables 6-6 and 7-7 are provided which store a weighting factor $W(x,y)$ for extracting a feature corresponding to a region of the fisheye lens image, and a process of extracting a moving figure is performed using a value $G_n(x,y)$ obtained by multiplying the inter-frame difference $D_n(x,y)$ by the weighting factor $W(x,y)$.

$D_n(x,y) = F_n(x,y) - P_{n-1}(x,y)$ ... (12)

[0101]

In other words, if the inter-frame difference signal output from the first inter-frame difference calculation unit 6-4 shown in Fig. 6, or a signal obtained by linearly combining

the inter-frame difference with the in-frame difference, output from the moving contour extraction unit 7-6 shown in Fig. 7 is assumed as a feature amount $D_n(x,y)$ for extracting a moving figure, a product $G_n(x,y)$ of the feature amount $D_n(x,y)$ and the weighting factor $W(x,y)$ corresponding to a region of the fisheye lens image is used as a feature amount for extracting a moving figure, using Equation (13).

$G_n(x,y) = W(x,y) \cdot D_n(x,y)$ ... (13)

[0102]

As such, through the process of performing extracting using the feature amount $G_n(x,y)$ which is weighted so as to correspond to a region of a fisheye lens image, it is possible to perform corresponding equivalent mask and emphasis operations for each region in a fisheye lens image area.

[0103]

Fig. 8 is an explanatory diagram of the weighting factor $W(x,y)$ corresponding to a region of a fisheye lens image. The same figure shows an example in which a region in a fisheye lens image is divided into three regions 8-1, 8-2 and 8-3, a weighting factor 0 is allocated to the region 8-1, a weighting factor 1 is allocated to the region 8-2, and a weighting factor 2 is allocated to the region 8-3.

[0104]

In the peripheral part of the fisheye lens image, a region having the same area is displayed smaller than in the central part. For this reason, accuracy of detecting a moving figure is reduced in the peripheral part, but a weighting factor W(x,y) of the peripheral part is set to a great value, and thus it is possible to compensate for the accuracy reduction in the peripheral part. In addition, since there is a high probability that there is a person's figure in the peripheral part, a great value is set in the peripheral part, and a value close to 0 is set in the central part.

[0105]

Further, since an imaging area is very wide in the fisheye lens camera, illumination or the like frequently directly enters the imaging area. Also in this case, an intense difference in luminance may be compensated for by an equivalent region mask so as to reduce errors in detecting a moving figure.

[0106]

The region extraction units 6-7 and 7-9 compare a feature amount which is weighted so as to correspond to a region with a preset threshold value (Thm) so as to perform a figure detection determining process of a person's figure or the like. A region extraction process accompanied by the figure detection determining process is performed on the entire screen of the fisheye lens image.

[0107]

Fig. 9 is a diagram illustrating an example of a figure of a person or the like of which a region is extracted. Fig.

9(a) shows a fisheye lens image area and shows an example of a fisheye lens image in a case where the fisheye lens camera is located upward on a desk or the like, and four persons are seated around the camera. The reference numerals 9-1 to 9-4 respectively indicate a person's figure detection area (A) to a person's figure detection area (D). Fig. 9(b) shows a shape of the person's figure of the fisheye lens image, and, in a case where the person is photographed from the bottom by the fisheye lens, this causes such a shape as a substantially trapezoidal shape in which the body bottom part is long and the parietal is short, and a person's figure can be normalized to this shape.

[0108]

When an image of the fisheye lens image area as shown in Fig. 9(a) is raster-scanned so as to detect a point having a large feature amount as a person's figure, a figure having a shape such as a substantially trapezoidal shape is searched for downward from the point, and a region thereof is cut.

[0109]

A size and a shape of the cut region are combined so as to determine whether or not the region is a region of a person's figure. The same process is performed on a plurality of regions together, and, when a plurality of persons' figures are detected, the plurality of persons' figures are cut together.

[0110]

In addition, the respective parameters for a parietal, a body bottom part, and a body height of a person as shown in Fig. 9(b) and color data inside thereof may be sampled for each cut region in horizontal and vertical directions, thereby generating a database for identifying a person's figure for each image.

[0111]

In relation to a process of extracting a region of a person's figure from the extracted feature amount, a typical algorithm for extracting a region from a camera picture may be basically used, but the fisheye lens image is circularly distorted and is disposed, and thus coordinate transform is required to be performed.

[0112]

There are the following two methods as coordinate transform methods. The first method is a method in which mapping transform is performed on a fisheye lens image so as to generate a coordinate-transformed picture as a panorama picture of 360 degrees. In this method, a circular fisheye lens imaging area is transformed into a rectangular area.

[0113]

The second method is a method in which typical raster scanning for extracting a region is performed, and only a coordinate system during the scanning is transformed from an orthogonal coordinate (x,y) to a polar coordinate (r,θ). In

other words, a process of extracting a region is performed using $x=r\cos\theta$ and $y=r\sin\theta$.

[0114]

The first method has a disadvantage in which a large volume of memory for development to a panorama picture is necessary but may employ a region extraction process for a normal image as it is after the transform is performed. In the second method, a region extraction process is performed while performing coordinate transform at all times, but only a memory amount for providing a fisheye lens image which is an original image is required as a memory amount to be used, and thus a compact system can be built.

[0115]

In addition, a feature amount is extracted, and a process of unifying regions is performed using a known mutual relationship of pictures such as a vertical relationship. For example, in a case of a fisheye lens camera oriented directly upward, regions are unified using a positional relationship of a picture in which a center of a fisheye lens image is set to an upper side, and a periphery thereof is set to a lower side, and a region in which the unified region varies from a background image to a person's figure is extracted.

[0116]

In relation to a process of tracking a moving figure such as invasion of a person, lattice points for vertically and horizontally equally dividing a person region having a substantially cut trapezoidal shape into a predefined division number are calculated, and color information signals at the lattice points are preserved as a feature amount of the person's figure. In addition, a process of registering the feature amount of the person's figure and a process of cutting the person's figure are repeatedly performed with any time interval, and thus each person's figure can be individually tracked even in a case where a plurality of persons' figures are in the fisheye lens camera imaging area.

[0117]

Fig. 10 is a flowchart illustrating a process of determining a person's figure extraction position according to an embodiment of the present invention. First, a command for a process of cutting a person's figure or the like in a fisheye lens image is given (10-1); a feature amount of the person's figure is extracted (10-3) based on an inter-frame difference or an inter-frame difference and an in-frame difference through a loop process for frames (10-2); a weighting process corresponding to the region in the fisheye lens image is performed (10-4); a raster loop process in a fisheye lens screen is performed (10-5) so as to detect a feature point (10-6); coordinate transform of the fisheye lens image is performed on an area having a substantially trapezoidal shape so as to perform a process of extracting the

feature point (10-7) and to determine whether or not there is a feature point (10-8); if there is a feature point, the extracted point is erased (10-9), and a maximum value and a minimum value of a region of (x,y) coordinates are stored (10-10); it is determined whether or not a line is a final line (10-11); and, if the line is a final line, the flow finishes (10-12).

[0118]

If there is no feature point in the determination (10-8) of whether or not there is a feature point, it is determined whether or not there are feature points in a plurality of continuous lines (10-13); if there are no continuous feature points, the number of regions is counted and the person regions are stored (10-14); and the flow proceeds to the above-described determination (10-11) of whether or not a line is a final line.

[0119]

If a plurality of continuous lines are not continuously located in the determination (10-13) of whether or not there are feature points in a plurality of continuous lines, the flow returns to the above-described process (10-6) of detecting a feature point. In addition, if the line is not a final line in the determination (10-11) of whether or not a line is a final line, the flow returns to the above-described process (10-6) of detecting a feature point.

[0120]

If a region where there is the person's figure is extracted, parameters for displaying a corrected fisheye lens image can be obtained from the region. Fig. 11 is an explanatory diagram of a configuration of cutting a region and creating a display screen according to an embodiment of the present invention. In the same figure, the reference numeral 11-1 indicates a region extraction unit, the reference numeral 11-2 indicates a region cutting unit, the reference numeral 11-3 indicates a fisheye lens image parameter determination unit, and the reference numeral 11-4 indicates a display screen creation unit.

[0121]

The region extraction unit 11-1 is the same as the region extraction units 6-7 and 7-9 shown in Figs. 6 and 7, detects a person's figure or the like on the basis of a feature amount, and outputs a detection flag signal and a region information signal when the region is extracted. The detection flag signal may be used as a signal for warning or notification. The region information signal is output to the region cutting unit 11-2.

[0122]

The region cutting unit 11-2 cuts the region on the basis of the region information signal, and the fisheye lens image parameter determination unit 11-3 determines parameters for displaying a corrected fisheye lens image for the entire cut

region, and sends signals of the parameters to the screen creation unit 11-4. The screen creation unit 11-4 generates a display screen on the basis of the signals of the parameters and outputs a picture signal.

[0123]

Here, for simplification, a description will be made of determination of the parameters of the fisheye lens image in a case of a camera angle which is oriented directly upward. As parameters for correcting a fisheye lens image, an azimuth angle θ, a vertex angle ϕ, and a magnification ratio m of an image frame are required.

[0124]

For example, it is assumed that the person's figure detection area (B) 9-2 of Fig. 9(a) is extracted from a region of the fisheye lens image so as to be displayed. In this case, an angle α regarding the central position of the person's figure detection area (B) 9-2 and an angle (solid angle) β of interposing the person's figure detection area (B) 9-2 from the center O of the fisheye lens image are calculated. In addition, a distance L from the center O of the fisheye lens image to the region uppermost part is calculated.

[0125]

An azimuth angle θ and a vertex angle ϕ of an image frame which displays the person's figure detection area (B) 9-2 can be obtained based on the angle α and the distance L. In other words, the azimuth angle θ is the same as the angle α as $\theta=\alpha$. In addition, the vertex angle ϕ can be obtained using Equation (3-1) to Equation (3-3) from a ratio of the radius R of the fisheye lens image and the distance L. Further, m which is a zoom ratio can be obtained using the solid angle β between the left and right ends of the region and the center O of the fisheye lens image. Based on these parameters, a display region of each person is cut so as to correct distortion of the fisheye lens image, and a picture signal is sent to a monitor television or the like.

[0126]

Fig. 12 is a diagram illustrating a picture obtained by combining images captured by a single fisheye lens camera. A state is schematically shown in which, as described above, person's figures are extracted from a fisheye lens image on the basis of feature amounts thereof, a distortion correction process is performed on the extracted images, and a single monitor television screen is divided into four so as to display the extracted person's figures.

[0127]

[Effects of the Invention]

As described above, according to the present invention, since a picture is obtained by the fisheye lens camera having a wide angle of view of about 180 degrees, an area of a wide range can be monitored with a single camera, and thus it is

possible to reduce the number of cameras to be installed and to correct the image at high speed with high accuracy for display.

[0128]

In addition, coordinate transform for correcting an installation angle of the fisheye lens camera and coordinate transform for correcting distortion of a fisheye lens image are operated in combination with each other, and thus it is possible to perform the image correction operation process at high speed regardless of an installation angle. Further, parameters for correcting distortion of a fisheye lens image are extracted from the captured fisheye lens image itself so as to correct distortion of the fisheye lens image, and thus it is possible to perform stable distortion correction with respect to adjustment on installation or aged deterioration.

[0129]

Since a region is extracted based on a feature amount multiplied by weighting factors which are different depending on an extent of distortion of a central part and a peripheral part of the fisheye lens image, a person's figure can be stably detected in the peripheral part with a large extent of distortion, and a non-extracted region is masked by further giving a different value thereto as the weighting factor so as to correspond to the region in a picture of the fisheye lens image, and thus it is possible to remove unstable factors in a process of extracting a person's figure or the like in advance.

[0130]

In addition, any part is cut from an image of a wide range captured by the fisheye lens camera and is displayed on a monitor television screen, and thus a degree of freedom of creating a picture is large, and it is possible to improve convenience through application to a camera of a remote monitoring system or a video conference system.

[0131]

In addition, it is possible to configure an electronic tracking type remote monitoring system or a video conference system which detects a figure that has movements such as a person intruding in a picture which is obtained through reflection by the fisheye lens camera, and automatically determines a monitor display region (cut region) of the figure so as to track the moving figure with smooth motion.

[Brief Description of Drawings]

[Fig. 1] Fig. 1 is a diagram illustrating a configuration of a fisheye lens camera apparatus according to an embodiment of the present invention.

[Fig. 2] Fig. 2 is an explanatory diagram of a picture taken by the fisheye lens camera according to the embodiment of the present invention.

[Fig. 3] Fig. 3 is an explanatory diagram of an image captured

by the fisheye lens camera oriented in a transverse direction.

[Fig. 4] Fig. 4 is an explanatory diagram of correction of a fisheye lens camera image oriented in the transverse direction.

[Fig. 5] Fig. 5 is an explanatory diagram of extraction of parameters of the fisheye lens camera.

[Fig. 6] Fig. 6 is a diagram illustrating a configuration of a moving figure detection device according to a first embodiment of the present invention.

[Fig. 7] Fig. 7 is a diagram illustrating a configuration of a moving figure detection device according to a second embodiment of the present invention.

[Fig. 8] Fig. 8 is an explanatory diagram of a weighting factor W(x,y) corresponding to a region of a fisheye lens image.

[Fig. 9] Fig. 9 is a diagram illustrating an example of a figure of a person or the like of which a region is extracted.

[Fig. 10] Fig. 10 is a flowchart illustrating a process of determining a person's figure extraction position according to an embodiment of the present invention.

[Fig. 11] Fig. 11 is an explanatory diagram of a configuration of cutting a region and creating a display screen according to an embodiment of the present invention.

[Fig. 12] Fig. 12 is a diagram illustrating a picture obtained by combining images captured by a single fisheye lens camera.

[Fig. 13] Fig. 13 is a diagram illustrating a configuration of a fisheye lens camera apparatus in the related art, and a remote monitoring system and a video conference system using the same.

[Fig. 14] Fig. 14 is an explanatory diagram of correction of distortion of a fisheye lens camera image in the related art.

[Reference Numerals]

1-1 FISHEYE LENS

1-2 CCD IMAGING DEVICE

1-3 PICTURE MEMORY (FRAME MEMORY)

1-4 IMAGE CORRECTION PROCESSING UNIT

1-41 CAMERA INSTALLATION ANGLE CORRECTION UNIT

1-42 PAN/TILT ANGLE ROTATION CORRECTION UNIT

1-43 ZOOM CORRECTION UNIT

1-44 PICTURE INTERPOLATION CREATION UNIT

1-5 CORRECTED PICTURE (NTSC) OUTPUT CIRCUIT

Fig. 1

DIAGRAM ILLUSTRATING CONFIGURATION OF FISHEYE LENS CAMERA APPARATUS ACCORDING TO EMBODIMENT OF THE PRESENT INVENTION

1-1 FISHEYE LENS

1-2 CCD IMAGING DEVICE

1-3 PICTURE MEMORY (FRAME MEMORY)

1-4 IMAGE CORRECTION PROCESSING UNIT

1-41 CAMERA INSTALLATION ANGLE CORRECTION UNIT

1-42 PAN/TILT ANGLE ROTATION CORRECTION UNIT

1-43 ZOOM CORRECTION UNIT

1-44 PICTURE INTERPOLATION CREATION UNIT

1-5 CORRECTED PICTURE (NTSC) OUTPUT CIRCUIT

Fig. 2

EXPLANATORY DIAGRAM OF PICTURE TAKEN BY FISHEYE LENS CAMERA ACCORDING TO EMBODIMENT OF THE PRESENT INVENTION

Fig. 3

EXPLANATORY DIAGRAM OF IMAGE CAPTURED BY FISHEYE LENS CAMERA ORIENTED IN TRANSVERSE DIRECTION

Fig. 4

EXPLANATORY DIAGRAM OF CORRECTION OF FISHEYE LENS CAMERA IMAGE ORIENTED IN TRANSVERSE DIRECTION

ROTATION OF ENTIRE COORDINATE SYSTEM

Fig. 5

EXPLANATORY DIAGRAM OF EXTRACTION OF PARAMETERS OF FISHEYE LENS CAMERA

Fig. 6

DIAGRAM ILLUSTRATING CONFIGURATION OF MOVING FIGURE DETECTION DEVICE ACCORDING TO FIRST EMBODIMENT OF THE PRESENT INVENTION

6-1: FISHEYE LENS CAMERA

PICTURE SIGNAL

6-2: FRAME BUFFER

6-3: FRAME BUFFER

6-4: INTER-FRAME DIFFERENCE CALCULATION UNIT

FRAME DIFFERENCE SIGNAL

6-5: INTER-FRAME DIFFERENCE CALCULATION UNIT

6-6: REGION WEIGHTING TABLE

6-7: REGION EXTRACTION UNIT

DETECTION FLAG

REGION INFORMATION

Fig. 7

DIAGRAM ILLUSTRATING CONFIGURATION OF MOVING FIGURE DETECTION DEVICE ACCORDING TO SECOND EMBODIMENT OF THE PRESENT INVENTION

7-1: FISHEYE LENS CAMERA

PICTURE SIGNAL

7-2: FRAME BUFFER

7-3: FRAME BUFFER

7-4: INTER-FRAME DIFFERENCE CALCULATION UNIT

7-5: IN-FRAME DIFFERENCE CALCULATION UNIT

7-6: MOVING CONTOUR EXTRACTION UNIT

7-7: REGION WEIGHTING TABLE

7-8: REGION EXTRACTION DETERMINING UNIT

7-9: REGION EXTRACTION UNIT

DETECTION FLAG

REGION INFORMATION

Fig. 8

EXPLANATORY DIAGRAM OF WEIGHTING FACTOR W(x,y) CORRESPONDING TO REGION OF FISHEYE LENS IMAGE

FISHEYE LENS IMAGING AREA

DETECTED REGION OF WEIGHTING FACTOR 2

DETECTED REGION OF WEIGHTING FACTOR 1

DETECTED REGION OF WEIGHTING FACTOR 0

Fig. 9

DIAGRAM ILLUSTRATING EXAMPLE OF FIGURE OF PERSON OR THE LIKE OF WHICH REGION IS EXTRACTED

(a)

9-1: PERSON'S FIGURE DETECTION AREA (A)

FISHEYE LENS IMAGING AREA

9-2: PERSON'S FIGURE DETECTION AREA (B)

AREA (B) CENTER

9-3: PERSON'S FIGURE DETECTION AREA (C)

9-4: PERSON'S FIGURE DETECTION AREA (D)

(b)

PARIETAL LENGTH

BODY HEIGHT

BODY BOTTOM PART LENGTH

Fig. 10

FLOWCHART ILLUSTRATING PROCESS OF DETERMINING PERSON'S FIGURE EXTRACTION POSITION ACCORDING TO EMBODIMENT OF THE PRESENT INVENTION

10-1: PROCESS OF CUTTING PERSON'S FIGURE IN FISHEYE LENS IMAGE

10-2: START FRAME PROCESSING

10-3: EXTRACT FEATURE AMOUNT OF PERSON'S FIGURE (INTER-FRAME DIFFERENCE/IN-FRAME DIFFERENCE)

10-4: PROCESS OF WEIGHTING CORRESPONDING TO FISHEYE LENS

10-5: RASTER LOOP PROCESS IN SCREEN

10-6: DETECT FEATURE POINT

10-7: EXTRACT FEATURE POINT FOR TRAPEZOIDAL AREA (FISHEYE LENS COORDINATE TRANSFORM)

10-8: IS THERE FEATURE POINT?

10-9: ERASE FEATURE POINT

10-10: STORE MAXIMUM VALUE AND MINIMUM VALUE OF x AND y REGIONS

10-13: ARE PLURAL LINES CONTINUOUSLY LOCATED?

10-14: STORE PERSON REGION (COUNT NUMBER OF REGIONS)

10-11: FINAL LINE?

10-12: END

Fig. 11

EXPLANATORY DIAGRAM OF CONFIGURATION OF CUTTING REGION AND CREATING DISPLAY SCREEN ACCORDING TO EMBODIMENT OF THE PRESENT INVENTION

11-1: REGION EXTRACTION UNIT

DETECTION FLAG (WARNING, NOTIFICATION)

REGION INFORMATION

11-2: REGION CUTTING UNIT

11-3: FISHEYE LENS IMAGE PARAMETER DETERMINATION UNIT

11-4: DISPLAY SCREEN CREATION UNIT

Fig. 12

DIAGRAM ILLUSTRATING PICTURE OBTAINED BY COMBINING IMAGES CAPTURED BY SINGLE FISHEYE LENS CAMERA

Fig. 13

DIAGRAM ILLUSTRATING CONFIGURATION OF FISHEYE LENS CAMERA APPARATUS IN THE RELATED ART, AND REMOTE MONITORING SYSTEM AND VIDEO CONFERENCE SYSTEM USING THE SAME

Fig. 14

EXPLANATORY DIAGRAM OF CORRECTION OF DISTORTION OF FISHEYE LENS

CAMERA IMAGE IN THE RELATED ART

65

EXHIBIT 6b

J305049

VERIFICATION OF TRANSLATION

I, Karen McGillicuddy

of 1950 Roland Clarke Place
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declare that I am well acquainted with both the Japanese and English languages, and that the attached is an accurate translation, to the best of my knowledge and ability, of Japanese Patent Laid-open Publication No. 2000-242773, published September 8, 2000.

Signature______________________ Date 05/09/14
Karen McGillicuddy

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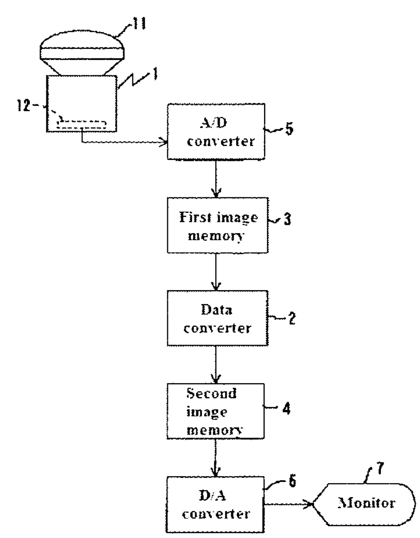
(54) [TITLE OF INVENTION]
IMAGE DATA CONVERSION DEVICE

(57) [ABSTRACT]
[PROBLEM] To convert image capture data of a full surrounding area obtained by a fish-eye lens such that distortion can be corrected and the image capture data can be displayed as a seamless single image.
[MEANS FOR SOLVING THE PROBLEM] With respect to a region for a portion of circular image data obtained by image capture using a fish-eye lens, a point ($g(\Theta)\cdot\cos\psi$, $g(\Theta)\cdot\sin\psi$) in the region on a planar Cartesian coordinate system whose origin point is a center of the circular image (where Θ is a parameter fulfilling $0 < \Theta < \pi/2$; $g(\Theta)$ is a function fulfilling $g(0) = 0$ and monotonically increasing in the range of Θ; and ψ is an angle formed by a line segment and a coordinate axis on the planar Cartesian coordinate system, the line segment linking the origin point of the planar Cartesian coordinate system and the point on the circular image) is converted into a point (R, ψ, $R/\tan\Theta$) on a cylindrical coordinate system where R is a constant.



[SCOPE OF THE CLAIMS]

[CLAIM 1] An image data conversion device wherein, with respect to a region for a portion of circular image data obtained by image capture using a fish-eye lens, a point ($g(\Theta)\cdot\cos\psi$, $g(\Theta)\cdot\sin\psi$) in the region on a planar Cartesian coordinate system whose origin point is a center of the circular image (where Θ is a parameter fulfilling $0 < \Theta < \pi/2$; $g(\Theta)$ is a function fulfilling $g(0) = 0$ and monotonically increasing in the range of Θ; and ψ is an angle formed by a line segment and a coordinate axis on the planar Cartesian coordinate system, the line segment linking the origin point of the planar Cartesian coordinate system and the point on the circular image) is converted into a point (R, ψ, $R/\tan\Theta$) on a cylindrical coordinate system where R is a constant.

[CLAIM 2] The image data conversion device according to claim 1, wherein the fish-eye lens has a property in which $h = g(\theta)$ (h being an image height and θ being a field angle).

[CLAIM 3] The image data conversion device according to claim 2, wherein the function $g(\theta)$ is $g(\theta) = 2f\cdot\tan(\theta/2)$ (f being a focal distance).

[CLAIM 4] The image data conversion device according to claim 2, wherein the function $g(\theta)$ is $g(\theta) = f\cdot\theta$ (f being a focal distance).

[CLAIM 5] A computer-readable storage medium storing a program executing operations of the image data conversion device according to any one of claims 1 to 4 on the computer.

[CLAIM 6] An image capture system comprising:

the fish-eye lens;

a conversion means converting an image obtained by the fish-eye lens into the image data;

the image data conversion device according to any one of claims 1 to 4; and

a display means displaying the image data on the cylindrical coordinate plane by projecting the image data onto a plane, the image data on the cylindrical coordinate plane having been converted by the image data conversion device.

[CLAIM 7] An image data conversion method wherein, with respect to a region for a portion of circular image data obtained by image capture using a fish-eye lens, a point ($g(\Theta)\cdot\cos\psi$, $g(\Theta)\cdot\sin\psi$) in the region on a planar Cartesian coordinate system whose origin point is a center of the circular image (where Θ is a parameter fulfilling $0 < \Theta < \pi/2$; $g(\Theta)$ is a function fulfilling $g(0) = 0$ and monotonically increasing in the range of Θ; and ψ is an angle formed by a line segment and a coordinate axis on the planar Cartesian coordinate system, the line segment linking the origin point of the planar Cartesian coordinate system and the point on the circular image) is converted into a point (R, ψ, R/tanΘ) on a cylindrical coordinate system where R is a constant.

[DETAILED DESCRIPTION OF THE INVENTION]

[0001]

[Technical Field of the Invention] The present invention relates to an image data conversion device and, specifically, relates to a device converting image data having a circular shape and obtained by image capture with a fish-eye lens into planar image data in which distortion is corrected and wide area display is possible.

[0002]

[Prior Art] Conventionally, in an in-store surveillance camera, a traffic regulating camera, and the like, in order to monitor a status of a surrounding area, a camera having a field of view that is limited to a forward view is typically rotated by a drive device such as a motor. However, when such a camera having a limited field of view is rotated, a rotation driver becomes necessary, and thus the device becomes complex. In addition, the camera must be rotated when a specific target is to be captured and so when the target is moving, it may not be possible to capture the target due to limitations of rotation speed. Furthermore, a plurality of directions cannot be imaged simultaneously, constantly resulting in blind spots in a monitored area, and therefore such a camera cannot be said to be sufficient for a monitoring function and the like.

[0003] Japanese Patent Publication No. H06-501585 suggests, as a technology resolving such problems, converting image data having a circular shape into a planar image, the image data being obtained by capturing an image of all orientations forward of a fish-eye lens. A simple description of the technology follows. The circular image data obtained by the fish-eye lens can include an image of all orientations, but the image becomes more distorted further toward an outer periphery. This distortion can be largely removed when the circular image data is translated onto a hemisphere surface, but image data translated to the hemisphere surface cannot be displayed on a planar monitor. In the above technology, the portion of the image data translated to the hemisphere surface is further projected onto a planar surface, thereby enabling the image data to be displayed by conversion into a plane. By using such a method, a device can be simplified by making a rotation drive mechanism unnecessary, and switching a display direction simply becomes a matter of control during data processing, and thus can also be sped up remarkably.

[0004]

[Problem to Be Solved by the Invention] However, even when circular image data obtained in this way by the fish-eye lens is configured to be converted directly into planar image data, an entire hemisphere surface cannot be projected onto a single planar surface with adequate distortion correction, and therefore the image obtained relates only to a specific direction. Accordingly, blind spots occur on a display screen even though the full surrounding area is captured by the fish-eye lens. In addition, as a method to eliminate blind spots, a method performing planar image conversion for a plurality of directions simultaneously and performing simultaneous display can be considered. However, in such a case, seams between images are not continuous and a plurality of different image conversions must be performed.

[0005] In order to resolve these problems, the present invention has as an object to convert image capture data of a full surrounding area obtained by a fish-eye lens such that distortion can be corrected and the image capture data can be displayed as a seamless single image.

[0006]

[Means for Solving the Problems] In order to resolve the above-noted problems, with respect to a region for a portion of circular image data obtained by image capture using a fish-eye lens, an image data conversion device according to the present invention converts a point $(g(\Theta)\cdot\cos\psi, g(\Theta)\cdot\sin\psi)$ in the region on a planar Cartesian coordinate system whose origin point is a center of the circular image (where Θ is a parameter fulfilling $0 < \Theta < \pi/2$; $g(\Theta)$ is a function fulfilling $g(0) = 0$ and monotonically increasing in the range of Θ; and ψ is an angle formed by a line segment and a coordinate axis on the planar Cartesian coordinate system, the line segment linking the origin point of the planar Cartesian coordinate system and the point on the circular image) into a point $(R, \psi, R/\tan\Theta)$ on a cylindrical coordinate system where R is a constant. Moreover, what is referred to as a fish-eye lens in the present invention includes not only what is typically called a fish-eye lens, having a viewing angle of substantially 180°, but also includes what is typically called a wide-angle lens, having a narrower viewing angle.

[0007] Moreover, the conversion is sufficient when a conversion is performed that, as a result, satisfies the above-noted relationship and the process of the conversion is not discussed. In other words, the above-noted formula need not be applied directly, and cases are also included where conversion is performed using a table showing correspondence between pre-conversion pixels and post-conversion pixels. In addition, the planar Cartesian coordinate system and the cylindrical coordinate system are mutually independent and directions of the coordinates can be defined as desired. In addition, the cylindrical coordinate system where R is a constant forms a cylindrical surface. However, herein, cases are also included where the above-described conversion is performed by projecting the image as a plane.

[0008] When configured in this way, first, when ψ is fixed and Θ is increased from a small value to a large value within a range where the point $(g(\Theta)\bullet\cos\psi, g(\Theta)\bullet\sin\psi)$ is in the region for the portion of the circular image data, a line segment oriented in a radial direction from the center of the circular image data is converted into the cylindrical coordinate system where R is a constant (i.e., as a line segment oriented from up to down on a cylindrical surface of radius R). This conversion is further performed for ψ in a maximum range of 360° such that the above-noted point is in the region for the portion of the circular image data. Therefore, the portion of the circular image data is smoothly converted into a cylindrical surface in a form where distortion is corrected, the portion of the circular image data including image data for a full surrounding area centered on the fish-eye lens and captured by the fish-eye lens. The image converted into a cylindrical surface can be readily made into a planar image by projecting the cylindrical surface. Therefore, distortion of the image capture data of the full surrounding area obtained by the fish-eye lens can be corrected and the image capture data can be displayed as a seamless single image.

[0009] In addition, when the fish-eye lens has a property in which $h = g(\theta)$ (h being an image height and θ being a field angle), an amount that $g(\Theta)$ increases accompanying an increase of Θ is the same as the amount that the image height h increases. Accordingly, in other words, changing Θ is the same as changing the field angle θ. In such a case, the circular image is converted into an ideal, undistorted hemisphere surface and, moreover, an image can be obtained in which a converted hemisphere surface image is projected with respect to the cylindrical surface using light projected from a center point of the hemisphere surface and oriented in a radial direction, the cylindrical surface being positioned such that a center axis matches the center axis of the hemisphere surface. Accordingly, an image capture region spanning the entire area on the sides of the fish-eye lens (i.e., an image on an outer peripheral side of the circular image) is converted into an image with almost no distortion.

[0010] In addition, when the function $g(\theta)$ indicating a property of the fish-eye lens is $g(\theta) = 2f\bullet\tan(\theta/2)$ (where f is a focal distance), an amount of data for the image on the outer peripheral side of the circular image data is greater. Therefore, reproducibility during conversion into a cylindrical surface of an image capture area spanning the entire area on the sides of the fish-eye lens can be improved.

[0011] Moreover, when the function $g(\theta)$ indicating a property of the fish-eye lens is $g(\theta) = f \cdot \theta$ (where f is a focal distance), the property is that of the most typically used fish-eye lens. Therefore, a low-cost, mass-produced fish-eye lens can be used and cost of the device can be reduced.

[0012] The image data conversion device can also be achieved by installing a program executing the operations of the image data conversion device onto a computer, and the program can be stored on a storage medium readable by the computer.

[0013] Moreover, in order to resolve the above problems, an image capture system according to the present invention includes the fish-eye lens; a conversion means converting an image obtained by the fish-eye lens into the image data; the image data conversion device according to any one of claims 1 to 4; and a display means displaying the image data on the cylindrical coordinate plane as a plane by projecting the cylindrical coordinate plane, the image data on the cylindrical coordinate plane having been converted by the image data conversion device.

[0014] According to such a configuration, the image capture system, as described above, displays the image on the cylindrical surface by projecting the image as a plane, the image data conversion device having corrected distortion of the image and converted the image to remove seams. Therefore, a situation of a surrounding area captured by the fish-eye lens can be entirely shown on one screen. Moreover, the projected plane also includes cases where the projected plane is processed as appropriate, e.g., a case where the projected plane is cut at a predetermined position and each cut section is arrayed as appropriate for display.

[0015] Also, in order to resolve the above-noted problems, with respect to a region for a portion of circular image data obtained by image capture using a fish-eye lens, an image data conversion method according to the present invention converts a point $(g(\Theta)\cdot\cos\psi, g(\Theta)\cdot\sin\psi)$ in the region on a planar Cartesian coordinate system whose origin point is a center of the circular image (where Θ is a parameter fulfilling $0 < \Theta < \pi/2$; $g(\Theta)$ is a function fulfilling $g(0) = 0$ and monotonically increasing in the range of Θ; and ψ is an angle formed by a line segment and a coordinate axis on the planar Cartesian coordinate system, the line segment linking the origin point of the planar Cartesian coordinate system and the point on the circular image) into a point $(R, \psi, R/\tan\Theta)$ on a cylindrical coordinate system where R is a constant. The image data conversion method also smoothly converts the portion of the circular image data into a cylindrical surface in a form where distortion is corrected, the portion of the circular image data including image data for a full surrounding area centered on the fish-eye lens and captured by the fish-eye lens. Therefore, distortion can be corrected and the image capture data for the full surrounding area obtained by the fish-eye lens can be displayed seamlessly.

[0016]

[Mode for Carrying out the Invention] Hereafter, a description of an embodiment of the present invention is given with reference to the drawings. Fig. 1 shows a block diagram illustrating a configuration of an image capture system according to the embodiment of the present invention. The image capture system is configured with a camera portion 1, a data converter 2, a first image memory 3, a second image memory 4, an A/D converter 5, a D/A converter 6, and a monitor 7.

[0017] The camera portion 1 uses a fish-eye lens 11 as a lens and is capable of image capture at a field angle of 90° or more at least with respect to an optical axis of the lens. Herein, a fish-eye lens is used having a property wherein

$$h = 2f \cdot \tan(\theta/2) \qquad ①$$

When a lens having such a property is used, an amount that an image height h increases relative to an increase in the field angle θ becomes greater in comparison to a typical lens where $h = f \cdot \theta$. Therefore, an amount of information can be greater for a range having a large field angle θ (i.e., a periphery of a circular image obtained by the fish-eye lens). The circular image obtained by the fish-eye lens 11 having this property is converted into an electronic signal by a CCD 12 for each RGB value of each pixel and is output to the A/D converter 5. Herein, the CCD is, for example, a CCD using 1280x1024 pixels.

[0018] The A/D converter 5 converts an analog signal transmitted from the CCD 12 into a digital signal and outputs the signal to the first image memory 3. The first image memory 3 is configured with a RAM and stores RGB values for each pixel based on the digital signal representing the transmitted circular image. The data converter 2 is equivalent to an image data conversion device according to the present invention and is configured with an arithmetic circuit performing calculations described below. The data converter 2 converts the circular image data stored in the first image memory 3 into cylindrical image data using a conversion described in detail hereafter, then outputs the image data to the second image memory 4.

[0019] The second image memory 4 is again configured with a RAM, and the RGB values for each pixel of the output image data are stored as a plane, described hereafter, onto which the cylindrical surface is projected. In addition, the image onto which the cylindrical surface is projected is long in a width direction. Therefore, in order to obtain the display data described below, when storing image data, the second image memory 4 stores the projected image such that the image is divided into halves and placed at a predetermined vertical interval. The D/A converter 6 reads the image data having digital values stored in the second image memory 4 and converts the image data into an analog signal, then transmits the analog signal as an image signal in order of scan lines of the monitor 7. The monitor 7 displays the image stored in the second image memory 4 based on the image signal transmitted by the D/A converter 6.

[0020] Moreover, portions of the present image capture system except the camera portion 1 can be achieved by installing a program to accomplish the above-noted functions and the below-noted operations on a typical computer. The program can be stored on a storage medium such as a floppy disk that is readable by the computer. In addition, the program can be installed on the computer through a communication means such as the Internet.

[0021] At this point, a conversion method of the data converter 2 is described in detail. The data converter 2 converts the image data on the circular surface onto a cylindrical surface. A correspondence relationship between points on the circular surface and points on the cylindrical surface is described with reference to Figs. 2 and 3. Fig. 2 is a view showing a relationship between a desired point P0 on a hemisphere surface O, which supposes an ideal full circumferential surface captured by the fish-eye lens 11, and a point P2 on the cylindrical surface C, which is the converted surface. In Fig. 2, in an xyz coordinate system, the hemisphere surface O has a base circle (a circle configuring an edge of the hemisphere surface) positioned on an xy plane and centered on the origin point. A z axis coincides with the optical axis of the fish-eye lens 11. Furthermore, the cylindrical surface C is a cylinder of radius R axially centered on the z axis. In other words, the cylindrical surface C can be represented as a curved surface in an $r\psi z$ cylindrical coordinate system where R is constant. In addition, herein, points on the cylindrical surface C are represented by (R, ψ, z) as points on the $r\psi z$ cylindrical coordinate system. However, ψ is an angle formed by a line segment and an x axis, the line segment being created by the origin point and a point of intersection between a vertical line down to the xy plane and the xy plane. Also, P2 is a point where a straight line extension of a line segment linking the origin point with the desired point P0 on the hemisphere surface O intersects with the cylindrical surface C. Moreover, an angle formed by the z axis and the line segment linking the origin point with the point P0 has a field angle θ with respect to the point P0.

[0022] The desired point P0 on the hemisphere surface O, which supposes the above-noted ideally captured full circumferential surface, indicates a position of a point P1 on a captured image surface F captured by the fish-eye lens 11 in Fig. 3. A circular region on the captured image surface F in Fig. 3 is a region on the CCD 12 bombarded by light through the fish-eye lens 11, and forms a circular surface S displaying converted image data. In Fig. 3, an origin point on an XY coordinate system is occupied by the center of the circular surface S. Moreover, directions of the X axis and the Y axis are configured to be opposite from the x axis and the y axis of the xyz coordinate system of Fig. 2. This is in order to handle P0 also being shown in a position inverted top to bottom and left to right because the image captured by the camera portion 1 is inverted top to bottom and left to right. However, the cylindrical surface is arbitrary, and so in an actual conversion there is also liberty in how coordinates are handled. In addition, the position of P1 is a position at an image height h distance from the origin point where an angle formed by the X axis and a line segment linking the origin point with P1 is ψ. h is expressed by the above noted formula 1 and is defined by the field angle θ.

[0023] The data converter 2 converts P1 shown in Fig. 3 into P2 shown in Fig. 2. Hereafter, a description is given of a concrete calculation. First, a case is considered where parameters are set to θ and ψ. In this case, the coordinates of P1 on the XY plane are $(h \cdot \cos\psi, h \cdot \sin\psi)$ and, when h is substituted out using the above-noted formula 1, are represented by $(2f \cdot \tan(\theta/2) \cdot \cos\psi, 2f \cdot \tan(\theta/2) \cdot \sin\psi)$. Meanwhile, for the coordinates of P2, R is a constant, and z has a relationship according to Fig. 2 in which $z = R / \tan\theta$, and thus the coordinates of P2 are represented by $(R, \psi, R / \tan\theta)$. Accordingly, the parameters θ and ψ can be moved to specify P1 on the circular image on the XY plane, and a point on the $r\psi z$ cylindrical coordinate system (that is, the point on the cylindrical surface C) can also be specified with respect thereto. Therefore, the image data can be converted according to a formula that indicates P1 and P2. However, in a case where $\theta = 0$, the z coordinate of P2 becomes infinitely large, and therefore in reality a value of θ is used which is a certain value or more. In the present embodiment, a range of $\pi/4 \leq \theta < \pi/2$ is used for θ.

[0024] In an actual conversion, calculation is facilitated by using data directly representing a position of each pixel in the captured CCD 12 or a post-conversion position of each pixel on the converted cylindrical surface C as the parameters. Use of x and ψ as parameters directly representing the post-conversion position of each pixel on the cylindrical surface C is considered. In such a case, when the point P2 on the cylindrical surface C is represented with the parameters z and ψ, the coordinates are (R, ψ, z). The converted cylindrical surface C is projected and displayed on the monitor 7, and each pixel is aligned at equal intervals of a pixel pitch d in a longitudinal direction and a lateral direction. Fig. 4 illustrates a view representing a relationship between the projected cylindrical surface C and the circular surface S. The longitudinal direction of the cylindrical surface C coincides with the parameter z. Therefore, when a change is made to the parameter z in units of the pixel pitch d, the changes coincide with the longitudinal direction pixel positions of the cylindrical surface C. An amount of change accompanying an amount of change in ψ in the lateral direction of the projected cylindrical surface can be represented by $R \cdot \psi$. Therefore, when the amount of change of the parameter ψ corresponding to the pixel pitch d of the cylindrical surface C is $\Delta\psi$, the amount of change can be represented as $\Delta\psi = d / R$. Accordingly, when a change is made to the parameter ψ in units of d / R, the change coincides with the lateral direction pixel positions of the cylindrical surface C. Moreover, a range where the circular surface S has hatching in the drawings is a range of the circular surface S corresponding to $\pi/4 \leq \theta < \pi/2$ and indicates the range converted into the cylindrical surface C.

[0025] Meanwhile, representing the point P1 on the circular image using the parameters z and ψ is considered. First, when transforming the above-noted formula ① using a double-angle formula for a trigonometric function,

$$h = 2f \cdot \tan(\theta/2) = 2f \cdot \{\sin\theta / (1 + \cos\theta)\} \qquad ①'$$

results. Fig. 2 shows that $\sin\theta = R / (R^2 + z^2)^{1/2}$, $\cos\theta = z / (R^2 + z^2)^{1/2}$, and therefore when these are substituted into the formula 1 and simplified, $h = 2f \cdot R / \{(R^2 + z^2)^{1/2} + z)\}$ results. Therefore, as a result, P1 is $(2f \cdot R \cdot \cos\psi / \{(R^2 + z^2)^{1/2} + z)\}, 2f \cdot R \cdot \sin\psi / \{(R^2 + z^2)^{1/2} + z)\})$. Accordingly, as noted above, changes are made to z in units of d, and changes are made to ψ in units of d / R, then the pixel positions on the circular surface S, in which each pixel position on the cylindrical surface C is converted by the formula, can be found. In such a case, the pixel positions obtained by calculation and the pixel positions actually captured by the CCD 12 fail to coincide completely, and therefore the nearest pixel is extracted. Specifically, obtained X coordinate values and Y coordinate values are, for example, divided by a pixel pitch ds of the CCD 12 and those values at or below a decimal point, for example, are discarded. Thereby, the obtained integer value can be extracted as a number for the pixel. Moreover, in such a case, where the origin point of the XY coordinates is (0, 0), each pixel of the CCD 12 is respectively defined with a positive or negative in accordance with each quadrant of the XY coordinates.

[0026] Using the above method, the data converter 2 calculates the circular surface S pixel position corresponding to each pixel on the post-conversion cylindrical surface C, then converts the pixel data of the pixel positions as respective pixel data on the cylindrical surface C. As a result, as shown in Fig. 4, the pixel data on the circular surface S is converted as respective pixel data on the cylindrical surface C. Moreover, an unambiguous determination is made as to which pixel position of the cylindrical surface each pixel of the circular image is transformed into. Therefore, the data converter 2 can be provided with a table showing a correspondence between the pixels of the circular image and the pixel positions on the cylindrical surface without performing calculations, and the data conversion can be performed based on this.

[0027] Next, a description is given of operations of the image capture system having the above-noted configuration. Moreover, the camera portion 1 is mounted inside a room, oriented downward from a center of a ceiling. Further, a range of z of the converted cylindrical surface is $0 < z \leq R$. In other words, the range of θ is defined as $\pi/2 > \theta \geq \pi/4$. Fig. 5 is a flowchart illustrating operations of the image capture system. First, a panoramic view of the room is captured by the camera portion 1 as a circular image through the fish-eye lens 11. The circular image is converted to an electrical signal by the CCD 12, then is further converted to digital values for each pixel by the A/D converter 5. Then, this data is stored in the first image memory 3 (s101). Furthermore, 0 is input for each of the parameters ψ and z as an initial value (s102).

[0028] Next, using the data converter 2, a parameter ψi is increased in units of d / R until i = 1~n (n = $2\pi R$ / d), and a parameter zj is increased in units of d until j = 1~m (m = R / d). Then, for each of the values,

$$Xi = [2f \bullet R \bullet \cos\psi i / \{(R^2 + zj^2)^{1/2} + zj\} \bullet ds]$$

$$Yj = [2f \bullet R \bullet \sin\psi i / \{(R^2 + zj^2)^{1/2} + zj\} \bullet ds]$$

is calculated and, based on the results, (Xi, Yj) order pixel data stored in the first image memory 3 is extracted and stored in the second image memory 4 as pixel data of the (i, j) order pixel in the cylindrical surface (s103 - s108). Moreover, in the second image memory 4, in order to display the image as shown in Fig. 6 on the monitor 7, the pixels (i, j) on the cylindrical surface are divided into two parts, one part in which i = 1~n/2 and j = 1~m and one part in which i = (n/2) + 1~n and j = 1~m, and are stored so as to obtain an image in which the latter part is positioned so as to be a predetermined interval below the former part. Moreover, text data indicating the angle, shown in Fig. 6, is pre-stored in the second image memory 4.

[0029] The image data stored in the second image memory 4 is output to the monitor 7 as an image signal by the D/A converter 6 (s109) and is displayed by the monitor 7 (s110). The image data is divided into two parts and formed so as to be positioned vertically, as noted above, and thus a screen shown in Fig. 6 is displayed. In this way, in the image capture system according to the present embodiment, footage of an environment in 360° captured by the fish-eye lens can be fully and seamlessly displayed, and a status of the environment of the lens can be fully monitored without blind spots.

[0030] In the above-described embodiment, a fish-eye lens was used having a property represented by the above formula 1. However, the fish-eye lens may also have a property not represented in formula 1. Specifically, when the property of the fish-eye lens is generalized to $h = g(\theta)$, P2 remains as described above and P1 can be represented with $(g(\theta)\cdot\cos\psi, g(\theta)\cdot\sin\psi)$. Therefore, in a case where the parameters are θ and ψ, it is sufficient to use the same. Moreover, in a case where the parameters are z and ψ, as described above, it is possible to use the expression $\theta = \mathrm{Tan}^{-1} (R / z)$, per Fig. 2. Therefore, P2 remains as described above and P1 can be represented with $(G(\mathrm{Tan}^{-1} (R / z)))\cdot\cos\psi, G(\mathrm{Tan}^{-1} (R / z))\cdot\sin\psi)$. Therefore, similar to the above, corresponding P2 and P1 pixel positions can be found while changing the values of z and ψ.

[0031] For example, in a case where a commonly used fish-eye lens having a property in which $h = f\cdot\theta$ is used as the fish-eye lens, it is sufficient to make similar conversions as above in which, when the parameters are θ and ψ, P1 is $(f\cdot\theta\cdot\cos\psi, f\cdot \theta\cdot\sin\psi)$, and when the parameters are z and ψ, P1 is $(f\cdot G(\mathrm{Tan}^{-1} (R / z)))\cdot\cos\psi, f\cdot G(\mathrm{Tan}^{-1} (R / z))\cdot\sin\psi)$. Moreover, $\mathrm{Tan}^{-1} (R / z)$ can be found using a known regression calculation.

[0032] Moreover, a fish-eye lens having a property in which $h = f\cdot\theta$ can be swapped for the fish-eye lens 11 in the above-described embodiment, while other components remain the same. This is because, although a rate of expansion and contraction of an image in a radial direction differs between the circular image obtained by the fish-eye lens having the property according to the above-noted formula 1 and the fish-eye lens circular image having the property $h = f\cdot\theta$, an adjacency relationship between the images does not change, and therefore the obtained image can fulfill a role as a surveillance image with only minor differences of expansion and contraction appearing in the z direction.

[0033] Even more generally, using a monotonically increasing function $g(\Theta)$ in a range where $0 < \Theta < \pi/2$, when P1 is $(g(\Theta)\cdot\cos\psi, g(\Theta)\cdot\sin\psi)$, images are displayed for various kinds of fish-eye lenses, the images differing only in the rate of expansion and contraction in the z direction. In addition, by using, as the function $g(\Theta)$, a function having a least amount of z-direction distortion in response to the property of the fish-eye lens being used, a surveillance image that is easier to see can be obtained.

[0034] Further, the image capture system in the above-described embodiment is configured to convert and display an image for all of a 360° environment captured by the fish-eye lens

11. However, in a case where the camera portion 1 is installed where a wall meets the ceiling, for example, converting and displaying a 180° portion excluding the wall direction is sufficient, and in a case where the camera portion 1 is installed in a corner, converting and displaying a 90° portion excluding the wall directions that enclose the corner is sufficient. In this way, depending on a situation, a range for conversion can be determined as desired.

[0035] In addition, in the image capture system of the above-noted embodiment, the range of $0 \leq \theta < \pi/4$ is not displayed. However, because this range has a small amount of distortion in the original circular image, the range may also be configured to be matched with the image of the cylindrical surface C and displayed on the monitor 7 as the circular image, without performing conversion.

[BRIEF DESCRIPTION OF THE DRAWINGS]

[FIG. 1] is a block diagram illustrating a configuration of an image capture system according to an embodiment.

[FIG. 2] is a view showing a relationship between a point on a hemisphere surface, which supposes an ideal full circumferential surface captured by a fish-eye lens, and a point on a converted cylindrical surface.

[FIG. 3] is a view showing a point on a captured image surface corresponding to a point on a hemisphere surface, which supposes an ideal full circumferential surface captured by the fish-eye lens.

[FIG. 4] is a view illustrating a projected cylindrical surface.

[FIG. 5] is a flowchart illustrating operations of the image capture system.

[FIG. 6] is a view illustrating a display screen using a monitor.

[DESCRIPTION OF REFERENCE NUMERALS]

1	Camera portion
2	Data converter
3	First image memory
4	Second image memory
5	A/D converter
6	D/A converter
7	Monitor
11	Fish-eye lens
12	CCD

Fig. 1

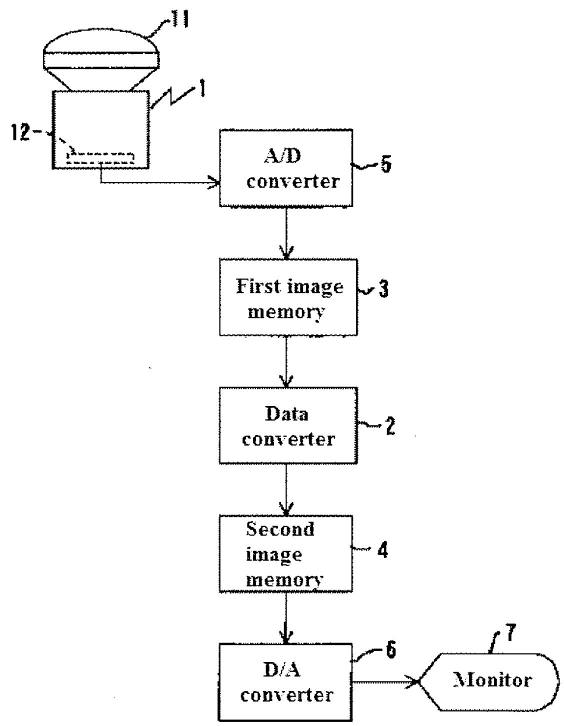
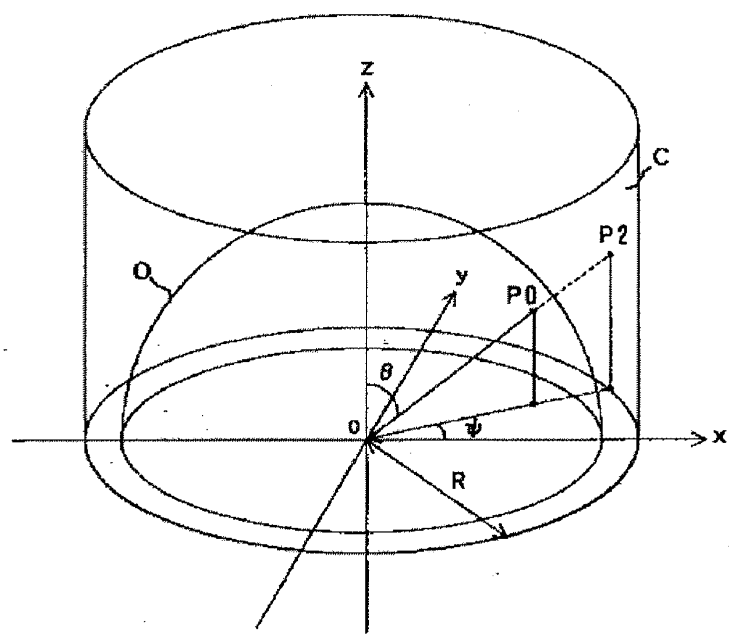


Fig. 2



{J305049 02051422.DOC}14

Fig. 3

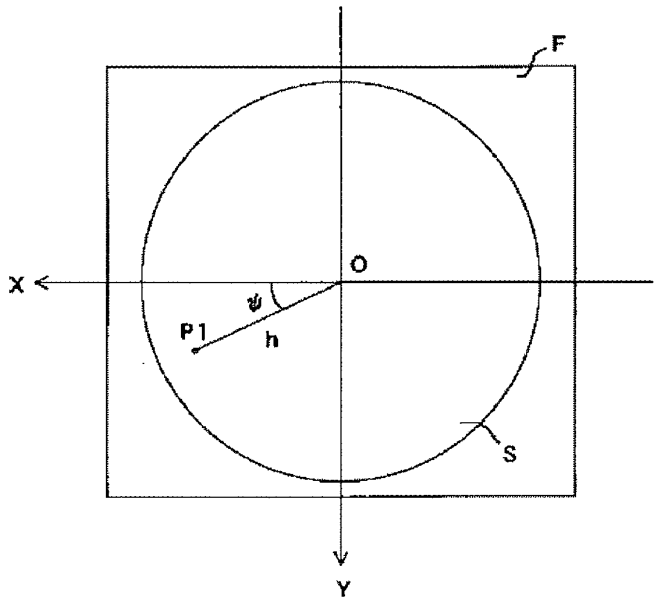


Fig. 4

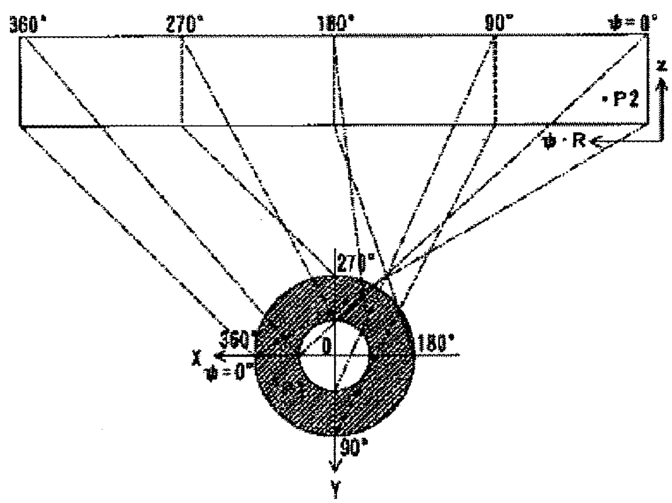


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Fig. 5

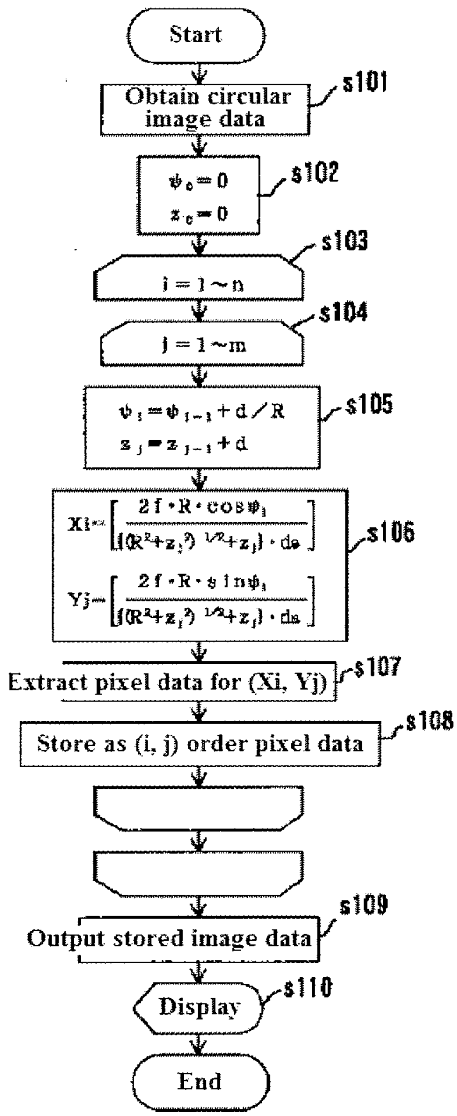
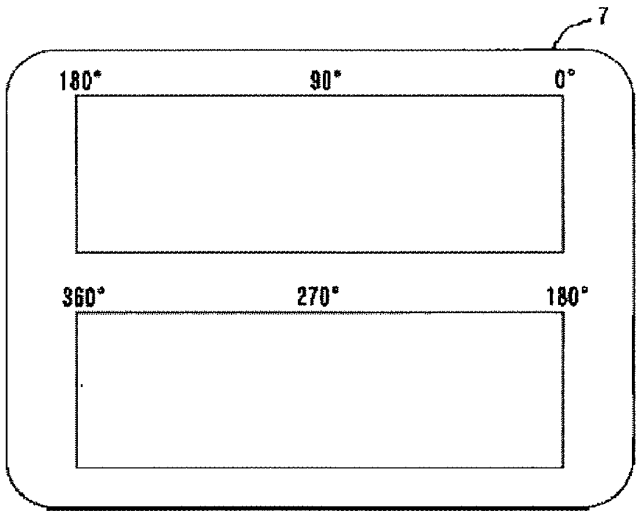

Start
Obtain circular image data
s101
$\psi_0 = 0$
$z_0 = 0$
s102
$i = 1 \sim n$
s103
$j = 1 \sim m$
s104
$\psi_i = \psi_{i-1} + d / R$
$z_j = z_{j-1} + d$
s105
$Xi = \left[\frac{2f \cdot R \cdot \cos\psi_i}{\{(R^2 + z_j^2)^{1/2} + z_j\} \cdot ds} \right]$
$Yj = \left[\frac{2f \cdot R \cdot \sin\psi_i}{\{(R^2 + z_j^2)^{1/2} + z_j\} \cdot ds} \right]$
s106
Extract pixel data for (Xi, Yj)
s107
Store as (i, j) order pixel data
s108
Output stored image data
s109
Display
s110
End

Fig. 6



Continued from front page

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CH01 CH11 DA16
5C022 AA05 AB68

EXHIBIT 1

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(12) United States Patent
Artonne et al.

(10) **Patent No.: US 6,844,990 B2**
(45) **Date of Patent: Jan. 18, 2005**

(54) **METHOD FOR CAPTURING AND DISPLAYING A VARIABLE RESOLUTION DIGITAL PANORAMIC IMAGE**

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(73) Assignee: **6115187 Canada Inc.**, Saint Laurent (CA)

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

(21) Appl. No.: **10/706,513**

(22) Filed: **Nov. 12, 2003**

(65) **Prior Publication Data**

US 2004/0136092 A1 Jul. 15, 2004

Related U.S. Application Data

(63) Continuation of application No. PCT/FR02/01588, filed on May 10, 2002.

(30) **Foreign Application Priority Data**

May 11, 2001 (FR) 01 06261

(51) **Int. Cl.**^{7} **G02B 13/06**; G02B 13/18
(52) **U.S. Cl.** **359/725**; 359/718
(58) **Field of Search** 359/718, 719, 359/725, 728

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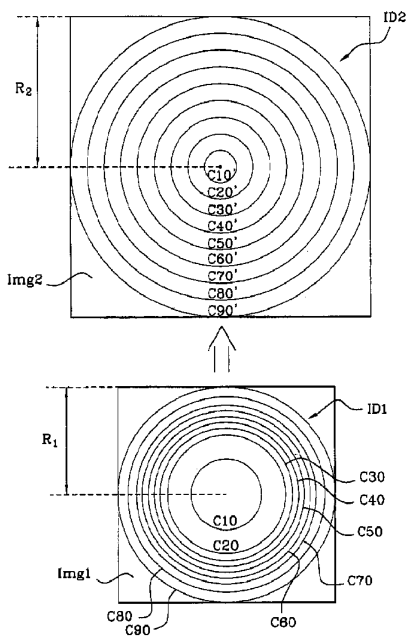
(57) **ABSTRACT**

A method for capturing a digital panoramic image includes projecting a panorama onto an image sensor by means of a panoramic objective lens. The panoramic objective lens has a distribution function of the image points that is not linear relative to the field angle of the object points of the panorama, such that at least one zone of the image obtained is expanded while at least another zone of the image is compressed. When a panoramic image obtained is then displayed, correcting the non-linearity of the initial image is required and is performed by means of a reciprocal function of the non-linear distribution function of the objective lens or by means of the non-linear distribution function.

26 Claims, 11 Drawing Sheets



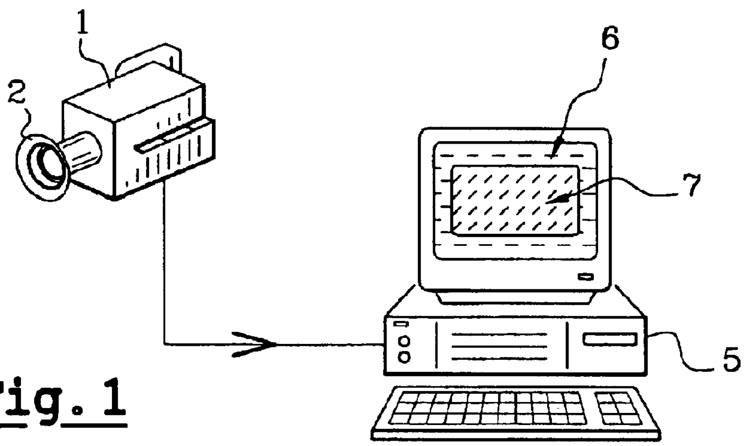


Fig. 1

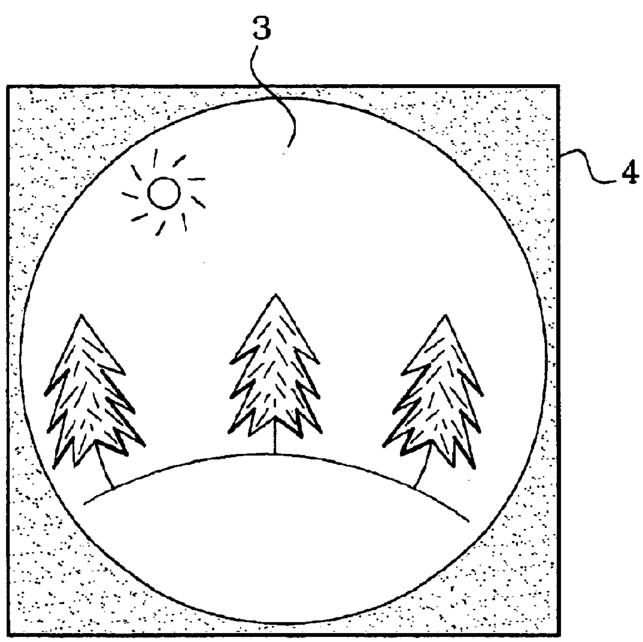


Fig. 2

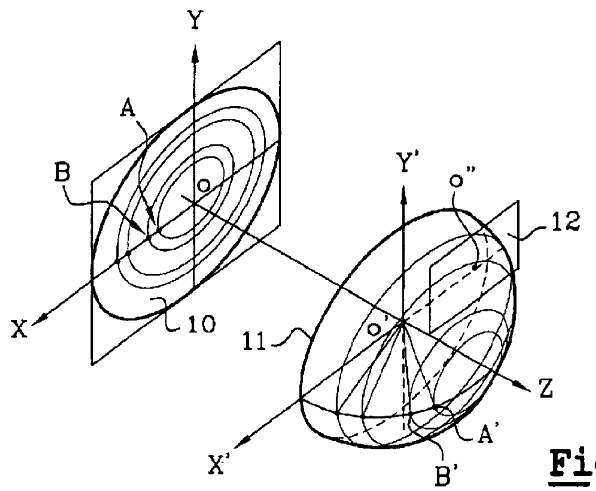


Fig. 3

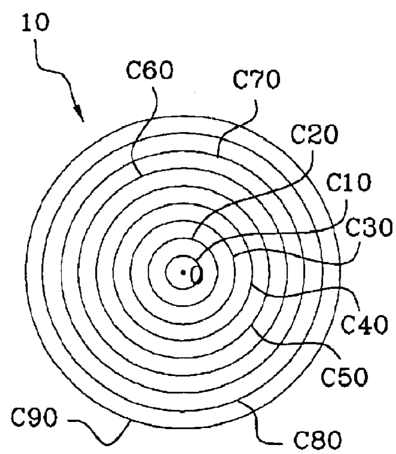


Fig. 4A

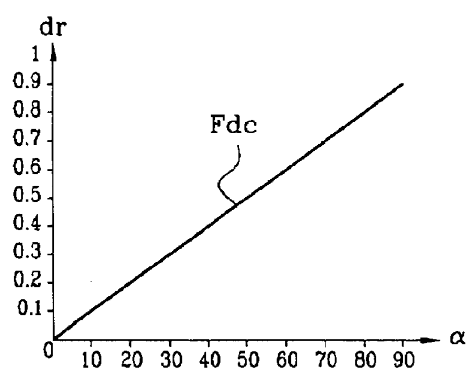


Fig. 4B

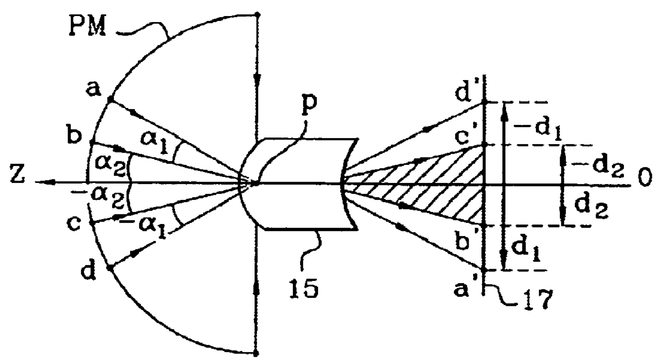


Fig. 5

PRIOR ART

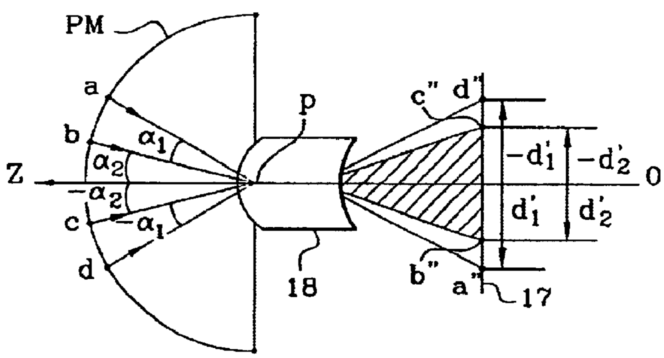


Fig. 6

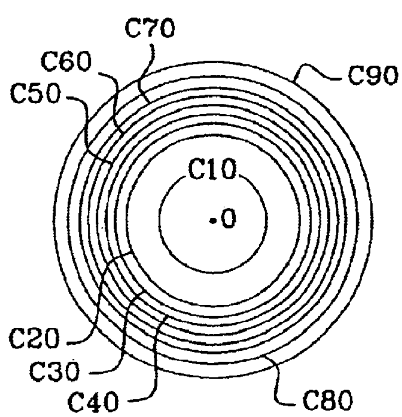


Fig. 7A

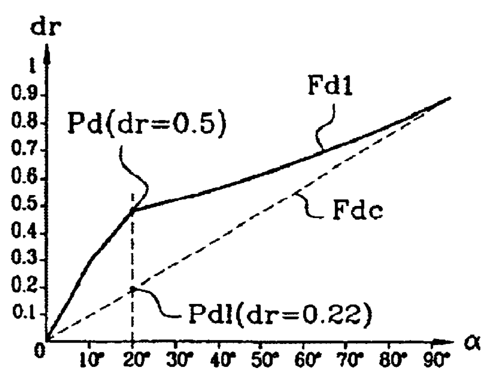


Fig. 7B

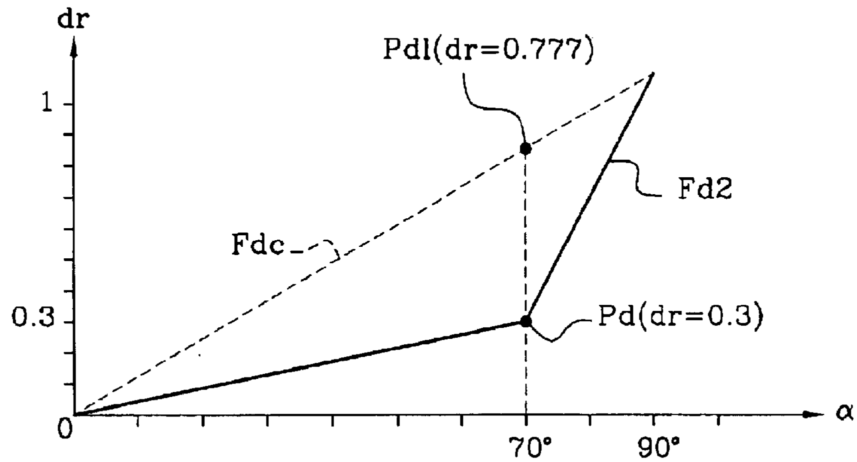
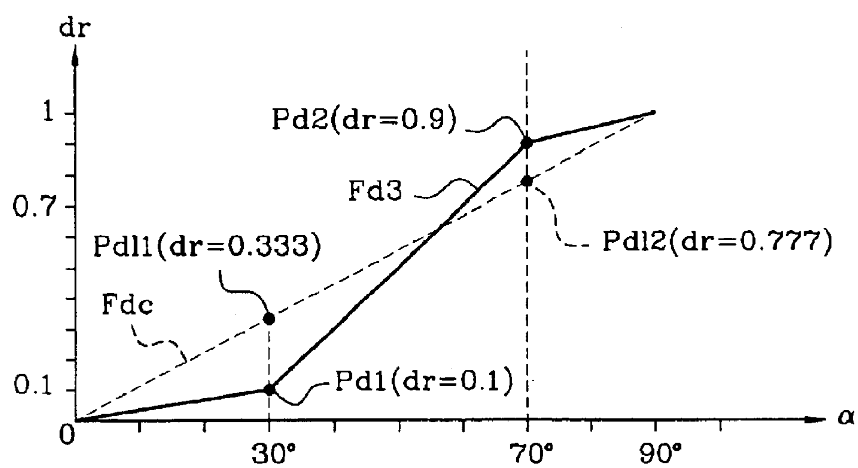

dr
1
0.3
0
Pdl(dr=0.777)
Fd2
Fdc
Pd(dr=0.3)
70°
90°
α

Fig. 8


dr
1
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0.1
0
Pd2(dr=0.9)
Fd3
Pdl2(dr=0.777)
Pdl1(dr=0.333)
Fdc
Pd1(dr=0.1)
30°
70°
90°
α

Fig. 9

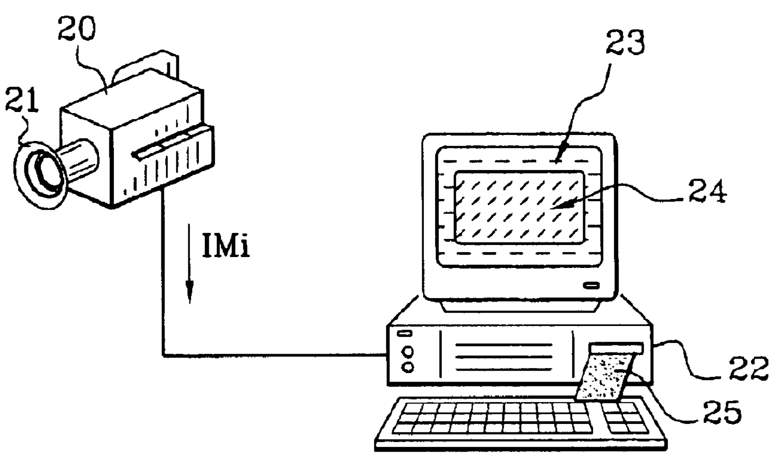


Fig. 10

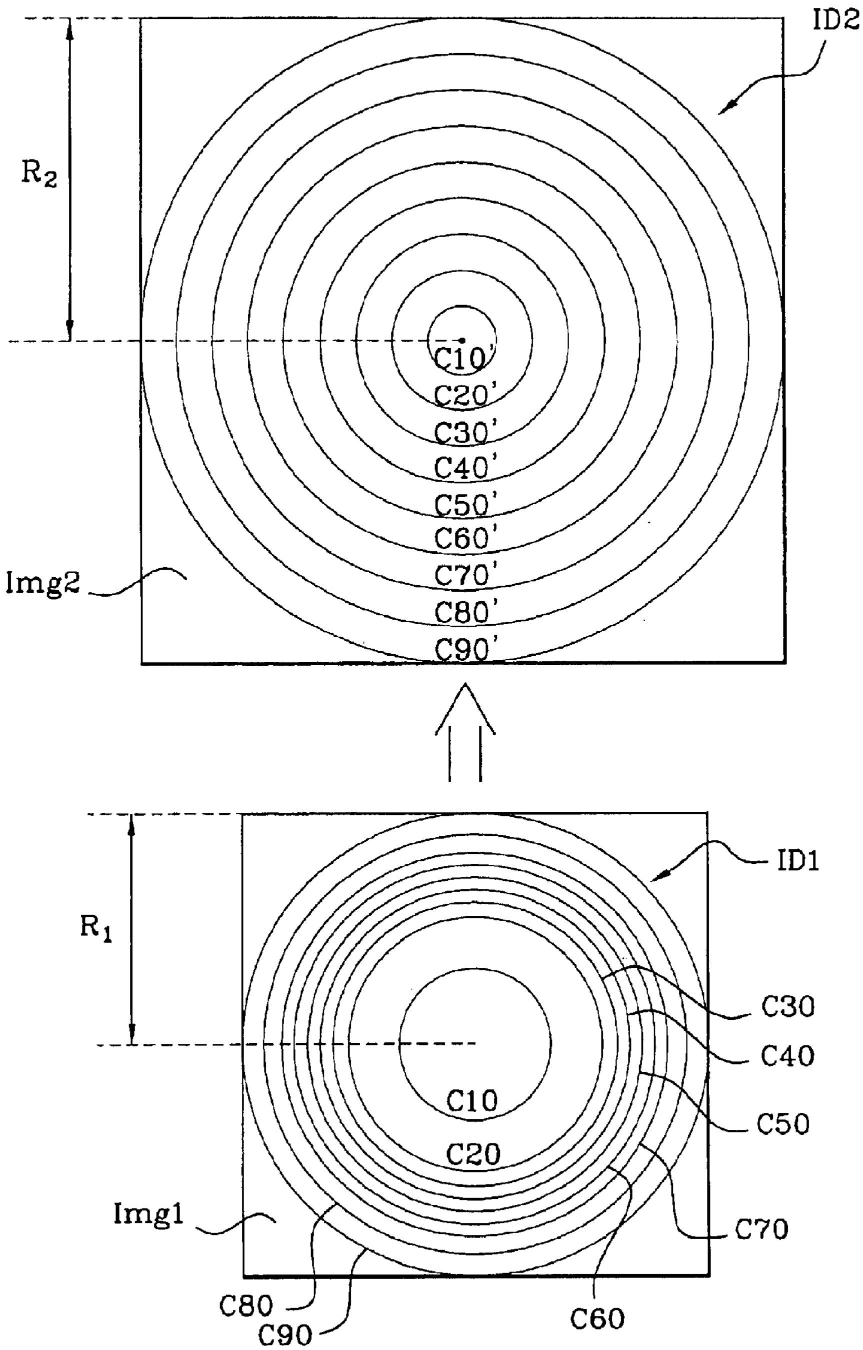

ID2
R2
C10'
C20'
C30'
C40'
C50'
C60'
C70'
C80'
C90'
Img2
ID1
R1
C30
C40
C50
C10
C20
C70
Img1
C80
C90
C60

Fig. 11

Fig. 12

S1 – Acquisition - Taking a panoramic image by means of a still digital camera or a digital video camera equipped with a panoramic lens having a non-linear distribution function Fd
S2 – Transfer of the image file into a computer - Transfer of the image file (image disk) into a microcomputer - Storage in the auxiliary storage (optional)
S3 -Linearisation of the image disk - Transfer of the image points of the initial image disk into a second virtual image disk comprising more image points than the initial image disk, by means of the function Fd^{-1} Obtaining a linear image disk
S4 – Digitisation - Transfer of the image points of the second image disk into a system of axes OXYZ in spherical coordinates Obtaining a panoramic image in a hemisphere
S5 – Interactive display - Determination of the image points of an image sector to be displayed - Display of the image sector on a display window - Detection of the user's actions on a screen pointer or any other control means, - Detection of the user's actions on keys for image enlargement, - Modification of the sector displayed (sliding the image sector displayed on the surface of the hemisphere and/or shrinking/expanding the image sector displayed)

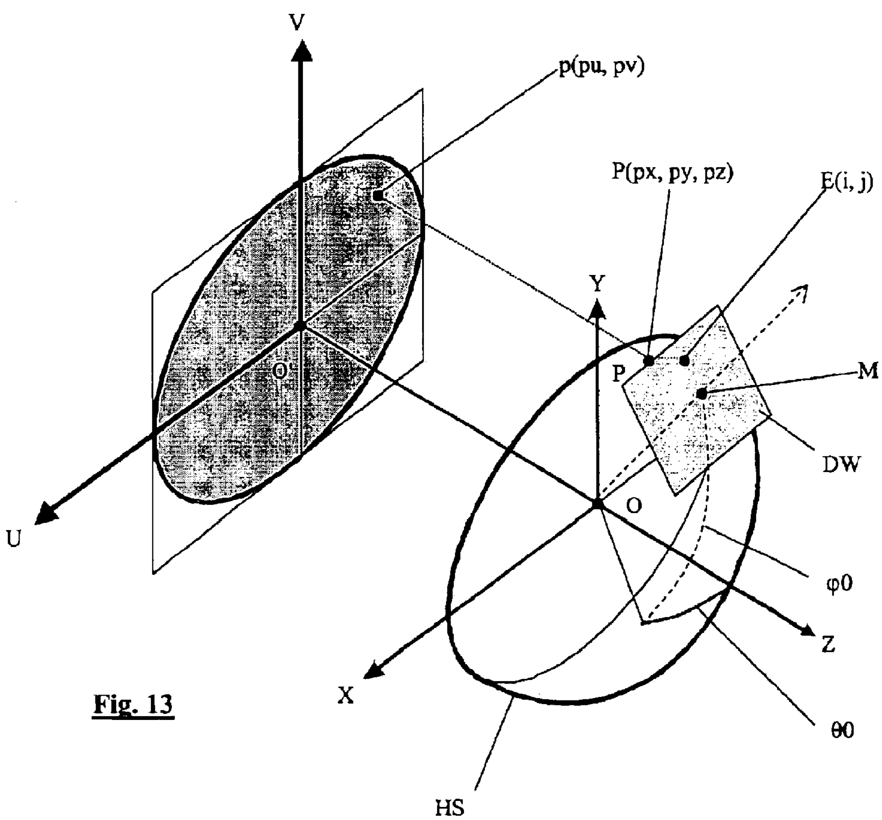


Fig. 13

Fig. 14

S1 – Acquisition
- Taking a panoramic image by means of a still digital camera or a digital video camera equipped with a panoramic lens having a non-linear distribution function Fd
S2 – Transfer of the image file into a computer
- Transfer of the image file (image disk) into a microcomputer - Storage in the auxiliary storage (optional)
S3' – Interactive display with implicit correction of the non-linearity of the initial image
A - Determination of the colour of the points E(i, j) of an image sector to be displayed using the points p(pu, pv) of the image disk: 1- determination of the coordinates Ex, Ey, Ez in the coordinate system OXYZ of each point E(i, j) of the sector to be displayed, 2- determination of the coordinates Px, Py, Pz of points P of the hemisphere corresponding to the points E(i, j), 3- calculation of the coordinates, in the coordinate system O'UV of the image disk, of the points p(pu, pv) corresponding to the points P of the hemisphere, by means of the function Fd, B - Presentation of the image sector in a display window, C - Detection of the user's actions on a screen pointer or any other control means, D - Detection of the user's actions on enlargement keys, E - Modification of the image sector displayed (moving and/or shrinking/expanding the image sector)

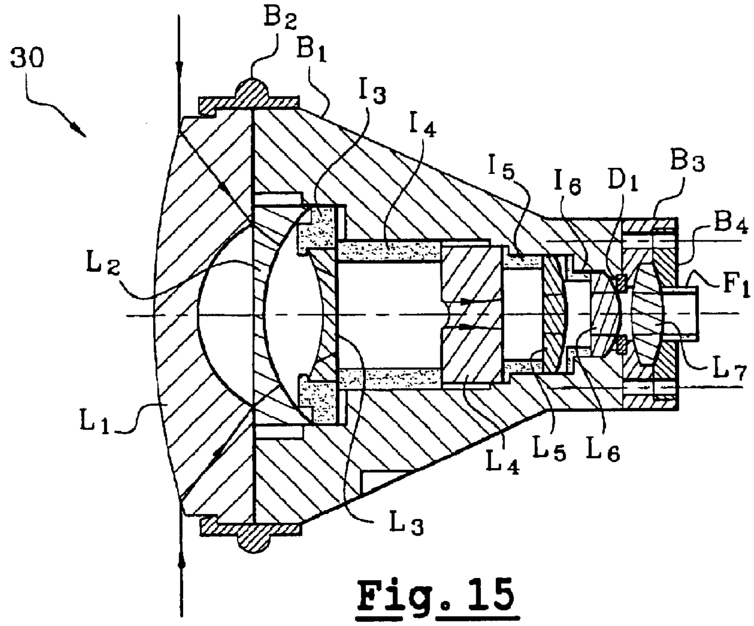


Fig. 15

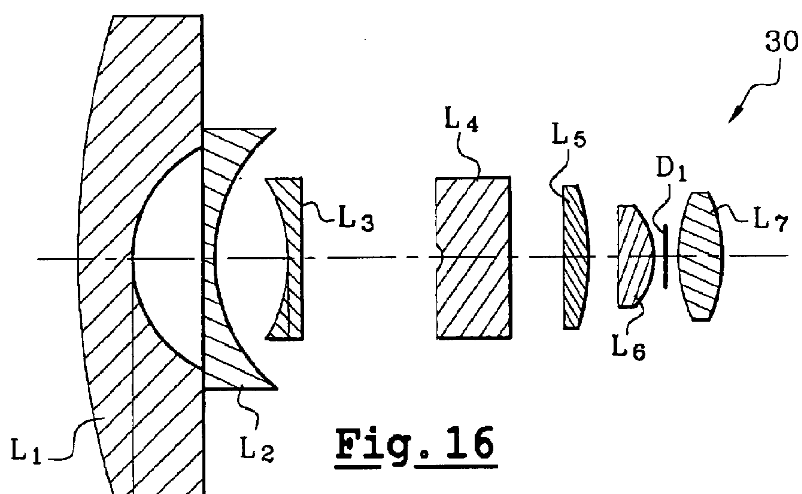


Fig. 16

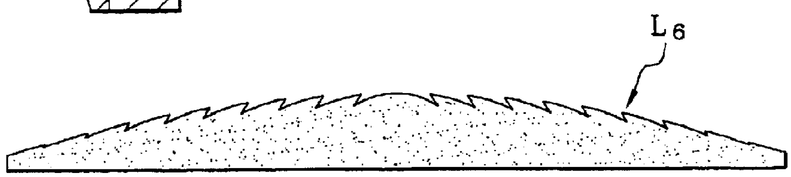


Fig. 17

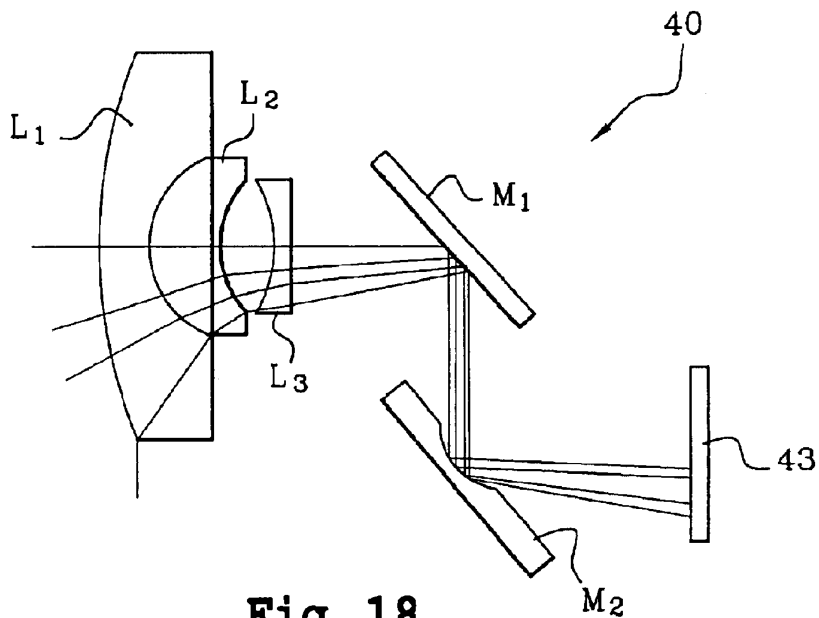


Fig. 18

METHOD FOR CAPTURING AND DISPLAYING A VARIABLE RESOLUTION DIGITAL PANORAMIC IMAGE

CROSS-REFERENCE TO RELATED APPLICATIONS

This application is a continuation of International Application No. PCT/FR02/01588, filed May 10, 2002 the disclosure of which is incorporated herein by reference.

BACKGROUND OF THE INVENTION

The present invention relates to obtaining digital panoramic images and displaying panoramic images on computer screens.

FIG. **1** represents a classical device allowing a digital panoramic image to be produced and presented on a computer screen. The device comprises a digital camera **1** equipped with a panoramic objective lens **2** of the "fish-eye" type, having an angular aperture on the order of 180°. The camera **1** is connected to a computer **5**, such as a microcomputer for example, equipped with a screen **6**. The connection to the microcomputer **5** may be permanent, when, for example, the camera **1** is a digital video camera, or temporary, when, for example, the camera **1** is a still digital camera equipped with an image memory, the connection then being carried out at the time the image files are to be transferred into the microcomputer.

FIG. **2** schematically represents the appearance of a panoramic image **3** obtained by means of the panoramic objective lens **2**. The round appearance of the image is characteristic of the axial symmetry of panoramic objective lenses and the image has dark edges **4** that will subsequently be removed. This digital panoramic image is delivered by the camera **1** in the form of a computer file containing image points coded RGBA arranged in a two-dimensional table, "R" being the red pixel of an image point, "G" the green pixel, "B" the blue pixel, and "A" the Alpha parameter or transparency. The parameters R, G, B, A are generally being coded on 8 bits.

The image file is transferred into the microcomputer **5** which transforms the initial image into a three-dimensional digital image, then presents the user with a sector of the three-dimensional image in a display window **7** occupying all or part of the screen **6**.

FIG. **3** schematically shows classical steps of transforming the two-dimensional panoramic image into a panoramic image offering a realistic perspective effect. After removing the black edges of the image, the microcomputer has a set of image points forming an image disk **10** of center O and axes OX and OY. The image points of the image disk are transferred into a three-dimensional space defined by an orthogonal coordinate system of axes O'X'Y'Z, the axis O'Z being perpendicular to the plane of the image disk. The transfer is performed by a mathematical function implemented by an algorithm executed by the microcomputer, and leads to obtaining a set of image points referenced in the coordinate system O'X'Y'Z. These image points are for example coded in spherical coordinates RGBA(ϕ,θ), ϕ being the latitude and θ the longitude of an image point. The angles ϕ and θ are coded in 4 to 8 bytes (IEEE standard). These image points form a hemisphere **11** when the panoramic objective lens used has an aperture of 180°, otherwise a portion of a hemisphere. The microcomputer thus has a virtual image in the shape of a hemisphere one sector **12** of which, corresponding to the display window **7**, is presented on the screen (FIG. **1**) considering that the observer is on the central point O' of the system of axes O'X'Y'Z, which defines with the center O" of the image sector **12**, a direction O'O" called "viewing direction".

In order to avoid the image sector displayed **12** having geometrical distortions unpleasant for the observer, the classical panoramic objective lenses must have a distribution function of the image points according to the field angle of the object points of a panorama that is as linear as possible. Therefore, if two points A', B', situated on the same meridian of the hemisphere **11**, and the corresponding points A, B on the image disk **10** are considered, the ratio between the angles (A'O'Z) and (B'O'Z) must be equal to the ratio between the distances OA and OB on the image disk.

Due to this property of linearity of a classical panoramic objective lens, image points corresponding to object points having an identical field angle form concentric circles C**10**, C**20** . . . C**90** on the image disk **10**, as represented in FIG. **4**A. Classically, "field angle of an object point" means the angle of an incident light ray passing through the object point considered and through the center of the panorama photographed, relative to the optical axis of the objective lens. The field angle of an object point can be between 0 and 90° for an objective lens having an aperture of 180°. Therefore, the circle C**10** is formed by the image points corresponding to object points having a field angle of 10°, the circle C**20** is formed by image points corresponding to object points having a field angle of 20°, etc., the circle C**90** being formed by the image points having a field angle of 90°.

FIG. **4**B represents the shape of the distribution function Fdc of a classical panoramic objective lens, which determines the relative distance dr of an image point in relation to the center of the image disk according to the field angle α of the corresponding object point. The relative distance dr is between 0 and 1 and is equal to the distance of the image point in relation to the center of the image divided by the radius of the image disk. The ideal form of the function Fdc is a straight line of gradient K:

$$dr=Fdc(\alpha)=K\alpha$$

in which the constant K is equal to 0.111 degree^{-1} (1/90°).

This technique of displaying a digital panoramic image sector on a computer screen has various advantages, particularly the possibility of "exploring" the panoramic image by sliding the image sector presented on the screen to the left, the right, upwards or downwards, until the limits of the panoramic image are reached. This technique also allows complete rotations of the image to be carried out when two complementary digital images have been taken and supplied to the microcomputer, the latter thus reconstituting a complete panoramic sphere by assembling two hemispheres. Another advantage provided by presenting a panoramic image on screen is to enable the observer to make enlargements or zooms on parts of the image. The zooms are performed digitally, by shrinking the image sector displayed and expanding the distribution of the image points on the pixels of the screen.

Various examples of interactive panoramic images can be found on the Web. Reference could be made in particular to the central site "http://www.panoguide.com" ("*The Guide to Panoramas and Panoramic Photography*") which gives a full overview of all the products available to the public to produce these images. Software programs allowing digital panoramic photographs to be transformed into interactive panoramic images are offered to the public in the form of downloadable programs or CD-ROMs available in stores.

Despite the various advantages that this technique for displaying digital images offers, the digital enlargements have the disadvantage of being limited by the resolution of the image sensor used when taking the initial image and the resolution of an image sensor is generally much lower than that of a classical photograph. Therefore, when the enlargement increases, the granulosity of the image appears as the limits of the resolution of the image sensor are being reached.

To overcome this disadvantage, it is well known to proceed with pixel interpolations so as to delay the apparition of the blocks of color which betray the limits of the resolution of the sensor. However, this method only improves the appearance of the enlarged image sector and does not in any way increase the definition. Another obvious solution is to provide an image sensor with a high resolution, higher than the resolution required to present an image sector without enlargement, so that there is a remaining margin of definition for zooms. However, this solution is expensive as the cost price of an image sensor rapidly rises with the number of pixels per unit of area.

Some attempts have been made to improve the quality of the enlargements, by changing the optical properties of the panoramic objective lenses themselves. Thus, U.S. Pat. No. 5,710,661 teaches capturing a panoramic image with two overlocking objective lenses using a set of mirrors. A first set of mirrors provides an overall view, and a mobile central mirror provides a detailed view on a determined zone of the panorama. However, this solution does not offer the same flexibility as digital zooms, particularly when the image is not displayed in real time, as the observer no longer has the possibility of choosing the image portion that he wants to enlarge once the photograph has been taken.

BRIEF SUMMARY OF THE INVENTION

Therefore, the present invention comprises a method allowing the physical limits of image sensors to be circumvented and the definition offered by digital enlargements concerning certain parts of a digital panoramic image to be improved, without the need to increase the number of pixels per unit of area of an image sensor or to provide an overlooking optical enlargement system in a panoramic objective lens.

The present invention is based on the observation that, in several applications, only certain zones of a panoramic image are of a practical interest and are likely to be expanded by the observer by means of a digital zoom. Thus, in applications such as video surveillance, videoconferencing, visio-conferencing, a panoramic camera can be installed against a wall or on the ceiling and there is generally no reason to make enlargements on the zones of the panoramic image corresponding to the wall or the ceiling. Similarly, as part of a videoconference performed by means of a panoramic camera, the most interesting zone is generally situated at a specific place situated towards the center of the image (in the case of individual use) or on the edges of the image (in the case of collective use or visio-conferencing). Furthermore, when used for recreation and leisure, most panoramic images comprise parts that are less interesting than others, such as the parts representing the sky or a ceiling for example, the most useful part generally being in the vicinity of the center of the image.

Therefore, the present invention is based on the premise that a panoramic image has some zones that are not very useful and that can tolerate a reasonable definition to the benefit of other zones of the image.

On the basis of this premise, the idea of the present invention is to produce panoramic photographs by means of a panoramic objective lens that is not linear, which expands certain zones of the image and compresses other zones of the image. The technical effect obtained is that the expanded zones of the image cover a number of pixels of the image sensor that is higher than if they were not expanded, and thus benefit from a better definition. By choosing an objective lens that expands the most useful zones of an image (which depend on the intended application), the definition is excellent in these zones and the definition is mediocre in the zones of lesser importance.

Thus, the present invention proposes a method for capturing a digital panoramic image, by projecting a panorama onto an image sensor by means of a panoramic objective lens, in which the panoramic objective lens has an image point distribution function that is not linear relative to the field angle of object points of the panorama, the distribution function having a maximum divergence of at least ±10% compared to a linear distribution function, such that the panoramic image obtained has at least one substantially expanded zone and at least one substantially compressed zone.

According to one embodiment, the objective lens has a non-linear distribution function that is symmetrical relative to the optical axis of the objective lens, the position of an image point relative to the center of the image varying according to the field angle of the corresponding object point.

According to one embodiment, the objective lens expands the center of the image and compresses the edges of the image.

According to one embodiment, the objective lens expands the edges of the image and compresses the center of the image.

According to one embodiment, the objective lens compresses the center of the image and the edges of the image, and expands an intermediate zone of the image located between the center and the edges of the image.

According to one embodiment, the objective lens comprises a set of lenses forming an apodizer.

According to one embodiment, the set of lenses forming an apodizer comprises at least one aspherical lens.

According to one embodiment, the set of lenses forming an apodizer comprises at least one diffractive lens.

According to one embodiment, the objective lens comprises a set of mirrors comprising at least one distorting mirror.

The present invention also relates to a method for displaying an initial panoramic image obtained in accordance with the method described above, comprising a step of correcting the non-linearity of the initial image, performed by means of a reciprocal function of the non-linear distribution function of the objective lens or by means of the non-linear distribution function.

According to one embodiment, the step of correcting comprises a step of transforming the initial image into a corrected digital image comprising a number of image points higher than the number of pixels that the image sensor comprises.

According to one embodiment, the method comprises a step of calculating the size of the corrected image, by means of the reciprocal function of the distribution function, so that the resolution of the corrected image is equivalent to the most expanded zone of the initial image, and a step of scanning each image point of the corrected image, searching for the position of a twin point of the image point on the initial image and allocating the color of the twin point to the image point of the corrected image.

According to one embodiment, the initial image and the corrected image comprise an image disk.

According to one embodiment, the method comprises a step of transferring the image points of the corrected image into a three-dimensional space and a step of presenting one sector of the three-dimensional image obtained on a display means.

According to one embodiment, the method comprises a step of determining the color of image points of a display window, by projecting the image points of the display window onto the initial image by means of the non-linear distribution function, and allocating to each image point of the display window the color of an image point that is the closest on the initial image.

According to one embodiment, the projection of the image points of the display window onto the initial image comprises a step of projecting the image points of the display window onto a sphere or a sphere portion, a step of determining the angle in relation to the center of the sphere or the sphere portion of each projected image point, and a step of projecting onto the initial image each image point projected onto the sphere or the sphere portion, the projection being performed by means of the non-linear distribution function considering the field angle that each point to be projected has in relation to the center of the sphere or the sphere portion.

The present invention also relates to a panoramic objective lens comprising optical means for projecting a panorama into an image plane of the objective lens, the panoramic objective lens having an image point distribution function that is not linear relative to the field angle of object points of the panorama, the distribution function having a maximum divergence of at least ±10% compared to a linear distribution function, such that a panoramic image obtained by means of the objective lens comprises at least one substantially expanded zone and at least one substantially compressed zone.

According to one embodiment, the panoramic objective lens has a non-linear distribution function that is symmetrical relative to the optical axis of the objective lens, the position of an image point relative to the center of an image obtained varying according to the field angle of the corresponding object point.

According to one embodiment, the panoramic objective lens expands the center of an image and compresses the edges of the image.

According to one embodiment, the panoramic objective lens expands the edges of an image and compresses the center of the image.

According to one embodiment, the panoramic objective lens compresses the center of an image and the edges of the image, and expands an intermediate zone of the image located between the center and the edges of the image.

According to one embodiment, the panoramic objective lens comprises a set of lenses forming an apodizer.

According to one embodiment, the set of lenses forming an apodizer comprises at least one aspherical lens.

According to one embodiment, the set of lenses forming an apodizer comprises at least one diffractive lens.

According to one embodiment, the panoramic objective lens comprises polymethacrylate lenses.

According to one embodiment, the panoramic objective lens comprises a set of mirrors comprising at least one distorting mirror.

BRIEF DESCRIPTION OF THE SEVERAL VIEWS OF THE DRAWINGS

The foregoing summary, as well as the following detailed description of preferred embodiments of the invention, will be better understood when read in conjunction with the appended drawings. For the purpose of illustrating the invention, there are shown in the drawings embodiments which are presently preferred. It should be understood, however, that the invention is not limited to the precise arrangements and instrumentalities shown.

In the drawings:

FIG. **1** described above represents a system for displaying a digital panoramic image on a screen;

FIG. **2** described above represents a panoramic image before it is processed by a computer;

FIG. **3** described above shows a classical method for transforming a two-dimensional panoramic image into a three-dimensional digital panoramic image;

FIGS. **4**A and **4**B described above show the linearity of a classical panoramic objective lens;

FIGS. **5** and **6** show one aspect of the method according to the present invention and respectively represent a distribution of image points obtained with a classical panoramic objective lens and a distribution of image points obtained with a non-linear panoramic objective lens according to the present invention;

FIGS. **7**A and **7**B show a first example of non-linearity of a panoramic objective lens according to the present invention;

FIG. **8** shows a second example of non-linearity of a panoramic objective lens according to the present invention;

FIG. **9** shows a third example of non-linearity of a panoramic objective lens according to the present invention;

FIG. **10** represents a system for displaying a digital panoramic image by means of which a method for correcting the panoramic image according to the present invention is implemented;

FIG. **11** schematically shows a first embodiment of the correction method according to the present invention;

FIG. **12** is a flow chart describing a method for displaying a panoramic image incorporating the first correction method according to the present invention;

FIG. **13** schematically shows a second embodiment of the correction method according to the present invention;

FIG. **14** is a flow chart describing a method for displaying a panoramic image incorporating the second correction method according to the present invention;

FIG. **15** is a cross-section of a first embodiment of a non-linear panoramic objective lens according to the present invention;

FIG. **16** is an exploded cross-section of a system of lenses present in the panoramic objective lens in FIG. **15**;

FIG. **17** is a side view of a lens present in the panoramic objective lens in FIG. **15**; and

FIG. **18** is the diagram of a second embodiment of a non-linear panoramic objective lens according to the present invention.

DETAILED DESCRIPTION OF THE INVENTION

A—Compression/Expansion of an Initial Image

FIG. **5** schematically represents a classical system for taking panoramic shots, comprising a panoramic objective lens **15** of optical axis OZ and a digital image sensor **17** arranged in the image plane of the objective lens **15**. Here, four object points a, b, c, d will be considered that belong to a panorama PM located opposite the objective lens and respectively having angles of incidence $\alpha 1$, $\alpha 2$, $-\alpha 2$, $-\alpha 1$. As explained in the preamble, the field angle of an object point is the angle that an incident light ray passing through the object point considered and through the center of the panorama PM, marked by a point "p" on FIG. **5**, has relative to the optical axis OZ of the objective lens. In this example, the angle $\alpha 1$ is equal to two times the angle $\alpha 2$. On the image sensor **17**, image points a', b', c', d' corresponding to the object points a, b, c, d are located at distances from the center of the image respectively equal to d1, d2, −d2, −d1. As the distribution of the image points according to the field angle of the object points is linear with a classical panoramic objective lens, the distances d1 and d2 are linked by the following relation:

$$d1/\alpha 1 = d2/\alpha 2$$

As the angle $\alpha 1$ is here equal to $2\alpha 2$, it follows that:

$$d1 = 2d2$$

As is well known by those skilled in the art, the term "linearity" here refers to a ratio of proportionality between the distance of an image point measured relative to the center of the image and the field angle of the corresponding object point. The notion of "linearity" in the field of panoramic objective lenses is therefore different from that prevailing in the field of paraxial optics (in the vicinity of the optical axis) when the conditions of Gauss are met.

FIG. **6** represents a system for taking shots of the same type as above, but in which the classical panoramic objective lens **15** is replaced by an objective lens **18** according to the present invention, the image sensor **17** being arranged in the image plane of the objective lens **15**. The projection onto the image sensor **17** of the object points a, b, c, d having angles of incidence $\alpha 1$, $\alpha 2$, $-\alpha 2$ and $-\alpha 1$ relative to the axis OZ of the objective lens and to the center "p" of the panorama are considered again. On the image sensor **17**, the corresponding image points a", b", c", d" are located at distances from the center of the image respectively equal to d1', d2', −d2', −d1'.

According to the present invention, the objective lens **18** has a distribution function of the image points that is not linear. The ratio of the distances d1', d2', −d2', −d1' are not equal to the ratio of the angles of incidence $\alpha 1$, $\alpha 2$, $-\alpha 2$, $-\alpha 1$. In the example represented, the distance d2' is clearly greater than d1'/2, such that the central part of the panoramic image projected onto the image sensor **17**, which corresponds to a solid angle $2\alpha 2$ centered on the optical axis OZ, occupies a greater area on the image sensor **17** than the area it occupies in FIG. **5** with the classical panoramic objective lens (hatched zone). This central part of the panoramic image is therefore projected onto the image sensor with expansion of its area, in relation to the area the central part would occupy if the objective lens were linear. The result is that the number of pixels of the image sensor covered by this part of the image is greater than in previous practices and that the definition obtained is improved. On the other hand, the part of the image delimited by two circles respectively passing through the points a", d" and through the points b", c" is compressed relative to the corresponding part in FIG. **5**, and the definition on the edges of the image is less than that obtained with a classical linear objective lens, to the benefit of the central part of the image.

By applying the principle according to the present invention, which involves expanding one part of the image and compressing another part of the image, the part to be expanded and the part to be compressed can be chosen according to the intended application, by producing several types of non-linear objective lenses and by choosing an objective lens suited to the intended application. Depending on the intended application, the most useful part of a panoramic image may be located in the center of the image, on the edge of the image, in an intermediate zone situated between the center and the edge of the image, etc.

FIGS. **7A**–**7B**, **8** and **9** show three examples of non-linear distribution functions according to the present invention.

The distribution function shown in FIGS. **7A** and **7B** corresponds to the example in FIG. **6**, that is a panoramic objective lens that expands the image in the center. FIG. **7A** represents equidistant concentric circles C**10**, C**20**, . . . , C**90** present on an image disk, each circle being formed by image points corresponding to object points having the same field angle. The circle C**10** is formed by the image points corresponding to object points having a field angle of 10°, the circle C**20** is formed by image points corresponding to object points having a field angle of 20°, etc. By comparing FIG. **7A** with FIG. **4A** described in the preamble, it appears that the circles C**10** and C**20** are further from the center of the image and further from each other than the circles C**10** and C**20** obtained with a classical objective lens, while the circles C**30** to C**90** are closer to each other. This panoramic image thus has an expanded zone in the center and a compressed zone on the edge of the image disk.

FIG. **4B** represents the curve of the corresponding distribution function Fd1. The classical linear distribution function, expressed by $Fdc=K\alpha$ and in the form of a straight line of gradient K, is also represented as a guide mark (the constant K being equal to 1/90 for an objective lens having an aperture of 180°, i.e., a gradient of 0.111 per degree). The field angle α of the object points is represented on the X-axis and is between 0 and 90°. The relative distance dr of an image point in relation to the center of the image disk is represented on the Y-axis and is between 0 and 1. The curve of the function Fd1 has a higher gradient than the straight line Fdc for angles α of between 0 and 20°, then a lesser gradient after 20° and up to 90°. A high gradient means an expansion of the image and a low gradient means a compression of the image.

As demonstrated in this example, the curve Fd**1** has a point of maximum divergence Pd at the angle $\alpha=20°$. "Point of maximum divergence" refers to the image point $Pd(\alpha)$ at which the greatest gap in relative distance dr in relation to a corresponding point $Pdl(\alpha)$ on the linear distribution straight line $K\alpha$ can be observed. In this example, the point $Pd(\alpha=20°)$ has a relative distance dr equal to 0.5 relative to the center of the image while the corresponding point $Pdl(\alpha=20°)$ on the linear curve Fdc has a relative distance dr of 0.222. The maximum divergence DIVmax of the distribution function Fd**1** according to the present invention can be calculated by a formula of the type:

$$DIV\max \% = [[dr(Pd) - dr(Pdl)]/[dr(Pd\mathbf{1})]]*100$$

i.e.:

$$DIV\max \% = [[dr(Pd) - K*\alpha(Pd)]/[K*\alpha(Pd)]]*100$$

In which dr(Pd) is the relative distance in relation to the center of the point of maximum divergence Pd, dr(Pdl) is the relative distance in relation to the center of the corresponding point on the linear distribution straight line Fdc, $\alpha(Pd)$ being the abscissa of the point Pd, i.e., the field angle of the corresponding object point.

In the example considered here, the maximum divergence is therefore equal to +125%. This value of maximum divergence according to the present invention is clearly higher than that due to the possible design errors or manufacturing errors of a classical panoramic objective lens, which is of a few percent. Generally speaking, a non-linear objective lens according to the present invention has a maximum divergence on the order of 10% at least, to obtain an expansion of the useful parts of the image which results in a clear increase in the number of pixels of the image sensor covered by the useful parts and a substantial improvement in the definition obtained.

An average rate TX of expansion or compression of one part of the image contained between two circles passing through points Pd1 and Pd2 is also defined. The rate TX is the ratio between the area delimited by the two circles passing through the points Pd1, Pd2 and the area delimited by two circles passing through points Pdl1, Pdl2 of the same abscissa belonging to the linear distribution function Fdc. The rate TX can be determined by a formula of the type:

$$TX=[dr(Pd1)^2-dr(Pd2)^2]/[(dr(Pdl1))^2-(dr(Pdl2))^2]$$

i.e.:

$$TX=[dr(Pd1)^2-dr(Pd2)^2]/[K^2[(\alpha(Pd1))^2-(\alpha(Pd2))^2]]$$

A rate TX higher than 1 indicates an expansion of the part of image considered while a rate TX lower than 1 indicates a compression of the part of image considered. In the example of function Fd1 considered here, the average rate of expansion/compression TX of the central part of the image, delimited by the circle C20, is equal to 5.07, i.e., an average expansion by a factor 5 of the central part of the image and consequently a 500% improvement of the definition obtained for a constant number of pixels of the image sensor.

FIG. 8 represents another example of distribution function Fd2 according to the present invention, here having a point of maximum divergence Pd at the angle α=70°, and having a relative distance in relation to the center of the image of 0.3. The maximum divergence of the curve Fd2 is −61.4% here, and the average rate of expansion/compression TX of the central part of the image delimited by the circle C70 (not represented) is 0.5, i.e., an average compression by a factor of 0.15 of the central part of the image. The expanded part of the image here is thus located here on the edge of the image, between the circle C70 and the circle C90, and has an average rate of expansion/compression of 2.3. Thus, an image disk obtained with a panoramic objective lens having a distribution function conforming to the function Fd2, has a high definition zone on its edges, that lend themselves well to digital enlargements, and a low definition zone in its central part.

FIG. 9 represents a third example of distribution function Fd3 according to the present invention, having a first point of maximum divergence Pd1 (α=30°, dr=0,1) and a second point of maximum divergence Pd2 (α=70°, dr=0,9). Thus, two maximum divergences can be seen, one negative and equal to−70%, and the other positive and equal to 15.8%. A compressed image zone can also be seen between the center O of the image and the circle C30 passing through the point Pd1, an expanded image zone between the circle C30 and the circle C70 passing through the point Pd2, and a compressed image zone between the circle C70 and the circle C90 forming the edge of the image disk. The average rates of expansion/compression TX(0, C30), TX(C30, C70), TX(C70, C90) for each of these zones are respectively equal to 0.09, 1.6 and 0.48. An image disk obtained with a panoramic objective lens having a distribution function conforming to the function Fd3, has a high definition zone in its intermediate part, which lends itself well to digital enlargements, and two low definition zones in its central part and on its edges.

B—Correction of the Non-linearity of the Initial Image

A first aspect of the present invention was described above, according to which a non-linear distribution of image points onto a digital image was provided to improve the definition of the image in expanded zones, by increasing the number of pixels of the image sensor covered by the expanded zones. Before describing examples of embodiments of non-linear panoramic objective lenses according to the present invention, a second aspect of the present invention will be described which involves correcting the non-linearity of the image disk obtained in order to present the observer with an image free from optical distortion.

This second aspect of the present invention is implemented at the stage of the processing of the initial image by computer, to present an interactive panoramic image on a screen. The means for implementing the method of the present invention are shown in FIG. 10 and are classical in themselves. A digital camera 20 can be equipped with a non-linear panoramic objective lens 21 and connected to a microcomputer 22 comprising a screen 23. The digital images IMi taken by means of the camera 20 are transferred to the microcomputer to be processed and displayed on the screen 23, in a display window 24. A processing program comprising an algorithm for transforming and displaying the images is first loaded into the microcomputer, by means of a CD-ROM 25 or by downloading via the Internet for example. The camera 20 can be a still digital camera or a digital video camera and the connection to the microcomputer can be permanent or otherwise. In the case of a video camera, the microcomputer receives a flow of images that it processes in real time to display them on the screen.

In this context, the correction method according to the present invention can be performed according to two embodiments. A first embodiment involves correcting the initial image by means of a function Fd^{-1} that is the reciprocal function of the distribution function Fd according to the present invention. As the distribution function Fd is known and determined at the time the non-linear objective lens is designed, it is easy to deduce the reciprocal function Fd^{-1} therefrom. This correction step allows a corrected image to be obtained in which the non-linearity due to the objective lens according to the present invention is removed. The corrected image is equivalent to an image taken by means of a classical panoramic objective lens and can then be processed by any classical display software program available in stores, provided for transferring the image points of an image disk into a three-dimensional space and for interactively displaying a sector of the image obtained.

The second alternative of the method involves using the distribution function Fd in an image display algorithm working backwards, that is defining in real time the color of the pixels of a display window using the image points of the image disk.

First Embodiment of the Correction Method

FIG. 11 shows the first embodiment of the method according to the present invention. Here it is assumed that there is an initial image Img1 comprising a non-linear image disk ID1 of radius R1, having for example an expansion zone in the center (circles C10 and C20). The initial image Img1 is transformed into a corrected image Img2 comprising a linear image disk ID2 of radius R2. The radius R2 of the image disk ID2 is higher than the radius R1 of the initial image disk ID1 and the image disk ID2 has a resolution equal or substantially equal to the resolution offered by the zone of the image disk Img1 in which the greatest density of information (i.e. the zone in which the image is the most expanded) is to be found. Here, the zone with the greatest density of information is the central part of the image delimited by the circle C20.

The main steps of this method are the following:

- initially, the size R2 of the linearized image disk ID2 is calculated by means of the reciprocal function Fd^{-1}, considering on the initial image disk ID1 the place in which the image is the most expanded, so that the corrected image Img2 has a resolution equal or substantially equal to the resolution offered by the zone of the image Img1 in which the greatest density of information is to be found,
- then each pixel of the image to be calculated Img2 is scanned, and the position of its twin point on the image Img1 is searched for, and then
- the color of the corresponding point on the initial image Img1 is allocated to the point of the new image Img2.

This method is implemented by means of an algorithm described below (algorithm 1), in which:

- A is the angular aperture of the objective lens,
- D is the distance of an image point relative to the center of the initial image disk ID1,
- R1 is the size in pixels of the radius of the initial image disk ID1 (i.e. the number of pixels between the center and the edge of the image disk),
- R2 is the size in pixels of the radius of the linearized image disk ID2,
- I and J are the coordinates of an image point in the image produced, the coordinate point (0,0) being in the center of the image,
- U and V are the coordinates of a twin point in the original image, the coordinate point (0,0) being in the center of the image,
- "Current_angle" and "Previous_angle" are iterative parameters,
- DAM is the minimum angular difference between two object points corresponding to two adjacent image points on the initial image disk ID1 (i.e., the maximum resolution of the image disk ID1 expressed in angular difference), and
- $Fdlin^{-1}$ is the reciprocal function of a distribution function of a classical linear objective lens, of the type: $Fdlin(\alpha)=K\alpha$, with K=2/A, i.e. K=1/90 with an objective lens having an angular aperture of 180°.

Algorithm 1

```
[finding DAM]
1/ DAM = A/2
2/ Current_angle = 0
3/ For D = 1 to R1 [with increments of 1]
4/     Previous_angle = Current_angle
5/     Current_angle = Fd^-1(D/R1)
6/     If DAM > (Current_angle - Previous_angle) then
7/         DAM = (Current_angle - Previous_angle)
8/     End if
9/ End for
[determining the radius R2 of the disk ID2]
10/ R2 = (A/2)/DAM
```

-continued

Algorithm 1

```
[calculating the new image]
[scanning each pixel of the image to be calculated Img2]
11/ For I =-R2 to +R2 [with an increment of 1]
12/   For J =-R2 to +R2 [with an increment of 1]
[searching for polar coordinates (R',θ) of the twin point
on the image Img1 using the coordinates
(R,θ) of the point of the image Img2]
13/       R = √(I²+J²)
14/       If R < R2 then
15/           If J < 0 then
16/               θ = arc cosine(I/R)
17/           If not
18/               θ = -arc cosine(I/R)
19/           End if
[conversion of the radius R to find the radius R']
                20/ R'= R1*Fd(Fdlin^-1 (R/R2))
as Fdlin^-1(R) = R/K and K=2/A, it follows that:
20'       /R'=R1*Fd((R/R2) * (A/2))
[return to the Cartesian coordinates]
21/       U = R'*cos(θ)
22/       V = R'*sin(θ)
[allocation of the color of the point]
23/       Img2[I,J] = Img1[U,V]
24/   If not
[allocation of the color black to the points outside the image disk]
25/       Img2[I,J] = Black
26/   End if
27/   End for
28/ End for
```

Note that the step 14 avoids calculating all the points situated outside the image disk (the points are outside the image disk when R>R2). Moreover, the algorithm 1 can be improved by subsequently performing a bilinear interpolation on the image Img2, in itself well known by those skilled in the art, so as to smooth out the final image.

FIG. 12 is a flow chart giving a general overview of the steps of a method for capturing and interactively presenting a panoramic image on a screen. This flow chart is described in table 1 in the Appendix, that is an integral part of the description. The steps S1 and S2, respectively the acquisition of the image and the transfer of the image into a computer, are classical in themselves. The step of linearising the image disk S3 is performed in accordance with the method of the present invention, by means of the algorithm described above for example. The step S4, called "digitization", is also classical. This step involves transferring the image points of the corrected image disk Img2 into a three-dimensional space of axes Oxyz in which the image points are for example referenced in spherical coordinates. The step S5 is also classical, and involves displaying a sector of the three-dimensional image called display window on a screen. The display window is moved upwards or downwards depending on the user's actions, or is enlarged at the user's request. When enlarged, the definition is better than in previous practices in the zones corresponding to the expanded parts of the initial image.

Second Embodiment of the Correction Method

The second embodiment of the correction method according to the present invention is shown in FIG. 13. Schematically, this method involves projecting the image points of an image sector corresponding to a display window DW onto the image disk ID1 of the initial image Img1. This method does not require calculating a corrected image disk, contrary to the previous embodiment.

The image points of the display window DW are referenced E(i,j) in the coordinate system of the display window, expressed in line coordinates i and in column coordinates j. The points E(i,j) are first projected onto a sphere portion HS of center O and of axes OX, OY, OZ, to obtain image points P(px, py, pz) belonging to the sphere portion. This sphere portion covers a solid angle that corresponds to the aperture of the objective lens used. The example considered until now was of a panoramic objective lens having an aperture of 180° and the sphere portion HS considered here is therefore a hemisphere. The image points P thus determined are then projected onto the image disk Img**1** by means of the non-linear distribution function Fd according to the present invention, which first requires calculating the field angle α of the points P in relation to the center O of the hemisphere. The center O of the hemisphere is the virtual equivalent of the center "p" of the panorama, having been used as the reference, in the description above, to determine the angles of incidence a of the object points and the shape of the function Fd. The projection of the image points P onto the image disk ID1 allows image points p(pu, pv) to be obtained on the image disk, in a coordinate system of center O' (corresponding to the center of the image disk) and of axes O'U and O'V. The axis OZ in the system of the hemisphere HS is perpendicular to the plane of the image disk ID**1** and passes through the center O' of the image disk, such that the axes O'Z and OZ are merged.

As it will be clear to those skilled in the art, the correction of the non-linearity of the image disk is implicit here since the image points p(pu, pv) corresponding to the image points E(i, j) of the display window DW are "retrieved" from the image disk ID**1**, by means of the function Fd.

The method according to the present invention is implemented by means of an algorithm described below (algorithm 2), in which:

- i and j are the coordinates of a point E(i, j) of the display window,
- Imax and Jmax are the number of columns and the number of lines of the display window, corresponding to the dimensions in number of pixels of the display window,
- Ex, Ey and Ez are the Cartesian coordinates of a point E(i,j) of the display window DW in the coordinate system OXYZ,
- Px, Py and Pz are the Cartesian coordinates of a point P on the hemisphere HS,
- pu and pv are the Cartesian coordinates of an image point p of the image disk in the coordinate system O'UV,
- L is the size of the image disk, in number of pixels,
- M is the center of the display window DW,
- the "viewing direction" is the direction materialised by the point O and the center of the display window M, the display window forming the base of a pyramid of vision of the observer the top of which is the point O (observer's position),
- θ0 and ϕ0 are the longitudes and latitudes corresponding to the viewing direction from the point O towards the center M of the display window,
- Screen_Pixel[i,j] is the color (RGBA) of a point E (i,j) of the display window DW,
- Image_Pixel[i,j] is the color of the point P(i,j) of the hemisphere HS corresponding to the image disk, the coordinate point (0,0) being situated in the center of the image disk,
- R is the radius of the hemisphere HS (arbitrary value chosen so as to improve the accuracy of the calculations, R is for example chosen to be equal to 10,000),
- α is the angle in relation to the center O of an image point "P situated on the hemisphere (represents the field angle at the moment the shot of the corresponding object point is taken),
- aux1, aux2are intermediate variables,
- "Zoom" is a variable defining the enlargement, having a default value equal to R, and
- "√" is the square root function.

Algorithm 2

```
1/ For i=-Imax/2 to i=Imax/2 do [by increments of 1]
2/     For j=-Jmax/2 to j=Jmax/2 do [by increments of 1]
[calculation of the Cartesian coordinates Ex, Ey, Ez
of the point E of the display window in the system OXYZ]
3/     Ey = j*cos(ϕ0) - Zoom*sin(ϕ0)
4/     Ez = Zoom*cos(ϕ0) + j*sin(ϕ0)
5/     aux1 = Ez
6/     Ez = Ez*cos(θ0) - i*sin(θ0)
7/     Ex = i*cos(θ0) + aux1*sin(θ0)
[calculation of the coordinates of the point P corresponding to the point E]
8/     aux2 = R/√(Ex*Ex + Ey*Ey + Ez*Ez)
9/     Px = Ex*aux2
10/    Py = Ey*aux2
11/    Pz = Ez*aux2
[calculation of the coordinates of the point p corresponding
to the point P, in the coordinate system
(O'UV), by means of the function Fd]
12/    X = Px/R
13/    Y = Py/R
14/    r = √(X*X + Y*Y)
15/    α = arcsine(r)
16/    U = X/r
17/    V = Y/r
18/    pu = L*U*Fd(α)
19/    pv = L*V*Fd(α)
20/    Screen_Pixel[i,j] = Image_Pixel[pu,pv]
21/  end for
22/ end for
```

A request for enlargement (zoom) by the user results in the algorithm modifying the "Zoom" parameter. When the "Zoom" parameter is equal to the radius R of the hemisphere, the display window DW is tangential to the hemisphere (FIG. **13**). When the parameter "Zoom" is higher than R, the window DW moves away from the hemisphere (along the axis given by the viewing position 0M), which corresponds to a shrinking of the pyramid of vision and an enlargement of the image sector presented in the window DW. The enlargement of the image sector presented to the observer is therefore equal to the ratio of the "Zoom" parameter by the radius R.

When the steps **18** and **19** have been performed with a "Zoom" parameter higher than R, a gain in definition is obtained in the zones in which the image has been expanded at the time the shot is taken as there are still. While the resolution limit is not reached, two adjacent pixels on the image disk which correspond to two adjacent pixels of the display window. In the compressed zones of the image, the search for the closest pixel by means of the relations L*U*Fd(α) and L*V*Fd(α) results, on the other hand, in the algorithm finding the same image pixel for several adjacent pixels of the display window on the image disk. However, these compressed image zones, benefiting from a lesser definition on the image disk, are considered secondary for the intended application, in accordance with the premise on which the present invention is based.

Generally speaking, any other projection method can be used, the essential step according to the present invention being that of finding the field angle a of the object points on the hemisphere, in relation to the center of the hemisphere, so as to use the distribution function Fd in the calculations.

It will be understood that the algorithm **2** is applicable when there are two complementary image disks, one corresponding to a front photograph and the other to a rear photograph of a panorama at 360°, the second photograph being taken by rotating the panoramic objective lens by 180° around an axis passing through the center of the panorama. In this case, two hemispheres and two image points called "Front_Image_Pixel" and "Rear_Image_Pixel" are defined:

Front_Image_Pixel[i,j]: color of a point E(i,j) on the hemisphere corresponding to the front photo, the coordinate point (0,0), being situated in the center of the image disk,

Rear_Image_Pixel[i,j]: color of a point E(i,j) on the hemisphere corresponding to the rear photo, the coordinate point (0,0) being situated in the center of the image disk.

The steps **18** and following of the algorithm 2 are therefore modified as follows:

```
18/   pu = L*U*Fd(α)
19/   pv = L*V*Fd(α)
20/   If Pz >= 0 then
21/   Screen_Pixel[i,j] = Front_Image_Pixel[pu,pv]
22/   If not Screen_Pixel[i,j] = Rear_Image_Pixel[L-pu,pv]
23/   End if
24/   end for
25/   end for
```

FIG. **14** is a flow chart giving a general overview of the steps of a method for capturing and interactively presenting a panoramic image on a screen. This flow chart is described in table 2 in the Appendix, that is an integral part of the description. The acquisition **S1** and transfer **S2** steps described above are again included. The step **S2** is followed by an interactive display step **S3**' performed in accordance with the method that has just been described, implicitly incorporating a correction of the non-linearity of the image disk through the use of the distribution function Fd to find the points corresponding to the pixels of the display window on the image disk.

II—EXAMPLES OF EMBODIMENTS OF A NON-LINEAR PANORAMIC OBJECTIVE LENS ACCORDING TO THE PRESENT INVENTION

Here, one object of the present invention is to provide a panoramic objective lens having a non-linear distribution function Fd, that is simple in structure and with a low cost price. Below, two examples of embodiments of non-linear panoramic objective lenses according to the present invention will be described, the first being a direct-type objective lens and the second of indirect type, that is using mirrors.

First Embodiment

Apodizers are optical systems well known by those skilled in the art, used to change the energy distribution (amount of light) of a source of light at the pupil. They are particularly used to level out the energy in a laser beam or even, in the field of photography, to limit the diffraction of light through the lenses. Using an apodizer as a filter is also well known, to cover the aperture of an optical instrument in order to remove the secondary rings of a diffraction pattern. When it is desirable to separate the images of two neighbouring pin-point sources, these secondary rings are a nuisance and reduce the resolution. "Apodization" can thus be performed, that is these secondary rings can be removed by placing an adequate filter in the plane of the pupil.

Here, the idea of the present invention is to use an apodizer for a different purpose: the principle of the apodizer is used to control the angular distribution of a panoramic objective lens and to obtain the non-linearity sought.

FIG. **15** represents, by a cross-section, an example of an embodiment of a non-linear objective lens **30** according to the present invention. The distribution function Fd obtained by means of the objective lens **30** is the function Fd**1** described above in relation with FIG. **7**B, the objective lens **30** thus expanding the image in the center.

The objective lens **30** comprises a system of lenses that is also represented in FIG. **16** by an exploded view. A divergent optical group formed by lenses L1, L**2**, L**3**, and a convergent optical group formed by lenses L**4**, L**5**, L**6**, L**7** can be distinguished. A diaphragm **D1** is arranged between the lenses L6 and L7.

Parts B1 to B**4** and parts I**3** to I**6** are provided to hold the lenses. The part B1 forms the body of the objective lens and comprises a cylindrical cavity in which the lenses L2 to L**6** are arranged. The part B**2** is screwed onto the body B1 and allows the front lens L1 to be fastened against the front of the part B1, the back of the lens L1 being in contact with the front of the lens L2. The parts B3 and B**4** are fastened with screws (not represented) against the rear part of the body B**1**. The part **B3** holds the diaphragm **D1** and comprises a cavity for receiving the back lens L7. The part B4 presses the lens L7 into the part B3 and comprises a rear sleeve F1 equipped with a thread allowing an image sensor to be fastened, such as a CCD sensor for example. The parts I**3** to I**6** are dividers allowing the distances between the lenses L2 to L**6** inside the body B1 to be adjusted with precision.

The divergent optical group L1, L2, L3 defines the field angle of the objective lens **30**, here of 180°. The front lens L1 is a divergent meniscus in PMMA with an aspherical front and a concave back. It must be said that PMMA or polymethacrylate is organic glass with a low cost price, belonging to the category of plastics. The lens L2 is of the planoconcave type and is made of borosilicate BK7 (standard optical mineral glass). Its front (plane side) is pressed against a flat part of the back of the lens L1, which extends at the periphery of the concave part (useful part) of the back of the lens L1. The lens L3 is also of the planoconcave type and is in BK7. Its concave side is oriented towards the front, opposite the back of the lens L**2**.

The convergent optical group **L4**, L5, L6, L7 forms an apodizer within the meaning of the present invention and determines the non-linear distribution function Fd, which is obtained here by means of a-spherical lenses and a diffractive lens.

The lens L4 is of the planoconcave type and is in PMMA. Its concave front is a-spherical. The lens **L5** is of the planoconvex type and is in BK7, its plane side being oriented towards the front. The lens L6 is a meniscus in PMMA having a concave and aspherical front and a diffractive convex back. This diffractive back has a diffraction grating made up of circular diffractive zones centered on the optical axis of the lens, the profile of which is represented in FIG. **17**. Finally, the back lens L7 is of the biconvex type and is in BK7. The back lens **L7** focuses the luminous flux onto the image plane, at the spot provided for the image sensor.

The aspherical fronts of the lenses L1, **L4** and **L6** are determined by means of a formula of the type:

$$z(r)=[(C*r^2)/(1+\sqrt{}(1-(1+k)*C^2*r^2)]+A_1r^2+A_2r^6+A^4r^8+A_5r^{10}$$

in which:

"k" is a conicity constant,

"**A1**", "A2", "**A3**", "**A4**", "**A5**" are constants for adjusting the coefficient of conicity according to the position, "z" is the shape of the surface,

"r" is the radius at the center, and

"C" is the radius of curvature.

The diffractive back of the lens **L6** allows the number of lenses required to produce the objective lens **30** to be reduced. In the present embodiment, it avoids for example providing at least three supplementary complex lenses. It is determined by means of a formula of the type:

$$\phi(r)=\alpha 1(r/R0)^2+\alpha 2(r/R0)^4$$

in which:

"r" is the distance in relation to the center of the lens of a point considered, located on the surface of the lens,

α1 and α2 are constants defining the phase shift of the wave surface,

"**R0**" is a constant allowing r to be normalized, and

"φ" is the phase shift introduced by the diffractive surface at the point considered.

The lenses in PMMA **L1**, L4 and **L6** are manufactured using a method called "diamond turning" well known by those skilled in the art, which involves milling the surface of the lenses along a mesh of points.

The solid angle of propagation of the light rays in each lens is marked on FIG. **15** by black lines. The light rays pass through the optical group L1, **L2**, **L3**, pass through the apodizer **L4**, **L5**, **L6**, **L7** while being stopped down by D1.

The determination of the parameters defining the aspherical sides mentioned above, the formula of the diffraction grating of the lens **L6**, the calculation of the diameters of the lenses and of the distances between the lenses, are within the understanding of those skilled in the art using the classical computer-aided lens design tools.

Second Embodiment

FIG. **18** schematically represents a non-linear objective lens **40** using a distorting mirror. The objective lens **40** comprises, at input, a divergent optical group consisting, for example, of the three lenses L1, **L2**, **L3** described above, defining the field angle of the objective lens. Opposite the optical group a plane mirror **M1** is located which reflects the luminous beam onto a distorting mirror **M2** of aspherical concave shape. The beam reflected by the mirror **M2** is sent onto an image sensor **43**.

In this embodiment, the irregularities of sphericity that the concave part of the mirror has determined the angular distribution function Fd sought for the intended application (distortion in the center, on the edges . . .). The result obtained is equivalent to that of the optical system described above. Obtaining the distribution function Fd is within the understanding of those skilled in the art using computer-aided lens design tools which allow, in addition to designing lenses, reflecting surfaces to be designed and focused.

One alternative of this embodiment involves providing several distorting mirrors so as to combine distortions or simplify complex distortions by characterising a type of distortion per mirror, which has the advantage of facilitating the engineering work.

Yet another alternative involves using one or more deformable mirrors to produce a so-called "adaptive" optical system. Deformable mirrors comprise a layer of piezoelectric micro-pistons covered by a reflecting layer. Each piezoelectric piston is activated individually, so that the distortions of the mirror can be controlled at several points to obtain the desired shape. This device can be driven by an integrated circuit comprising several configurations of the micro-pistons in its memory, to obtain a distribution function Fd that is adjustable according to the intended use, which avoids providing several objective lenses.

Generally speaking, adaptive optics are in themselves known by those skilled in the art and used in high-precision telescopes to correct the optical defects of the lenses or atmospheric distortions. Deformable mirrors also exist in the field of optical disks, if reference is made for example to the U.S. Pat. Nos. 5,880,896 and 5,745,278.

Therefore, means that are in themselves known are also used for different purposes, not to correct a lens but to obtain, on the contrary, a non-linear angular distribution function.

It will be understood that various other alternatives of the present invention may be made. In particular, although the description above was of non-linear panoramic objective lenses with axial symmetry relative to the optical axis, in which the position of an image point only varies with the field angle relative to this axis of the corresponding object point (which gives a distribution of points in concentric circles, as seen above), the framework of the present invention also covers providing objective lenses the non-linearity of which is not symmetrical relative to the optical axis, such that the expanded parts of the image may, in this case, not be set on the center of the image.

It will be appreciated by those skilled in the art that changes could be made to the embodiments described above without departing from the broad inventive concept thereof. It is understood, therefore, that this invention is not limited to the particular embodiments disclosed, but it is intended to cover modifications within the spirit and scope of the present invention as defined by the appended claims.

APPENDIX (Forming an Integral Part of the Description)

TABLE 1

S1 - Acquisition
Taking a panoramic image by means of a still digital camera or a digital video camera equipped with a panoramic objective lens having a non-linear distribution function Fd
S2 - Transfer of the image file into a computer
Transfer of the image file (image disk) into a microcomputer Storage in the auxiliary storage (optional)
S3 - Linearisation of the image disk
Transfer of the image points of the initial image disk into a second virtual image disk comprising more image points than the initial image disk, by means of the function Fd^{-1} ⇒ Obtaining a linear image disk
S4 - Digitization
Transfer of the image points of the second image disk into a system of axes OXYZ in spherical coordinates ⇒ Obtaining a panoramic image in a hemisphere
S5 - Interactive display
Determination of the image points of an image sector to be displayed Display of the image sector on a display window Detection of the user's actions on a screen pointer or any other control means, Detection of the user's actions on keys for image enlargement, Modification of the sector displayed (sliding the image sector displayed on the surface of the hemisphere and/or shrinking/expanding the image sector displayed)

TABLE 2

S1 - Acquisition

Taking a panoramic image by means of a still digital camera or a digital video camera equipped with a panoramic objective lens having a non-linear distribution function Fd

S2 - Transfer of the image file into a computer

Transfer of the image file (image disk) into a microcomputer
Storage in the auxiliary storage (optional)

S3' - Interactive display with implicit correction of the non-linearity of the initial image

A - Determination of the color of the points E(i, j) of an image sector to be displayed using the points p(pu, pv) of the image disk:
1 - determination of the coordinates Ex, Ey, Ez in the coordinate system OXYZ of each point E(i, j) of the sector to be displayed,
2 - determination of the coordinates Px, Py, Pz of points P of the hemisphere corresponding to the points E(i, j),
3 - calculation of the coordinates, in the coordinate system O'UV of the image disk, of points p(pu, pv) corresponding to the points P of the hemisphere, by means of the function Fd,
B - Presentation of the image sector in a display window,
C - Detection of the user's actions on a screen pointer or any other control means,
D - Detection of the user's actions on enlargement keys,
E - Modification of the image sector displayed (moving and/or shrinking/expanding the image sector)

We claim:

1. A method for capturing a digital panoramic image, by projecting a panorama onto an image sensor by means of a panoramic objective lens, the panoramic objective lens having an image point distribution function that is not linear relative to the field angle of object points of the panorama, the distribution function having a maximum divergence of at least ±10% compared to a linear distribution function, such that the panoramic image obtained has at least one substantially expanded zone and at least one substantially compressed zone.

2. The method according to claim 1, wherein the objective lens has a non-linear distribution function that is symmetrical relative to the optical axis of the objective lens, the position of an image point relative to the center of the image varying according to the field angle of the corresponding object point.

3. The method according to claim 1, wherein the objective lens expands the center of the image and compresses the edges of the image.

4. The method according to claim 1, wherein the objective lens expands the edges of the image and compresses the center of the image.

5. The method according to claim 1, wherein the objective lens compresses the center of the image and the edges of the image and expands an intermediate zone of the image located between the center and the edges of the image.

6. The method according to claim 1, wherein the objective lens comprises a set of lenses forming an apodizer.

7. The method according to claim 6, wherein the set of lenses forming an apodizer comprises at least one aspherical lens.

8. The method according to claim 6, wherein the set of lenses forming an apodizer comprises at least one diffractive lens.

9. The method according to claim 1, wherein the objective lens comprises a set of mirrors including at least one distorting mirror.

10. A method for displaying an initial panoramic image obtained in accordance with the method according to claim 1, the method for displaying comprising:

correcting the non-linearity of the initial image, performed by means of a reciprocal function of the non-linear distribution function of the objective lens or by means of the non-linear distribution function.

11. The method according to claim 10, wherein the step of correcting comprises a step of transforming the initial image into a corrected digital image comprising a number of image points higher than the number of pixels that the image sensor comprises.

12. The method according to claim 11, further comprising:

calculating the size of the corrected image, by means of the reciprocal function of the distribution function, so that the resolution of the corrected image is equivalent to the most expanded zone of the initial image, and

scanning each image point of the corrected image, searching for the position of a twin point of the image point on the initial image and allocating the color of the twin point to the image point of the corrected image.

13. The method according to claim 11, wherein the initial image and the corrected image comprise an image disk.

14. The method according to claim 11, further comprising:

transferring the image points of the corrected image into a three-dimensional space, and

presenting one sector of the three-dimensional image obtained on a display means.

15. The method according to claim 10, further comprising:

determining the color of image points of a display window, by projecting the image points of the display window onto the initial image by means of the non-linear distribution function, and

allocating to each image point of the display window the color of an image point that is the closest on the initial image.

16. The method according to claim 15, wherein the projection of the image points of the display window onto the initial image comprises:

projecting the image points of the display window onto a sphere or a sphere portion,

determining the angle in relation to the center of the sphere or the sphere portion of each projected image point, and

projecting onto the initial image each image point projected onto the sphere or the sphere portion, the projection being performed by means of the non-linear distribution function considering the field angle that each point to be projected has in relation to the center of the sphere or the sphere portion.

17. A panoramic objective lens comprising:

optical means for projecting a panorama into an image plane of the objective lens, the optical means having an image point distribution function that is not linear relative to the field angle of object points of the panorama, the distribution function having a maximum divergence of at least ±10% compared to a linear distribution function, such that a panoramic image obtained by means of the objective lens comprises at least one substantially expanded zone and at least one substantially compressed zone.

18. The panoramic objective lens according to claim 17, having a non-linear distribution function that is symmetrical relative to the optical axis of the objective lens, the position of an image point relative to the center of an image obtained varying according to the field angle of the corresponding object point.

19. The panoramic objective lens according to claim **17**, wherein the lens expands the center of an image and compresses the edges of the image.

20. The panoramic objective lens according to claim **17**, wherein the lens expands the edges of an image and compresses the center of the image.

21. The panoramic objective lens according to claim **17**, wherein the lens compresses the center of the image and the edges of the image, and expands an intermediate zone of the image located between the center and the edges of the image.

22. The panoramic objective lens according to claim **17**, further comprising a set of lenses forming an apodizer.

23. The panoramic objective lens according to claim **22**, wherein the set of lenses forming an apodizer comprises at least one aspherical lens.

24. The panoramic objective lens according to claim **22**, wherein the set of lenses forming an apodizer comprises at least one diffractive lens.

25. The panoramic objective lens according to claim **22**, comprising polymethacrylate lenses.

26. The panoramic objective lens according to claim **17**, comprising a set of mirrors comprising at least one distorting mirror.

* * * * *

UNITED STATES PATENT AND TRADEMARK OFFICE

CERTIFICATE OF CORRECTION

PATENT NO. : 6,844,990 B2 Page 1 of 1
DATED : January 18, 2005
INVENTOR(S) : Jean-Claude Artonne et al.

It is certified that error appears in the above-identified patent and that said Letters Patent is hereby corrected as shown below:

<u>Column 2,</u>
Line 34, "ax" should be replaced with -- α --;

<u>Column 13,</u>
Line 17, "a" should be replaced with -- α --;

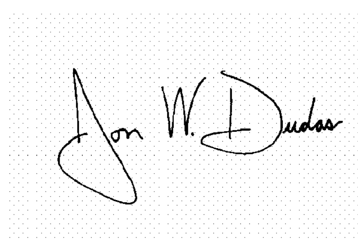
<u>Column 14,</u>
Line 65, "a" should be replaced with -- α --;

<u>Column 16,</u>
Line 62, the formula should read:

$$-- z(r) = \{(C*r^2)/(1 + \sqrt{}(1-(1+k)*C^2*r^2)] + A_1r^2 + A_2r^4 + A_3r^6 + A_4r^8 + A_5r^{10} --.$$

Signed and Sealed this

Twenty-fourth Day of May, 2005



JON W. DUDAS
Director of the United States Patent and Trademark Office

PTO/SB/57 (08-13)
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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.

(Also referred to as FORM PTO-1465)

REQUEST FOR *EX PARTE* REEXAMINATION TRANSMITTAL FORM

Address to:
Mail Stop *Ex Parte* Reexam
Commissioner for Patents
P.O. Box 1450
Alexandria, VA 22313-1450

Attorney Docket No.: 688266-21RX

Date: November 26, 2014

1. [x] This is a request for *ex parte* reexamination pursuant to 37 CFR 1.510 of patent number 6,844,990 issued January 18, 2005. The request is made by:
   [x] patent owner. [ ] third party requester.

2. [x] The name and address of the person requesting reexamination is:

   6115187 Canada Inc.
   2020 University Street
   Suite 2320
   Montreal, Quebec H3A 2A5
   CANADA

3. Requester claims [ ] small entity (37 CFR 1.27) or [ ] micro entity status (37 CFR 1.29) - only a patent owner requester can claim micro entity status.

4. [ ] a. A check in the amount of $ ________ is enclosed to cover the reexamination fee, 37 CFR 1.20(c)(1);
   [ ] b. The Director is hereby authorized to charge the fee as set forth in 37 CFR 1.20(c)(1) to Deposit Account No. ____________ ;
   [ ] c. Payment by credit card. Form PTO-2038 is attached; **or**
   [x] d. Payment made via EFS-Web.

5. [ ] Any refund should be made by [ ] check or [ ] credit to Deposit Account No. ____________ . 37 CFR 1.26(c). If payment is made by credit card, refund must be to credit card account.

6. [x] A copy of the patent to be reexamined having a double column format on one side of a separate paper is enclosed. 37 CFR 1.510(b)(4).

7. [ ] CD-ROM or CD-R in duplicate, Computer Program (Appendix) or large table
   [ ] Landscape Table on CD

8. [ ] 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 (2 copies) or CD-R (2 copies); **or**
      ii. [ ] paper
   c. [ ] Statements verifying identity of above copies

9. [x] A copy of any disclaimer, certificate of correction or reexamination certificate issued in the patent is included.

10. [x] Reexamination of claim(s) 1-4, 6-7, 10-11, 15-20, 22-23, and 25 is requested.

11. [x] A copy of every patent or printed publication relied upon is submitted herewith including a listing thereof on Form PTO/SB/08, PTO-1449, or equivalent.

12. [x] An English language translation of all necessary and pertinent non-English language patents and/or printed publications is included.

13. [x] The attached detailed request includes at least the following items:
   a. A statement identifying each substantial new question of patentability based on prior patents and printed publications. 37 CFR 1.510(b)(1).
   b. An identification of every claim for which reexamination is requested, and a detailed explanation of the pertinency and manner of applying the cited art to every claim for which reexamination is requested. 37 CFR 1.510(b)(2).

14. [x] A proposed amendment is included (only where the patent owner is the requester). 37 CFR 1.510(e).

15. [ ] a. It is certified that a copy of this request (if filed by other than the patent owner) has been served in its entirety on the patent owner as provided in 37 CFR 1.33(c).
   The name and address of the party served and the date of service are:

   Date of Service: ____________________ ; **or**

   [ ] b. A duplicate copy is enclosed since service on patent owner was not possible. An explanation of the efforts made to serve patent owner **is attached**. <u>See</u> MPEP § 2220.

16. Correspondence Address: Direct all communication about the reexamination to:

[x] The address associated with Customer Number: 00570

OR

[ ] Firm or Individual Name: PANITCH SCHWARZE BELISARIO & NADEL LLP

Address

City	Philadelphia	State	PA	Zip	19103
Country	US				
Telephone	(215) 965-1330	Email	usptomail@panitchlaw.com		

17. [ ] The patent is currently the subject of the following concurrent proceeding(s):
   [ ] a. Copending reissue Application No. ____________________
   [ ] b. Copending reexamination Control No. ____________________
   [ ] c. Copending Interference No. ____________________
   [ ] d. Copending litigation styled:

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.

/Stephen E. Murray/	November 26, 2014
Authorized Signature	Date
Stephen E. Murray	63,206
Typed/Printed Name	Registration No.

[x] For Patent Owner Requester

[ ] For Third Party Requester

Docket No.: 688266-21RX

IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

In re Patent of:
Jean-Claude ARTONNE et al.

Patent No.: 6,844,990 B2

Issue Date: January 18, 2005

For: METHOD FOR CAPTURING AND DISPLAYING A VARIABLE RESOLUTION DIGITAL PANORAMIC IMAGE

REQUEST BY PATENT OWNER FOR *EX PARTE* REEXAMINATION OF U.S. PATENT NO. 6,844,990

6115187 Canada Inc. ("Immervision") hereby respectfully requests *ex parte* reexamination under 35 U.S.C. § 302 and 37 C.F.R. § 1.510 of claims 1-4, 6-7, 10-11, 15-20, 22-23, and 25 of U.S. Patent No. 6,844,990 B2 ("the '990 patent") filed on November 12, 2003 by Jean-Claude Artonne, *et al*. and assigned to Immervision. The '990 patent is a continuation of International Patent Application No. PCT/FR02/01588, filed on May 10, 2002, which claims priority to French Patent Application No. FR 01-06261, filed on May 11, 2001. The '990 patent was issued on January 18, 2005 and is still in force. A copy of the '990 patent is attached hereto as Exhibit 1.

Payment of the fee for reexamination is included herewith. If any additional fee is due, please charge such fee to Deposit Account No. 50-1017.

I. Identification of Prior Art

The following patents and publications form the basis of the current request for *ex parte* reexamination:

1. *U.S. Patent No. 6,128,145 of Nagaoka*[1] *("Nagaoka")*: Nagaoka issued on October 3, 2000, more than one year before the earliest priority date (May 10, 2002) of the '990 patent. Thus, Nagaoka qualifies as prior art to the '990 patent under 35 U.S.C. §§ 102(b) and 103(a).[2]

2. *U.S. Patent No. 5,686,957 of Baker*[3] *("Baker")*: Baker issued on November 11, 1997, more than one year before the earliest priority date (May 10, 2002) of the '990 patent. Thus, Baker qualifies as prior art to the '990 patent under 35 U.S.C. §§ 102(b) and 103(a).

3. *U.S. Patent No. 3,953,111 of Fisher, et al.*[4] *("Fisher")*: Fisher issued on April 27, 1976, more than one year before the earliest priority date (May 10, 2002) of the '990 patent. Thus, Fisher qualifies as prior art to the '990 patent under 35 U.S.C. §§ 102(b) and 103(a).

4. *European Patent Publication No. EP 1 028 389 A2*[5] *("Shiota")*: Shiota was published on August 16, 2000, more than one year before the earliest priority date (May 10, 2002) of the '990 patent. Thus, Shiota qualifies as prior art to the '990 patent under §§ 102(b) and 103(a).

5. *Japanese Patent Publication No. JP 2000-242773*[6] *("Matsui")*: Matsui was published on September 8, 2000, more than one year before the earliest priority date (May 10, 2002) of the '990 patent. Thus, Matsui qualifies as prior art to the '990 patent under §§ 102(b) and 103(a).

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[1] Copy attached as Exhibit 2.
[2] All references to 35 U.S.C. §§ 102 and 103 herein are with respect to pre-AIA versions thereof.
[3] Copy attached as Exhibit 3.
[4] Copy attached as Exhibit 4.
[5] Copy attached as Exhibit 5.
[6] Copy of Japanese Publication attached as Exhibit 6a, a certified English translation thereof is attached as Exhibit 6b.

6. *Japanese Patent Publication No. JP H11-261868*[7] *("Enami")*: Enami was published on September 24, 1999, more than one year before the earliest priority date (May 10, 2002) of the '990 patent. Thus, Enami qualifies as prior art to the '990 patent under §§ 102(b) and 103(a).

7. *U.S. Patent No. 6,031,670 of Inoue*[8] *("Inoue")*: Inoue issued on February 29, 2000, more than one year before the earliest priority date (May 10, 2002) of the '990 patent. Thus, Inoue qualifies as prior art to the '990 patent under 35 U.S.C. §§ 102(b) and 103(a).

II. Identification of Claims for Which Reexamination is Requested

Reexamination is requested of claims 1-4, 6-7, 10-11, 15-20, 22-23, and 25 of the '990 patent in view of the prior art patents and printed publications listed below:

1. Reexamination of claims 1-2, 4, 6, 17-18, 20, and 22 is requested in view of Nagaoka.
2. Reexamination of claims 1-2, 4, 6, 17-18, 20, and 22 is requested in view of Baker.
3. Reexamination of claims 1-3, 6-7, 17-19, and 22-23 is requested in view of Fisher.
4. Reexamination of claims 10-11 is requested in view of Nagaoka in view of Shiota.
5. Reexamination of claim 10 is requested in view of Nagaoka in view of Matsui.
6. Reexamination of claims 10-11 is requested in view of Baker in view of Shiota.
7. Reexamination of claims 15-16 is requested in view of Nagaoka in view of Shiota and in further view of Enami.
8. Reexamination of claims 15-16 is requested in view of Baker in view of Shiota and in further view of Enami.
9. Reexamination of claim 25 is requested in view of Nagaoka in view of Inoue.
10. Reexamination of claim 25 is requested in view of Baker in view of Inoue.

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[7] Copy of Japanese Publication attached as Exhibit 7a, a certified English translation thereof is attached as Exhibit 7b.

[8] Copy attached as Exhibit 8.

III. Showing of Each Substantial New Question of Patentability

A. Nagaoka

Nagaoka was not of record in the file of the '990 patent, although its European equivalent (EP 1 004 915) was cited to the Examiner. Nagaoka discloses a monitoring system utilizing a fisheye lens 1 in conjunction with a camera 2 for image capture. The fisheye lens 1 may include one of several "non-linear" image point distribution functions, including ones having a maximum divergence from a linear distribution function of more than 10%, such as h = 1.2f tan(/1.6) and h = 1.6f tan(/2). These equations give the fisheye lens 1 an "expanded" zone near the periphery of the image and a "compressed zone" near the center of the image. (Nagaoka at Figs. 2, 3A-3B, 4A; col. 3, ln. 63-col. 4, ln. 15; col. 5, lns. 13-27). Because Nagaoka provides subject matter of claims 1-2, 4, 6, 17-18, 20, and 22 of the '990 patent, and the Examiner appears to have overlooked relevant portions of the disclosure of Nagaoka's European equivalent, the teachings of Nagaoka raise a substantial new question of patentability with respect to claims 1-2, 4, 6, 17-18, 20, and 22.

B. Baker

Baker was not of record in the file of the '990 patent, although its European equivalent (EP 0 695 085) was cited to the Examiner. Baker discloses a camera 10 having a lens 14 designed to capture and enhance peripheral content of a hemispheric scene, thereby compressing the center and expanding the periphery of the image. An example provided by Baker states that the lens would focus the lowest fifteen (15) degrees up from the horizon on fifty (50) percent of the imager area, which is greater than a 10% divergence from a linear distribution function. (Baker at Figs. 1, 3BA, 3BB; col. 6, lns. 48-56; col. 8, ln. 58-col. 9, ln. 4). Because Baker provides subject matter of claims 1-2, 4, 6, 17-18, 20, and 22 of the '990 patent, and the Examiner appears to have overlooked relevant portions of the disclosure of Baker's European equivalent, the teachings of Baker raise a substantial new question of patentability with respect to claims 1-2, 4, 6, 17-18, 20, and 22.

C. Fisher

Fisher was of record in the file of the '990 patent, but the Examiner appears to have overlooked certain aspects of the disclosure in Fisher that are relevant to various claims of the '990 patent. Fisher discloses a non-linear panoramic objective lens having three lens groupings A, B, C. The first grouping A provides a mapping function having a formula of $H = \sin^{1/3}$, which expands the center of the image and compresses the periphery thereof. (Fisher at Figs. 3, 6; col. 3, lns. 8-12; col. 5, lns. 52-60). Because Fisher provides subject matter of claims 1-3, 6-7, 17-19, and 22-23 of the '990 patent, and the Examiner appears to have overlooked relevant portions of the disclosure of Fisher, the teachings of Fisher raise a substantial new question of patentability with respect to claims 1-3, 6-7, 17-19, and 22-23.

D. Nagaoka and Shiota

As described above, Nagaoka itself was not of record in the file of the '990 patent, although a European equivalent was considered by the Examiner.

Shiota was not of record in the file of the '990 patent. Shiota discloses an arithmetic unit that transforms an image captured by a fisheye lens into a plane image for display. Points X_2, Y_2 on a plane are mapped to projection coordinates p1, q1 on an image pickup surface using an equation relying on k_2, which is derived using the distribution function (e.g., F( )). (Shiota at Fig. 1; paras. [0001], [0022], [0028]-[0041]).

Because the teachings of Nagaoka and Shiota, taken together, provide subject matter of claims 10-11 of the '990 patent, and because the Examiner did not have the benefit of examining Shiota in combination with the European equivalent of Nagaoka, Nagaoka and Shiota present a substantial new question of patentability with respect to claims 10-11.

E. Nagaoka and Matsui

As described above, Nagaoka itself was not of record in the file of the '990 patent, although a European equivalent was considered by the Examiner.

Matsui was not of record in the file of the '990 patent. Matsui discloses conversion of image data captured using a fisheye lens onto a converted cylindrical surface. The position on the captured image can be mapped with a point on the cylindrical surface using the distribution function, which in the example of Matsui is given as h = 2f tan(/2). (Matsui at Figs. 2-4, 6; translation at Abstract; para. [0025]).

Because the teachings of Nagaoka and Matsui, taken together, provide subject matter of claim 10 of the '990 patent, and because the Examiner did not have the benefit of examining Matsui in combination with the European equivalent of Nagaoka, Nagaoka and Matsui present a substantial new question of patentability with respect to claim 10.

F. Baker and Shiota

As described above, Baker itself was not of record in the file of the '990 patent, although a European equivalent was considered by the Examiner. As further described above, Shiota was not of record in the file of the '990 patent.

Because the teachings of Baker and Shiota, taken together, provide subject matter of claims 10-11 of the '990 patent, and because the Examiner did not have the benefit of examining Shiota in combination with the European equivalent of Baker, Baker and Shiota present a substantial new question of patentability with respect to claims 10-11.

G. Nagaoka, Shiota, and Enami

As described above, Nagaoka itself was not of record in the file of the '990 patent, although a European equivalent was considered by the Examiner. As further described above, Shiota was not of record in the file of the '990 patent.

Enami was also not of record in the file of the '990 patent. Enami discloses a fisheye lens apparatus and an image distortion correction method. The correction method includes extracting color information from the original image through projection using the distribution function and assigning the appropriate colors on the display point. (Enami at Figs. 2-4; translation at paras. [0072]-[0074], [0084]-[0085]).

Because the teachings of Nagaoka, Shiota, and Enami, taken together, provide subject matter of claims 15-16 of the '990 patent, and because the Examiner did not have the benefit of examining Enami in combination with the European equivalent of Nagaoka, Nagaoka, Shiota, and Enami present a substantial new question of patentability with respect to claims 15-16.

H. Baker, Shiota, and Enami

As described above, Baker itself was not of record in the file of the '990 patent, although a European equivalent was considered by the Examiner. As further described above, neither Shiota nor Enami was of record in the file of the '990 patent.

Because the teachings of Baker, Shiota, and Enami, taken together, provide subject matter of claims 15-16 of the '990 patent, and because the Examiner did not have the benefit of examining Enami in combination with the European equivalent of Baker, Baker, Shiota, and Enami present a substantial new question of patentability with respect to claims 15-16.

I. Nagaoka and Inoue

As described above, Nagaoka itself was not of record in the file of the '990 patent, although a European equivalent was considered by the Examiner.

Inoue was not of record in the file of the '990 patent. Inoue discloses a wide angle lens that may be made from PMMA. (Inoue at col. 2, lns. 42-44).

Because the teachings of Nagaoka and Inoue, taken together, provide subject matter of claim 25 of the '990 patent, and because the Examiner did not have the benefit of examining Inoue in combination with the European equivalent of Nagaoka, Nagaoka and Inoue present a substantial new question of patentability with respect to claim 25.

J. Baker and Inoue

As described above, Baker itself was not of record in the file of the '990 patent, although a European equivalent was considered by the Examiner. As further described above, Inoue was not of record in the file of the '990 patent.

Because the teachings of Baker and Inoue, taken together, provide subject matter of claim 25 of the '990 patent, and because the Examiner did not have the benefit of examining Inoue in combination with the European equivalent of Baker, Baker and Inoue present a substantial new question of patentability with respect to claim 25.

IV. Detailed Explanation under 37 CFR § 1.510(b) of Pertinence and Manner of Applying Cited Prior Art to Every Claim for which Reexamination is Requested

A. Nagaoka

Each element of claims 1-2, 4, 6, 17-18, 20, and 22 is set forth in the attached "Detailed Explanation of Pertinency of Nagaoka and Claim Analysis Chart for U.S. Patent No. 6,844,990 B2" (Appendix A) with an explanation as to how Nagaoka is pertinent to the recited features of each of claims 1-2, 4, 6, 17-18, 20, and 22.

B. Baker

Each element of claims 1-2, 4, 6, 17-18, 20, and 22 is set forth in the attached "Detailed Explanation of Pertinency of Baker and Claim Analysis Chart for U.S. Patent No. 6,844,990 B2" (Appendix B) with an explanation as to how Baker is pertinent to the recited features of each of claims 1-2, 4, 6, 17-18, 20, and 22.

C. Fisher

Each element of claims 1-3, 6-7, 17-19, and 22-23 is set forth in the attached "Detailed Explanation of Pertinency of Fisher and Claim Analysis Chart for U.S. Patent No. 6,844,990 B2" (Appendix C) with an explanation as to how Baker is pertinent to the recited features of each of claims 1-3, 6-7, 17-19, and 22-23.

D. Nagaoka and Shiota

Nagaoka teaches a monitoring system with a fisheye lens having a non-linear distribution function which expands the peripheral edges of the captured image. A person of ordinary skill in the art would recognize the need to correct the image captured by Nagaoka. Shiota, in the same field of endeavor, teaches a method of transforming a captured image into a plane image for display using the non-linear distribution function. Thus, one of ordinary skill in the art would have had reason to consult Shiota for a method of de-warping the image captured by the fisheye lens of Nagaoka for presentation to a user.

Each element of claims 10-11 is set forth in the attached "Detailed Explanation of Pertinency of Nagaoka and Shiota and Claim Analysis Chart for U.S. Patent No. 6,844,990 B2" (Appendix D) with an explanation as to how Nagaoka and Shiota are pertinent to the recited features of each of claims 10-11.

E. Nagaoka and Matsui

Nagaoka teaches a monitoring system with a fisheye lens having a non-linear distribution function which expands the peripheral edges of the captured image. A person of ordinary skill in the art would recognize the need to correct the image captured by Nagaoka. Matsui, in the same field of endeavor, teaches a method of transforming a captured image into a plane image for display using the non-linear distribution function. Thus, one of ordinary skill in the art would have had reason to consult Matsui for a method of de-warping the image captured by the fisheye lens of Nagaoka for presentation to a user.

Each element of claim 10 is set forth in the attached "Detailed Explanation of Pertinency of Nagaoka and Matsui and Claim Analysis Chart for U.S. Patent No. 6,844,990 B2" (Appendix E) with an explanation as to how Nagaoka and Matsui are pertinent to the recited features of claim 10.

F. Baker and Shiota

Baker teaches a camera with a lens for capturing a hemispheric scene, emphasizing the periphery of the image. A person of ordinary skill in the art would recognize the need to correct the image captured by Baker. Shiota, in the same field of endeavor, teaches a method of transforming a captured image into a plane image for display using the non-linear distribution function. Thus, one of ordinary skill in the art would have had reason to consult Shiota for a method of de-warping the image captured by the panoramic lens of Baker for presentation to a user.

Each element of claims 10-11 is set forth in the attached "Detailed Explanation of Pertinency of Baker and Shiota and Claim Analysis Chart for U.S. Patent No. 6,844,990 B2"

(Appendix F) with an explanation as to how Baker and Shiota are pertinent to the recited features of each of claims 10-11.

G. Nagaoka, Shiota, and Enami

Nagaoka and Shiota, taken together, teach a monitoring system with a fisheye lens having a non-linear distribution function which expands the peripheral edges of the captured image, and which corrects the captured image for display to a user by utilizing the non-linear distribution function. Enami is in the same field of endeavor and teaches color allocation during the image correction process. One of ordinary skill in the art would have had reason to further modify Nagaoka in order to ensure that mapped coordinates were assigned the appropriate color value and provide a more accurate corrected image.

Each element of claims 15-16 is set forth in the attached "Detailed Explanation of Pertinency of Nagaoka, Shiota, and Enami and Claim Analysis Chart for U.S. Patent No. 6,844,990 B2" (Appendix G) with an explanation as to how Nagaoka, Shiota, and Enami are pertinent to the recited features of each of claims 15-16.

H. Baker, Shiota, and Enami

Baker and Shiota, taken together, teach a camera with a lens having a non-linear distribution function which expands the peripheral edges of the captured hemispheric image, and which corrects the captured image for display to a user by utilizing the non-linear distribution function. Enami is in the same field of endeavor and teaches color allocation during the image correction process. One of ordinary skill in the art would have had reason to further modify Baker in order to ensure that mapped coordinates were assigned the appropriate color value and provide a more accurate corrected image.

Each element of claims 15-16 is set forth in the attached "Detailed Explanation of Pertinency of Baker, Shiota, and Enami and Claim Analysis Chart for U.S. Patent No. 6,844,990 B2" (Appendix H) with an explanation as to how Baker, Shiota, and Enami are pertinent to the recited features of each of claims 15-16.

I. Nagaoka and Inoue

Nagaoka teaches a monitoring system with a fisheye lens having a non-linear distribution function which expands the peripheral edges of the captured image. Inoue, in the same field of endeavor, teaches that material and manufacturing costs may be reduced using PMMA to manufacture the wide angle lens. (Inoue at col. 2, lns. 42-44). The '990 patent equates PMMA and polymethacrylate. One of ordinary skill in the art would have had reason to manufacture the fisheye lens of Nagaoka out of polymethacrylate, based on Inoue.

Each element of claim 25 is set forth in the attached "Detailed Explanation of Pertinency of Nagaoka and Inoue and Claim Analysis Chart for U.S. Patent No. 6,844,990 B2" (Appendix I) with an explanation as to how Nagaoka and Inoue are pertinent to the recited features of claim 25.

J. Baker and Inoue

Baker teaches a camera with a lens for capturing a hemispheric scene, emphasizing the periphery of the image. Inoue, in the same field of endeavor, teaches that material and manufacturing costs may be reduced using PMMA to manufacture the wide angle lens. (Inoue at col. 2, lns. 42-44). The '990 patent equates PMMA and polymethacrylate. One of ordinary skill in the art would have had reason to manufacture the fisheye lens of Baker out of polymethacrylate, based on Inoue.

Each element of claim 25 is set forth in the attached "Detailed Explanation of Pertinency of Baker and Inoue and Claim Analysis Chart for U.S. Patent No. 6,844,990 B2" (Appendix J) with an explanation as to how Baker and Inoue are pertinent to the recited features of claim 25.

V. Notification of Existence of Prior or Concurrent Proceedings and Decisions Thereon Under 37 C.F.R. § 1.565(a)

The '990 patent was previously asserted in a case entitled *Immervision, Inc. v. Vivotek, Inc., et al.*, Civil Action No. 2:13-cv-01117, filed in the United States District Court for the District of Nevada. The case was dismissed pursuant to a settlement between the parties on September 27, 2013.

The '990 patent was also previously asserted in a case entitled *6115187 Canada, Inc. d/b/a Immervision, Inc. v. CBC. Co., Ltd., et al.*, Civil Action No. 13-cv-1139, filed in the United States District Court for the District of Delaware. The case was dismissed pursuant to a settlement between the parties on August 5, 2014.

A petition for *inter partes* review of the '990 patent was filed on September 3, 2014, the record for which is electronically available through the Patent Review Processing System (PRPS) under Case No. IPR2014-01438. The proceeding was dismissed on November 26, 2014, prior to institution, pursuant to a joint motion to terminate as a result of a settlement between the parties.

There are presently no ongoing proceedings involving the '990 patent.

VI. Conclusion

In view of the foregoing and related Exhibits 1-8b and Appendices A-J, *ex parte* reexamination of claims 1-4, 6-7, 10-11, 15-20, 22-23, and 25 of the '990 patent is respectfully requested.

Dated: November 26, 2014

Respectfully submitted,

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Docket No.: 688266-21RX

IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

In re Patent of:
Jean-Claude ARTONNE et al.

Patent No.: 6,844,990 B2

Issue Date: January 18, 2005

For: METHOD FOR CAPTURING AND DISPLAYING A VARIABLE RESOLUTION DIGITAL PANORAMIC IMAGE

PROPOSED AMENDMENT UNDER 37 C.F.R. §§ 1.510(e) AND 1.530

This proposed amendment is being submitted pursuant to 37 C.F.R. §§ 1.510(e) and 1.530 in connection with the concurrently filed request for *ex parte* reexamination of the above-identified patent.

Prior to reexamination, please amend the above-identified U.S. patent as follows:

Amendments to and Listing of Claims Subject to Reexamination begin on page 2 of this paper.

Remarks/Arguments begin on page 10 of this paper.

AMENDMENTS TO AND LISTING OF CLAIMS SUBJECT TO REEXAMINATION

The following listing of claims subject to reexamination replaces all prior versions, and listings, of claims subject to reexamination.

1. (Cancelled).

2. (Amended) The method according to claim [1] <u>27</u>, wherein the objective lens has a non-linear distribution function that is symmetrical relative to the optical axis of the objective lens, the position of an image point relative to the center of the image varying according to the field angle of the corresponding object point.

3. (Amended) The method according to claim [1] <u>27</u>, wherein the objective lens expands the center of the image and compresses the edges of the image.

4. (Amended) The method according to claim [1] <u>27</u>, wherein the objective lens expands the edges of the image and compresses the center of the image.

5. (Not Subject to Reexamination).

6-7. (Cancelled).

8-9. (Not Subject to Reexamination).

10. (Amended) A method for displaying an initial panoramic image obtained in accordance with the method according to claim 1, the method for displaying comprising: correcting the non-linearity of the initial image, performed by means of a reciprocal function of the non-linear distribution function of the objective lens [or by means of the non-linear distribution function].

11. (Original) The method according to claim 10, wherein the step of correcting comprises a step of transforming the initial image into a corrected digital image comprising a number of image points higher than the number of pixels that the image sensor comprises.

12-14. (Not Subject to Reexamination).

15. (Amended) The method according to claim [10] <u>27</u>, further comprising:

determining the color of image points of a display window, by projecting the image points of the display window onto the initial image by means of the non-linear distribution function, and

allocating to each image point of the display window the color of an image point that is the closest on the initial image.

16. (Original) The method according to claim 15, wherein the projection of the image points of the display window onto the initial image comprises:

projecting the image points of the display window onto a sphere or a sphere portion,

determining the angle in relation to the center of the sphere or the sphere portion of each projected image point, and

projecting onto the initial image each image point projected onto the sphere or the sphere portion, the projection being performed by means of the non-linear distribution function considering the field angle that each point to be projected has in relation to the center of the sphere or the sphere portion.

17. (Original) A panoramic objective lens comprising: optical means for projecting a panorama into an image plane of the objective lens, the optical means having an image point distribution function that is not linear relative to the field angle of object points of the panorama, the distribution function having a maximum divergence of at least +/- 10% compared to a linear distribution function, such that a panoramic image obtained by means of the objective lens

comprises at least one substantially expanded zone and at least one substantially compressed zone.

18. (Original) The panoramic objective lens according to claim 17, having a non-linear distribution function that is symmetrical relative to the optical axis of the objective lens, the position of an image point relative to the center of an image obtained varying according to the field angle of the corresponding object point.

19. (Original) The panoramic objective lens according to claim 17, wherein the lens expands the center of an image and compresses the edges of the image.

20. (Original) The panoramic objective lens according to claim 17, wherein the lens expands the edges of an image and compresses the center of the image.

21. (Not Subject to Reexamination).

22. (Cancelled).

23. (Original) The panoramic objective lens according to claim 22, wherein the set of lenses forming an apodizer comprises at least one aspherical lens.

24. (Not Subject to Reexamination).

25. (Original) The panoramic objective lens according to claim 22, comprising polymethacrylate lenses.

26. (Not Subject to Reexamination).

27. (New) A method for displaying a digital panoramic image, the method comprising:

obtaining a digital panoramic image by projecting a panorama onto an image sensor using a panoramic objective lens, the panoramic objective lens having an image point distribution function that is not linear relative to a field angle of object points of the panorama, the distribution function having a maximum divergence of at least +/- 10% compared to a linear distribution function, such that the panoramic image obtained has at least one expanded zone and at least one compressed zone; and

displaying the obtained panoramic image by correcting the non-linearity of the initial image, performed by retrieving image points on the obtained image in a coordinate system of center O' using at least the non-linear distribution function and a size L of the obtained image.

28. (New) The method according to claim 27, wherein the objective lens compresses the center of the image and the edges of the image and expands an intermediate zone of the image located between the center and the edges of the image.

29. (New) The method according to claim 27, wherein the objective lens comprises a set of lenses forming an apodizer.

30. (New) The method according to claim 29, wherein the set of lenses forming an apodizer comprises at least one aspherical lens.

31. (New) The method according to claim 27, wherein the step of correcting comprises a step of transforming the initial image into a corrected digital image comprising a number of image points higher than the number of pixels that the image sensor comprises.

32. (New) A panoramic objective lens comprising:

a set of lenses configured to project a panorama into an image plane of the objective lens, the panoramic objective lens having an image point distribution function that is not linear relative to a field angle of object points of the panorama, the distribution function having a maximum divergence of at least +/- 10% compared to a linear distribution function, such that a panoramic image obtained using the objective lens comprises at least one expanded zone and at least one compressed zone,

wherein the panoramic image obtained by the objective lens is configured to be corrected by retrieving image points on the obtained image in a coordinate system of center O' using at least the non-linear distribution function, and a size L of the obtained image.

33. (New) The lens according to claim 32, wherein the objective lens has a non-linear distribution function that is symmetrical relative to the optical axis of the objective lens, the position of an image point relative to the center of the image varying according to the field angle of the corresponding object point.

34. (New) The lens according to claim 32, wherein the objective lens expands the center of the image and compresses the edges of the image.

35. (New) The lens according to claim 32, wherein the objective lens expands the edges of the image and compresses the center of the image.

36. (New) The lens according to claim 32, wherein the objective lens compresses the center of the image and the edges of the image and expands an intermediate zone of the image located between the center and the edges of the image.

37. (New) The lens according to claim 32, wherein the set of lenses comprises at least one aspherical lens.

38. (New) A method for capturing a digital panoramic image, by projecting a panorama onto an image sensor using a panoramic objective lens, the panoramic objective lens having an image point distribution function that is not linear relative to the field angle of object

points of the panorama, the distribution function having a maximum divergence of at least 10% compared to a linear distribution function, such that the panoramic image obtained has at least one expanded zone and at least two compressed zones.

39. (New) The method according to claim 38, wherein the objective lens has a non-linear distribution function that is symmetrical relative to the optical axis of the objective lens, the position of an image point relative to the center of the image varying according to the field angle of the corresponding object point.

40. (New) A method for displaying an initial panoramic image obtained in accordance with the method according to claim 38, the method for displaying comprising: correcting the non-linearity of the initial image, performed using a reciprocal function of the non-linear distribution function of the objective lens or using the non-linear distribution function.

41. (New) The method according to claim 40, wherein the step of correcting comprises a step of transforming the initial image into a corrected digital image comprising a number of image points higher than the number of pixels that the image sensor comprises.

42. (New) The method according to claim 41, further comprising:

calculating the size of the corrected image, using the reciprocal function of the distribution function, so that the resolution of the corrected image is equivalent to the most expanded zone of the initial image, and

scanning each image point of the corrected image, searching for the position of a twin point of the image point on the initial image and allocating the color of the twin point to the image point of the corrected image.

43. (New) The method according to claim 41, wherein the initial image and the corrected image comprise an image disk.

44. (New) The method according to claim 41, further comprising:

transferring the image points of the corrected image into a three-dimensional space, and presenting one sector of the three-dimensional image obtained on a display.

45. (New) The method according to claim 40, further comprising:

determining the color of image points of a display window, by projecting the image points of the display window onto the initial image using the non-linear distribution function, and

allocating to each image point of the display window the color of an image point that is the closest on the initial image.

46. (New) The method according to claim 45, wherein the projection of the image points of the display window onto the initial image comprises:

projecting the image points of the display window onto a sphere or a sphere portion,

determining the angle in relation to the center of the sphere or the sphere portion of each projected image point, and

projecting onto the initial image each image point projected onto the sphere or the sphere portion, the projection being performed using the non-linear distribution function considering the field angle that each point to be projected has in relation to the center of the sphere or the sphere portion.

47. (New) The method according to claim 38, wherein the objective lens compresses at least one zone near the center and at least one zone near the edge, and expands at least one intermediate zone of the image between the center and the edge of the image.

48. (New) A method for capturing a digital panoramic image, by projecting a panorama onto an image sensor by means of a panoramic objective lens, the panoramic objective lens having an image point distribution function that is not linear relative to the field angle of object points of the panorama, the distribution function having a maximum divergence of at least

+/-10% compared to a linear distribution function, such that the panoramic image obtained has at least one expanded zone and at least one compressed zone, wherein the objective lens has a non-linear distribution function that is not symmetrical relative to the optical axis of the objective lens.

REMARKS

Reexamination of claims 1-4, 6-7, 10-11, 15-20, 22-23, and 25 of U.S. Patent No. 6,844,990 ("the '990 Patent") has been requested. By virtue of the present proposed amendment, claims 27-48 have been added. Claims 1, 6-7, and 22 have been cancelled. Claim 10 has been amended to clarify the invention. Claims 2-4 and 15 have been amended for formalities only.

Status of Patent Claims pursuant to 37 C.F.R. § 1.530(e):

1, 6-7, and 22 – cancelled;
2-4, 10-11, 15-20, 23, and 25 – pending (reexamination requested);
5, 8-9, 12-14, 21, 24, and 26 – not subject to reexamination; and
27-48 – added (new).

No new matter has been added by the claim amendments and the amendments do not enlarge the scope of the original claims. Claim 10 was amended solely to remove one of the alternatives for correcting the non-linearity of the initial image. Claims 2-4 and 15 were amended to depend from new claim 27. Support for the new claims is provided in the chart below:

New Claim	Support Citations in '990 patent
27	Original claim 1; col. 12, ln. 59-col. 14, ln. 35
28	Original claim 5
29	Original claim 6
30	Original claim 7
31	Original claim 11
32	Original claim 17; col. 12, ln. 59-col. 14, ln. 35; col. 16, ln. 1-col. 17, ln.34; Figs. 15-16
33	Original claim 2
34	Original claim 3
35	Original claim 4
36	Original claim 5
37	Original claim 7; col. 16, lns. 31-61
38	Original claims 1 and 5; col. 9, ln. 53-col. 10, ln. 5; Fig. 9
39	Original claim 2
40	Original claim 10

New Claim	Support Citations in '990 patent
41	Original claim 11
42	Original claim 12
43	Original claim 13
44	Original claim 14
45	Original claim 15
46	Original claim 16
47	Original claim 5
48	Original claim 1; col. 18, lns. 17-28

Accordingly, entry of the proposed amendments to the claims is respectfully requested.

Claim 10

Claim 10 has been amended to remove "or by means of the non-linear distribution function." Thus, the only method remaining in claim 10 for correcting the non-linearity of the initial image is "by means of a reciprocal function of the non-linear distribution function of the objective lens." As described below, claim 10, as amended, would not have been obvious over the combinations of Nagaoka and Shiota, Nagaoka and Matsui, and Baker and Shiota proposed in the reexamination request

Neither Nagaoka nor Baker teaches a specific method for correcting the images captured by their respective panoramic lenses. Shiota discloses image correction through mapping of coordinates onto the image. The projection process includes the use of the non-linear distribution function of the lens to obtain certain coordinates. (Shiota at paras. [0001], [0022], [0028]-[0041]). However, in all instances, Shiota utilizes the non-linear distribution function itself, and does <u>not</u> teach the use of a reciprocal function of the non-linear distribution function as a way to correct the non-linearity of the initial image.

Matsui similarly discloses image correction by virtue of using the distribution function h = g( ), which can be non-linear (*see e.g.*, h = 2f·tan(/2)), to calculate points P1, P2 in projecting the image onto a cylindrical surface C. (Matsui at paragraphs [0023], [0025], [0030]-[0031]). Matsui, like Shiota, does not disclose using a <u>reciprocal</u> function of the non-linear distribution function to correct the original image. It has previously been suggested that paragraphs [0030]-

[0031] of Matsui teach this feature, but this assertion is incorrect. These paragraphs teach the use of the inverse tangent function when   is unknown. However, the distribution function itself is still used to obtain P1 and P2, but with a formula substituted in for . (Matsui at paras. [0030]-[0031]). A reciprocal of g( ) is not taught by Matsui for use in image correction.

When combining two or more references to establish a *prima facie* case of obviousness, the references together must teach or suggest all of the claim elements. *In re Royka*, 490 F.2d 981, 985 (C.C.P.A. 1974). Furthermore, "[a]ll words in a claim must be considered in judging the patentability of that claim against the prior art." *In re Wilson* 424 F.2d 1382, 1385 (CCPA 1970); M.P.E.P. § 2143.03. Accordingly, claim 10, as amended, would not have been obvious over any combination of Nagaoka and Shiota, Nagaoka and Matsui, or Baker and Shiota, because none of the combinations teaches or suggests correcting the non-linearity of the initial image by means of a reciprocal function of the non-linear distribution function of the objective lens. For at least this reason, Patent Owner submits that amended claim 10 is patentable over the cited references.

New Claims

Claims 27-48 are believed to be patentable over the references cited in the reexamination request for at least the following reasons.

Claims 2-4, 15, 16, and 27-37

Claim 27 recites that the non-linearity of the initial image is corrected by retrieving image points on the obtained image in a coordinate system of center O' using at least the non-linear distribution function and a size L of the obtained image. For example, the initial image may be in the form of an image disk having a size L, which may be provided in the number of pixels. Image points p (pu, pv) corresponding to image points E(i, j) of, for example, a display window, can be obtained using equations that multiply, among other things, the size of the image disk L with the non-linear distribution function at an angle □(*e.g.*, pu = L*U*Fd(□) and pv = L*V*Fd(□)). Claim 32 contains a similar recitation.

The references all fail to teach or suggest this feature of claims 27 or 32. As described above with respect to claim 10, Nagaoka, Baker, and Fisher do not describe any specific method for correcting the image. As for Shiota, the second projection points p_1 and q_1 are obtained using a coefficient k_2, which is equal to the distribution function divided by a distance r from the origin of the image disk to a point Q on the image disk. The coefficient k_2 is then multiplied by corresponding coordinates X_2, Y_2 on a hemisphere. (Shiota at Fig. 1; paras. [0033]-[0041]). The size of the image disk is not utilized to correct the image.

In Matsui, coordinates of a point P1 are obtained by multiplying the distribution function by cos □ and sin □, where □ represents an angle in the plane of the image disk of a point on the image disk. (Matsui at Figs 2-3; translation at paras. [0025], [0030]-[0031]). The size of the image disk is not taken into account for image correction. Enami also does not use the size of the image disk to correct the initial image. (Enami translation at paras. [0065]-[0074]). Inoue does not disclose any image correction techniques.

None of the other references teaches the use of the size of the image disk in correcting the non-linearity of the initial image. Accordingly, claims 27 and 32 are believed to be patentable over the references cited in the reexamination request. Claims 28-31 are dependent on claim 27, and claims 33-37 are dependent on claim 32. Thus, claims 28-31 and 33-37 are believed to be patentable over the references cited in the reexamination request due at least to their dependence on claim 38.

Moreover, based on the proposed amendments, claims 2-4 and 15-16 all depend from new claim 27, and are therefore believed to be patentable over the references cited in the reexamination request due at least to their dependence on claim 27.

Claims 38-47

Claim 38 recites that the panoramic image obtained using a panoramic objective lens has at least one expanded zone and at least two compressed zones. For example, Fig. 9 of the '990 patent shows a non-linear distribution function having a compressed zone between 0° and 30°, an expanded zone between 30° and 70°, and another compressed zone between 70° and 90°. None of the cited references discloses this feature.

In Nagaoka, only two of the illustrated distribution functions have both an expanded zone and a compressed zone (h = 1.6f tan(/2) and h = 1.2f tan(/1.6)). (See Nagaoka at Figs. 3A, 3B). This is demonstrated through the comparison of the slope at different angles compared with the linear distribution function (h = f). That is, shallower slopes indicate compression and steeper slopes indicate expansion. <u>None</u> of the distribution functions shown in Nagaoka have <u>two</u> compressed zones in addition to an expanded zone.

In Baker, no specific distribution function is given, but Baker's stated purpose is to compress the center of the image while expanding the periphery. (Baker at col. 8, lns. 32-62). Fig. 3BB shows only two zones in the image, one compressed (X') and the other expanded (Y'). Thus, Baker does not teach the image having at least two compressed zones in addition to an expanded zone.

Fisher uses the distribution function of $H = \sin^{1/3}$, which is plotted in Fig. 3 along with the linear distribution function. As can be seen from Fig. 3, Fisher's lens will create an expanded zone in the center, and <u>one</u> compressed zone starting at around 30° and extending to the edge. This is in accordance with Fisher's goal, which is to have objects near the optical axis of the lens occupy a disproportionately large area of the image sensor. (Fisher at col. 2, lns. 19-24).

None of the other references teaches a distribution function that creates an image having at least two compressed zones and at least one expanded zone either. Accordingly, claim 38 is believed to be patentable over the references cited in the reexamination request. Claims 39-47 are dependent on claim 38, and are also believed to be patentable over the references cited in the reexamination request due at least to their dependence on claim 38.

<u>Claim 48</u>

Claim 48 recites that the objective lens has a non-linear distribution function that is not symmetrical relative to the optical axis of the objective lens. That is, the position of an image point may vary not only with the field angle of the corresponding object point relative to the optical axis, but also with the angle of the corresponding object point in the image plane. Thus, image points would not be distributed in concentric circles, as with symmetric distribution functions.

None of the main references teaches a non-symmetrical distribution function. In Nagaoka, for example, all of the images show concentric circular distributions of image points, indicating symmetric distribution functions. (Nagaoka at Figs. 4A-4D). Baker similarly shows a concentric circular distribution of image points. (Baker at Fig. 3BB). Fig. 4 of Fisher also implies that the variations in image height are due only to field angle. (Fisher at Fig. 4). None of the other references cited in the reexamination teaches or suggests a non-symmetrical distribution function either. Accordingly, claim 48 is believed to be patentable over the references cited in the reexamination request.

Dated: November 26, 2014

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Bib Data Sheet

CONFIRMATION NO. 4682

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90/013,410	11/26/2014 RULE	359	3992	688266-21RX

AIA (First Inventor to File): YES

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** **CONTINUING DATA** *************************

This application is a REX of 10/706,513 11/12/2003 PAT 6844990
which is a CON of PCT/FR02/01588 05/10/2002

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

FRANCE 01 06261 05/11/2001

	STATE OR COUNTRY	SHEETS DRAWING	TOTAL CLAIMS	INDEPENDENT CLAIMS
Foreign Priority claimed ☐ yes ☐ no 35 USC 119 (a-d) conditions met ☐ yes ☐ no ☐ Met after Allowance Verified and Acknowledged ________ Examiner's Signature Initials			26	2

ADDRESS

570

TITLE

METHOD FOR CAPTURING AND DISPLAYING A VARIABLE RESOLUTION DIGITAL PANORAMIC IMAGE

FILING FEE RECEIVED		
120.00	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

Patent Assignment Abstract of Title

Total Assignments: 1

Application #: 10706513 **Filing Dt:** 11/12/2003 **Patent #:** 6844990 **Issue Dt:** 01/18/2005

PCT #: NONE **Intl Reg #:** **Publication #:** US20040136092 **Pub Dt:** 15-JUL-04

Inventors: Jean-Claude Artonne, Christophe Moustier, Benjamin Blanc

Title: METHOD FOR CAPTURING AND DISPLAYING A VARIABLE RESOLUTION DIGITAL PANORAMIC IMAGE

Assignment: 1

Reel/Frame: 015071 / 0574 **Received:** 03/17/2004 **Recorded:** 03/15/2004 **Mailed:** 09/03/2004 **Pages:** 3

Conveyance: ASSIGNMENT OF ASSIGNORS INTEREST (SEE DOCUMENT FOR DETAILS).

Assignors: ARTONNE, JEAN-CLAUDE **Exec Dt:** 11/26/2003

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Search Results as of: 11/28/2014 02:38 PM

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Web interface last modified: Jul 25, 2014 v.2.4

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REEXAM CONTROL NUMBER	FILING OR 371 (c) DATE	PATENT NUMBER
90/013,410	11/26/2014	6844990

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REEXAMINATION REQUEST NOTICE

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OC000000072122766

Date Mailed: 12/02/2014

NOTICE OF REEXAMINATION REQUEST FILING DATE

(Patent Owner Requester)

Requester is hereby notified that the filing date of the request for reexamination is 11/26/2014, the date the required fee of $2,520 was received. (See CFR 1.510(d)).

A decision on the request for reexamination will be mailed within three months from the filing date of the request for reexamination. (See 37 CFR 1.515(a)).

Pursuant to 37 CFR 1.33(c), future correspondence in this reexamination proceeding will be with the latest attorney or agent of the record in the patent file.

The paragraphs checked below are part of this communication:

___ 1. The party receiving the courtesy copy is the latest attorney or agent of record in the patent file.

___ 2. The person named to receive the correspondence in this proceeding has not been made the latest attorney or agent of record in the patent file because:

___ A. Requester's claim of ownership of the patent is not verified by the record.

___ B. The request papers are not signed with a real or apparent binding signature.

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___ 3. Addressee is the latest attorney or agent of record in the patent file.

___ 4. Other ____

/rbell/

Legal Instruments Examiner
Central Reexamination Unit 571-272-7705; FAX No. 571-273-9900

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Date Mailed: 12/02/2014

NOTICE OF ASSIGNMENT OF REEXAMINATION REQUEST

The above-identified request for reexamination has been assigned to Art Unit 3992. All future correspondence to the proceeding should be identified by the control number listed above and directed to the assigned Art Unit.

A copy of this Notice is being sent to the latest attorney or agent of record in the patent file or to all owners of record. (See 37 CFR 1.33(c)). If the addressee is not, or does not represent, the current owner, he or she is required to forward all communications regarding this proceeding to the current owner(s). An attorney or agent receiving this communication who does not represent the current owner(s) may wish to seek to withdraw pursuant to 37 CFR 1.36 in order to avoid receiving future communications. If the address of the current owner(s) is unknown, this communication should be returned within the request to withdraw pursuant to Section 1.36.

/rbell/

Legal Instruments Examiner
Central Reexamination Unit 571-272-7705; FAX No. 571-273-9900

Litigation Search Report CRU 3999

Reexam Control No. 90/013,410

TO: Examiner Location: CRU Art Unit: 3992 Date: 12/04/14 Case Serial Number: 90/013,410	From: Tredelle Jackson Location: CRU 3999 MDE 4B21 Phone: (571) 272-2783 Tredelle.Jackson@uspto.gov

Search Notes

Litigation Search for U.S. Patent Number 6,844,990.

Sources:

Status (OPEN) IPR2014-01438 Panasonic System Networks Co., Ltd. Vs. 6115187 CANADA INC.
Status (CLOSED) 1:13cv1139 Immervision Inc. V. Cbc Co. Ltd. Et Al
Status (CLOSED) 2:13cv1117 Immervision, Inc. V. Vivotek, Inc.

1) I performed a KeyCite Search in Westlaw, which retrieves all history on the patent including any litigation.

2) I performed a search on the patent in Lexis CourtLink for any open dockets or closed cases.

3) I performed a search in Lexis in the Federal Courts and Administrative Materials databases for any cases found.

4) I performed a search in Lexis in the IP Journal and Periodicals database for any articles on the patent.

5) I performed a search in Lexis in the news databases for any articles about the patent or any articles about litigation on this patent.

Westlaw.

Date of Printing: Dec 04, 2014

KEYCITE

C US PAT 6844990 METHOD FOR CAPTURING AND DISPLAYING A VARIABLE RESOLUTION DIGITAL PANORAMIC IMAGE, Assignee: 6115187 Canada Inc. (Jan 18, 2005)

History

Direct History

=> 1 **METHOD FOR CAPTURING AND DISPLAYING A VARIABLE RESOLUTION DIGITAL PANORAMIC IMAGE,** US PAT 6844990, 2005 WL 109751 (U.S. PTO Utility Jan 18, 2005)

Patent Family

2 PANORAMIC DIGITAL IMAGE PROCESSING SYSTEM USES WIDE ANGLE LENS CAUSING IMAGE DISTORTION, AND DIGITAL PROCESSING COUNTERACTING DISTORTION, Derwent World Patents Legal 2003-148422

Patent Status Files

.. AIA Trial Proceedings Filed before The Patent Trial and Appeal Board, (OG DATE: Oct 28, 2014)

.. Patent Suit(See LitAlert Entries),

.. Patent Suit(See LitAlert Entries),

.. Certificate of Correction, (OG DATE: Jun 14, 2005)

Docket Summaries

7 IMMERVISION INC. v. CBC CO. LTD. ET AL, (D.DEL. Jun 25, 2013) (NO. 1:13CV01139), (35 USC 271 PATENT INFRINGEMENT)

8 IMMERVISION, INC. v. VIVOTEK, INC. ET AL, (D.NEV. Jun 25, 2013) (NO. 2:13CV01117), (35 USC 145 PATENT INFRINGEMENT)

Litigation Alert

9 Derwent LitAlert P2013-35-01 (Jun 25, 2013) Action Taken: NOTICE TO COUNSEL PURSUANT TO LOCAL RULE IA 10-2 COUNSEL FREDERICK A TECCE, JOHN D. SIMMONS, STEPHEN E MURRAY TO COMPLY WITH COMPLETION AND ELECTRONIC FILING OF THE DESIGNATION OF LOCAL COUNSEL AND VERIFIED PETITION

10 Derwent LitAlert P2013-26-137 (Jun 25, 2013) Action Taken: CAUSE - 35 USC 271 - COMPLAINT FOR PATENT INFRINGEMENT

11 Derwent LitAlert P2013-26-140 (Jun 25, 2013) Action Taken: CAUSE - 35 USC 145 - COM-

Prior Art (Coverage Begins 1976)

C 12 DEFORMABLE MIRROR, US PAT 5880896Assignee: Sharp Kabushiki Kaisha, (U.S. PTO Utility 1999)

C 13 INNOVATIVE DEFORMABLE MIRROR ACTUATOR CONFIGURATION, US PAT 5745278Assignee: Raytheon Optical Systems, Inc., (U.S. PTO Utility 1998)

C 14 INTEGRATED PANORAMIC AND HIGH RESOLUTION SENSOR OPTICS, US PAT 5710661Assignee: Hughes Electronics, (U.S. PTO Utility 1998)

C 15 NON-LINEAR LENS, US PAT 3953111Assignee: McDonnell Douglas Corporation, (U.S. PTO Utility 1976)

C 16 OMNIRAMIC OPTICAL SYSTEM HAVING CENTRAL COVERAGE MEANS WHICH IS ASSOCIATED WITH A CAMERA, PROJECTOR, OR SIMILAR ARTICLE, US PAT 6333826 (U.S. PTO Utility 2001)

C 17 SOLID CATADIOPTRIC OMNIDIRECTIONAL OPTICAL SYSTEM HAVING CENTRAL COVERAGE MEANS WHICH IS ASSOCIATED WITH A CAMERA, PROJECTOR, MEDICAL INSTRUMENT, OR SIMILAR ARTICLE, US PAT 6449103 (U.S. PTO Utility 2002)

C 18 WIDE-ANGLE LENS, US PAT 6031670Assignee: Sankyo Seiki Mfg. Co., Ltd., (U.S. PTO Utility 2000)

United States Patent Trial and Appeals Board

US Patent Trial and Appeals Board - Alexandria (Alexandria)

IPR2014-01438

Panasonic System Networks Co., Ltd. Vs. 6115187 CANADA INC.

This case was retrieved from the court on Wednesday, November 12, 2014

Header

Case Number:	IPR2014-01438
Date Filed:	09/03/2014
Date Full Case Retrieved:	11/12/2014
Status:	Open
Misc:	Civil

[Summary][Participants][Proceedings]

Summary

Court Case Status:	Pending
Case Type:	IPR: Inter partes review
Technical Center Number:	2800
Patent Application Number:	10706513
Patent Number:	6844990

Participants

Litigants

Panasonic System Networks Co., Ltd.
Petitioner

6115187 Canada Inc.
PatentOwner

Proceedings

File Date	Details	Document Type	Paper/Exhibit No.	Filed By	Public?
09/03/2014	Power of Attorney	Power of Attorney	1	Petitioner	Yes
09/03/2014	IPR Petition	Petition	2	Petitioner	Yes
09/03/2014	U.S. Patent No. 6,844,990	Exhibit	1001	Petitioner	Yes
09/03/2014	U.S. Patent No. 5,686,957	Exhibit	1002	Petitioner	Yes
09/03/2014	U.S. Patent No. 6,128,145	Exhibit	1003	Petitioner	Yes

09/03/2014	U.S. Patent No. 3,953,111	Exhibit	1004	Petitioner	Yes
09/03/2014	Ep 1386480 B1	Exhibit	1005	Petitioner	Yes
09/03/2014	EP 1386480 B1 Amendment of May 6, 2010	Exhibit	1006	Petitioner	Yes
09/03/2014	U.S. Patent No. 6,031,670	Exhibit	1007	Petitioner	Yes
09/03/2014	European Patent Publication EP 1 028 389 A2	Exhibit	1008	Petitioner	Yes
09/03/2014	Japanese Patent Publication P2000-242773A	Exhibit	1009	Petitioner	Yes
09/03/2014	English translation of Matsui with verification	Exhibit	1010	Petitioner	Yes
09/03/2014	Japanese Unexamined Patent Application Publication 11-261868	Exhibit	1011	Petitioner	Yes
09/03/2014	English translation of Enami	Exhibit	1012	Petitioner	Yes
09/03/2014	Declaration of Jack Feinberg, Ph.D.	Exhibit	1013	Petitioner	Yes
09/03/2014	Declaration of Shishir K. Shah, Ph.D.	Exhibit	1014	Petitioner	Yes
09/11/2014	Notice of Filing Date Accorded to Petition and Defective Petition	Notice of Filing Date Accorded to Petition	3	Board	Yes
09/16/2014	Response to Notice	Reply	4	Petitioner	Yes
09/16/2014	Amended Petition	Reply	5	Petitioner	Yes
09/23/2014	Notice of Accepting Corrected Petition	Notice	6	Board	Yes
09/24/2014	Power of Attorney	Power of Attorney	7	Potential Patent Owner	Yes
09/24/2014	Related Matters	Notice	8	Potential Patent Owner	Yes

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US District Court Civil Docket

U.S. District - Delaware
(Wilmington)

1:13cv1139

Immervision Inc. v. Cbc Co. Ltd. et al

This case was retrieved from the court on Friday, August 16, 2013

Date Filed:	**06/25/2013**
Assigned To:	**Judge Sue L. Robinson**
Referred To:	**Judge Sherry R. Fallon**
Nature of suit:	**Patent (830)**
Cause:	**Patent Infringement**
Lead Docket:	**None**
Other Docket:	**None** **None** **None** **None** **None**
Jurisdiction:	**Federal Question**

Class Code:	**CLOSED**
Closed:	**08/05/2014**
Statute:	**35:271**
Jury Demand:	**Plaintiff**
Demand Amount:	**$0**
NOS Description:	**Patent**

Litigants	**Attorneys**
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Plaintiff

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Cbc Co. Ltd. Defendant	Melanie K. Sharp LEAD ATTORNEY;ATTORNEY TO BE NOTICED Young, Conaway, Stargatt & Taylor LLP Rodney Square 1000 North King Street Wilmington , DE 19801 USA (302) 571-6681 Fax: (302) 571-1253 Email:Msharp@ycst.Com Samantha G. Wilson ATTORNEY TO BE NOTICED Young, Conaway, Stargatt & Taylor LLP Rodney Square 1000 North King Street Wilmington , DE 19801 USA 302-571-5018 Email:Swilson@ycst.Com
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6115187 Canada Inc. doing business as ImmerVision Inc. Counter Defendant	
Cbc (America) Corporation Counter Claimant	Melanie K. Sharp LEAD ATTORNEY;ATTORNEY TO BE NOTICED Young, Conaway, Stargatt & Taylor LLP Rodney Square 1000 North King Street Wilmington , DE 19801 USA

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Cbc Co. Ltd. Counter Claimant	Melanie K. Sharp LEAD ATTORNEY;ATTORNEY TO BE NOTICED Young, Conaway, Stargatt & Taylor LLP Rodney Square 1000 North King Street Wilmington , DE 19801 USA (302) 571-6681 Fax: (302) 571-1253 Email:Msharp@ycst.Com Samantha G. Wilson ATTORNEY TO BE NOTICED Young, Conaway, Stargatt & Taylor LLP Rodney Square 1000 North King Street Wilmington , DE 19801 USA 302-571-5018 Email:Swilson@ycst.Com
Immervision Inc. [Term: 03/11/2014] Counter Defendant	Joseph James Farnan , III LEAD ATTORNEY;ATTORNEY TO BE NOTICED [Term: 03/11/2014] Farnan LLP 919 North Market Street 12th Floor Wilmington , DE 19801 USA (302) 777-0300 Fax: (302) 777-0301 Email:Jjfarnan@farnanlaw.Com Brian E. Farnan ATTORNEY TO BE NOTICED [Term: 03/11/2014] Farnan LLP 919 North Market Street 12th Floor Wilmington , DE 19801 USA (302) 777-0300 Fax: (302) 777-0301 Email:Bfarnan@farnanlaw.Com Michael J. Farnan ATTORNEY TO BE NOTICED [Term: 03/11/2014] Farnan LLP 919 North Market Street 12th Floor

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Date	#	Proceeding Text	Source
06/25/2013	1	COMPLAINT filed with Jury Demand against CBC (America) Corporation, CBC Co. Ltd. - Magistrate Consent Notice to Pltf. (Filing fee $ 400, receipt number 311-1317132.) - filed by ImmerVision Inc.. (Attachments: # 1 Exhibit A, # 2 Exhibit B, # 3 Exhibit C, # 4 Civil Cover Sheet)(dmp,) (Entered: 06/26/2013)	
06/25/2013	2	Notice, Consent and Referral forms re: U.S. Magistrate Judge jurisdiction. (dmp,) (Entered: 06/26/2013)	
06/25/2013	3	Report to the Commissioner of Patents and Trademarks for Patent/Trademark Number(s) US 6,844,900 B2;. (dmp,) (Entered: 06/26/2013)	
06/25/2013		No Summons Issued. (dmp,) (Entered: 06/26/2013)	
07/03/2013		Case Assigned to Judge Sue L. Robinson. Please include the initials of the Judge (SLR) after the case number on all documents filed. (rjb) (Entered: 07/03/2013)	
10/15/2013	4	WAIVER OF SERVICE returned executed by ImmerVision Inc.: For CBC Co. Ltd. waiver sent on 10/14/2013, answer due 1/13/2014. (Farnan, Joseph) (Entered: 10/15/2013)	Events since last full update
10/15/2013	5	WAIVER OF SERVICE returned executed by ImmerVision Inc.: For CBC (America) Corporation waiver sent on 10/14/2013, answer due 12/13/2013. (Farnan, Joseph) (Entered: 10/15/2013)	Events since last full update
12/10/2013	6	MOTION for Extension of Time to Respond to Complaint - Unopposed - filed by ImmerVision Inc.. (Attachments: # 1 Text of Proposed Order)(Farnan, Michael) (Entered: 12/10/2013)	Events since last full update
12/12/2013	--	SO ORDERED, re 6 MOTION for Extension of Time to Respond to Complaint - Unopposed filed by ImmerVision Inc., Set/Reset Answer Deadlines: CBC (America) Corporation answer due 1/13/2014. CBC Co. Ltd answer due 1/13/2014. Signed by Judge Sue L. Robinson on 12/12/2013. (fms) (Entered: 12/12/2013)	Events since last full update
01/13/2014	7	ANSWER to 1 Complaint, with Jury Demand , COUNTERCLAIM against ImmerVision Inc. by CBC (America) Corporation, CBC Co. Ltd..(Wilson, Samantha) (Entered: 01/13/2014)	Events since last full update
01/13/2014	8	Disclosure Statement pursuant to Rule 7.1: No Parents or Affiliates Listed filed by CBC Co. Ltd.. (Wilson, Samantha) (Entered: 01/13/2014)	Events since last full update
01/13/2014	9	Disclosure Statement pursuant to Rule 7.1: identifying Corporate Parent CBC Co. Ltd. for CBC (America) Corporation, CBC (America) Corporation filed by CBC (America) Corporation. (Wilson, Samantha) (Entered: 01/13/2014)	Events since last full update
01/13/2014	10	MOTION for Pro Hac Vice Appearance of Attorney Nick G. Saros, Miwa Shoda, Kristopher R. Kiel and Yusuf Esat - filed by CBC (America) Corporation, CBC Co. Ltd.. (Sharp, Melanie) (Entered: 01/13/2014)	Events since last full update
01/14/2014	--	SO ORDERED, re 10 MOTION for Pro Hac Vice Appearance of	Events

		Attorney Nick G. Saros, Miwa Shoda, Kristopher R. Kiel and Yusuf Esat filed by CBC (America) Corporation, CBC Co. Ltd. Signed by Judge Sue L. Robinson on 1/14/2014. (fms) (Entered: 01/14/2014)	 since last full update
01/31/2014	11	ANSWER to 7 Answer to Complaint, Counterclaim by ImmerVision Inc..(Farnan, Michael) (Entered: 01/31/2014)	Events since last full update
02/07/2014	12	Order Setting Telephonic Scheduling Conference: A Scheduling Conference is set for 3/10/2014 at 04:00 PM before Judge Sue L. Robinson. Signed by Judge Sue L. Robinson on 2/7/2014. (nmfn) (Entered: 02/07/2014)	Events since last full update
02/11/2014	13	MOTION for Pro Hac Vice Appearance of Attorney of John D. Simmons, Frederick A. Tecce, and Dennis J. Butler - filed by ImmerVision Inc.. (Farnan, Michael) (Entered: 02/11/2014)	Events since last full update
02/12/2014	--	SO ORDERED, re 13 MOTION for Pro Hac Vice Appearance of Attorney of John D. Simmons, Frederick A. Tecce, and Dennis J. Butler filed by ImmerVision Inc. Signed by Judge Sue L. Robinson on 2/12/2014. (fms) (Entered: 02/12/2014)	Events since last full update
02/24/2014	--	Pro Hac Vice Attorney Frederick Tecce for ImmerVision Inc. added for electronic noticing. (els) (Entered: 02/24/2014)	Events since last full update
02/24/2014	--	Pro Hac Vice Attorney John D. Simmons for ImmerVision Inc. added for electronic noticing. (els) (Entered: 02/24/2014)	Events since last full update
02/25/2014	--	Pro Hac Vice Attorney Dennis J. Butler for ImmerVision Inc. added for electronic noticing. (els) (Entered: 02/25/2014)	Events since last full update
03/04/2014	14	ORDER REFERRING CASE to Mediation. Signed by Judge Sue L. Robinson on 3/4/2014. (nmfn) (Entered: 03/04/2014)	Events since last full update
03/04/2014	15	ORDER Setting Teleconference: Plaintiffs counsel shall initiate the call. A Telephone Conference is set for 3/10/2014 at 11:30 AM before Judge Sherry R. Fallon to discuss ADR. Signed by Judge Sherry R. Fallon on 3/4/2014. (lih) (Entered: 03/04/2014)	Events since last full update
03/07/2014	16	STIPULATION to Amend Caption by ImmerVision Inc.. (Farnan, Michael) (Entered: 03/07/2014)	Events since last full update
03/07/2014	17	PROPOSED ORDER Proposed Scheduling Order by ImmerVision Inc.. (Attachments: # 1 Letter to The Honorable Sue L. Robinson)(Farnan, Michael) (Entered: 03/07/2014)	Events since last full update
03/10/2014	--	Minute Entry for proceedings held before Judge Sue L. Robinson - Scheduling Conference held on 3/10/2014. (Court Reporter not present.) (nmfn) (Entered: 03/10/2014)	Events since last full update
03/10/2014	18	SCHEDULING ORDER: Case referred to the Magistrate Judge for the purpose of exploring ADR. Case referred to Magistrate Judge Fallon for non-dispositive motions and discovery as outlined in the scheduling order. Joinder of Parties due by 12/7/2014. Amended Pleadings due by 12/7/2014. A Discovery Conference is set for 9/18/2014 at 04:30 PM in Courtroom 4B before Judge Sue L. Robinson. A Status Conference re: Expert Discovery is set for 6/18/2015 at 04:30 PM in Courtroom 4B before Judge Sue L. Robinson. An Oral Argument is set for 11/19/2015 at 01:00 PM in Courtroom 4B before Judge Sue L. Robinson. Claim Construction Opening Brief due by 1/15/2015. Claim Construction Answering Brief due by 2/5/2015. Claim	Events since last full update

		Construction Reply Brief due by 2/19/2015. Claim Construction Surreply Brief due by 3/5/2015. A Final Pretrial Conference is set for 2/10/2016 at 04:30 PM in Courtroom 4B before Judge Sue L. Robinson. A Jury Trial is set for 3/7/2016 at 09:00 AM in Courtroom 4B before Judge Sue L. Robinson. Signed by Judge Sue L. Robinson on 3/10/2014. (nmfn) (Entered: 03/10/2014)	
03/11/2014	--	SO ORDERED, re 16 Stipulation To Amend Caption. Signed by Judge Sue L. Robinson on 3/11/2014. (fms) (Entered: 03/11/2014)	Events since last full update
03/12/2014	19	ORDER Setting Mediation Conferences: A Mediation Conference is set for 4/15/2014 and 4/16/2014 at 10:00 AM in Courtroom 6C before Judge Sherry R. Fallon. Signed by Judge Sherry R. Fallon on 3/12/2014. (lih) (Entered: 03/12/2014)	Events since last full update
03/17/2014	20	NOTICE OF SERVICE of Plaintiff ImmerVision's Initial Disclosures Pursuant to Federal Rule 26(a)(1)(A) filed by 6115187 Canada Inc..(Farnan, Michael) (Entered: 03/17/2014)	Events since last full update
03/17/2014	21	NOTICE OF SERVICE of Defendants' Rule 26(a)(1) Initial Disclosures filed by CBC (America) Corporation, CBC Co. Ltd.. (Sharp, Melanie) (Entered: 03/17/2014)	Events since last full update
03/17/2014	22	NOTICE of Withdrawal of Kristopher R. Kiel as Counsel for Defendants CBC Co., Ltd and CBC (America) Corporation by CBC (America) Corporation, CBC Co. Ltd. (Wilson, Samantha) (Entered: 03/17/2014)	Events since last full update
03/24/2014	23	Letter to Counsel from Judge Robinson regarding changes to the way the Court processes patent cases. (nmfn) (Entered: 03/24/2014)	Events since last full update
03/26/2014	24	Order Setting Patent Scheduling Conference: An In-Person Scheduling Conference is set for 4/21/2014 at 01:00 PM in Courtroom 4B before Judge Sue L. Robinson. Signed by Judge Sue L. Robinson on 3/26/2014. (nmfn) (Entered: 03/26/2014)	Events since last full update
04/09/2014	25	Joint STIPULATION TO EXTEND TIME for the parties to exchange disclosures pursuant to Paragraph 3 of the Default Standard for Discovery, and for plaintiff to produce information pursuant to Paragraph 4 of same to May 9, 2014 - filed by CBC (America) Corporation, CBC Co. Ltd.. (Wilson, Samantha) (Entered: 04/09/2014)	Events since last full update
04/10/2014	--	SO ORDERED, re 25 Joint STIPULATION TO EXTEND TIME for the parties to exchange disclosures pursuant to Paragraph 3 of the Default Standard for Discovery, and for plaintiff to produce information pursuant to Paragraph 4 of same to May 9, 2014 filed by CBC (America) Corporation, CBC Co. Ltd. Signed by Judge Sue L. Robinson on 4/10/2014. (fms) (Entered: 04/10/2014)	Events since last full update
04/18/2014	26	PROPOSED ORDER Revised Scheduling Order by 6115187 Canada Inc.. (Attachments: # 1 Letter to The Honorable Sue L. Robinson)(Farnan, Michael) (Entered: 04/18/2014)	Events since last full update
04/21/2014	--	Reset Hearings: The In-Person Scheduling Conference has been rescheduled per request of counsel for 5/19/2014 at 04:30 PM in Courtroom 4B before Judge Sue L. Robinson. (nmfn) (Entered: 04/21/2014)	Events since last full update
04/24/2014	--	ORAL ORDER- IT IS HEREBY ORDERED that: a Telephone Mediation Conference is set for 5/1/2014 at 12:00 PM before Judge Sherry R. Fallon. Ordered by Judge Sherry R. Fallon on 4/24/2014. (lih) (Entered: 04/24/2014)	Events since last full update
05/09/2014	27	NOTICE OF SERVICE of CBC's Disclosures Pursuant to Paragraph	Events

		3 of the District of Delaware Default Standard for Discovery, Including Discovery of Electronically Stored Information ("ESI") filed by CBC (America) Corporation, CBC Co. Ltd..(Sharp, Melanie) (Entered: 05/09/2014)	 since last full update
05/09/2014	28	NOTICE OF SERVICE of (i) Plaintiff ImmerVision's Electronic Discovery Disclosures and (ii) Plaintiff ImmerVision's Initial Patent Disclosures filed by 6115187 Canada Inc..(Farnan, Michael) (Entered: 05/09/2014)	Events since last full update
05/16/2014	--	The scheduling conference originally set for 5/19/2014 at 4:30 p.m. has been cancelled. It will be rescheduled soon. (nmfn) (Entered: 05/16/2014)	Events since last full update
05/16/2014	--	Reset Hearings: The In-Person Scheduling Conference is rescheduled for 6/24/2014 at 04:30 PM in Courtroom 4B before Judge Sue L. Robinson. (nmfn) (Entered: 05/16/2014)	Events since last full update
06/03/2014	--	Reset Hearings: The In-Person Scheduling Conference is rescheduled for 6/24/2014 at 03:30 PM in Courtroom 4B before Judge Sue L. Robinson. (nmfn) (Entered: 06/03/2014)	Events since last full update
06/05/2014	29	PROPOSED ORDER Stipulated Protective Order by 6115187 Canada Inc.. (Farnan, Michael) (Entered: 06/05/2014)	Events since last full update
06/06/2014	--	SO ORDERED, re 29 Proposed Stipulated Protective Order filed by 6115187 Canada Inc.. Signed by Judge Sue L. Robinson on 6/6/2014. (fms) (Entered: 06/06/2014)	Events since last full update
06/10/2014	30	NOTICE OF SERVICE of Core Technical Documents Pursuant to Paragraph 4(b) of the D. Del. Default Standard for Discovery filed by CBC (America) Corporation, CBC Co. Ltd..(Wilson, Samantha) (Entered: 06/10/2014)	Events since last full update
06/23/2014	31	PROPOSED ORDER Scheduling Order by 6115187 Canada Inc.. (Attachments: # 1 Letter to The Honorable Sue L. Robinson) (Farnan, Michael) (Entered: 06/23/2014)	Events since last full update
06/24/2014	--	Minute Entry for proceedings held before Judge Sue L. Robinson - Scheduling Conference held on 6/24/2014. (Court Reporter V. Gunning.) Counsel to submit the final proposed scheduling order to the court. (nmfn) (Entered: 06/24/2014)	Events since last full update
06/25/2014	32	PROPOSED ORDER Scheduling Order by 6115187 Canada Inc.. (Attachments: # 1 Letter to The Honorable Sue L. Robinson) (Farnan, Michael) (Entered: 06/25/2014)	Events since last full update
06/26/2014	--	SO ORDERED, re 32 SCHEDULING ORDER: Case referred to the Magistrate Judge for the purpose of exploring ADR. Case referred to the Magistrate Judge for discovery and all motions to dismiss, to amend, to transfer and any discovery motions permitted by a Magistrate Judge.(Joinder of Parties due by 12/8/2014., Amended Pleadings due by 12/8/2014., Discovery due by 7/15/2015., A Status Conference re: Expert Discovery is set for 6/18/2015 at 04:30 PM in Courtroom 4B before Judge Sue L. Robinson, Dispositive Motions due by 8/21/2015., An Oral Argument is set for 11/19/2015 at 01:00 PM in Courtroom 4B before Judge Sue L. Robinson., Claim Construction Opening Brief due by 1/15/2015., Claim Construction Answering Brief due by 2/5/2015., Claim Construction Reply Brief due by 2/19/2015., Claim Construction Surreply Brief due by 3/5/2015., A Markman Hearing is set for 3/27/2015 at 09:30 AM in Courtroom 4B before Judge Sue L. Robinson., A Final Pretrial Conference is set for 2/10/2016 at 04:30 PM in Courtroom 4B before Judge Sue L. Robinson., A Jury Trial is set for 3/7/2016 at 09:00 AM in Courtroom 4B before Judge Sue L. Robinson.). Signed by Judge	Events since last full update

		Sue L. Robinson on 6/26/2014. (nmfn) (Entered: 06/26/2014)	
06/27/2014	33	NOTICE OF SERVICE of Plaintiff ImmerVision's Damages Model under Paragraph 1 (c) (2) of Patent Replacement Scheduling Order filed by 6115187 Canada Inc..(Farnan, Michael) (Entered: 06/27/2014)	Events since last full update
07/09/2014	34	STIPULATION TO EXTEND TIME for Initial Claim Chart and Initial Invalidity Contentions to 8/8/2014 and 9/8/2014 respectively - filed by 6115187 Canada Inc.. (Farnan, Michael) (Entered: 07/09/2014)	Events since last full update
08/05/2014	35	STIPULATION of Dismissal by 6115187 Canada Inc.. (Farnan, Michael) (Entered: 08/05/2014)	Events since last full update
08/05/2014	--	CASE CLOSED per D.I. 35 . (nmfn) (Entered: 08/05/2014)	Events since last full update
08/07/2014	36	Report to the Commissioner of Patents and Trademarks for Patent/Trademark Number(s) US 6,844,900 B2. (Attachments: # 1 Stipulation)(fms) (Entered: 08/07/2014)	Events since last full update

US District Court Civil Docket

U.S. District - Nevada
(Las Vegas)

2:13cv1117

Immervision, Inc. v. Vivotek, Inc.

This case was retrieved from the court on Friday, August 16, 2013

Date Filed:	**06/25/2013**		
Assigned To:	**Judge Andrew P. Gordon**		
Referred To:	**Magistrate Judge Carl W. Hoffman**	**Class Code:**	**CLOSED**
		Closed:	**09/27/2013**
Nature of suit:	**Patent (830)**	**Statute:**	**35:145**
		Jury Demand:	**Plaintiff**
Cause:	**Patent Infringement**	**Demand Amount:**	**$0**
Lead Docket:	**None**	**NOS Description:**	**Patent**
Other Docket:	**None**		
Jurisdiction:	**Federal Question**		

Litigants	Attorneys
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Vivotek, Inc.
Defendant

Vivotek USA, Inc.
Defendant

Vivotek Holdings, Inc.
Defendant

Date	#	Proceeding Text	Source
06/25/2013	1	COMPLAINT against Vivotek, Inc. (Filing fee $400 receipt number 0978-2866350), filed by ImmerVision, Inc.. Certificate of Interested Parties due by 7/5/2013. Proof of service due by 10/23/2013. (Attachments: # 1 Exhibit Ex. A to Complaint, # 2 Exhibit Ex. B to Complaint, # 3 Exhibit Ex. C to Complaint, # 4 Civil Cover Sheet Civil Cover Sheet) (Ballif, Philip) (Entered: 06/25/2013)	
06/25/2013		Case assigned to Judge Andrew P. Gordon and Magistrate Judge Carl W. Hoffman. Nature of Suit: 830 Patent Case (MAJ) (Entered: 06/25/2013)	
06/25/2013	2	NOTICE PURSUANT TO LOCAL RULE IB 2-2: In accordance with 28 USC § 636(c) and FRCP 73, the parties in this action are provided with a link to the "AO 85 Notice of Availability, Consent, and Order of Reference - Exercise of Jurisdiction by a U.S. Magistrate Judge" form on the Court's website - www.nvd.uscourts.gov. Consent forms should NOT be electronically filed. Upon consent of all parties, counsel are advised to manually file the form with the Clerk's Office. A copy of form AO 85 has been mailed to parties not receiving electronic service. (no image attached) (MAJ) (Entered: 06/25/2013)	
06/25/2013	3	NOTICE TO COUNSEL PURSUANT TO LOCAL RULE IA 10-2. Counsel Frederick A. Tecce, John D. Simmons, Stephen E Murray to comply with completion and electronic filing of the Designation of Local Counsel and Verified Petition. For your convenience, click on the following link to obtain the form from the Court's website - www.nvd.uscourts.gov/Forms.aspx. Counsel is also required to register for the Court's Case Management and Electronic Case Filing (CM/ECF) system and the electronic service of pleadings. Please visit the Court's website www.nvd.uscourts.gov to register Attorney(s) upon approval of the Verified Petition. Verified Petition due by 8/9/2013.(no image attached) (MAJ) (Entered: 06/25/2013)	
06/25/2013	4	AO 120 - REPORT on the filing or determination of an action regarding a patent or trademark. E-mailed to the US Patent and Trademark Office. (MAJ) (Entered: 06/25/2013)	

07/02/2013	5	CERTIFICATE of Interested Parties filed by ImmerVision, Inc. that identifies all parties that have an interest in the outcome of this case. Other Affiliate 9116-6271 Quebec Inc for ImmerVision, Inc. added. . (Ballif, Philip) (Entered: 07/02/2013)	
08/09/2013	6	Emergency MOTION for Extension of Time to File Verified Petitions Pursuant to Local Rule IA 10-2; filed by Plaintiff ImmerVision, Inc.. Motion ripe 8/9/2013. (Ballif, Philip) (Entered: 08/09/2013)	
08/12/2013	7	MINUTE ORDER IN CHAMBERS of the Honorable Judge Andrew P. Gordon, on 8/12/2013. By Judicial Assistant: Cathy Stuchell. Plaintiff's Emergency Motion for Extension of Time to File Verified Petitions [Dkt. #6] is GRANTED. Verified Petitions are now due on September 13, 2013.(no image attached) (Copies have been distributed pursuant to the NEF - CS) (Entered: 08/12/2013)	
09/27/2013	8	NOTICE of Dismissal Pursuant to Rule 41(a)(1) of the Federal Rules of Civil Procedure by ImmerVision, Inc.. (Ballif, Philip) (Entered: 09/27/2013)	Events since last full update
09/27/2013	9	AO 120 - REPORT on the filing or determination of an action regarding a patent or trademark. E-mailed to the US Patent and Trademark Office. (Attachments: # 1 Notice of Voluntary Dismissal) (AC) (Entered: 09/27/2013)	Events since last full update

1. The Sports Network, June 8, 2014 Sunday 5:55 PM EST, , PGA TOUR - MEN'S PROFESSIONAL GOLF; Statistics, 1977 words, PGA Tour Statistics - Final Round Scoring Average; (Complete Through FedEx St. Jude Classic)

...	**6**	Webb Simpson	10	69.40	70.15	694 ...
...	34	Camilo Villegas	12	70.33	70.98	**844**
	35	Boo Weekley	12	70.33	71.25	**844** ...
...	54	Zach Johnson	14	70.71	70.16	**990**
	55	Scott Brown	14	70.71	70.83	**990**
	56	Brian Davis	14	70.71	71.47	**990** ...

2. News Bites US Markets, September 12, 2014 Friday, 916 words, CAI International decreases 1.2% - trailing 93% of stocks 12 September, 2014 16:00 EDT

   ... NYSE market of 2,071 stocks and 34 units traded today, the stock has a **6**-month relative price strength of 7 indicating it is trailing 93% of the market. ...
   ... 1000) invested one year ago in CAI International is US$**844,** for a capital loss of US$156. ...
   ... CAP.NYSE 992 **990 844**
   S&P 500 Index **990** 1,027 1,195 ...

3. News Bites - Middle East & North Africa: Palestine, November 20, 2014 Thursday, STOCK, 322 words, Weekly: Palestine Electric in its biggest trailing week loss for 7 months

   ... week. - In the Palestinian market of 18 stocks traded today, the stock has a **6**-month relative strength of 7 indicating it is trailing 93.0% of the market. ...
   ... value of US$1,000 invested two years ago is US$**844** for a capital loss of US$156. ...
   ... PEC 947 **844** ...
   ... Al-Quds **990** 944 1,077 ...

4. News Bites US Markets, October 1, 2014 Wednesday, 622 words, AV Homes in 2nd daily fall, nears twenty two-month low 01 October, 2014 16:00 EDT

   ... last three months the stock has hit a new 52-week low **six** times, pointing to a downtrend. + The Moving Average Convergence Divergence (MACD) indicator of ...
   ... 1000) invested one year ago in AV Homes is US$**844,** for a capital loss of US$156. ...
   ... AVHI.NASDAQ **990** 918 **844** ...

5. The Sampson Independent (Clinton, North Carolina), October 21, 2014 Tuesday, ANNOUNCEMENTS, 844 words, Community Bulletin Board, Emily Hobbs

   ... progress report pickup for all students and parents on Oct. 27, **6** p.m.A Senior Information Night with graduation supply ordering, scholarship information, Sampson ...
   ... by Stephen Mallatratt at The Victor R. Small House. Thursday, Nov. **6,** 7:30 p.m.; Friday, Nov. 7, 7:30 p.m.; Saturday, Nov. 8, ...
   ... out, or delivery. FMI or to purchase a plate, call Skippy Jackson at **990**-9554, Glenn Jernigan at **990**-0969 or L.S. Guy at 910-267-6441. If you would like to make a ...
   ... Planning and Zoning Board — meets the first Tuesday of every month at **6** p.m. while training through the N.C. Department of Commerce is being held. The business ...

6. The Sports Network, April 7, 2013 Sunday 4:47 PM EST, , NATIONWIDE TOUR - GOLF; Statistics, 1671 words, Web.com Tour Statistics - Scoring Average; (Complete Through

Brasil Classic)

... **6**	Wes Roach	2	68.38	547 ...
... 82	Philip Pettitt, Jr.	5	70.33	**844**
82	Nick Flanagan	4	70.33	**844**
82	Sam Saunders	4	70.33	**844** ...
... 112	J.J. Killeen	5	70.71	**990**
112	Cliff Kresge	4	70.71	**990** ...

7. Independent.co.uk, August 27, 2014 Wednesday 1:05 AM GMT, , UK POLITICS, 328 words, Authorities failing in hunt for 'most wanted' tax dodgers who owe HMRC £844m; Campaign that publicly identified those sought has seen results, but many have fled abroad, Kunal Dutta

   ... year's list include Ahmed Salim Khezr, an Iranian national sentenced to **six** years for selling non-UK duty paid cigarettes across the UK and ...
   ... Others are Murugasan Natarajan, who is thought to have fled to India after receiving a **six**-year sentence last December for smuggling garlic - incorrectly declared as ginger - into the UK. HMRC say that the frauds have collectively cost the UK more than £**844** million. The appeal provided intelligence on the alleged offenders, and the whereabouts of 16 others are now known, HMRC says, with **990** prosecutions having taken place in the last year. But authorities have punished just ...
   ... said: "These fugitives were involved in frauds that have collectively cost the UK more than £**844** million but the success of our campaign means those on the run should know that HMRC will ...

8. Johannesburg Stock Exchange News Service, March 26, 2014 Wednesday, 2569 words, KDV - KAYDAV GROUP LIMITED - Condensed audited consolidated results for the year ended 31 December 2013

... Profit for the year	23 710 **844**	20 350 534 ...
... equity holders of the parent	23 710 **844**	20 350 534 ...
... Earnings	23 710 **844**	20 350 534 ...
... Current assets	184 **990** 190	165 011 970 ...
... Short-term portion of interest-bearing liabilities	**6** 124 965	'5 538 192 ...
... Total comprehensive income for the year	23 710 **844**	20 350 534 ...
... Board distribution	37 932 997	29 806 **990** ...

9. Pivotal Sources, November 6, 2014 Thursday, 128 words, Skladowisko Odpadow secures contract for Refuse and waste related services, Poland

   Poland, Nov. **6** -- Contract Id: 98432 Description: POLAND based Skladowisko Odpadow has secured contract ...
   The contract is valued approximately 2 **844 990** PLN, Including VAT. VAT rate (%) 8. Country: Poland Sector: ...
   November **6,** 2014

10. The Sports Network, July 6, 2014 Sunday 9:25 PM EST, , NATIONWIDE TOUR - GOLF; Statistics, 1733 words, Web.com Tour Statistics - Second Round Scoring Average; (Complete Through Nova Scotia Open)

... **6**	Roland Thatcher	12	68.75	70.27	825 ...
... 48	Cameron Percy	12	70.33	70.15	**844**
49	Hugo Leon	12	70.33	70.68	**844**
50	Brett Lederer	12	70.33	71.23	**844** ...
... 65	Manuel Villegas	14	70.71	70.75	**990** ...

Source: **Combined Source Set 4 [i] - English Language News (Most recent Two Years)**
Terms: **6844990 or 6,844,990** (Suggest Terms for My Search | Feedback on Your Search)
View: Cite
Date/Time: Thursday, December 4, 2014 - 4:30 PM EST

869449 (06) 4963097 October 16, 1990

UNITED STATES PATENT AND TRADEMARK OFFICE GRANTED PATENT

4963097

Get Drawing Sheet 1 of 12
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Link to Claims Section

October 16, 1990

Display apparatus for a group education system

INVENTOR: Anju, Shinji - Saitama, Japan (JP)

APPL-NO: 869449 (06)

FILED-DATE: April 27, 1986

GRANTED-DATE: October 16, 1990

CORE TERMS: display, seat, screen, designated, symbol, cursor, displayed, switch, electrode, classroom, correspond, column, row, assigned, actuation, terminal, seating, designatable, stored, microcomputer, array, teacher, console, actuated, memory, corner, designation, switching, seated, select

ENGLISH-ABST:

In a group education system of the type having a teacher console and a plurality of terminals at seat positions assignable for student use, a display apparatus includes a display screen adapted to display a seating pattern which corresponds to the seating arrangement of terminals within the classroom. The displayed pattern is created by designating certain areas of the display screen to correspond to seat positions actually assigned for student use, and identifying symbols may be displayed in each of these areas. The display apparatus also includes pattern selecting keys for reordering the designated areas to correspond to a selected on of a plurality of predetermined patterns. In an information display made of the apparatus, actuation of a switch corresponding to a respective one of these areas causes the display of information related to the student occupying the corresponding seat in the classroom.

DETDESC:
... key for causing this rearrangement, where the information and data relating to each individual student is retained unchanged, but the information is associated with different ones of the designatable image areas according to the selected pattern. Function keys **PATNO** 1-4 provide this function.

In FIGS. 6A and 6B the numbers shown may be considered to be identifying marks or symbols associated with the respective image areas. Alternatively, FIG. 6A and 6B may be used to illustrate the operation of function keys **PATNO** 1 to 4, by identifying the pattern number of the image areas within each pattern.

Thus, for instance, suppose that pattern number 1 is the pattern that appears in FIG. 6C. It should be understood that the symbols ...

Terms: **patno=6844990** (Suggest Terms for My Search)
View: SuperKWIC
Date/Time: Thursday, December 4, 2014 - 4:32 PM EST

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.
90/013,410	11/26/2014	6844990	688266-21RX	4682

570 7590 12/19/2014

PANITCH SCHWARZE BELISARIO & NADEL LLP
ONE COMMERCE SQUARE
2005 MARKET STREET, SUITE 2200
PHILADELPHIA, PA 19103

EXAMINER	
LEUNG, CHRISTINA Y	

ART UNIT	PAPER NUMBER
3992	

MAIL DATE	DELIVERY MODE
12/19/2014	PAPER

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.

PTOL-90A (Rev. 04/07)

Ex Parte Reexamination Interview Summary – Pilot Program for Waiver of Patent Owner's Statement	**Control No.** 90/013,410	**Patent For Which Reexamination is Requested** 6844990
	Examiner Christina Leungl	**Art Unit** 3992

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

All participants (USPTO official and patent owner):

(1) Tredelle D. Jackson (3)

(2) MURRAY, STEPHEN 63206 (4)

Date of Telephonic Interview: 12/09/14.

The USPTO official requested waiver of the patent owner's statement pursuant to the pilot program for waiver of patent owner's statement in *ex parte* reexamination proceedings.*

☒ The patent owner **agreed** to waive its right to file a patent owner's statement under 35 U.S.C. 304 in the event reexamination is ordered for the above-identified patent.

☐ The patent owner **did not agree** to waive its right to file a patent owner's statement under 35 U.S.C. 304 at this time.

The patent owner is not required to file a written statement of this telephone communication under 37 CFR 1.560(b) or otherwise. However, any disagreement as to this interview summary must be brought to the immediate attention of the USPTO, and no later than one month from the mailing date of this interview summary. Extensions of time are governed by 37 CFR 1.550(c).

*For more information regarding this pilot program, see *Pilot Program for Waiver of Patent Owner's Statement in Ex Parte Reexamination Proceedings*, 75 *Fed. Reg.* 47269 (August 5, 2010), available on the USPTO Web site at http://www.uspto.gov/patents/law/notices/2010.jsp.

☐ USPTO personnel were unable to reach the patent owner.

The patent owner may contact the USPTO personnel at the telephone number provided below if the patent owner decides to waive the right to file a patent owner's statement under 35 U.S.C. 304.

/Tredelle. D. Jackson/ 571-272-2783
Signature and telephone number of the USPTO official who contacted or attempted to contact the patent owner.

cc: Requester (if third party requester)

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.	FILING DATE	FIRST NAMED INVENTOR	ATTORNEY DOCKET NO.	CONFIRMATION NO.
90/013,410	11/26/2014	6844990	688266-21RX	4682

570 7590 01/09/2015

PANITCH SCHWARZE BELISARIO & NADEL LLP
ONE COMMERCE SQUARE
2005 MARKET STREET, SUITE 2200
PHILADELPHIA, PA 19103

EXAMINER	
LEUNG, CHRISTINA Y	

ART UNIT	PAPER NUMBER
3992	

MAIL DATE	DELIVERY MODE
01/09/2015	PAPER

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.

PTOL-90A (Rev. 04/07)

Order Granting / Denying Request For Ex Parte Reexamination	**Control No.** 90/013,410	**Patent Under Reexamination** 6844990
	Examiner Christina Y. Leung	**Art Unit** 3992

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

The request for *ex parte* reexamination filed 26 November 2014 has been considered and a determination has been made. An identification of the claims, the references relied upon, and the rationale supporting the determination are attached.

Attachments: a)☐ PTO-892, b)☒ PTO/SB/08, c)☐ Other: _____

1. ☒ The request for *ex parte* reexamination is GRANTED.

RESPONSE TIMES ARE SET AS FOLLOWS:

For Patent Owner's Statement (Optional): TWO MONTHS from the mailing date of this communication (37 CFR 1.530 (b)). **EXTENSIONS OF TIME ARE GOVERNED BY 37 CFR 1.550(c).**

For Requester's Reply (optional): TWO MONTHS from the **date of service** of any timely filed Patent Owner's Statement (37 CFR 1.535). **NO EXTENSION OF THIS TIME PERIOD IS PERMITTED.** If Patent Owner does not file a timely statement under 37 CFR 1.530(b), then no reply by requester is permitted.

2. ☐ The request for *ex parte* reexamination is DENIED.

This decision is not appealable (35 U.S.C. 303(c)). Requester may seek review by petition to the Commissioner under 37 CFR 1.181 within ONE MONTH from the mailing date of this communication (37 CFR 1.515(c)). **EXTENSION OF TIME TO FILE SUCH A PETITION UNDER 37 CFR 1.181 ARE AVAILABLE ONLY BY PETITION TO SUSPEND OR WAIVE THE REGULATIONS UNDER 37 CFR 1.183.**

In due course, a refund under 37 CFR 1.26 (c) will be made to requester:

a) ☐ by Treasury check or,

b) ☐ by credit to Deposit Account No. _____, or

c) ☐ by credit to a credit card account, unless otherwise notified (35 U.S.C. 303(c)).

/Christina Y. Leung/
Primary Examiner, Art Unit 3992

cc:Requester (if third party requester)

DECISION GRANTING EX PARTE REEXAMINATION

Decision on the Request

The present request for *ex parte* reexamination raises a substantial new question of patentability with respect to claims 1-4, 6, 7, 10, 11, 15-20, 22, 23, and 25 of United States Patent 6,844,990 to Artonne.

References Cited in the Request

Nagaoka (US 6,128,145 A)

Baker (US 5,686,957 A)

Fisher (US 3,953,111 A)

Shiota (EP 1 028 389 A2)

Matsui (JP 2000-242773)

Enami (JP H11-261868)

Inoue (US 6,031,670 A)

Issues Raised by the Request

Issue 1

The request alleges that Nagaoka raises a substantially new question of patentability with respect to claims 1, 2, 4, 6, 17, 18, 20, and 22.

Issue 2

The request alleges that Baker raises a substantially new question of patentability with respect to claims 1, 2, 4, 6, 17, 18, 20, and 22.

Issue 3

The request alleges that Fisher raises a substantially new question of patentability with respect to claims 1-3, 6, 7, 17-19, 22, and 23.

Issue 4

The request alleges that Nagaoka in view of Shiota raises a substantially new question of patentability with respect to claims 10 and 11.

Issue 5

The request alleges that Nagaoka in view of Matsui raises a substantially new question of patentability with respect to claim 10.

Issue 6

The request alleges that Baker in view of Shiota raises a substantially new question of patentability with respect to claims 10 and 11.

Issue 7

The request alleges that Nagaoka in view of Shiota and Enami raises a substantially new question of patentability with respect to claims 15 and 16.

Issue 8

The request alleges that Baker in view of Shiota and Enami raises a substantially new question of patentability with respect to claims 15 and 16.

Issue 9

The request alleges that Nagaoka in view of Inoue raises a substantially new question of patentability with respect to claim 25.

Issue 10

The request alleges that Baker in view of Inoue raises a substantially new question of patentability with respect to claim 25.

Scope of Reexamination

Since the requester did not request reexamination of claims 5, 8, 9, 12-14, 21, 24, and 26, and did not assert the existence of a substantial new question of patentability for those claims (see 35 U.S.C. § 31 l(b)(2); see also 37 CFR 1.915b and 1.923), those claims will not be reexamined. This matter was squarely addressed in *Sony Computer Entertainment America lnc., et al. v. Jon W. Dudas*, 85 USPQ2d 1594 (E.D. Va 2006). The District Court upheld the Office's discretion to not reexamine claims in an *inter partes* reexamination proceeding other than those claims for which reexamination had been specifically requested. The Court stated:

"To be sure, a party may seek, and the PTO may grant, *inter partes* review of each and every claim of a patent. Moreover, while the PTO in its discretion may review claims for which inter partes review was not requested, nothing in the statute compels it to do so. To ensure that the PTO considers a claim for *inter partes* review, § 311(b)(2) requires that the party seeking reexamination demonstrate why the PTO should reexamine each and every claim for which it seeks review. Here, it is undisputed that Sony did not seek review of every claim under the '213 and '333 patents. Accordingly, Sony cannot now claim that the PTO wrongly failed to reexamine claims for which Sony never requested review, and its argument that AIPA compels a contrary result is unpersuasive."

The Sony decision's reasoning and statutory interpretation apply analogously to *ex parte* reexamination, as the same relevant statutory language applies to both *inter partes* and *ex parte* reexamination. 35 U.S.C. § 302 provides that the *ex parte* reexamination "request must set forth the pertinency and manner of applying cited prior art *to every claim for which reexamination is requested*" (emphasis added), and 35 U.S.C. § 303 provides that "the Director will determine whether a substantial new question of patentability affecting *any claim of the patent* concerned is *raised by the request*" (emphasis added). These provisions are analogous to the language of 35 U.S.C. § 311(b)(2) and 35 U.S.C. § 312 applied and construed in Sony, and would be construed in the same manner. As the Director can decline to reexamine non-requested claims in an *inter partes* reexamination proceeding, the Director can likewise do so in *ex parte* reexamination proceeding. See *Notice of Clarification of Office Policy To Exercise Discretion in Reexamining Fewer Than All the Patent Claims* (signed Oct. 5, 2006) 1311 OG 197 (Oct. 31, 2006). See also MPEP § 2240, Rev. 5, Aug. 2006.

The Artonne Patent

Artonne is generally directed to a method for capturing a digital panoramic image. Claim 1 is representative:

1. A method for capturing a digital panoramic image, by projecting a panorama onto an image sensor by means of a panoramic objective lens, the panoramic objective lens having an image point distribution function that is not linear relative to the field angle of object points of the panorama, the distribution function having a maximum divergence of at least +/-10% compared to a linear distribution function, such that the panoramic image obtained has at least one substantially expanded zone and at least one substantially compressed zone.

Prosecution History

Artonne issued 18 January 2005 from application 10/706,513 filed 12 November 2003, which claims priority to application PCT/FR02/01588 filed on 10 May 2002.

12 November 2003: Applicant filed claims 1-26.

14 September 2004: Examiner allowed claims 1-26, noting that

"The prior art fails to teach a combination of all the claimed features as presented, for example, in independent claims 1 and 17, which include a panoramic objective lens having an image point distribution function that is not linear relative to the field angle of object points of the panorama, the distribution function having a maximum divergence of at least +/-10% compared to a linear distribution function, such that the panoramic image obtained has at least one substantially expanded zone and at least on substantially compressed zone."

Detailed Analysis

Claims 1-4, 6, 7, 10, 11, 15-20, 22, 23, and 25 will be reexamined.

In view of the prosecution history, a substantial new question of patentability is raised by the evaluation of a prior art reference (or a combination of prior art references) that teaches a panoramic objective lens having an image point distribution function that is not linear relative to the field angle of object points of the panorama, the distribution function having a maximum divergence of at least +/-10% compared to a linear distribution function, such that the panoramic image obtained has at least one substantially expanded zone and at least on substantially compressed zone

Issues 1, 4, 5, 7, and 9

The request alleges that Nagaoka alone or in view of Shiota, Matsui, Enami, and/or Inoue raise substantially new questions of patentability with respect to claims 1, 2, 4, 6, 10, 11, 15-18, 20, 22, and 25.

Nagaoka, in the form of European equivalent patent EP 1 004 915 A1, was previously cited in an Information Disclosure Statement (IDS) during the prosecution of Artonne. However, the teachings of Nagaoka were not discussed on the record by the Examiner or the applicant. Shiota, Matsui, Enami, and Inoue were not previously cited and are new prior art.

The request provides new view of Nagaoka by alleging that Nagaoka generally teaches a panoramic objective lens (Figure 2) having an image point distribution function that is not linear relative to the field angle of object points of the panorama, the distribution function having a maximum divergence of at least +/-10% compared to a linear distribution function, such that the panoramic image obtained has at least one substantially expanded zone and at least on substantially compressed zone (e.g., lenses having functions $h = 1.2f \bullet \tan(\theta/1.6)$ or $1.6f \bullet \tan(\theta/2)$. See Figures 3A-B.

Since this teaching is directly related to subject matter considered the basis for allowability of claims 1, 2, 4, 6, 10, 11, 15-18, 20, 22, and 25, a reasonable examiner would consider evaluation of this new view of Nagaoka important in determining the patentability of the claims. Therefore, Nagaoka as discussed on the record by the request, alone or in view of Shiota, Matsui, Enami, and/or Inoue, raises a substantial new question of patentability with respect to claims 1, 2, 4, 6, 10, 11, 15-18, 20, 22, and 25.

Issues 2, 6, 8, and 10

The request alleges that Baker alone or in view of Shiota, Enami, and/or Inoue raises substantially new questions of patentability with respect to claims 1, 2, 4, 6, 10, 11, 15-18, 20, 22, and 25.

Baker, in the form of European equivalent patent EP 0695 085 A1, was previously cited in an IDS during the prosecution of Artonne. However, the teachings of Baker were not discussed on the record. Shiota, Enami, and Inoue were not previously cited and are new prior art.

The request provides new view of Baker by alleging that Baker generally teaches a panoramic objective lens having an image point distribution function that is not linear relative to the field angle of object points of the panorama (Figures 3BA and 3BB), the distribution function having a maximum divergence of at least +/-10% compared to a linear distribution function, such that the panoramic image obtained has at least one substantially expanded zone and at least on substantially compressed zone (column 6, lines 48-56; and column 12, lines 29-32).

Since this teaching is directly related to subject matter considered the basis for allowability of claims 1, 2, 4, 6, 10, 11, 15-18, 20, 22, and 25, a reasonable examiner would consider evaluation of this new view of Baker important in determining the patentability of the claims. Therefore, Baker as discussed on the record by the request, alone or in view of Shiota, Matsui, Enami, and/or Inoue, raises a substantial new question of patentability with respect to claims 1, 2, 4, 6, 10, 11, 15-18, 20, 22, and 25.

Issue 3

The request alleges that Fisher raises substantially new questions of patentability with respect to claims 1-3, 6, 7, 17-19, 22, and 23.

Fisher was previously cited in an IDS during the prosecution of Artonne. However, the teachings of Fisher were not discussed on the record. The request provides new view of Fisher by alleging that Fisher generally teaches a panoramic objective lens (Figures 3 and 6) having an image point distribution function that is not linear relative to the field angle of object points of the panorama, the distribution function having a maximum divergence of at least +/-10% compared to a linear distribution function (e.g., the function labeled "Non-Linear Lens" in Figure 3, which is $H=\sin^{1/3}\theta$), such that the panoramic image obtained has at least one substantially expanded zone and at least on substantially compressed zone (column 3, lines 4-12).

Since this teaching is directly related to subject matter considered the basis for allowability of claims 1-3, 6, 7, 17-19, 22, and 23, a reasonable examiner would consider evaluation of this new view of Fisher important in determining the patentability of the claims. Therefore, Fisher raises a substantial new question of patentability with respect to claims 1-3, 6, 7, 17-19, 22, and 23.

Conclusion

Extensions of time under 37 CFR 1.136(a) will not be permitted in these proceedings because the provisions of 37 CFR 1.136 apply only to "an applicant" and not to parties in a reexamination proceeding. Additionally, 35 U.S.C. 305 requires that *ex parte* reexamination proceedings "will be conducted with special dispatch" (37 CFR 1.550(a)). Extensions of time in *ex parte* reexamination proceedings are provided for in 37 CFR 1.550(c).

The patent owner is reminded of the continuing responsibility under 37 CFR 1.565(a) to apprise the Office of any litigation activity, or other prior or concurrent proceeding, involving Patent No. 6,844,990 throughout the course of this reexamination proceeding. See MPEP §§ 2207, 2282 and 2286.

All correspondence relating to this *ex parte* reexamination proceeding should be directed:

By mail to: Mail Stop *Ex Parte* Reexam
Central Reexamination Unit

Commissioner for Patents
United States Patent & Trademark Office
P.O. Box 1450
Alexandria, VA 22313-1450

By fax to: (571) 273-9900
Central Reexamination Unit

By hand to: Customer Service Window
Randolph Building
401 Dulany Street
Alexandria, VA 22314

Any inquiry concerning this communication should be directed to the Central Reexamination Unit at telephone number (571) 272-7705.

/Christina Y. Leung/

Primary Examiner, Art Unit 3992

Conferees:

/D.M.H./, PE AU3992

/SUDHANSHU PATHAK/
Supervisory Patent Examiner, Art Unit 3992

Order Granting / Denying Request For Ex Parte Reexamination	**Control No.** 90/013,410	**Patent Under Reexamination** 6844990
	Examiner Christina Y. Leung	**Art Unit** 3992

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

The request for *ex parte* reexamination filed 26 November 2014 has been considered and a determination has been made. An identification of the claims, the references relied upon, and the rationale supporting the determination are attached.

Attachments: a)☐ PTO-892, b)☒ PTO/SB/08, c)☐ Other: _____

1. ☒ The request for *ex parte* reexamination is GRANTED.

RESPONSE TIMES ARE SET AS FOLLOWS:

For Patent Owner's Statement (Optional): TWO MONTHS from the mailing date of this communication (37 CFR 1.530 (b)). **EXTENSIONS OF TIME ARE GOVERNED BY 37 CFR 1.550(c).**

For Requester's Reply (optional): TWO MONTHS from the **date of service** of any timely filed Patent Owner's Statement (37 CFR 1.535). **NO EXTENSION OF THIS TIME PERIOD IS PERMITTED.** If Patent Owner does not file a timely statement under 37 CFR 1.530(b), then no reply by requester is permitted.

2. ☐ The request for *ex parte* reexamination is DENIED.

This decision is not appealable (35 U.S.C. 303(c)). Requester may seek review by petition to the Commissioner under 37 CFR 1.181 within ONE MONTH from the mailing date of this communication (37 CFR 1.515(c)). **EXTENSION OF TIME TO FILE SUCH A PETITION UNDER 37 CFR 1.181 ARE AVAILABLE ONLY BY PETITION TO SUSPEND OR WAIVE THE REGULATIONS UNDER 37 CFR 1.183.**

In due course, a refund under 37 CFR 1.26 (c) will be made to requester:

a) ☐ by Treasury check or,

b) ☐ by credit to Deposit Account No. _____, or

c) ☐ by credit to a credit card account, unless otherwise notified (35 U.S.C. 303(c)).

/Christina Y. Leung/ Primary Examiner, Art Unit 3992		

cc:Requester (if third party requester)

Search Notes	Application/Control No. 90013410	Applicant(s)/Patent Under Reexamination 6844990
	Examiner CHRISTINA Y LEUNG	**Art Unit** 3992

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
Reviewed cited references and patented file's prosecution history.	1-5-15	/CL/

INTERFERENCE SEARCH

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

	/CHRISTINA Y LEUNG/ Primary Examiner.Art Unit 3992

Reexamination	Application/Control No. 90/013,410	Applicant(s)/Patent Under Reexamination 6844990
	Certificate Date	**Certificate Number**

Requester	**Correspondence Address:**	☒ **Patent Owner**	☐ **Third Party**

PANITCH SCHWARZE BELISARIO & NADEL LLP
ONE COMMERCE SQUARE
2005 MARKET STREET, SUITE 2200
PHILADELPHIA, PA 19103

LITIGATION REVIEW ☒	**/CL/** (examiner initials)	**1-5-15** (date)
Case Name		Director Initials
1:13cv1139, Immervision Inc. v. Cbc Co. Ltd. et al.		
2:13cv1117, Immervision, Inc. v. Vivotek, Inc.		

COPENDING OFFICE PROCEEDINGS	
TYPE OF PROCEEDING	**NUMBER**
1. Inter partes review of 6,844,990	IPR2014-01438
2.	
3.	
4.	

U.S. Patent and Trademark Office DOC. CODE **RXFILJKT**

INFORMATION DISCLOSURE STATEMENT BY APPLICANT (**Not for submission under 37 CFR 1.99)**		
	Application Number	90/013,410
	Filing Date	
	First Named Inventor	Jean-Claude ARTONNE
	Art Unit	
	Examiner Name	
	Attorney Docket Number	688266-21RX

U.S.PATENTS Remove

Examiner Initial*	Cite No	Patent Number	Kind Code1	Issue Date	Name of Patentee or Applicant of cited Document	Pages,Columns,Lines where Relevant Passages or Relevant Figures Appear
/CL/	1	6128145		2000-10-03	Nagaoka	
/CL/	2	5686957		1997-11-11	Baker	
/CL/	3	3953111		1976-04-27	Fisher, et al.	
/CL/	4	6031670		2000-02-29	Inoue	

If you wish to add additional U.S. Patent citation information please click the Add button. Add

U.S.PATENT APPLICATION PUBLICATIONS Remove

Examiner Initial*	Cite No	Publication Number	Kind Code1	Publication Date	Name of Patentee or Applicant of cited Document	Pages,Columns,Lines where Relevant Passages or Relevant Figures Appear
	1					

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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

INFORMATION DISCLOSURE STATEMENT BY APPLICANT (Not for submission under 37 CFR 1.99)		
	Application Number	90/013,410
	Filing Date	
	First Named Inventor	Jean-Claude ARTONNE
	Art Unit	
	Examiner Name	
	Attorney Docket Number	688266-21RX

/CL/	1	1028389	EP	A2	2000-08-16	Shiota, et al.		☐
/CL/	2	2000-242773	JP	A	2000-09-08	Matsui, et al.		☒
/CL/	3	11-261868	JP	A	1999-09-24	Enami		☒

If you wish to add additional Foreign Patent Document citation information please click the Add button Add

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
	1		☐

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

EXAMINER SIGNATURE

Examiner Signature	/Christina Leung/	Date Considered	01/05/2015

*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.

EFS Web 2.1.17

INFORMATION DISCLOSURE STATEMENT BY APPLICANT (**Not for submission under 37 CFR 1.99)**		
	Application Number	90013410
	Filing Date	2014-11-26
	First Named Inventor	Jean-Claude ARTONNE
	Art Unit	3992
	Examiner Name	Christina Y. Leung
	Attorney Docket Number	688266-21RX

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					

If you wish to add additional U.S. Patent citation information please click the Add button. Add

U.S.PATENT APPLICATION PUBLICATIONS

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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					

If you wish to add additional U.S. Published Application citation information please click the Add button. Add

FOREIGN PATENT DOCUMENTS

Remove

Examiner Initial*	Cite No	Foreign Document Number[3]	Country Code[2] i	Kind Code[4]	Publication Date	Name of Patentee or Applicant of cited Document	Pages,Columns,Lines where Relevant Passages or Relevant Figures Appear	T[5]
	1							☐

If you wish to add additional Foreign Patent Document citation information please click the Add button Add

NON-PATENT LITERATURE DOCUMENTS

Remove

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

INFORMATION DISCLOSURE STATEMENT BY APPLICANT (**Not for submission under 37 CFR 1.99)**		
	Application Number	90013410
	Filing Date	2014-11-26
	First Named Inventor	Jean-Claude ARTONNE
	Art Unit	3992
	Examiner Name	Christina Y. Leung
	Attorney Docket Number	688266-21RX

	1	Applied Photographic Optics; Lenses and optical systems for photography, film, video and electronic imaging. Second Edition by Sidney F. Ray (1998)	☐

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

EXAMINER SIGNATURE

Examiner Signature		Date Considered	

*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	90013410
	Filing Date	2014-11-26
	First Named Inventor	Jean-Claude ARTONNE
	Art Unit	3992
	Examiner Name	Christina Y. Leung
	Attorney Docket Number	688266-21RX

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	/Stephen E. Murray/	Date (YYYY-MM-DD)	2015-01-09
Name/Print	Stephen E. Murray	Registration Number	63206

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 the Freedom of Information Act requires disclosure of these record s.

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 inspections or an issued patent.

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

Attorney Docket No.: 688266-21RX

IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

In re Patent of: Jean-Claude ARTONNE et al.	Patent No.: 6,844,990 B2
Reexamination Control No.: 90/013,410	Art Unit 3992
Filing Date: November 26, 2014	Conf. No.: 4682
For: METHOD FOR CAPTURING AND DISPLAYING A VARIABLE RESOLUTION DIGITAL PANORAMIC IMAGE	Examiner Christina Y. Leung

INFORMATION DISCLOSURE STATEMENT (IDS) UNDER 37 C.F.R. § 1.555

Enclosed is an Information Disclosure Citation Form PTO/SB/08A and/or 08B in accordance with 37 C.F.R. § 1.98 listing all patents, publications, applications, and/or other information being submitted for consideration which may be material to this reexamination proceeding and/or for which there may be a duty to disclose in accordance with 37 C.F.R. § 1.56.

In accordance with M.P.E.P. § 2280, this Information Disclosure Statement is being filed within two months of the date of the order for reexamination.

The enclosed reference is an excerpt from the second edition of "Applied Photographic Optics" that is directed to design development and features of a "fisheye" lens.

The filing of this Information Disclosure Statement shall not be construed as an admission that any of the listed documents constitutes prior art, nor as an admission against interest in any manner.

No fee is believed to be due in connection with the filing of this Information Disclosure Statement. However, if any fee is due, please charge the fee to Deposit Account No. 50-1017.

It is respectfully requested that this Information Disclosure Statement and the document listed on the attached Form PTO/SB/08A and/or 08B and attached herewith be considered and acknowledged by the Examiner in connection with the above-identified reexamination, be made of record therein, and that the listed document be cited in reexamination certificate.

Dated: January 9, 2015

Respectfully submitted,

By /Stephen E. Murray/

Stephen E. Murray
Registration No.: 63,206
PANITCH SCHWARZE BELISARIO & NADEL LLP
One Commerce Square
2005 Market Street, Suite 2200
Philadelphia, Pennsylvania 19103
(215) 965-1307
(215) 965-1331 (Fax)
smurray@panitchlaw.com (E-Mail)

Electronic Acknowledgement Receipt

EFS ID:	21170689
Application Number:	90013410
International Application Number:	
Confirmation Number:	4682
Title of Invention:	METHOD FOR CAPTURING AND DISPLAYING A VARIABLE RESOLUTION DIGITAL PANORAMIC IMAGE
First Named Inventor/Applicant Name:	6844990
Customer Number:	570
Filer:	Stephen Murray/Kathy Higgins
Filer Authorized By:	Stephen Murray
Attorney Docket Number:	688266-21RX
Receipt Date:	09-JAN-2015
Filing Date:	26-NOV-2014
Time Stamp:	16:09:42
Application Type:	Reexam (Patent Owner)

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	Non Patent Literature	Applied_Photographic_Optics_-_Sidney_F__Ray.PDF	311990 d90f60cb0f369bcb2e7d6002b17735442a5bdf6c	no	6

Warnings:

Information:

2	Information Disclosure Statement (IDS) Form (SB08)	Information_Disclosure_Statement_Fillable_PDF.PDF	612225 264e88a0cdc5d8200b383629df7eeb1165ca8890	no	4

Warnings:

Information:

A U.S. Patent Number Citation or a U.S. Publication Number Citation is required in the Information Disclosure Statement (IDS) form for autoloading of data into USPTO systems. You may remove the form to add the required data in order to correct the Informational Message if you are citing U.S. References. If you chose not to include U.S. References, the image of the form will be processed and be made available within the Image File Wrapper (IFW) system. However, no data will be extracted from this form. Any additional data such as Foreign Patent Documents or Non Patent Literature will be manually reviewed and keyed into USPTO systems.

3	Transmittal Letter	00694035.PDF	453506 36ca8ad97ddca53ef28bf50024e68ef6a90965af	no	2

Warnings:

Information:

Total Files Size (in bytes):	1377721

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
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.
90/013,410	11/26/2014	6844990	688266-21RX	4682

570 7590 01/29/2015

PANITCH SCHWARZE BELISARIO & NADEL LLP
ONE COMMERCE SQUARE
2005 MARKET STREET, SUITE 2200
PHILADELPHIA, PA 19103

EXAMINER	
LEUNG, CHRISTINA Y	

ART UNIT	PAPER NUMBER
3992	

MAIL DATE	DELIVERY MODE
01/29/2015	PAPER

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.

PTOL-90A (Rev. 04/07)

Office Action in Ex Parte Reexamination	**Control No.** 90/013,410	**Patent Under Reexamination** 6844990	
	Examiner Christina Y. Leung	**Art Unit** 3992	**AIA (First Inventor to File) Status** No

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

a. ☒ Responsive to the communication(s) filed on *26 November 2014* .
☐ A declaration(s)/affidavit(s) under **37 CFR 1.130(b)** was/were filed on _____.

b. ☐ This action is made FINAL.

c. ☐ A statement under 37 CFR 1.530 has not been received from the patent owner.

A shortened statutory period for response to this action is set to expire *2* month(s) from the mailing date of this letter.
Failure to respond within the period for response will result in termination of the proceeding and issuance of an *ex parte* reexamination certificate in accordance with this action. 37 CFR 1.550(d). **EXTENSIONS OF TIME ARE GOVERNED BY 37 CFR 1.550(c).**
If the period for response specified above is less than thirty (30) days, a response within the statutory minimum of thirty (30) days will be considered timely.

Part I THE FOLLOWING ATTACHMENT(S) ARE PART OF THIS ACTION:

1. ☐ Notice of References Cited by Examiner, PTO-892.
2. ☐ Information Disclosure Statement, PTO/SB/08.
3. ☐ Interview Summary, PTO-474.
4. ☐ _____.

Part II SUMMARY OF ACTION

1a. ☒ Claims *1-4,6,7,10,11,15-20,22,23,25 and 27-48* are subject to reexamination.

1b. ☒ Claims *5,8,9,12-14,21,24 and 26* are not subject to reexamination.

2. ☒ Claims *1,6,7 and 22* have been canceled in the present reexamination proceeding.

3. ☒ Claims *10 and 11* are patentable and/or confirmed.

4. ☒ Claims *2-4,15-20,23,25 and 27-48* are rejected.

5. ☐ Claims _____ are objected to.

6. ☐ The drawings, filed on _____ are acceptable.

7. ☐ The proposed drawing correction, filed on _____ has been (7a) ☐ approved (7b) ☐ disapproved.

8. ☐ Acknowledgment is made of the priority claim under 35 U.S.C. § 119(a)-(d) or (f).

a) ☐ All b) ☐ Some* c) ☐ None of the certified copies have

1 ☐ been received.

2 ☐ not been received.

3 ☐ been filed in Application No. _____ .

4 ☐ been filed in reexamination Control No. _____.

5 ☐ been received by the International Bureau in PCT application No. _____.

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

9. ☐ Since the proceeding appears to be in condition for issuance of an *ex parte* reexamination certificate 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.

10. ☐ Other: _____

cc: Requester (if third party requester)

DETAILED ACTION

Reexamination

1. *Ex parte* reexamination of claims 1-4, 6, 7, 10, 11, 15-20, 22, 23, and 25 of **Artonne** (US 6,844,990 B2) has been granted. Claims 5, 8, 9, 12-14, 21, 24, and 26 are not subject to reexamination in this proceeding. Patent Owner (PO) filed a preliminary claim amendment with the request for reexamination on 26 November 2014, canceling claims 1, 6, 7, and 22; amending claims 2-4, 10, and 15; and adding new claims 27-48.

2. The claims currently pending in this proceeding are claims 2-4, 10, 11, 15-20, 23, 25, and 27-48.

References and Documents Cited in this Action

Artonne (US 6,844,990 B2)

Nagaoka (US 6,128,145 A)

Baker (US 5,686,957 A)

Fisher (US 3,953,111 A)

Shiota (EP 1 028 389 A2)

Matsui (JP 2000-242773; see English-language translation filed by PO on 26 November 2014)

Enami (JP H11-261868; see English-language translation filed by PO on 26 November 2014)

Inoue (US 6,031,670 A)

PO Request (request for reexamination filed by PO on 26 November 2014)

PO Remarks (remarks filed by PO with a preliminary amendment on 26 November 2014)

Claim Rejections - 35 USC § 305

3. **Claims 2-4, 15, 16, and 27-48** are rejected under 35 U.S.C. 305 as enlarging the scope of the claim(s) of the patent being reexamined. In 35 U.S.C. 305, it is stated that "[n]o proposed amended or new claim enlarging the scope of a claim of the patent will be permitted in a reexamination proceeding... ." A claim presented in a reexamination "enlarges the scope" of the patent claim(s) where the claim is broader than any claim of the patent. A claim is broader in scope than the original claims if it contains within its scope any conceivable product or process which would not have infringed the original patent. A claim is broadened if it is broader in any one respect, even though it may be narrower in other respects.

Regarding independent **claims 27, 38, and 48,** claims 27, 38, and 48 each include steps and limitations recited in original claim 1, except claims 27 and 48 recite "such that the panoramic image obtained has at least one expanded zone and at least one compressed zone" and claim 38 recites "such that the panoramic image obtained has at least one expanded zone and at least two compressed zones." In contrast, original claim 1 recites "at least one substantially expanded zone and at least one substantially compressed zone." Claims 27, 38, and 48 are rejected under 35 U.S.C. 305 because they are broader than the original claims in at least this aspect. The claims do not require a "substantially expanded" and a "substantially compressed" zone (i.e., expanded and compressed zones that are not "substantially" expanded and compressed would be contained within its scope).

Claims 2-4, 15, 16, 28-31, and 39-47 are also rejected under 35 U.S.C. 305 for the above reason because they depend on claim 27 or 38.

Similarly, regarding independent **claim 32**, claim 32 includes elements and limitations recited in original claim 17, except claim 32 recites "such that a panoramic image obtained using the objective lens comprises at least one expanded zone and at least one compressed zone." In contrast, original claim 17 recites "at least one substantially expanded zone and at least one substantially compressed zone." Claim 32 is rejected under 35 U.S.C. 305 because it is broader than the original claims in at least this aspect. The claim does not require a "substantially expanded" and a "substantially compressed" zone (i.e., expanded and compressed zones that are not "substantially" expanded and compressed would be contained within its scope).

Claims 33-37 are also rejected under 35 U.S.C. 305 for the above reason because they depend on claim 32.

Claim Rejections - 35 USC § 112

4. The following is a quotation of the first paragraph of 35 U.S.C. 112(a):

> (a) IN GENERAL.—The specification shall contain a written description of the invention, and of the manner and process of making and using it, in such full, clear, concise, and exact terms as to enable any person skilled in the art to which it pertains, or with which it is most nearly connected, to make and use the same, and shall set forth the best mode contemplated by the inventor or joint inventor of carrying out the invention.

The following is a quotation of the first paragraph of pre-AIA 35 U.S.C. 112:

> The specification shall contain a written description of the invention, and of the manner and process of making and using it, in such full, clear, concise, and exact terms as to enable any person skilled in the art to which it pertains, or with which it is most nearly connected, to make and use the same, and shall set forth the best mode contemplated by the inventor of carrying out his invention.

5. **Claim 48** is rejected under 35 U.S.C. 112(a) or 35 U.S.C. 112 (pre-AIA), first paragraph, as failing to comply with the enablement requirement. The claim(s) contains subject matter

which was not described in the specification in such a way as to enable one skilled in the art to which it pertains, or with which it is most nearly connected, to make and/or use the invention.

Claim 48 recites the limitation "wherein the objective lens has a non-linear distribution function that is not symmetrical relative to the optical axis of the objective lens." In PO Remarks (page 11), PO cites column 18, lines 17-28 to support this limitation:

> "In particular, although the description above was of non-linear panoramic objective lenses with axial symmetry relative to the optical axis, in which the position of an image point only varies with the field angle relative to this axis of the corresponding object point (which gives a distribution of points in concentric circles, as seen above), the framework of the present invention also covers providing objective lenses the non-linearity of which is not symmetrical relative to the optical axis, such that the expanded parts of the image may, in this case, not be set on the center of the image." (Artonne, column 18, lines 17-28)

However, although the above contends that "the framework of the present invention also covers" the limitations recited in claim 48, Artonne does not disclose or illustrate any examples of objective lenses with a non-linear distribution that is not symmetrical relative to the optical axis. The embodiments described in Figures 1-18 and throughout the specification only include objective lenses with a symmetrical non-linear distribution. There is no embodiment disclosed in Artonne having a non-symmetrical non-linear distribution. Artonne also does not describe how to make an objective lens with a non-linear distribution that is not symmetrical relative to the optical axis. Therefore, claim 48 contains subject matter which was not described in the specification in such a way as to enable one skilled in the art to which it pertains, or with which it is most nearly connected, to make and/or use the invention.

Claim Rejections - 35 USC § 102

6. The following is a quotation of the appropriate paragraphs of pre-AIA 35 U.S.C. 102 that form the basis for the rejections under this section made in this Office action:

> A person shall be entitled to a patent unless –
>
> (a) the invention was known or used by others in this country, or patented or described in a printed publication in this or a foreign country, before the invention thereof by the applicant for a patent.
>
> (b) the invention was patented or described in a printed publication in this or a foreign country or in public use or on sale in this country, more than one year prior to the date of application for patent in the United States.
>
> (e) the invention was described in (1) an application for patent, published under section 122(b), by another filed in the United States before the invention by the applicant for patent or (2) a patent granted on an application for patent by another filed in the United States before the invention by the applicant for patent, except that an international application filed under the treaty defined in section 351(a) shall have the effects for purposes of this subsection of an application filed in the United States only if the international application designated the United States and was published under Article 21(2) of such treaty in the English language.

7. **Claims 17, 18, and 20** are rejected under pre-AIA 35 U.S.C. 102(a) or 102(e) as being anticipated by **Nagaoka**.

Regarding **claim 17**, Nagaoka discloses a panoramic objective lens (e.g., fisheye lens 1; Figure 2) comprising:

optical means for projecting a panorama into an image plane of the objective lens (i.e., CCD image sensor 30),

the optical means having an image point distribution function that is not linear relative to the field angle of object points of the panorama (e.g., Nagaoka discloses non-linear lenses with functions h=1.2f • tan (θ/1.6) and h=1.6f • tan (θ/2); Figures 3A-B' column 5, lines 34-67; column 6, lines 1-13),

the distribution function having a maximum divergence of at least +/- 10% compared to a linear distribution function (e.g., the function h=1.2f • tan (θ/1.6) diverges about 18% and the function h=1.6f • tan (θ/2) diverges about 16% compared to a linear distribution function at θ = 45°), such that a panoramic image obtained by means of the objective lens comprises at least one substantially expanded zone and at least one substantially compressed zone (Figure 3B shows the functions h=1.2f • tan (θ/1.6) and h=1.6f • tan (θ/2) each having a slope less than the linear distribution function between 0° and about 60° and a slope greater than the linear distribution function between about 60° and 90°, which correspond to an image with a compressed zone in the center and an a expanded zone near the periphery).

Regarding **claim 18**, Nagaoka discloses a non- linear distribution function that is symmetrical relative to the optical axis of the objective lens, the position of an image point relative to the center of an image obtained varying according to the field angle of the corresponding object point. For example, the lenses having the functions h=1.2f • tan (θ/1.6) and h=1.6f • tan (θ/2) each have functions that are symmetrical relative to the optical axis (column 5, lines 34-67; column 6, lines 1-13; see Figures 3A-B and also Figures 4A-D, which show symmetry relative to the optical axis for lenses with related non-linear distribution functions).

Regarding **claim 20**, Nagaoka discloses that wherein the lens expands the edges of an image and compresses the center of the image. For example, Figure 3B shows the functions h=1.2f • tan (θ/1.6) and h=1.6f • tan (θ/2) each having a slope less than the linear distribution function between 0° and about 60° and a slope greater than the linear distribution function between about 60° and 90°, which correspond to an image with a compressed zone in the center and an a expanded zone near the periphery.

8. **Claims 17, 18, and 20** are rejected under pre-AIA 35 U.S.C. 102(b) as being anticipated by **Baker**.

Regarding **claim 17**, Baker discloses a panoramic objective lens (e.g., the lens shown in Figures 3BA and 3BB) comprising

optical means for projecting a panorama into an image plane of the objective lens (i.e., a CCD; column 13, lines 14-17),

the optical means having an image point distribution function that is not linear relative to the field angle of object points of the panorama (Figures 3BA and 3BB; column 12, lines 23-25),

the distribution function having a maximum divergence of at least +/- 10% compared to a linear distribution function (e.g., Baker discloses, compared to a linear distribution lens that would focus "the lowest 15 percent degrees from the horizon on ten percent of the imager," a non-linear lens that focuses that 15 degrees on "fifty percent of the imager" [column 6, lines 48-56], which corresponds to a greater than 10% divergence of the image height at 75°),

such that a panoramic image obtained by means of the objective lens comprises at least zone substantially expanded zone and at least one substantially compressed zone (i.e., Baker discloses that the periphery of the image is expanded and the center of the image is compressed; column 12, lines 29-32; see also Figure 3BB compared to the linear lens image in Figure 2B).

Regarding **claim 18**, Baker discloses a non-linear distribution function that is symmetrical relative to the optical axis of the objective lens, the position of an image point relative to the center of an image obtained varying according to the field angle of the corresponding object point (Figure 3BB).

Regarding **claim 20**, Baker discloses that the lens expands the edges of an image and compresses the center of the image (Figure 3BB shows an expanded periphery and a compressed center compared to the linear lens image in Figure 2B).

9. **Claims 17-19 and 23** are rejected under pre-AIA 35 U.S.C. 102(b) as being anticipated by **Fisher**.

Regarding **claim 17**, Fisher discloses a panoramic objective lens (Figures 3 and 6) comprising:

optical means for projecting a panorama into an image plane of the objective lens (Abstract; column 3, lines 48-49; column 4, lines 35-45),

the optical means having an image point distribution function that is not linear relative to the field angle of object points of the panorama (Figure 3; column 1, lines 9-11; column 2, lines 6-8),

the distribution function having a maximum divergence of at least +/- 10% compared to a linear distribution function (Figure 3 shows the function labeled “Non-Linear Lens” 3, which is $H=\sin^{1/3}\theta$, having a divergence of greater than 10% compared to the linear distribution function of the “Fisheye Lens”),

such that a panoramic image obtained by means of the objective lens comprises at least one substantially expanded zone and at least one substantially compressed zone (Fisher discloses that the center objects “occupy a disproportionately large share of the image cast by the lens when compared with other objects closer to the periphery of the field of view for the lens”; column 3, lines 4-12; see also Figure 4, which compares the object space to the image plane).

Regarding **claim 18**, Fisher discloses a non- linear distribution function that is symmetrical relative to the optical axis of the objective lens, the position of an image point relative to the center of an image obtained varying according to the field angle of the corresponding object point (Figure 4; column 3, lines 21-42).

Regarding **claim 19**, Fisher discloses that the lens expands the center of an image and compresses the edges of the image. Specifically, Fisher discloses that the center objects "occupy a disproportionately large share of the image cast by the lens when compared with other objects closer to the periphery of the field of view for the lens" (column 3, lines 4-12; see also Figure 4 and column 3, lines 21-42).

Regarding **claim 23**, Fisher discloses a panoramic objective lens according to claim 17 as discussed above, and further discloses a set of lenses forming an apodizer (as recited in claim 22, which is not subject to reexamination in this proceeding), at least in the sense that Fisher discloses that the lenses provide a non-linear distribution of image points relative to the field angle of the object points (see Artonne, Figure 15 and column 16, lines 1-4, which describe lenses forming an apodizer; and Fisher, Figure 6, which shows a set of lenses providing a non-linear distribution and thereby forming an apodizer). Further regarding claim 23, Fisher discloses that the set of lenses forming an apodizer comprises at least one aspherical lens (e.g., lens element "a" having aspherical surface R1 and lens element "b" having aspherical surface R3' Figure 6; column 5, lines 61-68).

Claim Rejections - 35 USC § 103

10. 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.

11. **Claim 25** is rejected under pre-AIA 35 U.S.C. 103(a) as being unpatentable over **Nagaoka** in view of **Inoue**.

Regarding **claim 25**, Nagaoka discloses a panoramic objective lens according to claim 17 as discussed above, and further discloses a set of lenses forming an apodizer (as recited in claim 22, which is not subject to reexamination in this proceeding), at least in the sense that Nagaoka discloses that the lenses provide a non-linear distribution of image points relative to the field angle of the object points (see Artonne, Figure 15 and column 16, lines 1-4, which describe lenses forming an apodizer; and Nagaoka, Figure 2, which shows a set of lenses providing a non-linear distribution and thereby forming an apodizer).

Further regarding claim 25, Nagaoka does not specifically disclose polymethacrylate lenses. However, Inoue teaches a lens system that is related to the one disclosed by Nagaoka including polymethacrylate lenses (i.e., “PMMA”; column 2, lines 42-44). It would have been obvious to one of ordinary skill in the art to include polymethacrylate lenses as taught by Inoue in the system disclosed by Nagaoka in order to advantageously reduce the size, weight, and costs of the lens materials (Inoue, column 1, lines 28-31; column 2, lines 42-44).

12. **Claim 25** is rejected under pre-AIA 35 U.S.C. 103(a) as being unpatentable over **Baker** in view of **Inoue**.

Regarding **claim 25**, Baker discloses a panoramic objective lens according to claim 17 as discussed above, and further discloses a set of lenses forming an apodizer (as recited in claim 22, which is not subject to reexamination in this proceeding), at least in the sense that Baker discloses that the lenses provide a non-linear distribution of image points relative to the field angle of the object points (see Artonne, Figure 15 and column 16, lines 1-4, which describe lenses forming an apodizer; and Baker, Figures 3BA and 3BB, which shows a set of lenses providing a non-linear distribution and thereby forming an apodizer).

Further regarding claim 25, Baker does not specifically disclose polymethacrylate lenses. However, Inoue teaches a lens system that is related to the one disclosed by Baker including polymethacrylate lenses (i.e., "PMMA"; column 2, lines 42-44). It would have been obvious to one of ordinary skill in the art to include polymethacrylate lenses as taught by Inoue in the system disclosed by Baker in order to advantageously reduce the size, weight, and costs of the lens materials (Inoue, column 1, lines 28-31; column 2, lines 42-44).

13. **Claim 48** is rejected under pre-AIA 35 U.S.C. 103(a) as being unpatentable over **Nagaoka**.

Regarding **claim 48**, as similarly discussed above with respect to claim 17, Nagaoka discloses a method for capturing a digital panoramic image, by projecting a panorama onto an image sensor by means of a panoramic objective lens (e.g., onto CCD image sensor 30 by means of fisheye lens 1; Figure 2),

the panoramic objective lens having an image point distribution function that is not linear relative to the field angle of object points of the panorama (e.g., Nagaoka discloses non-linear lenses with functions $h=1.2f \bullet \tan(\theta/1.6)$ and $h=1.6f \bullet \tan(\theta/2)$; Figures 3A-B' column 5, lines 34-67; column 6, lines 1-13),

the distribution function having a maximum divergence of at least +/-10% compared to a linear distribution function (e.g., the function $h=1.2f \bullet \tan(\theta/1.6)$ diverges about 18% and the function $h=1.6f \bullet \tan(\theta/2)$ diverges about 16% compared to a linear distribution function at $\theta = 45°$),

such that the panoramic image obtained has at least one expanded zone and at least one compressed zone (Figure 3B shows the functions $h=1.2f \bullet \tan(\theta/1.6)$ and $h=1.6f \bullet \tan(\theta/2)$ each having a slope less than the linear distribution function between 0° and about 60° and a slope greater than the linear distribution function between about 60° and 90°, which correspond to an image with a compressed zone in the center and an a expanded zone near the periphery).

Further regarding claim 48, Nagaoka does not specifically disclose that the objective lens has a non-linear distribution function that is not symmetrical relative to the optical axis of the objective lens. Instead, Nagaoka discloses a non- linear distribution function that is symmetrical relative to the optical axis of the objective lens. For example, the lenses having the functions $h=1.2f \bullet \tan(\theta/1.6)$ and $h=1.6f \bullet \tan(\theta/2)$ each have functions that are symmetrical relative to the optical axis (column 5, lines 34-67; column 6, lines 1-13; see Figures 3A-B and also Figures 4A-D, which show symmetry relative to the optical axis for lenses with related non-linear distribution functions). However, as well as the claim may be understood with respect to 35 U.S.C. 112, first paragraph, discussed above, the Artonne specification suggests that providing an objective lens having a non-linear distribution function that is asymmetrical instead of symmetrical would be accomplished by one of ordinary skill in the art without undue experimentation. In that case, it would have been obvious to one of ordinary skill in the art to include a non-linear distribution function that is not symmetrical relative to the optical axis of the objective lens in the system disclosed by Nagaoka in order to create a resulting image with compressed and expanded zones that do not include the entire center or entire periphery as desired by the user. The development of the lens with the asymmetrical function would have been obvious to try with a reasonable expectation of success.

14. **Claim 48** is rejected under pre-AIA 35 U.S.C. 103(a) as being unpatentable over **Baker**.

Regarding **claim 48**, as similarly discussed above with respect to claim 17, Baker discloses a method for capturing a digital panoramic image, by projecting a panorama onto an image sensor by means of a panoramic objective lens (e.g., onto a CDD by means of the lens shown in Figure 3BA; column 13, lines 14-17)

the panoramic objective lens having an image point distribution function that is not linear relative to the field angle of object points of the panorama (Figures 3BA and 3BB; column 12, lines 23-25),

the distribution function having a maximum divergence of at least +/- 10% compared to a linear distribution function (e.g., Baker discloses, compared to a linear distribution lens that would focus “the lowest 15 percent degrees from the horizon on ten percent of the imager,” a non-linear lens that focuses that 15 degrees on “fifty percent of the imager” [column 6, lines 48-56], which corresponds to a greater than 10% divergence of the image height at 75°),

such that a panoramic image obtained by means of the objective lens comprises at least zone substantially expanded zone and at least one substantially compressed zone (i.e., Baker discloses that the periphery of the image is expanded and the center of the image is compressed; column 12, lines 29-32; see also Figure 3BB compared to the linear lens image in Figure 2B).

Further regarding **claim 48**, Baker does not specifically disclose that the objective lens has a non-linear distribution function that is not symmetrical relative to the optical axis of the objective lens. Instead, Baker discloses a non- linear distribution function that is symmetrical relative to the optical axis of the objective lens (see Figure 3BB). However, as well as the claim may be understood with respect to 35 U.S.C. 112, first paragraph, discussed above, the Artonne specification suggests that providing an objective lens having a non-linear distribution function that is asymmetrical instead of symmetrical would be accomplished by one of ordinary skill in the art without undue experimentation. In that case, it would have been obvious to one of ordinary skill in the art to include a non-linear distribution function that is not symmetrical relative to the optical axis of the objective lens in the system disclosed by Baker in order to create a resulting image with compressed and expanded zones that do not include the entire center or entire periphery as desired by the user. The development of the lens with the asymmetrical function would have been obvious to try with a reasonable expectation of success.

15. **Claim 48** is rejected under pre-AIA 35 U.S.C. 103(a) as being unpatentable over **Fisher**.

Regarding **claim 48**, as similarly discussed above with respect to claim 17, Fisher discloses a method for capturing a digital panoramic image, by projecting a panorama onto an image sensor by means of a panoramic objective lens (Figures 3 and 6; Abstract; column 3, lines 48-49; column 4, lines 35-45),

the panoramic objective lens having an image point distribution function that is not linear relative to the field angle of object points of the panorama (Figure 3; column 1, lines 9-11; column 2, lines 6-8),

the distribution function having a maximum divergence of at least +/- 10% compared to a linear distribution function (Figure 3 shows the function labeled "Non-Linear Lens" 3, which is $H=\sin^{1/3}\theta$, having a divergence of greater than 10% compared to the linear distribution function of the "Fisheye Lens"),

such that a panoramic image obtained by means of the objective lens comprises at least one substantially expanded zone and at least one substantially compressed zone (Fisher discloses that the center objects "occupy a disproportionately large share of the image cast by the lens when compared with other objects closer to the periphery of the field of view for the lens"; column 3, lines 4-12; see also Figure 4, which compares the object space to the image plane).

Further regarding claim 48, Fisher does not specifically disclose that the objective lens has a non-linear distribution function that is not symmetrical relative to the optical axis of the objective lens. Instead, Fisher discloses a non- linear distribution function that is symmetrical relative to the optical axis of the objective lens (Figure 4; column 3, lines 21-42). However, as well as the claim may be understood with respect to 35 U.S.C. 112, first paragraph, discussed above, the Artonne specification suggests that providing an objective lens having a non-linear distribution function that is asymmetrical instead of symmetrical would be accomplished by one of ordinary skill in the art without undue experimentation. In that case, it would have been obvious to one of ordinary skill in the art to include a non-linear distribution function that is not symmetrical relative to the optical axis of the objective lens in the system disclosed by Fisher in order to create a resulting image with compressed and expanded zones that do not include the entire center or entire periphery as desired by the user. The development of the lens with the asymmetrical function would have been obvious to try with a reasonable expectation of success.

Patentable Claims

16. **Claims 10 and 11** are patentable. **Claims 2-4, 15, 16, and 27-47** may contain patentable subject matter if amended to overcome the rejection under 35 U.S.C. 305 discussed above.

17. **Enami** generally teaches an image distortion correction method including extracting color information through projection using the distribution function and assigning appropriate colors on the display (Figures 2-4; paragraphs [0072]-[0074], [0084], and [0085]).

18. **Shiota** and **Matsui** each generally teach correcting the non-linearity of an image captured by a lens (Shiota, Figure 1; paragraphs [0001], [00022], and [0028]-[0041]; Matsui, Figures 2-4 and 6; Abstract and paragraph [0025]).

19. However, the prior art of record, including Nagaoka, Baker, Fisher, Shiota, Matsui, Enami, and Inoue, does not specifically disclose or fairly teach a method for capturing a digital panoramic image or a panoramic objective lens including all of the elements, steps, and limitations recited in claims 2-4, 10, 11, 15, 16, and 27-47 (including all of the limitations of any respective parent claims), particularly including

correcting the non-linearity of the initial image, performed by means of a reciprocal function of the non-linear distribution function of the objective lens (e.g., claims 10 and 11); or

displaying the obtained panoramic image by correcting the non-linearity of the initial image, performed by retrieving image points on the obtained image in a coordinate system of center O' using at least the non-linear distribution function and a size L of the obtained image (e.g., claims 2-4, 15, 16, and 27-31);

or particularly wherein

the panoramic image obtained by the objective lens is configured to be corrected by retrieving image points on the obtained image in a coordinate system of center O' using at least the non-linear distribution function, and a size L of the obtained image (e.g., claims 32-37); or

the panoramic image obtained has at least one expanded zone and at least two compressed zones (e.g., claims 38-47).

Conclusion

20. In order to ensure full consideration of any amendments, affidavits or declarations, or other documents as evidence of patentability, such documents must be submitted in response to this Office action. Submissions after the next Office action, which is intended to be a final action, will be governed by the requirements of 37 CFR 1.116, after final rejection and 37 CFR 41.33 after appeal, which will be strictly enforced.

21. Extensions of time under 37 CFR 1.136(a) will not be permitted in these proceedings because the provisions of 37 CFR 1.136 apply only to "an applicant" and not to parties in a reexamination proceeding. Additionally, 35 U.S.C. 305 requires that reexamination proceedings "will be conducted with special dispatch" (37 CFR 1.550(a)). Extension of time in *ex parte* reexamination proceedings are provided for in 37 CFR 1.550(c).

22. The patent owner is reminded of the continuing responsibility under 37 CFR 1.565(a), to apprise the Office of any litigation activity, or other prior or concurrent proceeding, involving Patent No. 6,844,990 throughout the course of this reexamination proceeding. See MPEP §§ 2207, 2282 and 2286.

23. **All** correspondence relating to this ex parte reexamination proceeding should be directed:

By mail to:
Mail Stop *Ex Parte* Reexam
Central Reexamination Unit
Commissioner for Patents
United States Patent & Trademark Office
P.O. Box 1450
Alexandria, VA 22313-1450

By fax to:
(571) 273-9900
Central Reexamination Unit

By hand to:
Customer Service Window
Randolph Building

401 Dulany Street
Alexandria, VA 22314

Any inquiry concerning this communication should be directed to the Central Reexamination Unit at telephone number (571) 272-7705.

/Christina Y. Leung/

Primary Examiner, Art Unit 3992

Conferees:

/D.M.H./, PE AU3992

/JENNIFER MCNEIL/
Supervisory Patent Examiner, Art Unit 3992

Search Notes	Application/Control No. 90013410	Applicant(s)/Patent Under Reexamination 6844990
	Examiner CHRISTINA Y LEUNG	Art Unit 3992

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
Reviewed cited references and patented file's prosecution history.	1-5-15	/CL/

INTERFERENCE SEARCH

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

Reexamination	Application/Control No. 90/013,410	Applicant(s)/Patent Under Reexamination 6844990
	Certificate Date	**Certificate Number**

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LITIGATION REVIEW ☒	/CL/ (examiner initials)	(date)
Case Name		Director Initials
1:13cv1139, Immervision Inc. v. Cbc Co. Ltd. et al.		/JM/ for IY
2:13cv1117 Immervision, Inc. v. Vivotek, Inc.		/JM/ for IY

COPENDING OFFICE PROCEEDINGS	
TYPE OF PROCEEDING	**NUMBER**
1. Inter partes review of 6,844,990	IPR2014-01438
2.	
3.	
4.	

U.S. Patent and Trademark Office DOC. CODE **RXFILJKT**

Docket No.: 688266-21RX

IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

In re Patent of: Jean-Claude ARTONNE et al.	Patent No. 6,844,990
Reexamination Control No.: 90/013,410	Confirmation No.: 4682
Filed: November 26, 2014	Art Unit: 3992
For: METHOD FOR CAPTURING AND DISPLAYING A VARIABLE RESOLUTION DIGITAL PANORAMIC IMAGE	Examiner: C. Y. Leung

AMENDMENT UNDER 37 C.F.R. §§ 1.111 AND 1.530

The following Amendment and Remarks are being submitted in response to the Office Action dated January 29, 2015, and are being timely filed within the two month period set for reply, namely by March 29, 2015. No fee is believed to be due with this response, but if any fee is due, please charge such fee to Deposit Account No. 50-1017.

Amendments to and Listing of the Claims Subject to Reexamination begin on page 2 of this paper.

Remarks/Arguments begin on page 9 of this paper.

AMENDMENTS TO AND LISTING OF CLAIMS SUBJECT TO REEXAMINATION

The following listing of claims subject to reexamination replaces all prior versions, and listings, of claims subject to reexamination.

1. (Cancelled).

2. (Amended) The method according to claim [1] 27, wherein the objective lens has a non-linear distribution function that is symmetrical relative to the optical axis of the objective lens, the position of an image point relative to the center of the image varying according to the field angle of the corresponding object point.

3. (Amended) The method according to claim [1] 27, wherein the objective lens expands the center of the image and compresses the edges of the image.

4. (Amended) The method according to claim [1] 27, wherein the objective lens expands the edges of the image and compresses the center of the image.

5. (Not Subject to Reexamination).

6-7. (Cancelled).

8-9. (Not Subject to Reexamination).

10. (Amended) A method for displaying an initial panoramic image obtained in accordance with the method according to claim 1, the method for displaying comprising: correcting the non-linearity of the initial image, performed by means of a reciprocal function of the non-linear distribution function of the objective lens [or by means of the non-linear distribution function].

11. (Original) The method according to claim 10, wherein the step of correcting comprises a step of transforming the initial image into a corrected digital image comprising a number of image points higher than the number of pixels that the image sensor comprises.

12-14. (Not Subject to Reexamination).

15. (Amended) The method according to claim [10] 27, further comprising:

determining the color of image points of a display window, by projecting the image points of the display window onto the initial image by means of the non-linear distribution function, and

allocating to each image point of the display window the color of an image point that is the closest on the initial image.

16. (Original) The method according to claim 15, wherein the projection of the image points of the display window onto the initial image comprises:

projecting the image points of the display window onto a sphere or a sphere portion,

determining the angle in relation to the center of the sphere or the sphere portion of each projected image point, and

projecting onto the initial image each image point projected onto the sphere or the sphere portion, the projection being performed by means of the non-linear distribution function considering the field angle that each point to be projected has in relation to the center of the sphere or the sphere portion.

17-20. (Cancelled).

21. (Not Subject to Reexamination).

22-23. (Cancelled).

24. (Not Subject to Reexamination).

25. (Cancelled).

26. (Not Subject to Reexamination).

27. (New) A method for displaying a digital panoramic image, the method comprising:

obtaining a digital panoramic image by projecting a panorama onto an image sensor using a panoramic objective lens, the panoramic objective lens having an image point distribution function that is not linear relative to a field angle of object points of the panorama, the distribution function having a maximum divergence of at least +/- 10% compared to a linear distribution function, such that the panoramic image obtained has at least one substantially expanded zone and at least one substantially compressed zone; and

displaying the obtained panoramic image by correcting the non-linearity of the initial image, performed by retrieving image points on the obtained image in a coordinate system of center O' using at least the non-linear distribution function and a size L of the obtained image.

28. (New) The method according to claim 27, wherein the objective lens compresses the center of the image and the edges of the image and expands an intermediate zone of the image located between the center and the edges of the image.

29. (New) The method according to claim 27, wherein the objective lens comprises a set of lenses forming an apodizer.

30. (New) The method according to claim 29, wherein the set of lenses forming an apodizer comprises at least one aspherical lens.

31. (New) The method according to claim 27, wherein the step of correcting comprises a step of transforming the initial image into a corrected digital image comprising a number of image points higher than the number of pixels that the image sensor comprises.

32. (New) A panoramic objective lens comprising:

a set of lenses configured to project a panorama into an image plane of the objective lens, the panoramic objective lens having an image point distribution function that is not linear relative to a field angle of object points of the panorama, the distribution function having a maximum divergence of at least +/- 10% compared to a linear distribution function, such that a panoramic image obtained using the objective lens comprises at least one substantially expanded zone and at least one substantially compressed zone,

wherein the panoramic image obtained by the objective lens is configured to be corrected by retrieving image points on the obtained image in a coordinate system of center O' using at least the non-linear distribution function, and a size L of the obtained image.

33. (New) The lens according to claim 32, wherein the objective lens has a non-linear distribution function that is symmetrical relative to the optical axis of the objective lens, the position of an image point relative to the center of the image varying according to the field angle of the corresponding object point.

34. (New) The lens according to claim 32, wherein the objective lens expands the center of the image and compresses the edges of the image.

35. (New) The lens according to claim 32, wherein the objective lens expands the edges of the image and compresses the center of the image.

36. (New) The lens according to claim 32, wherein the objective lens compresses the center of the image and the edges of the image and expands an intermediate zone of the image located between the center and the edges of the image.

37. (New) The lens according to claim 32, wherein the set of lenses comprises at least one aspherical lens.

38. (New) A method for capturing a digital panoramic image, by projecting a panorama onto an image sensor using a panoramic objective lens, the panoramic objective lens having an image point distribution function that is not linear relative to the field angle of object points of the panorama, the distribution function having a maximum divergence of at least 10% compared to a linear distribution function, such that the panoramic image obtained has at least one substantially expanded zone and at least two substantially compressed zones.

39. (New) The method according to claim 38, wherein the objective lens has a non-linear distribution function that is symmetrical relative to the optical axis of the objective lens, the position of an image point relative to the center of the image varying according to the field angle of the corresponding object point.

40. (New) A method for displaying an initial panoramic image obtained in accordance with the method according to claim 38, the method for displaying comprising: correcting the non-linearity of the initial image, performed using a reciprocal function of the non-linear distribution function of the objective lens or using the non-linear distribution function.

41. (New) The method according to claim 40, wherein the step of correcting comprises a step of transforming the initial image into a corrected digital image comprising a number of image points higher than the number of pixels that the image sensor comprises.

42. (New) The method according to claim 41, further comprising:

calculating the size of the corrected image, using the reciprocal function of the distribution function, so that the resolution of the corrected image is equivalent to the most expanded zone of the initial image, and scanning each image point of the corrected image, searching for the position of a twin point of the image point on the initial image and allocating the color of the twin point to the image point of the corrected image.

43. (New) The method according to claim 41, wherein the initial image and the corrected image comprise an image disk.

44. (New) The method according to claim 41, further comprising:

transferring the image points of the corrected image into a three-dimensional space, and

presenting one sector of the three-dimensional image obtained on a display.

45. (New) The method according to claim 40, further comprising:

determining the color of image points of a display window, by projecting the image points of the display window onto the initial image using the non-linear distribution function, and

allocating to each image point of the display window the color of an image point that is the closest on the initial image.

46. (New) The method according to claim 45, wherein the projection of the image points of the display window onto the initial image comprises:

projecting the image points of the display window onto a sphere or a sphere portion,

determining the angle in relation to the center of the sphere or the sphere portion of each projected image point, and

projecting onto the initial image each image point projected onto the sphere or the sphere portion, the projection being performed using the non-linear distribution function considering the field angle that each point to be projected has in relation to the center of the sphere or the sphere portion.

47. (New) The method according to claim 38, wherein the objective lens compresses at least one zone near the center and at least one zone near the edge, and expands at least one intermediate zone of the image between the center and the edge of the image.

48. (Cancelled).

REMARKS

Claims 1-4, 6-7, 10-11, 15-20, 22-23, 25, and 27-48 of U.S. Patent No. 6,844,990 ("the '990 Patent") are subject to reexamination. Claims 1, 6-7, and 22 were previously cancelled, claims 27-48 were previously added, and claims 2-4, 10, and 15 were previously amended by an amendment submitted with the request for reexamination. By virtue of the present amendment, claims 17-20, 23, 25, and new claim 48 have been cancelled. Further, claims 27, 32, and 38 have been amended to add the term "substantially" to the "compressed" and "expanded" zones, as was present in original claims 1 and 17 of the '990 Patent.

Status of Patent Claims pursuant to 37 C.F.R. § 1.530(e):

1, 6-7, 17-20, 22-23, 25, and 48 – cancelled;

2-4, 10-11, 15-16, and 27-47 – pending; and

5, 8-9, 12-14, 21, 24, and 26 – not subject to reexamination.

No new matter has been added by the claim amendments and the amendments do not enlarge the scope of the original claims. The changes to claims 27, 32, and 38 are supported by original claims 1 and 17 of the '990 Patent, in addition to col. 4, lns. 11-21 and col. 5, lns. 29-39. Accordingly, entry of the amendments to the claims is respectfully requested.

Patentable Subject Matter

Patent Owner wishes to thank the Examiner for the indication that claims 10 and 11 are patentable, and that claims 2-4, 15, 16, and 27-47 contain patentable subject matter if amended to overcome the formality rejections. By virtue of the present amendment, Patent Owner has amended claims 27, 32, and 38 to address the issues highlighted by the Examiner.

Claim Rejections Under 35 U.S.C. § 305

Claims 2-4, 15, 16, and 27-48 were rejected under 35 U.S.C. § 305 as impermissibly broadening the scope of the original claims of the patent being reexamined. Specifically, independent claims 27, 32, 38, and 48 omitted the term "substantially," which was present before the claimed "expanded" and "compressed zones" in original claims 1 and 17 of the '990 Patent.

The Examiner asserts that the omission of this term expands the scope of the claims beyond original claims 1 and 17. Claim 48 has been cancelled, and the rejection thereof rendered moot.

While not necessarily agreeing with the rejection as to remaining claims 2-4, 15, 16, and 27-47, solely for the purpose of advancing the present reexamination proceeding, claims 27, 32, and 38 have each been amended to insert the term "substantially" prior to the claimed "expanded" and "compressed" zones. Patent Owner therefore respectfully requests withdrawal of the rejection of claims 2-4, 15, 16, and 27-47 under 35 U.S.C. § 305.

Claim Rejection Under 35 U.S.C. § 112, first paragraph

Claim 48 was rejected under 35 U.S.C. § 112, first paragraph as lacking enablement for the feature of "wherein the objective lens has a non-linear distribution function that is not symmetrical relative to the optical axis of the objective lens." While not necessarily agreeing with the rejection, and solely for the purpose of advancing the reexamination proceeding, claim 48 has been cancelled, and the rejection thereof rendered moot. Patent Owner therefore respectfully requests withdrawal of the rejection.

Claim Rejections Under 35 U.S.C. §§ 102 and 103(a)

Claims 17-20, 23, and 25

Claims 17-20 and 23 were each rejected under 35 U.S.C. § 102 as being anticipated by one or more of Nagaoka, Baker, and Fisher. Claim 25, which depends from claim 17, was also rejected under 35 U.S.C. § 103(a) as being obvious over the combinations of Nagaoka in view of Inoue and Baker in view of Inoue. While not necessarily agreeing with the rejections, and solely for the purpose of advancing the reexamination proceeding, claims 17-20, 23, and 25 have all been cancelled, and the rejections thereof rendered moot. Patent Owner therefore respectfully requests withdrawal of these prior art rejections.

Claim 48

Claim 48 was separately rejected as being obvious under 35 U.S.C. § 103 over any of Nagaoka, Baker, or Fisher. As explained above, claim 48 has been cancelled, and the rejections thereof are therefore rendered moot. Patent Owner therefore respectfully requests withdrawal of these prior art rejections.

CONCLUSION

In view of the foregoing Amendment and Remarks, Patent Owner respectfully submits that claims 2-4, 10-11, 15-16, and 27-47 are patentable, and issuance of a Reexamination Certificate confirming the same is earnestly solicited.

Dated: February 12, 2015

Respectfully submitted,

By ______________________

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Electronic Acknowledgement Receipt

EFS ID:	21482987
Application Number:	90013410
International Application Number:	
Confirmation Number:	4682
Title of Invention:	METHOD FOR CAPTURING AND DISPLAYING A VARIABLE RESOLUTION DIGITAL PANORAMIC IMAGE
First Named Inventor/Applicant Name:	6844990
Customer Number:	570
Filer:	Stephen Murray/Andrea Bennett
Filer Authorized By:	Stephen Murray
Attorney Docket Number:	688266-21RX
Receipt Date:	12-FEB-2015
Filing Date:	26-NOV-2014
Time Stamp:	13:36:47
Application Type:	Reexam (Patent Owner)

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	Amendment.PDF	527896 958d861a02378e2456b7a34993574d8b590dbb5e	no	11

Warnings:

Information:

Total Files Size (in bytes):	527896

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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.

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APPLICATION NO.	FILING DATE	FIRST NAMED INVENTOR	ATTORNEY DOCKET NO.	CONFIRMATION NO.
90/013,410	11/26/2014	6844990	688266-21RX	4682

570 7590 04/21/2015
PANITCH SCHWARZE BELISARIO & NADEL LLP
ONE COMMERCE SQUARE
2005 MARKET STREET, SUITE 2200
PHILADELPHIA, PA 19103

EXAMINER	
LEUNG, CHRISTINA Y	

ART UNIT	PAPER NUMBER
3992	

MAIL DATE	DELIVERY MODE
04/21/2015	PAPER

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.

PTOL-90A (Rev. 04/07)

Notice of Intent to Issue Ex Parte Reexamination Certificate	**Control No.** 90/013,410	**Patent Under Reexamination** 6844990	
	Examiner Christina Y. Leung	**Art Unit** 3992	**AIA (First Inventor to File) Status** No

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

1. ☒ Prosecution on the merits is (or remains) closed in this *ex parte* reexamination proceeding. This proceeding is subject to reopening at the initiative of the Office or upon petition. *Cf.* 37 CFR 1.313(a). A Certificate will be issued in view of
   (a) ☒ Patent owner's communication(s) filed: *12 February 2015*.
   (b) ☐ Patent owner's failure to file an appropriate timely response to the Office action mailed: _____.
   (c) ☐ Patent owner's failure to timely file an Appeal Brief (37 CFR 41.31).
   (d) ☐ The decision on appeal by the ☐ Board of Patent Appeals and Interferences ☐ Court dated _____
   (e) ☐ Other: _____.
2. The Reexamination Certificate will indicate the following:
   (a) Change in the Specification: ☐ Yes ☒ No
   (b) Change in the Drawing(s): ☐ Yes ☒ No
   (c) Status of the Claim(s):
      (1) Patent claim(s) confirmed: _____.
      (2) Patent claim(s) amended (including dependent on amended claim(s)): *2-4,10,11,15 and 16*
      (3) Patent claim(s) canceled: *1,6,7,17-20,22,23 and 25*.
      (4) Newly presented claim(s) patentable: 27-47.
      (5) Newly presented canceled claims: 48.
      (6) Patent claim(s) ☐ previously ☐ currently disclaimed: _____
      (7) Patent claim(s) not subject to reexamination: 5,8,9,12-14,21,24 and 26.
3. ☐ A declaration(s)/affidavit(s) under **37 CFR 1.130(b)** was/were filed on _____.
4. ☒ Note the attached statement of reasons for patentability and/or confirmation. Any comments considered necessary by patent owner regarding reasons for patentability and/or confirmation must be submitted promptly to avoid processing delays. Such submission(s) should be labeled: "Comments On Statement of Reasons for Patentability and/or Confirmation."
5. ☐ Note attached NOTICE OF REFERENCES CITED (PTO-892).
6. ☒ Note attached LIST OF REFERENCES CITED (PTO/SB/08 or PTO/SB/08 substitute).
7. ☐ The drawing correction request filed on _____ is: ☐ approved ☐ disapproved.
8. ☒ Acknowledgment is made of the priority claim under 35 U.S.C. § 119(a)-(d) or (f).
   a)☒ All b)☐ Some* c)☐ None of the certified copies have
   ☐ been received.
   ☐ not been received.
   ☒ been filed in Application No. *10/706,513*.
   ☐ been filed in reexamination Control No. _____.
   ☐ been received by the International Bureau in PCT Application No. _____.

   * Certified copies not received: _____.
9. ☐ Note attached Examiner's Amendment.
10. ☐ Note attached Interview Summary (PTO-474).
11. ☐ Other: _____.

All correspondence relating to this reexamination proceeding should be directed to the **Central Reexamination Unit** at the mail, FAX, or hand-carry addresses given at the end of this Office action.

/Christina Y. Leung/
Primary Examiner, Art Unit 3992

cc: Requester (if third party requester)

STATEMENT OF REASONS FOR PATENTABILITY AND/OR CONFIRMATION

1. Claims 1-4, 6, 7, 10, 11, 15-20, 22, 23, and 25 of **Artonne** (US 6,844,990 B2) are being reexamined. Claims 1, 6, 7, 17-20, 22, 23, 25, and 48 have been canceled. Claims 5, 8, 9, 12-14, 21, 24, and 26 are not subject to reexamination.

2. **Claims 2-4, 10, 11, 15, and 16, and new claims 27-47** are patentable.

3. The following is an examiner's statement of reasons for patentability and/or confirmation of the claims found patentable in this reexamination proceeding:

Patent Owner's (PO's) amendment filed 12 February 2015 has overcome all of the rejections in the previous Office action mailed 29 January 2015. As noted in that action, the prior art of record, including Nagaoka, Baker, Fisher, Shiota, Matsui, Enami, and Inoue, does not specifically disclose or fairly teach a method for capturing a digital panoramic image or a panoramic objective lens including all of the elements, steps, and limitations recited in claims 2-4, 10, 11, 15, 16, and 27-47 (including all of the limitations of any respective parent claims), particularly including

correcting the non-linearity of the initial image, performed by means of a reciprocal function of the non-linear distribution function of the objective lens (e.g., claims 10 and 11); or

displaying the obtained panoramic image by correcting the non-linearity of the initial image, performed by retrieving image points on the obtained image in a coordinate system of center O' using at least the non-linear distribution function and a size L of the obtained image (e.g., claims 2-4, 15, 16, and 27-31);

or particularly wherein

the panoramic image obtained by the objective lens is configured to be corrected by retrieving image points on the obtained image in a coordinate system of center O' using at least the non-linear distribution function, and a size L of the obtained image (e.g., claims 32-37); or

the panoramic image obtained has at least one expanded zone and at least two compressed zones (e.g., claims 38-47).

4. Any comments considered necessary by PATENT OWNER regarding the above statement must be submitted promptly to avoid processing delays. Such submission by the patent owner should be labeled: "Comments on Statement of Reasons for Patentability and/or Confirmation" and will be placed in the reexamination file.

5. **All** correspondence relating to this ex parte reexamination proceeding should be directed:

By mail to: Mail Stop *Ex Parte* Reexam
Central Reexamination Unit
Commissioner for Patents
United States Patent & Trademark Office
P.O. Box 1450
Alexandria, VA 22313-1450

By fax to: (571) 273-9900
Central Reexamination Unit

By hand to: Customer Service Window
Randolph Building
401 Dulany Street
Alexandria, VA 22314

Any inquiry concerning this communication should be directed to the Central Reexamination Unit at telephone number (571) 272-7705.

/Christina Y. Leung/

Primary Examiner, Art Unit 3992

Conferees:

/Deandra M. Hughes/, Reexamination Specialist AU 3992

/Woo H. Choi/
SPRS, Art Unit 3992

PTO/SB/08a (01-10)
Approved for use through 07/31/2012. OMB 0651-0031
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INFORMATION DISCLOSURE STATEMENT BY APPLICANT (**Not for submission under 37 CFR 1.99)**		
	Application Number	90013410
	Filing Date	2014-11-26
	First Named Inventor	Jean-Claude ARTONNE
	Art Unit	3992
	Examiner Name	Christina Y. Leung
	Attorney Docket Number	688266-21RX

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INFORMATION DISCLOSURE STATEMENT BY APPLICANT (**Not for submission under 37 CFR 1.99)**		
	Application Number	90013410
	Filing Date	2014-11-26
	First Named Inventor	Jean-Claude ARTONNE
	Art Unit	3992
	Examiner Name	Christina Y. Leung
	Attorney Docket Number	688266-21RX

/CL/	1	Applied Photographic Optics; Lenses and optical systems for photography, film, video and electronic imaging. Second Edition by Sidney F. Ray (1998)	☐

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EXAMINER SIGNATURE

Examiner Signature	/Christina Leung/	Date Considered	02/24/2015

*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.

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BIB DATA SHEET

CONFIRMATION NO. 4682

SERIAL NUMBER	FILING or 371(c) DATE	CLASS	GROUP ART UNIT	ATTORNEY DOCKET NO.
90/013,410	11/26/2014 **RULE**	359	3992	688266-21RX

APPLICANTS

INVENTORS

6844990, Residence Not Provided;
6115187 CANADA, INC., QUEBEC, CANADA;
PATENT OWNER, Residence Not Provided;

** **CONTINUING DATA** *************************

This application is a REX of 10/706,513 11/12/2003 PAT 6844990
which is a CON of PCT/FR02/01588 05/10/2002

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

FRANCE 01 06261 05/11/2001

** **IF REQUIRED, FOREIGN FILING LICENSE GRANTED** **

		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 /CHRISTINA Y LEUNG/ Examiner's Signature	☐ Met after Allowance Initials			26	2

ADDRESS

PANITCH SCHWARZE BELISARIO & NADEL LLP
ONE COMMERCE SQUARE
2005 MARKET STREET, SUITE 2200
PHILADELPHIA, PA 19103
UNITED STATES

TITLE

METHOD FOR CAPTURING AND DISPLAYING A VARIABLE RESOLUTION DIGITAL PANORAMIC IMAGE

FILING FEE RECEIVED	FEES: Authority has been given in Paper	
12000	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).

Reexamination	Application/Control No. 90/013,410	Applicant(s)/Patent Under Reexamination 6844990
	Certificate Date	**Certificate Number** C1

Requester Correspondence Address: ☒ **Patent Owner** ☐ **Third Party**

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2005 MARKET STREET, SUITE 220
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LITIGATION REVIEW ☒	/CL/ (examiner initials)	2-24-2015 (date)
Case Name		Director Initials
1:13cv1139, Immervision, Inc. v. Cbc Co. Ltd. et al.		
2:13cv1117 Immervision, Inc. v. Vivotek, Inc.		

COPENDING OFFICE PROCEEDINGS	
TYPE OF PROCEEDING	**NUMBER**
1. Inter partes review of 6,844,990	IPR2014-01438
2.	
3.	
4.	

U.S. Patent and Trademark Office DOC. CODE **RXFILJKT**

Search Notes	Application/Control No. 90013410	Applicant(s)/Patent Under Reexamination 6844990
	Examiner CHRISTINA Y LEUNG	**Art Unit** 3992

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
Reviewed cited references and patented file's prosecution history.	1-5-15	/CL/
Reviewed cited references and patented file's prosecution history.	2-24-15	/CL/

INTERFERENCE SEARCH

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

	/CHRISTINA Y LEUNG/ Primary Examiner.Art Unit 3992

Issue Classification	Application/Control No. 90013410	Applicant(s)/Patent Under Reexamination 6844990
	Examiner CHRISTINA Y LEUNG	Art Unit 3992

CPC					
Symbol				Type	Version
H04N	5	/	2254	F	2013-01-01
G02B	13	/	06	I	2013-01-01
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NONE (Assistant Examiner)	(Date)	Total Claims Allowed: 28	
/CHRISTINA Y LEUNG/ Primary Examiner.Art Unit 3992 (Primary Examiner)	02/25/2015 (Date)	O.G. Print Claim(s) 27	O.G. Print Figure 11

U.S. Patent and Trademark Office Part of Paper No. 20150224

Issue Classification

	Application/Control No. 90013410	**Applicant(s)/Patent Under Reexamination** 6844990
	Examiner CHRISTINA Y LEUNG	**Art Unit** 3992

US ORIGINAL CLASSIFICATION

CLASS	SUBCLASS
359	725

CROSS REFERENCE(S)

CLASS	SUBCLASS (ONE SUBCLASS PER BLOCK)				
348	E5.028				
359	718				

INTERNATIONAL CLASSIFICATION

CLAIMED					NON-CLAIMED				
G	0	2	B	13 / 06 (2006.01.01)	G	0	2	B	13 / 06 (2006.01.01)
H	0	4	N	5 / 225 (2006.01.01)	H	0	4	N	5 / 225 (2006.01.01)

NONE (Assistant Examiner)	(Date)	**Total Claims Allowed:** 28	
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	90013410	6844990
	Examiner	**Art Unit**
	CHRISTINA Y LEUNG	3992

☒ **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

NONE (Assistant Examiner)	(Date)	**Total Claims Allowed:** 28	
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US006844990C1

(12) EX PARTE REEXAMINATION CERTIFICATE (10588th)

United States Patent

Artonne et al.

(10) Number: US 6,844,990 C1

(45) Certificate Issued: May 8, 2015

(54) **METHOD FOR CAPTURING AND DISPLAYING A VARIABLE RESOLUTION DIGITAL PANORAMIC IMAGE**

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Related U.S. Application Data

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(30) **Foreign Application Priority Data**

May 11, 2001 (FR) 01 06261

(51) **Int. Cl.**
G02B 13/06 (2006.01)
H04N 5/225 (2006.01)

(52) **U.S. Cl.**
CPC ***H04N 5/2254*** (2013.01); ***G02B 13/06*** (2013.01)

(58) **Field of Classification Search**
None
See application file for complete search history.

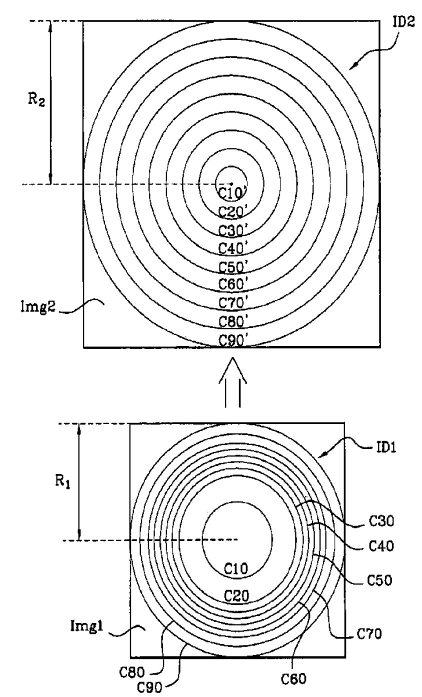
(56) **References Cited**

To view the complete listing of prior art documents cited during the proceeding for Reexamination Control Number 90/013,410, please refer to the USPTO's public Patent Application Information Retrieval (PAIR) system under the Display References tab.

Primary Examiner — Christina Y Leung

(57) **ABSTRACT**

A method for capturing a digital panoramic image includes projecting a panorama onto an image sensor by means of a panoramic objective lens. The panoramic objective lens has a distribution function of the image points that is not linear relative to the field angle of the object points of the panorama, such that at least one zone of the image obtained is expanded while at least another zone of the image is compressed. When a panoramic image obtained is then displayed, correcting the non-linearity of the initial image is required and is performed by means of a reciprocal function of the non-linear distribution function of the objective lens or by means of the non-linear distribution function.



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EX PARTE REEXAMINATION CERTIFICATE ISSUED UNDER 35 U.S.C. 307

THE PATENT IS HEREBY AMENDED AS INDICATED BELOW.

Matter enclosed in heavy brackets [ ] appeared in the patent, but has been deleted and is no longer a part of the patent; matter printed in italics indicates additions made to the patent.

AS A RESULT OF REEXAMINATION, IT HAS BEEN DETERMINED THAT:

Claims **1**, **6**, **7**, **17-20**, **22**, **23** and **25** are cancelled.

Claims **2-4**, **10** and **15** are determined to be patentable as amended.

Claims **11** and **16**, dependent on an amended claim, are determined to be patentable.

New claims **27-47** are added and determined to be patentable.

Claims **5**, **8**, **9**, **12-14**, **21**, **24** and **26** were not reexamined.

2. The method according to claim **[1]** *27*, wherein the objective lens has a non-linear distribution function that is symmetrical relative to the optical axis of the objective lens, the position of an image point relative to the center of the image varying according to the field angle of the corresponding object point.

3. The method according to claim **[1]** *27*, wherein the objective lens expands the center of the image and compresses the edges of the image.

4. The method according to claim **[1]** *27*, wherein the objective lens expands the edges of the image and compresses the center of the image.

10. A method for displaying an initial panoramic image obtained in accordance with the method according to claim **1**, the method for displaying comprising:

correcting the non-linearity of the initial image, performed by means of a reciprocal function of the non-linear distribution function of the objective lens **[**or by means of the non-linear distribution function**]**.

15. The method according to claim **[10]** *27*, further comprising:

determining the color of image points of a display window, by projecting the image points of the display window onto the initial image by means of the non-linear distribution function, and

allocating to each image point of the display window the color of an image point that is the closest on the initial image.

27. A method for displaying a digital panoramic image, the method comprising:

obtaining a digital panoramic image by projecting a panorama onto an image sensor using a panoramic objective lens, the panoramic objective lens having an image point distribution function that is not linear relative to a field angle of object points of the panorama, the distribution function having a maximum divergence of at least +/−10% compared to a linear distribution function, such that the panoramic image obtained has at least one substantially expanded zone and at least one substantially compressed zone; and

displaying the obtained panoramic image by correcting the non-linearity of the initial image, performed by retrieving image points on the obtained image in a coordinate system of center O' using at least the non-linear distribution function and a size L of the obtained image.

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28. The method according to claim 27, wherein the objective lens compresses the center of the image and the edges of the image and expands an intermediate zone of the image located between the center and the edges of the image.

29. The method according to claim 27, wherein the objective lens comprises a set of lenses forming an apodizer.

30. The method according to claim 29, wherein the set of lenses forming an apodizer comprises at least one aspherical lens.

31. The method according to claim 27, wherein the step of correcting comprises a step of transforming the initial image into a corrected digital image comprising a number of image points higher than the number of pixels that the image sensor comprises.

32. A panoramic objective lens comprising:

a set of lenses configured to project a panorama into an image plane of the objective lens, the panoramic objective lens having an image point distribution function that is not linear relative to a field angle of object points of the panorama, the distribution function having a maximum divergence of at least +/−10% compared to a linear distribution function, such that a panoramic image obtained using the objective lens comprises at least one substantially expanded zone and at least one substantially compressed zone,

wherein the panoramic image obtained by the objective lens is configured to be corrected by retrieving image points on the obtained image in a coordinate system of center O' using at least the non-linear distribution function, and a size L of the obtained image.

33. The lens according to claim 32, wherein the objective lens has a non-linear distribution function that is symmetrical relative to the optical axis of the objective lens, the position of an image point relative to the center of the image varying according to the field angle of the corresponding object point.

34. The lens according to claim 32, wherein the objective lens expands the center of the image and compresses the edges of the image.

35. The lens according to claim 32, wherein the objective lens expands the edges of the image and compresses the center of the image.

36. The lens according to claim 32, wherein the objective lens compresses the center of the image and the edges of the image and expands an intermediate zone of the image located between the center and the edges of the image.

37. The lens according to claim 32, wherein the set of lenses comprises at least one aspherical lens.

38. A method for capturing a digital panoramic image, by projecting a panorama onto an image sensor using a panoramic objective lens, the panoramic objective lens having an image point distribution function that is not linear relative to the field angle of object points of the panorama, the distribution function having a maximum divergence of at least 10% compared to a linear distribution function, such that the panoramic image obtained has at least one substantially expanded zone and at least two substantially compressed zones.

39. The method according to claim 38, wherein the objective lens has a non-linear distribution function that is symmetrical relative to the optical axis of the objective lens, the position of an image point relative to the center of the image varying according to the field angle of the corresponding object point.

40. A method for displaying an initial panoramic image obtained in accordance with the method according to claim 38, the method for displaying comprising:

correcting the non-linearity of the initial image, performed using a reciprocal function of the non-linear distribution function of the objective lens or using the non-linear distribution function.

41. The method according to claim 40, wherein the step of correcting comprises a step of transforming the initial image into a corrected digital image comprising a number of image points higher than the number of pixels that the image sensor comprises.

42. The method according to claim 41, further comprising:

calculating the size of the corrected image, using the reciprocal function of the distribution function, so that the resolution of the corrected image is equivalent to the most expanded zone of the initial image, and

scanning each image point of the corrected image, searching for the position of a twin point of the image point on the initial image and allocating the color of the twin point to the image point of the corrected image.

43. The method according to claim 41, wherein the initial image and the corrected image comprise an image disk.

44. The method according to claim 41, further comprising:

transferring the image points of the corrected image into a three-dimensional space, and

presenting one sector of the three-dimensional image obtained on a display.

45. The method according to claim 40, further comprising:

determining the color of image points of a display window, by projecting the image points of the display window onto the initial image using the non-linear distribution function, and

allocating to each image point of the display window the color of an image point that is the closest on the initial image.

46. The method according to claim 45, wherein the projection of the image points of the display window onto the initial image comprises:

projecting the image points of the display window onto a sphere or a sphere portion,

determining the angle in relation to the center of the sphere or the sphere portion of each projected image point, and

projecting onto the initial image each image point projected onto the sphere or the sphere portion, the projection being performed using the non-linear distribution function considering the field angle that each point to be projected has in relation to the center of the sphere or the sphere portion.

47. The method according to claim 38, wherein the objective lens compresses at least one zone near the center and at least one zone near the edge, and expands at least one intermediate zone of the image between the center and the edge of the image.

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