BRUCE WECKER (CA Bar No. 078530)
bwecker@hausfeld.com
HAUSFELD LLP
600 Montgomery Street, Suite 3200
San Francisco, CA 94111
415-633-1908 tel
415-358-4980 fax
Attorneys for Plaintiff FULLVIEW, INC.

UNITED STATES DISTRICT COURT
FOR THE NORTHERN DISTRICT OF CALIFORNIA

FULLVIEW, INC., a Delaware corporation, Plaintiff, vs. POLYCOM, INC., a California corporation, Defendant.	Case No. 3:18-cv-00510 EMC **SECOND AMENDED COMPLAINT** Filing Date of Original Complaint: January 23, 2018 **JURY TRIAL DEMANDED**

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Plaintiff FullView, Inc. ("FullView" or "Plaintiff") hereby files its Second Amended Complaint against Defendant Polycom, Inc. ("Polycom" or "Defendant") for patent infringement. For its complaint, Plaintiff alleges on personal knowledge as to its own acts and on information and belief as to all other matters, as follows:

PARTIES

1. Plaintiff FullView is a corporation organized under the laws of the State of Delaware and has its principal place of business in Holmdel, New Jersey. FullView is and was at all pertinent times the assignee and owner of the patents at issue in this case.

2. Defendant Polycom is incorporated under the laws of the State of California and has its principal place of business in San Jose, California.

JURISDICTION AND VENUE

3. This Complaint asserts a cause of action for patent infringement under the Patent Act, 35 U.S.C. § 271.

4. This Court has subject matter jurisdiction over this matter by virtue of 28 U.S.C. § 1338(a).

5. The venue of this Court is proper by virtue of 28 U.S.C. § 1391(b) and (c) and 28 U.S.C. § 1400(b) in that (i) Polycom may be found in this district, (ii) Polycom committed acts of infringement in this district, (iii) a substantial portion of the events or omissions giving rise to this complaint occurred in this district, and (iv) a substantial portion of the property that is the subject of this complaint is situated in this district.

6. This Court has personal jurisdiction over Polycom because Polycom provided infringing products in the Northern District of California.

BACKGROUND

The FullView Patents

7. Plaintiff owns several patents, all deriving from the inventions of Dr. Vishvjit Singh (Vic) Nalwa, who has been President of FullView since founding it with Bell Labs in 2000.

8. FullView is a Prime Contractor for the U.S. Navy that provides the Navy with up-to-360° panoramic cameras for its most advanced aircraft carriers, such as the USS Ford.

9. Dr. Nalwa received the B.Tech. Degree from the Indian Institute of Technology, Kanpur in 1983 and the Ph.D. Degree from Stanford University in 1987, both in Electrical Engineering. He was then a Principal Investigator at Bell Labs Research, until he co-founded FullView in 2000. In 1989, he was also on the faculty of Princeton University. From 1994 to 1998, he was an Associate Editor of the *IEEE Transactions on Pattern Analysis and Machine Intelligence*, the preeminent journal in his field. He holds 14 U.S. patents on his omni-directional camera inventions for which he was elected a Fellow of the IEEE in 2004 — an honor awarded to no more than 1 in 1000 of IEEE's total voting membership in a year. He has given invited technical talks worldwide, including at MIT, Stanford, UC Berkeley, CMU, Harvard, Princeton, Yale, Google, Technion, UBC, TU Delft, HKU, IIT Delhi and INRIA. He is the author of *A Guided Tour of Computer Vision*, Addison-Wesley, 1993, a course text adopted for Ph.D. qualifying exams in Artificial Intelligence and Computer Science, as by Stanford University.

10. U.S. Patent No. 6,700,711 ("the '711 Patent") entitled "Panoramic viewing system with a composite field of view" issued on March 2, 2004 and expired on November 30, 2015. A true and correct copy of the '711 Patent is attached as Exhibit "A" and is incorporated herein by reference. Plaintiff is the legal and rightful owner of the '711 Patent.

11. U.S. Patent 6,128,143 ("the '143 Patent") entitled "Panoramic viewing system with support stand" issued on October 3, 2000 and expired on August 28, 2018. A true and correct copy of the '143 Patent is attached as Exhibit "B" and is incorporated herein by reference. Plaintiff is the legal and rightful owner of the '143 Patent.

12. The ’711 Patent contains thirty-nine (39) patent claims covering a unique and novel method, product of method *(i.e., composite image)*, and system and apparatus for an omni-directional or panoramic viewer. It describes several cameras looking out in different directions off mirrors, from offset rather than coincident viewpoints, to provide the user with seamless 360° composite images to the viewer’s eye that allow the user to look in any direction, as in Exhibit “E.” This invention enhances videoconferencing by allowing an *unlimited number* of remote users to *simultaneously* simulate sitting in a physical meeting room in which the invention is placed — perhaps in a different country — with each user free to look in any direction in the room.

13. The ’143 Patent contains eighteen (18) patent claims covering a unique and novel system and apparatus for a compact and non-intrusive omni-directional or panoramic viewer in which several cameras look off a mirrored pyramid, this pyramid and these cameras secured to a support member that intersects an inner volume of the pyramid. This invention builds on the invention of the ’711 Patent by providing it with ease and preciseness in its assembly and calibration, thereby reducing its manufacturing cost.

FullView License to Polycom

14. Effective April 1, 2011, Polycom licensed from FullView its ’711 and ’143 Patents among others under an Intellectual Property Agreement (“IPA”) between the parties that allowed Polycom to manufacture and sell infringing low-resolution products worldwide, including its CX5000 product (“CX5000”) that provides panoramic 360° video for videoconferencing applications.

15. Polycom’s CX5000 product was previously manufactured and marketed as the RoundTable product (“RoundTable”) by Microsoft Corporation (“Microsoft”), also under license from FullView. As the two products are identical but for their labeling, Polycom has often referred to “CX5000” as “RoundTable” in its communications with FullView.

16. Polycom gave FullView a notice on July 2, 2012 to terminate their IPA effective October 1, 2012, but then disavowed this date for an earlier date after both dates had elapsed — even though the IPA required a 90-day termination notice. FullView responded by initiating arbitration as per the IPA in 2016. In this arbitration, which concluded in 2019, FullView:

(i) prevailed with costs,

(ii) discovered Polycom had not reported all its sales or paid royalty on them as per the IPA,

(iii) could not resolve certain perceived discrepancies in Polycom's sales and manufacturing disclosures because of the arbitration's restricted discovery, and

(iv) uncovered document manipulation by Polycom after Polycom mistakenly emailed to it bulletins with end-of-life dates for "CX5000 HD" — after providing which Polycom claimed such electronic bulletins "weren't locatable" for the licensed CX5000 — after having contended a year earlier that "'End-of-life' date is not a term" "used by Polycom."

***Inter Partes* Reexamination (IPX) of the '711 Patent**

17. In 2011–2012, before Polycom gave FullView a termination notice for their IPA that was in effect at the time, the parties unsuccessfully negotiated a license for products with higher image resolution than that licensed by the IPA ("CX5000 Successor Products").

18. Polycom then requested an *Inter Partes* Reexamination ("IPX") of the '711 Patent at the United States Patent and Trademark Office ("USPTO") on January 26, 2012, proffering 20 prior art references and 53 issues to challenge *every one* of the 39 claims of the '711 Patent. The Examiner allowed only two references, "Uehira" and "Lelong," and only two issues, one for each reference individually. Polycom then petitioned the Director to reinstate all the disallowed references and issues, a petition the Director denied entirely in a final and nonappealable decision.

19. Soon after filing its request for an IPX in January 2012, Polycom began selling CX5000 Successor Products worldwide — these products manufactured, or made or had made, and imported and sold worldwide by Polycom at dates unknown to FullView.

20. Sometime in 2011–2012, again at a date unknown to FullView, Polycom stopped manufacturing the CX5000 product while continuing to sell this product worldwide beyond the IPA's termination date, into 2013, without reporting these sales to FullView as the IPA required.

21. On January 4, 2017, the Patent and Trial Board ("PTAB") of the USPTO affirmed the validity of *every one* of the 39 claims of the '711 Patent in the IPX — but not before the PTAB had first disallowed *every* claim in its Original Decision on September 29, 2014, this decision swayed by a persistent technical misrepresentation by Polycom that Polycom ultimately abandoned when it proffered an expert declaration to counter an expert declaration by FullView.

22. The Original PTAB Decision, by asserting a "new" issue of patentability that combined the two IPX references as disallowed by the Director, had allowed FullView to reopen prosecution and establish that "Uehira," when properly read, does not render any claim of the '711 Patent obvious or anticipated.

23. Polycom appealed the final PTAB IPX decision to the U.S. Court of Appeals for the Federal Circuit ("CAFC"), which affirmed the decision on April 29, 2019.

***Inter Partes* Review (IPR) of the '143 Patent**

24. On January 31, 2019, Polycom challenged claims 1–3 and 10–12 of FullView's '143 Patent in an *Inter Partes* Review ("IPR") Petition.

25. This Petition included another technical misrepresentation, now through an expert declaration that FullView countered with its own expert declaration by Dr. Nalwa. The PTAB denied Polycom's Petition, and then denied Polycom's Rehearing Request on September 10, 2019.

26. Polycom thus exhausted *every* possible challenge at the USPTO, and then CAFC, to the validity of every claim of the '711 Patent and to claims 1–3 and 10–12 of the '143 Patent.

Polycom's Infringing Goods And Services

27. As alleged above, the ’711 Patent issued on March 2, 2004 and the ’143 Patent on October 3, 2000. On information and belief, Polycom was well aware of these and other FullView patents before Microsoft and Polycom announced on March 30, 2009 that Polycom would be selling the “Microsoft Roundtable” product worldwide as the “Polycom CX5000.”

28. On June 15, 2009, Dr. Nalwa emailed Mr. Robert C. Hagerty, Chairman and CEO of Polycom at the time, and now again, informing him that Microsoft’s license to FullView’s patents for its RoundTable product excluded any “right to sublicense” FullView’s patents.

29. On July 16, 2009, Dr. Nalwa described FullView’s patents to Polycom in a presentation he gave at its San Jose offices under a non-disclosure agreement (“NDA”) retroactive to that date. He *specifically* pointed out at this meeting, including to Mr. Jeff Rodman, co-founder of Polycom, that FullView’s patent license to Microsoft was “non-sublicensable.”

30. Dr. Nalwa subsequently also informed Mr. Keith Rutherford of Polycom’s outside counsel law firm that FullView’s patent license to Microsoft was “non-sublicensable,” both by email and in a video conference, to both of which Mr. Rodman was a party.

31. Nevertheless, on information and belief, Polycom sold unlicensed and infringing CX5000 Successor Products — such as CX5000 HD, CX5100, CX5500, CX8000 360º and RealPresence Centro — over 2012–2018.

32. Polycom’s infringement is both central to its products, Exhibit “G,” and the work of a “wanton and malicious pirate” — done “with no doubts about [the patent’s] validity or any notion of a defense.” See *Halo Electronics, Inc. v. Pulse Electronics, Inc.,* 136 S. Ct. 1923 (2016).

Infringement of the ’711 Patent

33. The invention of the ’711 Patent is captured in its “process” or method claims, such as 1, 2, 5 and 9 below; in its “machine” or apparatus claims, such as 16; and in its “manufacture” or product-of-method claims, such as 25, 26, 29 and 33:

1. A method of producing a composite image with a plurality of sensors each having an individual field of view, comprising the steps of:

for at least one of the plurality of sensors, redirecting at least a portion of its individual field of view with a reflective area; and

merging images corresponding to the individual fields of view to produce the composite image having a corresponding field of view, wherein each one of at least two fields of view corresponding to images that are merged has a portion, where the images are merged, that has viewing directions that are substantially similar to the viewing directions of the other portion, and wherein the viewing directions within each one of such two portions appear to originate substantially from a point that is offset from the point for the other one of such two portions.

2. The method of claim **1**, wherein the field of view corresponding to the composite image has at least one blind region that encompasses at least a portion of an edge of a reflective area and that lies between the two portions of the two individual fields of view.

5. The method of claim 1, wherein images corresponding to the individual fields of view are merged electronically by merging data representative of the fields of view to produce data representative of the composite image and data representative of the composite image is stored by electronic means.

9. The method of claim 5, further comprising displaying at least a portion of the composite image remotely after transmitting this portion over a communication network.

34. Although all 39 claims of the ’711 Patent are infringed by each of Polycom’s accused products, to simplify these proceedings, FullView asserts only the following 18 claims here: 1, 2, 4, 5, 9, 11, 13, 15, 16, 18, 25, 26, 28, 29, 33, 35, 37 and 39.

35. In the Joint CMC Statement filed with this court on October 17, 2019, Polycom conceded “Polycom now uses” “the very solution Microsoft independently developed,” thereby admitting that CX5000 Successor Products implement the method, apparatus and product-of-method of the Microsoft RoundTable (Polycom CX5000) product. Then, to establish that *any* accused product infringes *any* claim, it is sufficient to establish that the RoundTable product infringes that claim.

36. The RoundTable product provides panoramic 360° video for videoconferencing applications using the camera–mirror arrangement of Figure 2 of the ’711 Patent, but with five cameras (“sensors”) instead of four. A five-sided mirrored pyramid “redirecting at least a portion

of" each camera's "individual field of view with a reflective area" (mirror) is followed by "merging images corresponding to the individual fields of view to produce the composite image" (claim 1). This "composite image" — created "electronically by merging data representative of the fields of view to produce data representative of the composite image" that "is stored by electronic means" (claim 5) — excludes views of the world within five "blind regions," each of which "encompasses at least a portion of an edge of a reflective area" (claim 2). And "at least a portion of the composite image" is displayed "remotely after transmitting this portion over a communication network" (claim 9).

37. The only claim limitations in any '711 Patent claim not expressly demonstrated by the specification of the RoundTable product are the following two, which were the focus of the parties' dispute in the IPX and are both infringed by the RoundTable, as shown below:

(i) Portions of the "two fields of view" "where the images are merged" have "viewing directions that are substantially similar" but "appear to originate substantially" from "offset" points (claim 1) — each such "offset" point, which is equivalent to a "pinhole" in a "pinhole camera," called a "viewpoint" in the IPX and here.

(ii) A "blind region that encompasses at least a portion of an edge of a reflective area" "lies between the two" foregoing "portions of the two individual fields of view" (claim 2).

38. To see how the RoundTable infringes '711, first consider Exhibit "C," which shows the RoundTable camera head, both assembled and disassembled. In the upper photograph, there is clearly an "offset" between the apparent apertures of adjoining cameras lenses as seen in the mirrors — that is, the lens apertures appear to be side by side after reflection, rather than coincident — which establishes the "offset" viewpoints of claim 1 in the RoundTable.

39. Next, consider Exhibit "D," which shows two sets of video stills from the RoundTable product captured by Dr. Nalwa at Bell Labs, Murray Hill, NJ on September 17, 2008 and on April 15, 2009. Each video still, of a portion of the composite image of a yardstick placed across the same mirror edge, has missing from it roughly an eighth of an inch where the

annotating arrow points, *no matter what the distance of the yardstick* from the mirror edge. This is verified by counting in each image the visible number of eighth-inch intervals in an inch of the yardstick across where the annotating arrow points. Nothing within roughly an eighth-inch thick planar sheet that embraces the mirror edge — a "blind region" — where the annotating arrow points, can be seen in any composite image. But *of utmost importance* is that each composite image is otherwise "substantially" geometrically continuous across each "blind region."

40. The foregoing "blind regions" and the "substantial" geometric image continuity across them establish that where images from adjoining cameras are merged in a composite image, the RoundTable implements every aspect of Figure 14 of the '711 Patent — as seen by envisaging a "pinhole" of a "pinhole camera" at each viewpoint of Figure 14 of the '711 Patent:

(i) a "blind region" of roughly constant width within "the field of view corresponding to the composite image," this "blind region" such that it "encompasses at least a portion of an edge of a reflective area" and "lies between the two portions of the two individual fields of view" of claim 1 "where the images are merged," both these limitations as in claim 2;

(ii) "viewing directions that are substantially similar" in portions of the "two fields of view" "where the images are merged," as in claim 1 — as else objects across the "blind region" would not appear "substantially" geometrically continuous in the composite image *irrespective of the object viewed and its orientation and position* in the scene; and

(iii) "offset" viewpoints of "such two portions" of "two fields of view," as in claim 1 — as also seen from Exhibit "C" — as else the "blind region" would expand with distance.

41. This showing that the RoundTable implements *every* aspect of Figure 14 of the '711 Patent, each of these aspects *purely geometric*, is unaffected by whether the RoundTable also matches image color and brightness across each "blind region" — as it does successfully in only one of the two sets of images in Exhibit "C." "Uehira" and a FullView expert declaration in the IPX attest to image color and brightness matching across "bind regions" not affecting the geometric relationship between the (fields of view of the) merged and composite images.

42. Thus, *every* claim of the ’711 Patent is infringed by *every* accused product.

43. Whereas Polycom alleges in the Joint CMC Statement that the RoundTable, “the very solution” “Polycom now uses,” was “independently developed” by Microsoft, it is no coincidence that the RoundTable implements the geometry of Figure 14 of the ’711 Patent:

(i) Around January 1996, Dr. Nalwa shared with Dr. Richard Szeliski of Microsoft Research, a Bell Labs Technical Memorandum describing Dr. Nalwa’s original implementation of ’711 — with eighth-inch-thick “blind regions” and image color and brightness matching.

(ii) In October 2002, Microsoft had unsuccessfully sought to borrow from FullView its FC-1005 product that incorporated the ’711 and ’143 inventions, was described on FullView’s website and sold for upward of $70,000.

(iii) By then, the ’143 Patent and several parents of the ’711 Patent had issued, while Microsoft had been pursuing a mirrorless multi-camera design called RingCam for years, Exhibit “F,” with which it was unable to match the quality of the composite images on FullView’s website, images such as from FullView’s prototype in Exhibit “E” that was used to webcast a widely publicized live performance by Mr. David Bowie in New York City in May 1999 (“FullView’s Bowie Prototype”). This prototype embodied every claim limitation of ’711 even though its “offset” is not as easily discernable from Exhibit “E” as is the RoundTable’s “offset” from Exhibit “C,” because of the former’s smaller size.

(iv) In November 2003, FullView offered to license its patents to Microsoft, but to no avail.

(v) Instead, in 2007, Microsoft launched its RoundTable product that closely resembled the prototype of Exhibit “E” — with *five* cameras, “blind regions” and “offset” viewpoints.

(vi) On April 29, 2008, FullView filed a complaint against Microsoft in this Court, alleging that Microsoft had willfully infringed the ’711 Patent.

(vii) Effective June 25, 2008, that is, within two months, Microsoft settled this complaint to become a licensee of FullView under a Settlement and License Agreement (“SLA”).

Infringement of the '143 Patent

44. The invention described and claimed in the '143 Patent generally relates to "machine" or apparatus claims such as claims 10, 11 and 12 below:

> **10**. A panoramic viewing apparatus, comprising:
>
> [a] plurality of image processing devices, each having an optical center and a field of view;
>
> a pyramid shaped element having a plurality of reflective side facets facing in different directions, each of at least two of the plurality of reflective side facets redirecting a field of view of one of the plurality of image processing devices to create a plurality of virtual optical centers; and
>
> a support member intersecting an inner volume of the pyramid shaped element, the pyramid shaped element being secured to the support member and the plurality of image processing devices being secured to the support member.
>
> **11**. The panoramic viewing apparatus of claim 10, wherein the plurality of image processing devices are secured to a portion of the support member extending out from the pyramid shaped element.
>
> **12**. The panoramic viewing apparatus of claim 10, wherein the support member is hollow.

45. The lower photograph in Exhibit "C" shows "image processing devices" (cameras) un-"secured" from a "hollow" "support member" "secured" to and "extending out" from an "inner volume" of a "pyramid shaped element" with "reflective side facts." This establishes that each of claims 10–12, and therefore 1–3, is infringed by the RoundTable product.

46. Because, on information and belief, every accused product is structurally similar to the RoundTable product, every accused product also infringes each of claims 1–3 and 10–12.

47. Nevertheless, to simplify these proceedings, FullView asserts only claims 10–12.

Exceptionality and Willfulness

48. On March 30, 2009, Microsoft and Polycom announced, "Polycom has licensed the right to distribute RoundTable, effective April 13, 2009" as the "Polycom CX5000" — Exhibit "H" ("Renaming Announcement").

49. On February 28, 2011, Microsoft gave FullView a notice to terminate its license effective March 30, 2011. After FullView informed Polycom of this, and only then, did the two negotiate and enter into a patent license, IPA, from FullView to Polycom effective April 1, 2011.

50. Over 2011–2012, Polycom discontinued selling licensed CX5000 products and began manufacturing and selling unlicensed CX5000 Successor Products.

51. Concurrently, after the parties failed to reach agreement on royalties for CX5000 Successor Products, Polycom initiated the aforementioned IPX proceedings before the USPTO in which Polycom engaged in litigation abuse — designed to mislead and confuse the Examiner and the PTAB and to delay the proceedings to beyond the expiration of the ’711 Patent — by *inter alia* insisting that prior art “Uehira” teaches “blind regions” and “offset viewpoints.”

52. Whereas Polycom conceded early in the IPX that “Uehira” does not teach “blind regions,” it insisted for close to three years in the same IPX — in the face of textbook-like tutorials by FullView — that “Uehira” teaches “offset viewpoints,” recanting this misrepresentation *only after* PTAB’s Original Decision disallowed *every one* of the 39 claims of ’711 without explicitly relying on “Uehira” to teach “offset viewpoints.”

53. In the IPR proceedings too, Polycom admitted it had misrepresented (“slightly exaggerated”) a prior art — “Iwerks” — but only after the PTAB had already determined this.

54. Polycom is a large, sophisticated multinational that not only employs full-time legal and intellectual property counsel and technical experts, but also retains outside counsel and outside experts. Therefore, on information and belief, its following decisions sprung not from ignorance or good faith, but from careful deliberation with full knowledge of their potential legal and financial implications:

(i) It gave a termination notice for the IPA, but then *disavowed its own termination notice*.

(ii) It engaged in *document manipulation* in the ensuing arbitration.

(iii) It *sold unlicensed CX5000 Successor Products* starting 2012.

(iv) It sought to invalidate FullView patents at the USPTO through *factual misrepresentations*.

Mr. Rutherford, an experienced intellectual property lawyer, along with his partners and associates, participated in *at least* (i), (ii) and, above all, (iv).

55. Polycom's infringement is *willful* because Polycom admitted in its answer to FullView's arbitration complaint that "Polycom has since [April 1, 2011] learned that the CX[5000] 'is not [a] Licensed Product,' because it does not infringe on a valid enumerated patent," but it "learned" this through a noninfringement opinion (a) only on '711, (b) only from Mr. Rutherford and his firm and (c) only in 2011or 2012. This opinion, therefore, lacks:

(i) *Good faith.* Given how Mr. Rutherford and his firm worked hand-in-glove with Polycom in its pattern of bad faith above, especially in attempting to invalidate '711 under false pretenses, Polycom's reliance on this firm's opinion could not have been in good faith.

(ii) *Relevance.* A noninfringement opinion on '711, the only patent Polycom challenged at the USPTO until 2019, has no bearing on the willfulness of any infringement of '143 or on any infringement of '711 prior to when Polycom received its opinion on '711.

(iii) *Timing.* Above all, by the time Polycom procured this opinion, after refusing FullView's licensing offer, it had no choice but to procure such an opinion, even if a sham, because:

(a) By then, Polycom had paid and further committed to pay Microsoft substantial sums for the right to manufacture and sell CX5000 Successor Products worldwide.

(b) As far back as April 21, 2008, Celestica, Inc. ("Celestica"), a contract manufacturer for Polycom, had approached Dr. Nalwa for his help in redesigning successors to the RoundTable and so Polycom was heavily invested in their development by then.

56. When Microsoft licensed to Polycom both CX5000 Successor Products in 2010 and CX5000 in 2011, Microsoft not only stipulated Polycom must license FullView's patents, but also excluded from its indemnification of Polycom any damage to it from it not doing so.

57. Polycom then had every reason to believe before it committed itself to infringing FullView's patents that FullView's patents were valid and would be infringed by the accused

products, because Microsoft — with its formidable technical expertise and direct personal knowledge of the development of its RoundTable product vis-à-vis FullView's patents — had:

(i) licensed FullView's patents for its RoundTable product, the very product Polycom admits is the "very solution" it "uses" in the accused products,

(ii) stipulated Polycom also license FullView's patents for the accused products,

(iii) refused to indemnify Polycom for damages to Polycom from it not doing so, and

(iv) discounted its royalties and fees to Polycom for requiring it to license FullView's patents.

58. Given the above and *Octane Fitness, LLC v. ICON Health & Fitness, Inc.,* 134 S. Ct. 1749 (2014), Polycom's infringement is not only willful, but also *exceptional* because of *both*:

(i) the unreasonable manner in which Polycom litigated the case at the USPTO for 7 years and

(ii) the substantive strength of FullView's litigating position, which includes:

(a) the intact allowance of each of the 39 claims of '711 by both PTAB and CAFC in the IPX,

(b) the denial by PTAB of both Polycom's '143 IPR Petition and its Rehearing Request,

(c) Microsoft's RoundTable product copying FullView's Bowie Prototype, as was likely known to Polycom

(d) Microsoft licensing FullView's patents for its RoundTable product,

(e) Polycom's accused products using the "very solution" Microsoft licensed from FullView,

(f) Microsoft requiring in its Polycom licenses that Polycom also license FullView's patents,

(g) Polycom committing to infringe the asserted patents before receiving an opinion on either,

(h) Polycom licensing the '711 and '143 Patents until a royalty dispute with FullView, and

(i) Polycom voluntarily acknowledging, publicly, that CX5000 infringes valid '711 claims: During the IPA, the CX5000 Primary Label retained the mark "FullView, Inc., U.S. Pat. No. 6,700,711" (Exhibit "I") as per the SLA, even though the IPA stipulated a different mark: *Technology licensed from FullView, Inc., or equivalent, along with "www.fullview.com".*

COUNT 1: Patent Infringement

59. Plaintiff incorporates by reference all the allegations above.

60. Plaintiff is the owner of the ’711 and ’143 Patents.

61. Polycom has infringed the ’711 and ’143 Patents in this country by, without authority, consent, right or license, manufacturing, making, having made for it, using, importing/exporting, offering for sale and/or selling products using the methods, products of methods and apparatuses claimed in these patents in this country. This conduct constitutes infringement under 35 U.S.C. § 271(a).

62. In addition, Polycom has infringed the ’711 and ’143 Patents in this country, through, *inter alia*, its active inducement of others to make, use, import/export, offer for sale and/or sell the systems, products, methods and products of methods claimed in one or more claims of the ’711 Patent and the ’143 Patent. This conduct constitutes infringement under 35 U.S.C. § 271(b) in conjunction with each of § 271 (a) and § 271 (g).

63. In addition, Polycom has infringed the ’711 and ’143 Patents in this country through, *inter alia*, providing and selling goods and services designed for use in practicing one or more claims of the patents, where the goods and services constitute a material part of the invention and are not staple articles of commerce and have no use other than infringing one or more claims of the patents. Polycom has committed these acts with knowledge that the goods and services it provides are specially made for use in a manner that directly infringed the ’711 and ’143 Patents. This conduct constitutes infringement under 35 U.S.C. § 271(c).

64. Polycom's infringing conduct is willful as provided in 35 U.S.C. § 284.

65. Polycom’s conduct is exceptional as provided in 35 U.S.C. § 285.

66. As a result of Polycom's infringement, FullView has been damaged.

PRAYER FOR RELIEF

WHEREFORE, Plaintiff prays:

a) That this Court find Polycom has committed acts of patent infringement under the Patent Act, 35 U.S.C. § 271;

b) That this Court enter judgment that:

(i) The ’711 and ’143 Patents are valid and enforceable; and

(ii) Polycom has willfully infringed the ’711 and ’143 Patents

c) That this Court award Plaintiff the damages to which it is entitled due to Polycom's patent infringement, with both pre-judgment and post-judgment interest;

d) That this Court adjudge Polycom's infringement of the ’711 and ’143 Patents to be willful and it therefore increase damages to Plaintiff by three times the amount found or assessed, pursuant to 35 U.S.C. § 284;

e) That this Court adjudge this case to be exceptional and it therefore award Plaintiff its attorney's fees and costs in this action, pursuant to 35 U.S.C. § 285; and

f) That this Court grant Plaintiff such other and further relief, in law or in equity, both general and special, to which it may be entitled.

Dated: July 02, 2020

Respectfully submitted,

/s/ Bruce Wecker

BRUCE WECKER (CA Bar No. 078530)
bwecker@hausfeld.com
HAUSFELD LLP
600 Montgomery Street, Suite 3200
San Francisco, CA 94111
415-633-1908 telephone
415-358-4980 fax
Attorneys for Plaintiff FULLVIEW, INC.

ECF CERTIFICATION

I, Bruce Wecker, am the ECF user whose ID and password are being used to file this **SECOND AMENDED COMPLAINT.**

DATED: July 02, 2020

/s/ *Bruce J. Wecker*
Bruce J. Wecker

CERTIFICATE OF SERVICE

I, Bruce Wecker, declare that I am over the age of eighteen (18) and not a party to the entitled action. I am of counsel at the law firm of HAUSFELD LLP, and my office is located at 600 Montgomery Street, Suite 3200, San Francisco, California 94111.

On July 02, 2020 I caused to be filed the

SECOND AMENDED COMPLAINT

with the Clerk of the Court using the Official Court Electronic Document Filing System, which served copies on all interested Parties registered for electronic filing.

I also certify that I caused true and correct Chambers Copies of the foregoing document to be delivered to Judge Edward M. Chen pursuant to Civil L.R. 3-12(b) by noon of the following Court day.

I declare under penalty of perjury that the foregoing is true and correct.

DATED: July 02, 2020

/s/ *Bruce J. Wecker*
Bruce J. Wecker

EXHIBIT A:

US Patent 6,700,711

(Panoramic viewing system
with a composite field of view)

US006700711B2

(12) **United States Patent**
Nalwa

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(45) **Date of Patent: *Mar. 2, 2004**

(54) **PANORAMIC VIEWING SYSTEM WITH A COMPOSITE FIELD OF VIEW**

(75) Inventor: **Vishvjit Singh Nalwa**, Holmdel, NJ (US)

(73) Assignee: **Fullview, Inc.**, Holmdel, NJ (US)

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

This patent is subject to a terminal disclaimer.

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Related U.S. Application Data

(63) Continuation of application No. 09/431,400, filed on Dec. 27, 1999, now Pat. No. 6,356,397, which is a continuation of application No. 08/946,443, filed on Oct. 7, 1997, now Pat. No. 6,111,702, which is a continuation-in-part of application No. 08/565,501, filed on Nov. 30, 1995, now Pat. No. 6,115,176.

(51) **Int. Cl.**[7] **G02B 13/06**; G02B 23/08; H04N 7/00

(52) **U.S. Cl.** **359/725**; 359/363; 359/403; 353/94; 348/36

(58) **Field of Search** 359/362–363, 359/367, 399, 402–403, 725–732, 831–837; 348/36–39; 353/30, 94, 98–99; 352/69–71

(56) **References Cited**

U.S. PATENT DOCUMENTS

5,187,571 A * 2/1993 Braun et al. 358/85

* cited by examiner

Primary Examiner—Thong Nguyen

(57) **ABSTRACT**

Cameras are positioned so that at least a portion of the field of view of at least one camera is redirected by a reflective surface. Images from these cameras are merged to produce a composite image while disregarding at least a portion of a camera's field of view such that there is at least one blind region in the composite field of view. Advantageously, such blind regions can be made to encompass edges of mirror surfaces that would otherwise produce image artifacts in the composite image; this can be accomplished without introducing gaps in the angular span of the composite field of view. Data representative of the composite image is stored in a memory from which it may be retrieved selectively using a control means to display a portion of the composite image. The image and control data may be transmitted over a communication network to facilitate remote control and display.

39 Claims, 8 Drawing Sheets

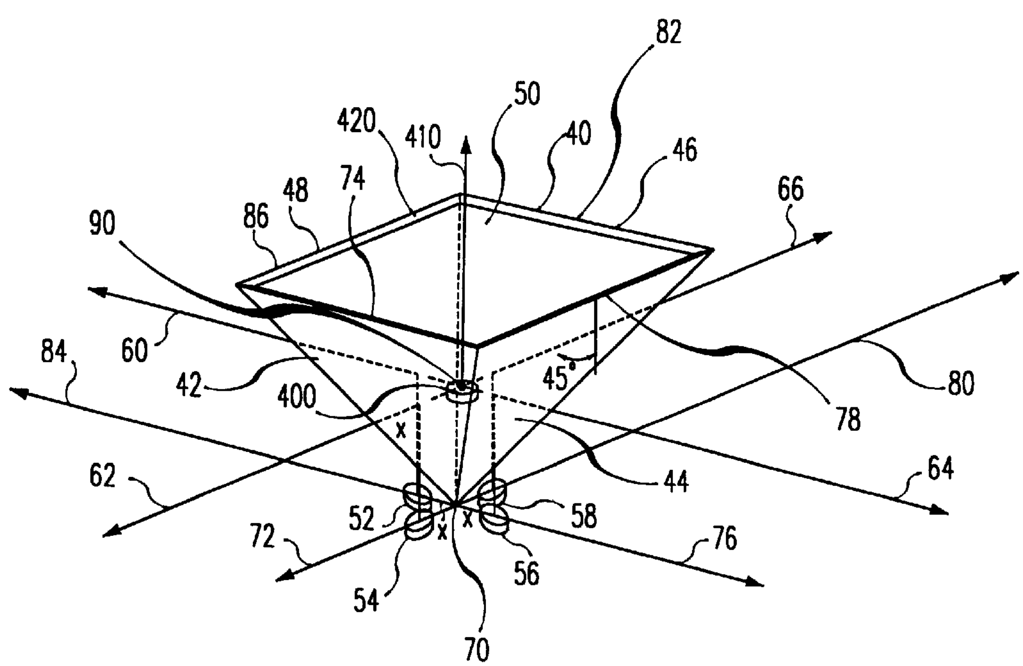


FIG. 1

PRIOR ART

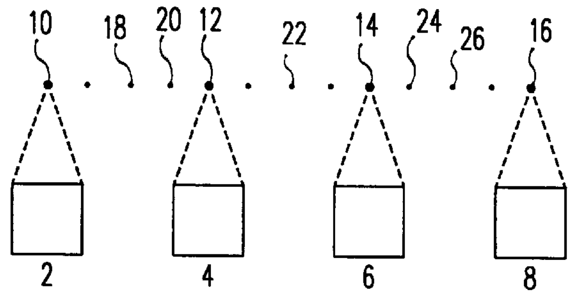


FIG. 2

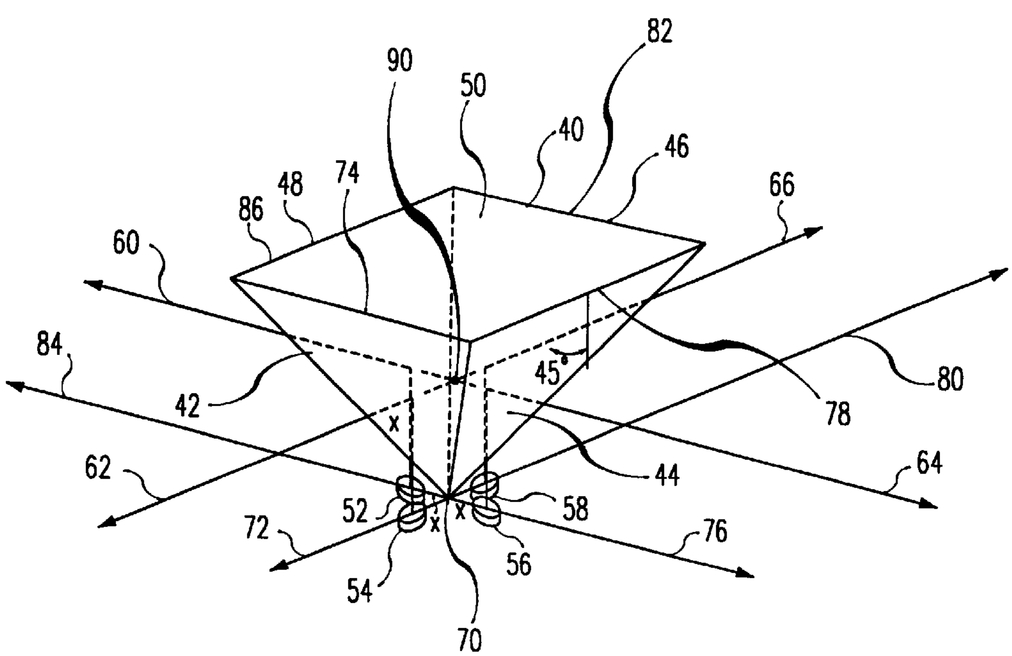


FIG. 3

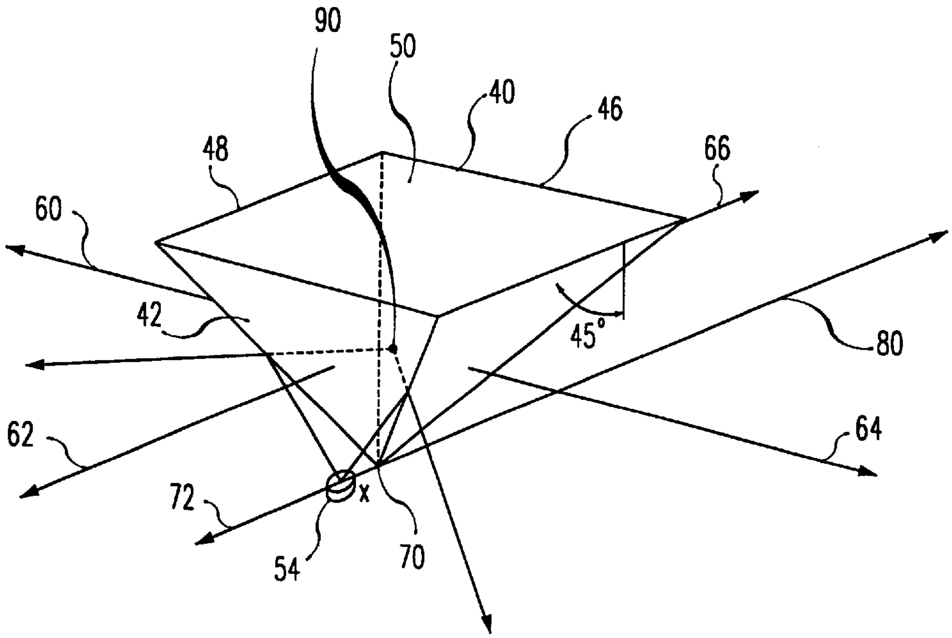


FIG. 4

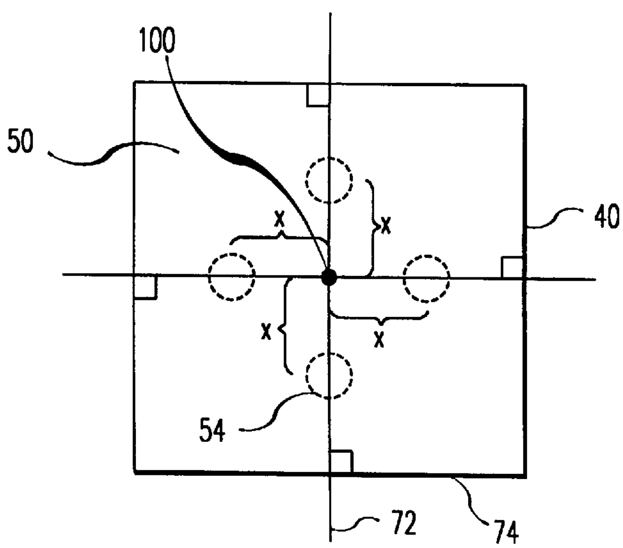


FIG. 5

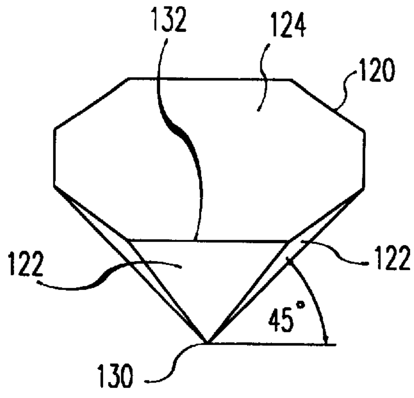


FIG. 6

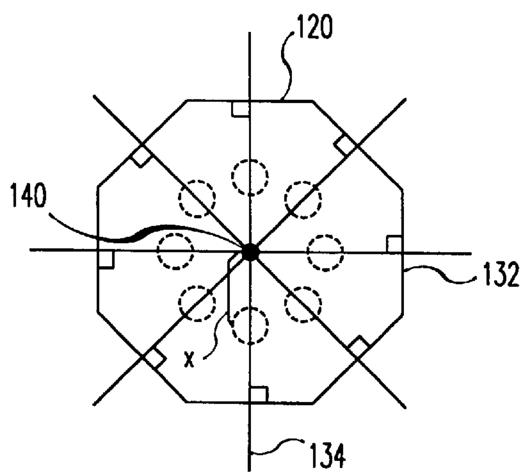


FIG. 7

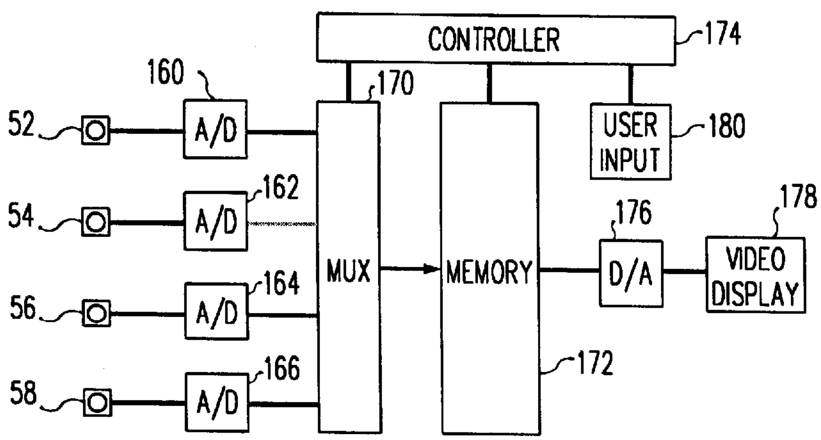


FIG. 8

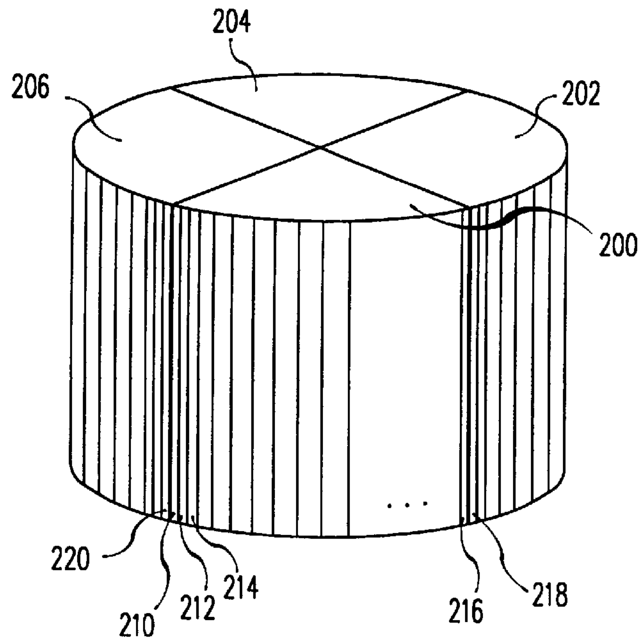

204
206
202
200
220
210
212
214
216
218

FIG. 9

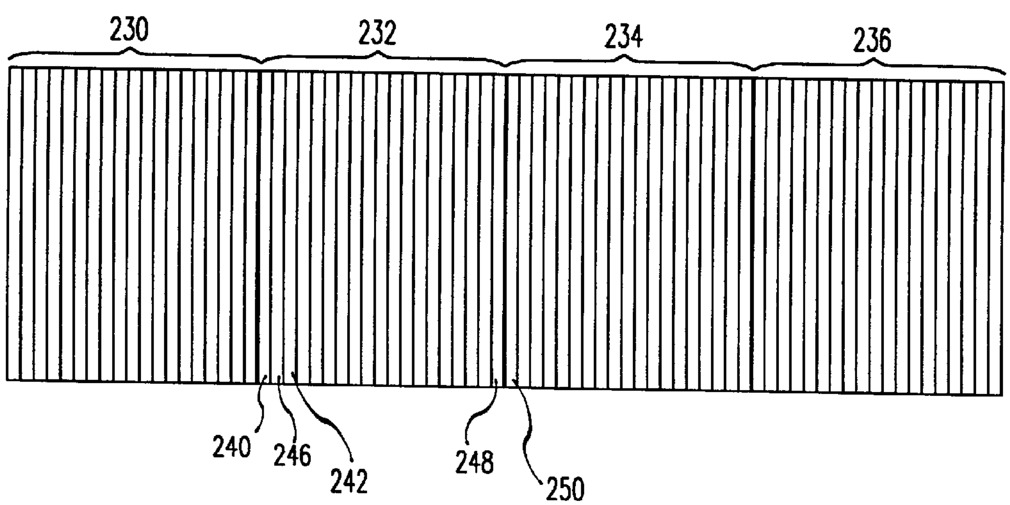

230
232
234
236
240
246
242
248
250

FIG. 10

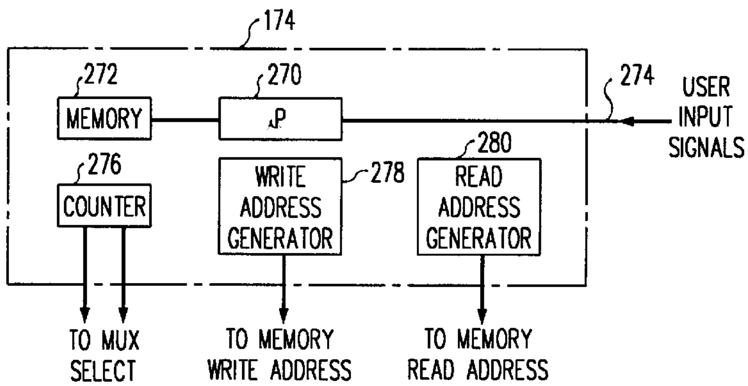

174
272
MEMORY
270
μP
274
USER INPUT SIGNALS
276
COUNTER
WRITE ADDRESS GENERATOR
278
280
READ ADDRESS GENERATOR
TO MUX SELECT
TO MEMORY WRITE ADDRESS
TO MEMORY READ ADDRESS

FIG. 11

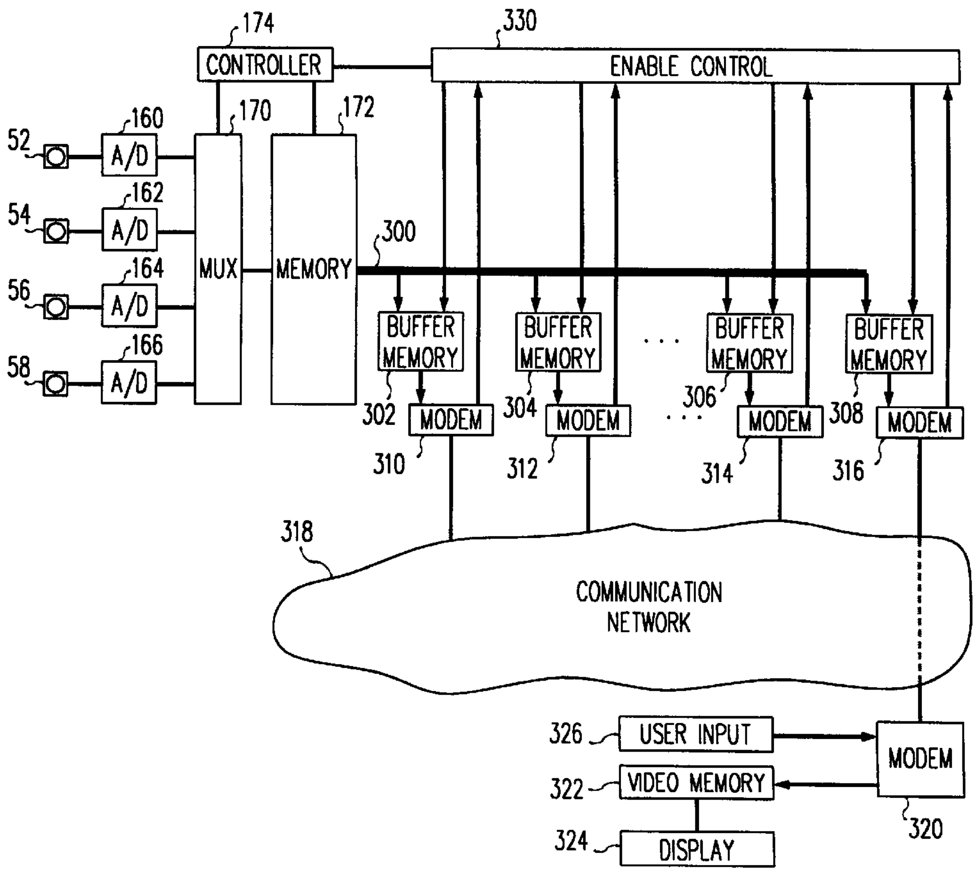
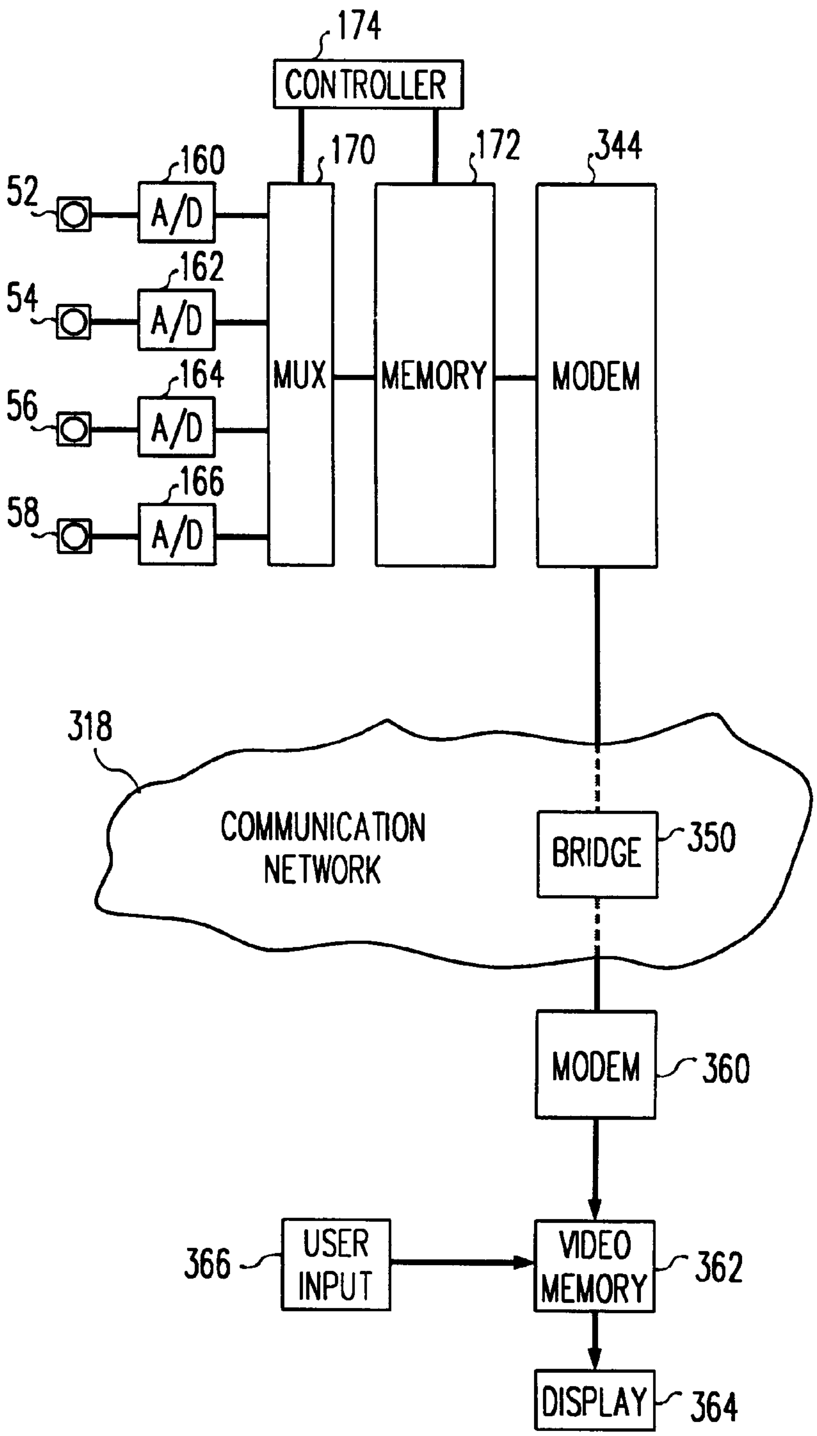

174
CONTROLLER
330
ENABLE CONTROL
52
54
56
58
160
162
164
166
A/D
A/D
A/D
A/D
170
MUX
172
MEMORY
300
BUFFER MEMORY
BUFFER MEMORY
BUFFER MEMORY
BUFFER MEMORY
302
304
306
308
MODEM
MODEM
MODEM
MODEM
310
312
314
316
318
COMMUNICATION NETWORK
326
USER INPUT
322
VIDEO MEMORY
324
DISPLAY
MODEM
320

FIG. 12



174
CONTROLLER
170
172
344
160
52
A/D
162
54
A/D
164
56
A/D
166
58
A/D
MUX
MEMORY
MODEM
318
COMMUNICATION NETWORK
BRIDGE
350
MODEM
360
366
USER INPUT
VIDEO MEMORY
362
DISPLAY
364

FIG. 13

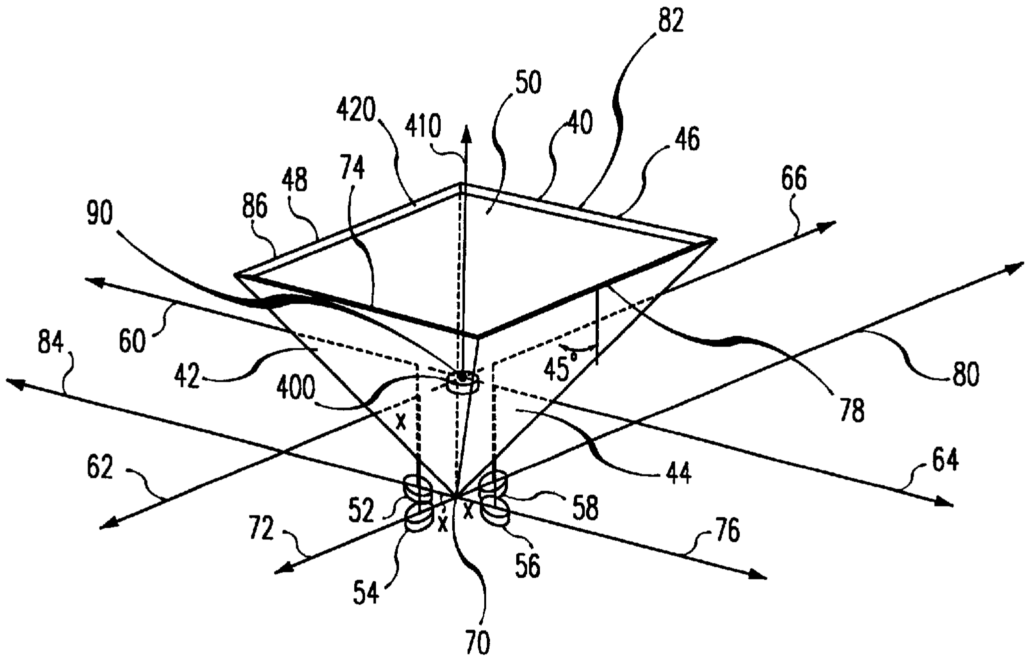

82
50
420
410
40
46
74
48
86
66
90
84
60
42
400
45°
78
80
x
44
64
62
52
x
x
58
72
76
54
56
70

FIG. 14

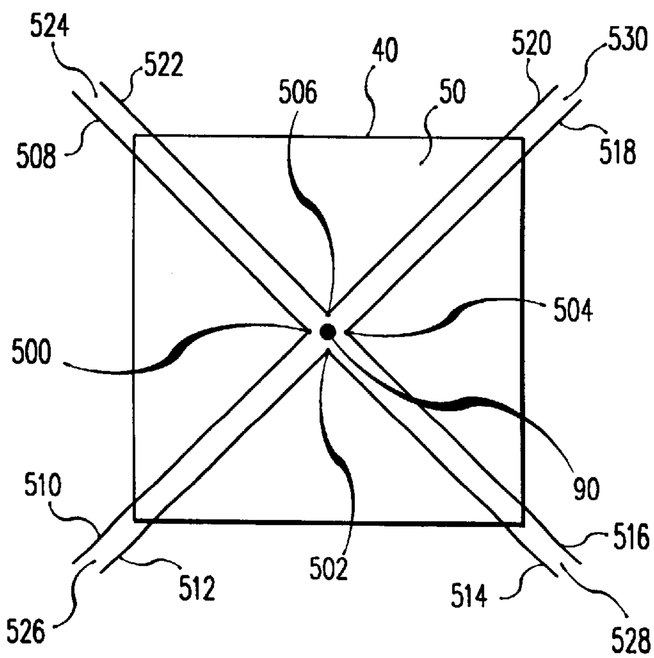
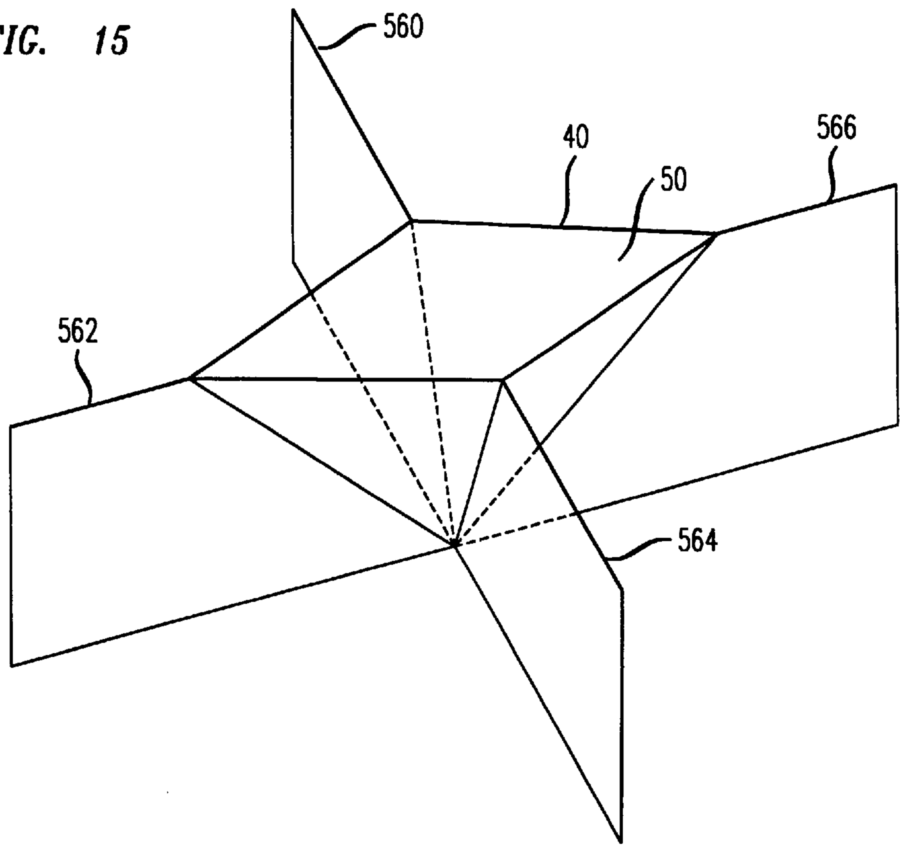

524
522
40
520
530
506
50
508
518
504
500
90
510
516
502
512
514
526
528

FIG. 15



PANORAMIC VIEWING SYSTEM WITH A COMPOSITE FIELD OF VIEW

CROSS REFERENCE TO RELATED APPLICATIONS

This application is a continuation of commonly assigned U.S. Patent application entitled "Panoramic Viewing System With Shades", Ser. No. 09/431,400, filed Dec. 27, 1999, which issued as U.S. Patent No. 6,356,397 on Mar. 12, 2002, which is a continuation of commonly assigned U.S. Patent application entitled "Panoramic Viewing System With Offset Virtual Optical Centers", Ser. No. 08/946,443, filed Oct. 7, 1997, which issued as U.S. Pat. No. 6,111,702 on Aug. 29, 2000, which is a continuation-in-part of commonly assigned U.S. Patent application entitled "Spherical Viewing/Projection Apparatus", Ser. No. 08/565,501 filed Nov. 30, 1995, which issued as U.S. Pat. No. 6,115,176 on Sep. 5, 2000; and is related to commonly assigned U.S. Patent Application entitled "Panoramic Viewing Apparatus", Ser. No. 08/431,356, filed Apr. 28, 1995, which issued as U.S. Pat. No. 5,745,305 on Apr. 28, 1998 and to commonly assigned U.S. Patent Application entitled "Method and System for Panoramic Viewing", Ser. No. 08/431,354, filed Apr. 28, 1995, which issued as U.S. Pat. No. 5,990,934 on Nov. 23, 1999.

BACKGROUND OF THE INVENTION

1. Field of the Invention

The present invention relates to a viewing system; more particularly, a spherical viewing system.

2. Description of the Related Art

In an effort to operate more efficiently, it is desirable to perform some tasks using telepresence. Telepresence refers to providing visual or other types of sensory information from a device at a remote site to a user that make the user feel as if he/she is present at the remote site. For example, many businesses now hold meetings using telepresence. Telepresence is also useful for distance learning and remote viewing of events such as concerts and sporting events. A more realistic telepresence is provided to a user by providing the user with the capability to switch between views, and thereby mimic, for example, looking around a meeting room.

In the past, when several views were made available to a user, several cameras with different optical centers were used. Such a situation is illustrated in FIG. **1**. FIG. **1** illustrates cameras **2**, **4**, **6** and **8** with optical centers **10**, **12**, **14**, and **16**, respectively. When the user decided to change views, he or she simply switched between cameras. In more sophisticated systems, when a user decided to change views, he or she was able to obtain a view from optical centers **10**, **12**, **14**, or **16** as well as from additional optical centers **18**, **20**, **22**, **24** or **26**. Views associated with optical centers such as **18**, **20**, **22**, **24**, and **26** were obtained by using views from the two cameras nearest to the selected optical center. For example, a view from optical center **18** was obtained by using the views from cameras **2** and **4** and interpolating between the two views so as to simulate a view from optical center **18**. Such procedures introduced irregularities into views. In addition, forming these interpolated views required a large amount of computational power and time, and thereby made this technique expensive and slow to respond to a user's commands. This computational overhead also limited the number of users that can simultaneously use the system.

Other prior art discloses that the several views made available to a user can also be derived from a single

wide-angle view that is created from multiple individual views captured by multiple distinct cameras. However, prior-art arrangements to create a single wide-angle view from multiple individual views have been unsatisfactory. In some arrangements, there is substantial parallax between the individual views, parallax that would lead to artifacts where the individual views would overlap or adjoin in any composite image; such artifacts are avoided in some cases by intentionally fragmenting the wide-angle view to have substantial gaps between individual images upon their display (e.g., U.S. Pat. No. 2,942,516). In some other arrangements, even though parallax between individual views may be minimal or absent, image artifacts remain and there is no suggestion on how to prevent these image artifacts from occurring where individual views would adjoin in any composite image (e.g., U.S. Pat. Nos. 3,118,340, 3,356,002, 4,890,314, 5,187,571). In some other arrangements, the number of individual cameras is limited to be no more than three and precise optical alignment of cameras and projectors is required to create a composite wide-angle image that is optical, rather than electronic, for all practical purposes precluding the use of such a composite image in providing multiple views to a user as described above (e.g., U.S. Pat. Nos. 2,931,267, 3,031,920, 4,890,314). Of particular relevance here are prior-art arrangements that use one or more mirrors with more than one camera to create a wide-angle composite image: One problem that has remained unaddressed in such arrangements is how to rid the composite image of image artifacts due to portions of individual images being captured off edges of mirrors (e.g., U.S. Pat. Nos. 2,931,267, 3,031,920, 3,118,340, 4,890,314, 5,187,571); further, even in those of such arrangements in which an attempt is made to reduce other image artifacts, which occur due to causes other than reflection off edges of mirrors and occur where individual images come together in a composite image, the arrangements and techniques proposed are limited to using no more than three cameras and are purely optical rather than electronic, requiring precise optical alignment of cameras and projectors and not lending themselves to providing multiple views to a user as described above (e.g., U.S. Pat. Nos. 2,931,267, 3,031,920). Some other prior art devices have no particular advantage with respect to acquiring a wide-angle field of view and also fail to avoid the above-mentioned image artifacts caused by portions of individual images being captured off edges of mirrors (e.g., U.S. Pat. Nos. 5,016,109, 5,194,959). These are just some of the drawbacks of the prior art that prevent it from being used to create high-quality composite wide-angle images that can be used to provide multiple views to a user as described above.

SUMMARY OF THE INVENTION

One embodiment of the present invention provides an omnidirectional or panoramic viewer where several cameras have a common optical center. The cameras are positioned so that they each view a different reflective surface of a polyhedron such as a pyramid. This results in each camera having a virtual optical center positioned within the pyramid. The field of view of each of the cameras is merged with the individual fields of view of the other cameras and arranged to form a composite field of view which is a continuous 360 degree view of an area when taken as a whole. The user can sweep through 360 degrees of viewing, where each view has the same or nearly the same optical center, by simply using the output of one camera or the combination of two cameras without requiring the computational overhead of interpolation used in the prior art. Such an arrangement may be used to enhance use of virtual meeting rooms by allowing a viewer to see the meeting room in a more natural format. This format corresponds closely to a person sitting in the actual meeting who simply turns his or her head to change the view at a particular time.

In another embodiment of the present invention, a nearly spherical view is provided to a user by placing a camera with its optical center at the common virtual optical center of the viewer. In order to enhance the spherical view, the camera at the common virtual optical center may use a wide angle lens.

In still another embodiment of the invention, the cameras are positioned so that their effective optical centers are offset from each other. The offsets produce narrow blind regions that remove image distortions received from the edges of the pyramid's reflective surfaces. Additionally, planar shades that extend in an outward direction are positioned in the blind regions.

In yet another embodiment of the present invention, the viewing device may include any type of image transducer or processing device. If the image transducer or processing device is a camera or other type of image capture device, a panoramic or spherical image is captured for the user, and if the image transducer or processing device is a projector or other type of image producing device, a panoramic or spherical image is produced for the user.

BRIEF DESCRIPTION OF THE DRAWING

FIG. **1** illustrates a prior art multiple camera viewing system;

FIG. **2** illustrates a four camera omnidirectional or panoramic viewing system using a four-sided pyramid with reflective surfaces;

FIG. **3** illustrates how a reflective surface of the pyramid is used to provide each camera with a common optical center;

FIG. **4** illustrates the top view of the pyramid illustrating the camera positions;

FIG. **5** illustrates an eight-sided pyramid with reflective side surfaces;

FIG. **6** is a top view of the pyramid of FIG. **5**;

FIG. **7** is a block diagram of a system to control data produced by the cameras;

FIG. **8** illustrates the association between the data received from the cameras and the view presented to a user;

FIG. **9** illustrates an addressing scheme for the memory of FIG. **7**;

FIG. **10** is a block diagram of the controller of FIG. **7**;

FIG. **11** illustrates using a telecommunications network to provide a selection of views to a plurality of users;

FIG. **12** illustrates a second embodiment for providing a selection of views to multiple users over a telecommunications network;

FIG. **13** illustrates the viewing system of FIG. **2** with a fifth camera;

FIG. **14** illustrates a top view of the pyramid of FIG. **2** with displaced virtual optical centers; and

FIG. **15** illustrates the pyramid of FIG. **14** with shades positioned in blind regions.

DESCRIPTION OF THE PREFERRED EMBODIMENT

FIG. **2** illustrates a four camera system for providing a 360 degree view to a user, where the cameras each have a

common virtual optical center within the pyramid. Pyramid **40** has reflective sides **42**, **44**, **46** and **48** and may be a hollow or solid structure. In a preferred embodiment, each of the reflective sides forms a 45 degree angle with a plane parallel to base **50** and passing through the vertex of pyramid **40**. Cameras **52**, **54**, **56** and **58** are associated with pyramid reflective surfaces **48**, **42**, **44**, and **46**, respectively. The cameras may be image gathering devices such as an optical scanner. As a result, camera **52** views a reflection from surface **48** to enable it to view objects in the direction of arrow **60**. Camera **54** views a reflection from surface **42** to view objects in the direction of arrow **62**. Camera **56** views a reflection from surface **44** to view objects in the direction of arrow **64**, and camera **58** views a reflection from surface **46** to view objects in the direction of arrow **66**. Each camera has a 90 degree field of view. The combination of the four cameras viewing reflections from their associated reflective surfaces on pyramid **40**, produce a 360 degree view of the area surrounding pyramid **40**. It is desirable to locate the optical center of each camera on a plane that is parallel to base **50** and intersects vertex **70** of pyramid **40**. Each camera's optical center should also be located on a line that passes through vertex **70** and is perpendicular to the base line of the camera's associated reflective surface. For example, the optical center of camera **54** is located on line **72**. Line **72** is perpendicular to base line **74** of reflective surface **42**. Line **72** is in a plane that passes through vertex **70** and is parallel to base **50**. Likewise, the optical center of camera **56** is positioned on line **76** which is perpendicular to baseline **78**, the optical center of camera **58** is positioned on line **80** which is perpendicular to base line **82**, and the optical center of camera **52** is positioned on base line **84** which is perpendicular to base line **86**.

Each camera optical center is positioned on one of the above described lines at a distance X from vertex **70** and each camera has its optical axes or direction of view pointing perpendicular to base **50**. (The distance X should be such that the reflective surface reflects as much of the camera's field of view as desired; however, the defects in the reflective surface become more visible when the camera is moved closer to the reflective surface.) This positioning of optical centers results in the cameras sharing a virtual optical center located at position **90**. Virtual optical center **90** is located a distance X from the vertex **70** on a line that passes through vertex **70** and is perpendicular to base **50**.

FIG. **3** illustrates another view of pyramid **40** where only camera **54** is shown for the sake of simplicity. Camera **54** is positioned on line **72** so as to have a virtual optical center at position **90** within pyramid **40**. If camera **54** has a 90 degree field of view in the direction perpendicular to base **50**, and if the optical center of camera **54** is at a distance of X from vertex **70** along line **72**, camera **54** has a 90 degree view in the direction of arrow **62**. In similar fashion, cameras **56**, **58**, and **52** have 90 degree views in the direction of arrows **64**, **66**, and **60**, respectively. This arrangement inexpensively produces a 360 degree field of view of an area because cameras with a 90 degree field of view have relatively inexpensive optics.

FIG. **4** is a top view of pyramid **40**. FIG. **4** illustrates the placement of the optical center of camera **54** along line **72**. Line **72** should be in a plane that passes through vertex **70** and is parallel to base **50**. The line should also be perpendicular to base line **74** of pyramid **40**. The camera's optical center should be positioned a distance X from vertex **70** along line **72**. The distance X should be such that the reflective surface reflects as much of the camera's field of view as desired. Point **100** is located on base **50** at a position where a line from vertex **70** perpendicularly intersects base **50**. In a similar fashion, the optical centers of cameras **56**, **58** and **52** are positioned the distance X along lines **76**, **80** and **84**, respectively.

FIG. **5** illustrates an eight-sided pyramid **120**. Pyramid **120** has reflective surfaces **122** where each of surfaces **122** forms a 45 degree angle with a plane that passes through vertex **130** and is parallel to base **124**. As with the four-sided pyramid of FIG. **2**, each reflective surface of FIG. **5** may have a camera associated with it. Each camera's optical center is positioned on a line that is in a plane that passes through vertex **130** and is parallel to base **124**. The line is perpendicular to base line **132** of the reflective surface associated with the camera to be positioned. Using an eight-sided pyramid offers the advantage of using cameras with only a 45 degree field of view to obtain a 360 degree view. Cameras with only a 45 degree field of view have inexpensive optics and enable a 360 degree view to be constructed using relatively inexpensive components.

FIG. **6** is a top view of pyramid **120**. As discussed with regard to FIG. **5**, each camera's optical center is positioned along a line **134** which is in a plane that passes through vertex **130** and is parallel to base **124**. The optical centers are positioned a distance X along line **134** which is perpendicular to the appropriate base line **132**. Point **140** is on base **124** at the point of intersection between base **124** and a line that passes through vertex **130** and is perpendicular to base **124**.

Pyramids having more or less reflective sides may be used. The advantage of using pyramids having a large number of sides is that cameras with moderate to small fields of view may be used. Cameras with moderate fields of view have relatively inexpensive optics. The number of sides used in a pyramid is somewhat limited by the cost of providing a large number of cameras. A 360 degree view of a scene may be provided using a pyramid having three reflective sides. It may be expensive to use only a three-sided pyramid in order to provide a 360 degree field of view. This embodiment of the invention uses three cameras each with a 120 degree field of view, and cameras with such a wide field of view use relatively expensive optical components.

In applications where a full 360 degree view is not desired, it is possible to build a viewer that does not have a camera associated with each reflective surface of the pyramid.

FIG. **7** illustrates a block diagram of a system for controlling data produced by the cameras of a viewing device such as the viewing device described in FIGS. **2** through **4**. Cameras **52**, **54**, **56** and **58** obtain a 360 degree view of an area via their associated reflective surfaces of pyramid **40**. The image signal or output signal of cameras **52**, **54**, **56** and **58** are passed through analog to digital converters (A/D) **160**, **162**, **164**, and **166**, respectively. The output of the cameras can be thought of as a stream of pixels and the output of the A/Ds can be thought of as data representative of the pixels from the cameras. The output of the A/Ds are passed through mux **170**. Mux **170** allows the pixel data from each of the A/Ds to reach memory **172**. Controller **174** cycles the select lines of mux **170** so that the outputs of all of the A/Ds are stored in memory **172**. Mux **170** is switched at a rate that is four times the pixel rate of the cameras. If more or less cameras are used, the rate at which mux **170** is switched will be increased or slowed accordingly. It is also possible to eliminate mux **170** and to store the output of each A/D in a separate memory. Controller **174** is implemented using a microprocessor which provides control signals to counters that control the switching of mux **170** and counters used to provide addressing to memory **172**. The control signals to the counters include reset, enable and a starting offset.

As a result of the pixel information being passed to memory **172**, memory **172** contains a 360 degree view of a scene. Pixel information stored in memory **172** is passed through digital to analog converter (D/A) **176** and to video display **178**. The actual portion of memory **172** that is passed to video display **178** via D/A **176** is controlled via user input device **180**. User input device **180** may be a common device such as a mouse, joystick, or keyboard. The user may simply lean a joystick to the right to shift his view to the right, lean the joystick to the left to shift the view to the left, or leave the joystick in the center to keep the view unchanged. Based on the input from user device **180**, controller **174** varies offsets and starting addresses that are used to provide addressing to memory **172**.

FIG. **8** illustrates the relationship between the data provided by the cameras and the view available to the user. Since the cameras share a virtual optical center, the view can be thought of as a cylindrical view. Sector **200** can be thought of as representing the information provided by camera **52**, sector **202** can be thought of as representing the information provided by camera **54**, sector **204** can be thought of as representing the information provided by camera **56**, and sector **206** can be thought of as representing the information provided by camera **58**. The surface of the cylinder in each sector can be thought of as a collection of columns, where each column is composed of pixels. For example, sector **200** can be thought of as a collection of columns including columns **210**, **212**, **214** and **216**. Likewise, the output produced by camera **54** can be thought of as a collection of columns which include column **218** in sector **202** and the output of camera **58** can include columns such as column **220** in sector **206**. The column of pixels near the sector boundaries are closer together than the columns near the center of a sector. This occurs because the cameras capture the image on a plane while FIG. **8** shows the columns projected onto a cylindrical surface.

FIG. **9** illustrates how memory **172** is divided to provide easy access to different views based on signals from user input device **180**. Sections **230**, **232**, **234** and **236** correspond to sectors **206**, **200**, **202** and **204**, respectively. Each of sections **230**, **232**, **234** and **236** can be thought of as a block within memory **172**. The blocks in memory **172** are broken into columns of sequential addresses. The first column of memory segment **230** corresponds to the first column of pixels of sector **206**. The number of memory positions associated with a column should be at least sufficient to have one location for each pixel in a particular column. For example, if a column of pixels from FIG. **8** includes 1000 pixels, each column associated with the memory segments of FIG. **9** should have at least 1000 locations. The number of columns associated with a particular memory segment should be at least equal to the number of columns associated with a particular section of the cylinder of FIG. **8**.

If a camera scans in a horizontal direction, sequential pixels are written in adjacent columns, but possibly different rows, of a particular memory segment by simply changing an offset to a counter generated address. The overall write address is generated by adding the offset to the counter's output. This offset is changed at the rate in which the horizontally scanned pixels are received. After a horizontal scan is completed, the counter is incremented and once again the offsets are changed at the horizontal scan rate. As a result, when addressing a particular segment of memory during a write cycle, the columns are addressed by changing the offset at the horizontal pixel scan rate, and incrementing the counter at the vertical scan rate. This type of addressing scheme is used for accessing columns within each memory segment. When addressing different memory segments during a write cycle, a write segment offset is added to the sum of the counter output and the column offset. The write segment offset permits addressing memory segments **230**, **232**, **234**, and **236**. The segment offset is changed at the same rate as mux **170** is switched.

Pixel data is read from memory **172** in a similar fashion. The sum of a counter output and two sets of offsets are used to generate a read address. Once an initial starting column has been picked, the read address is generated by switching a read column offset at a rate that is equal to the horizontal scan rate of a video display. After reading one horizontal scans worth of data, the read counter is incremented and the read column offsets are changed at a rate equal to the horizontal scan rate of the display. As a result, the offset addresses are changing at the display's horizontal display rate and the counter is incremented at a rate equal to the vertical scan rate of a display. It is possible to read data out at a rate faster or slower than required by the video display; however, if read out faster, a buffer memory should be used, if read out slower the video display may appear choppy to the viewer.

It should be noted that the cylindrical arrangement of pixels of FIG. **8** is typically displayed on a flat or nearly flat display. As a result, the image is displayed by compensating for converting between a cylindrical surface and a flat surface. This may be carried out using a simple conversion algorithm within a common digital signal processing integrated circuit. Methods for these types of conversions are well known in the art and can be found in "A Guided Tour of Computer Vision," Vishvjit S. Nalwa, Addison-Wesley Publishing Co., Reading, Mass., 1993. It is also possible to carry out the conversion using a very high resolution display.

It should be noted that if the view selected by a user corresponds exactly to the view of a particular camera, such as camera **52**, columns **240**–**248** are read from memory **170**. Column **240** is the first column in segment **232** and column **248** is the last column in segment **232**. If the user decides to move the view in a counter-clockwise direction, the start column will shift to the right so that the read operation begins at column **246** and ends at column **250**. It should be noted that column **246** is the second column associated with memory segment **232** which has the pixel data from camera **52**, and that column **250** is the first column of pixel data associated with camera **56**. As the user shifts the view, the starting column shifts in relationship to the user's commands. For example, if the user indicates that the view should shift in a counter-clockwise direction, the start column of FIG. **9** moves to the right, similarly, if the viewer indicates that the view should shift in a clockwise direction, the start column shifts to the left. As before, columns are addressed by using offsets, if the offsets involve moving between memory segments, a read segment offset is added to the sum of the column offset and counter output.

It should be recalled that the columns near the sector boundaries of FIG. **8** are closer together. As a result, when the user commands a change in a view and when the border of that view is near a sector boundary, the start column changes by a larger number of columns for a given angular rotation of the view. Conversely, when the border of the view is near the center of the sector, the start column changes by a smaller number of columns for a given angular rotation.

FIG. **10** illustrates a block diagram of controller **174**. Controller **174** includes microprocessor **270** and memory **272**. Memory **272** includes RAM and ROM. Processor **270** receives commands on line **274** from user input device **180**. Microprocessor **270** controls start, stop and reset of counter **276**. Counter **276** controls the select lines of mux **170**. Counter **276** counts at a rate that is four times the horizontal scan rate of the cameras. Write address generator **278** provides write addressing for memory **172**. Write address generator **278** includes a counter, register for storing offsets and adder for adding the offsets and counter output. Microprocessor **270** controls the offset selection and the counters used by write address generator **278**. The write addresses are formed as described with regard to FIG. **9**. Read address generator **280** provides read addresses to memory **172**. Read address generator **280** includes a counter, register for storing offsets and adder for adding the offsets and counter output. As with write address generator **278**, microprocessor **270** controls the offset selection and the counters of read address generator **280**. Microprocessor **270** also controls the starting column used by the counters based on inputs provided on line **274** from user input **180**.

The write and read addresses are provided to memory **172** separately if memory **172** is implemented using a two port memory. If memory **172** is implemented with a single port memory, the write and read addresses are multiplexed to memory **172**.

FIG. **11** illustrates an embodiment where a panoramic viewer is used to provide views to several users over a communications network. In this embodiment, all of the columns of pixel data are read from memory **172** and placed on bus **300**. Buffer memories **302**, **304**, **306** and **308** receive the data from bus **300**. The buffer memories are enabled only when desired columns are available on bus **300**. The buffer memories then pass their information to modems **310**, **312**, **314** and **316**, which then provide the pixel data to telecommunications network **318**. Telecommunications network **318** then delivers the information from the modems to the users. In one example, a user receives information from modem **316** using modem **320**. Modem **320** then provides the pixel information that was in memory **308** to a local video memory **322**. Video memory provides the pixel information to display **324** for viewing. The user at this location controls the view using user input device **326** which may be a device such as a mouse, keyboard or joystick. Modem **320** transmits the user input device signals over telecommunications network **318** to modem **316** which then provides the signals to enable controller **330**. Enable controller **330** receives a signal from controller **174** that indicates which column is being read from memory **172**. When the appropriate column is available, the enable controller **330** enables the buffer memory **308** to receive the columns of data specified by the user input device signals received over the communication network. As discussed with regard to FIG. **9**, enable controller **330** simply moves the start column based on signals from the user input device. In this embodiment, enable controller **330** enables the input to the buffer memory when the pixel data from the start column is on bus **300**. Enable controller **330** disables the input to the buffer memory when the total number of columns of pixels to be viewed are provided to the buffer memory. FIG. **11** illustrates a system where four users can individually control their viewing; however, more users may be accommodated by simply increasing the number of buffer memories, modems, and ports on enable controller **330**.

FIG. **12** illustrates another embodiment in which multiple viewers can use the panoramic viewer. As the pixel data is read from memory **172**, all of the data is passed over telecommunications network **318** to telecommunications bridge **350**. The information from memory **172** is provided to bridge **350** via modem **344**; however, the data may be passed to bridge **350** without use of modem **344** if a digital connection is made between memory **172** and bridge **350**. Bridge **350** then distributes all of the data received from memory **172** to each user in communication with bridge **350**. If bridge **350** provides analog link to users, a modem should be used at each user port. If the bridge has a digital link to the user ports, a modem is not required. In the case of an analog link, the data from memory **172** passes from modem **344** via bridge **350** to modem **360** at a user port. Modem **360** passes the pixel data to video memory **362**. Video memory **362** then passes the pixel information to video display **364** under control of a user via user input device **366**. User input device may be a mouse, joystick or computer keyboard. In this embodiment, the entire contents of memory **172** is fed to video memory **362**. The data read from memory **362** and passed to video display **364** is controlled using user input device **366** in a fashion similar to that which was described with regard to FIG. **9**.

FIG. **13** illustrates the viewing system of FIG. **2** with a fifth camera. Camera or image gathering device **400** is located in pyramid **40** with the optical center of camera **400** located at virtual optical center **90**. Camera **400** views objects in the direction of arrow **410**. It is desirable to provide camera **400** with a wide angle lens. The resulting wide angle view coupled with the views of the remaining four cameras, provides a nearly spherical view. If the cameras of FIG. **13** are replaced with image producing devices, the nearly spherical viewing system becomes a nearly spherical projection system. It should be noted that a camera or projection device may be placed at the virtual optical center of viewing/projection devices having pyramids with three, four or more sides. It should also be noted that edges **420** of the reflective surfaces should be beveled to avoid undesirable obstruction of camera **400**'s field of view. It is also possible to avoid undesirable image artifacts from base edges **420** by moving camera or image processing device **400**. Device **400** should be moved so that device **400**'s optical center is positioned away from virtual optical center **90** in the direction of arrow **410**. Device **400**'s optical center should be positioned so that the device's field of view does not include edges **420**.

FIG. **14** illustrates a top view of the pyramid of FIG. **2**. In reference to FIG. **2**, camera **52**, **54**, **56** and **58** have been moved upward in the direction of base **50**. As a result, virtual optical centers **500**, **502**, **504** and **506**, which correspond to cameras **52**, **54**, **56** and **58**, respectively, are moved away from virtual optical center **90**. It is desirable to move the virtual optical centers so that camera **52** captures an image between lines **508** and **510**, camera **54** captures an image between lines **512** and **514**, camera **56** captures an image between lines **516** and **518**, and camera **58** captures an image between lines **520** and **522**. This results in the cameras not capturing useful images from narrow planar shaped regions. In particular, planar regions **524**, **526**, **528** and **530** are not used by the cameras and form blind regions. This offers the advantage of removing portions of the cameras' fields of view that are received from the edges of the reflective pyramid. Eliminating these portions of the fields of view alleviates the need to provide image processing that compensates for image artifacts at the edges. It is desirable to keep virtual optical centers **500**, **502**, **504** and **506** closely clustered so that planes **524**, **526**, **528** and **530** are only as thin as necessary to avoid edge artifacts. By maintaining such thin planes, the need to process the images at their common boundaries is removed while minimizing the noticeable effect seen by a user.

From the foregoing description, it is readily apparent that moving the virtual optical centers outward, as in FIG. **14**, facilitates the creation of a composite image that excludes images of mirror edges lying between portions of the fields of view of individual cameras. From the geometry that has been described, it is apparent that the mirror edges lie within, or are encompassed by, the blind regions of the composite field of view corresponding to the composite image. It is also apparent that the narrow planar shaped blind regions lie between portions of adjacent individual fields of view that extend outwardly in substantially similar directions, and that these blind regions do not expand in size with increasing distance from the viewing system. Such expansion of the blind regions would be undesirable because it would allow them to envelope objects that are increasingly large with increasing distance from the viewing system. As described earlier in reference to FIG. **7**, the individual images, and the composite image, are stored as data in memory **172**. Accordingly, eliminating portions of the individual fields of view corresponding to the blind regions of the composite field of view, as described above with reference to FIG. **14**, results in a collection of stored data in memory **172** that excludes data representing images of mirror edges that lie within the blind regions, and it will be immediately apparent to those skilled in the art that the described exclusion of images of mirror edges from useful camera images may be accomplished by disregarding in memory **172**, or discarding from this memory, image data that corresponds to portions of the fields of view of the cameras that contain these mirror edges.

FIG. **15** illustrates the pyramid of FIG. **14** with shades **560**, **562**, **564** and **566** positioned in planar regions **524**, **526**, **528**, and **530**, respectively. The shades reduce the amount of unwanted light that enters the cameras. Similar shades may be placed in blind regions between device **400**'s field of view and one or more of the other image processing devices' field of view. For example, if we recall that moving image device **400** in the direction of arrow **410** removes base edges **420** from the device's field of view, a shade may be placed in one or more of the planar blind regions that extend out from a base edge **420**.

What is claimed is:

1. A method of producing a composite image with a plurality of sensors each having an individual field of view, comprising the steps of:

for at least one of the plurality of sensors, redirecting at least a portion of its individual field of view with a reflective area; and

merging images corresponding to the individual fields of view to produce the composite image having a corresponding field of view, wherein each one of at least two fields of view corresponding to images that are merged has a portion, where the images are merged, that has viewing directions that are substantially similar to the viewing directions of the other portion, and wherein the viewing directions within each one of such two portions appear to originate substantially from a point that is offset from the point for the other one of such two portions.

2. The method of claim **1**, wherein the field of view corresponding to the composite image has at least one blind region that encompasses at least a portion of an edge of a reflective area and that lies between the two portions of the two individual fields of view.

3. The method of claim **2**, wherein the number of sensors each of whose field of view is redirected at least in part by a reflective area is at least three.

4. The method of claim 2, wherein the number of sensors each of whose field of view is redirected at least in part by a reflective area is at least five.

5. The method of claim 1, wherein images corresponding to the individual fields of view are merged electronically by merging data representative of the fields of view to produce data representative of the composite image and data representative of the composite image is stored by electronic means.

6. The method of claim 5, further comprising displaying the composite image selectively using a control means to select a portion of the composite image to be displayed.

7. The method of claim 6, wherein the number of sensors each of whose field of view is redirected at least in part by a reflective area is at least three.

8. The method of claim 6, wherein the number of sensors each of whose field of view is redirected at least in part by a reflective area is at least five.

9. The method of claim 5, further comprising displaying at least a portion of the composite image remotely after transmitting this portion over a communication network.

10. The method of claim 9, wherein the number of sensors each of whose field of view is redirected at least in part by a reflective area is at least three.

11. The method of claim 9, wherein the number of sensors each of whose field of view is redirected at least in part by a reflective area is at least five.

12. The method of claim 5, wherein the number of sensors each of whose field of view is redirected at least in part by a reflective area is at least three.

13. The method of claim 5, wherein the number of sensors each of whose field of view is redirected at least in part by a reflective area is at least five.

14. The method of claim 1, wherein the number of sensors each of whose field of view is redirected at least in part by a reflective area is at least three.

15. The method of claim 1, wherein the number of sensors each of whose field of view is redirected at least in part by a reflective area is at least five.

16. A viewing apparatus having a composite field of view, comprising:

at least two image sensors, each having an individual field of view;

at least one reflective area that redirects at least part of the individual field of view associated with one of the image sensors,

the individual fields of view of at least two image sensors being merged to produce the composite field of view, at least portions of each of the two individual merged fields of view having substantially similar viewing directions where they are merged, and the merged fields of view creating in the composite field of view at least one blind region that encompasses at least a portion of an edge of the reflective area and that lies between portions of two individual fields of view; and

a memory for storing data representative of said composite field of view electronically.

17. The viewing apparatus of claim 16, wherein the number of sensors each of whose individual field of view is redirected at least in part by a reflective area is at least three.

18. The viewing apparatus of claim 16, wherein the number of sensors each of whose individual field of view is redirected at least in part by a reflective area is at least five.

19. A viewing apparatus having a composite field of view, comprising:

at least two image sensors, each having an individual field of view;

at least one reflective area that redirects at least part of the individual field of view associated with one of the image sensors,

the individual fields of view of at least two image sensors being merged to produce the composite field of view, at least portions of each of the two merged individual fields of view having substantially similar viewing directions where they are merged, and the merged fields of view creating in the composite field of view at least one blind region that encompasses at least a portion of an edge of the reflective area and that lies between portions of two individual fields of view;

a memory for storing data representative of said composite field of view electronically; and

control means for selectively retrieving said data from said memory in response to user signals produced in response to a user's input.

20. The viewing apparatus of claim 19, wherein the number of sensors each of whose individual field of view is redirected at least in part by a reflective area is at least three.

21. The viewing apparatus of claim 19, wherein the number of sensors each of whose individual field of view is redirected at in part by a reflective area is at least five.

22. A viewing apparatus having a composite field of view, comprising:

at least two image sensors, each having an individual field of view; at least one reflective area that redirects at least part of the individual field of view associated with one of the image sensors,

the individual fields of view of at least two images sensors being merged to produce the composite field of view, at least portions of each of the two merged individual fields of view having substantially similar viewing directions where they are merged, and the merged fields of view creating in the composite field of view at least one blind region that encompasses at least a portion of an edge of the reflective area and that lies between portions of two individual fields of view;

a memory for storing data representative of said composite field of view electronically;

control means for selectively retrieving said data from said memory in response to user signals produced in response to a users input; and

communication network interface means for transmitting said data retrieved from said memory over a communications network and for receiving said user signals over said communications network.

23. The viewing apparatus of claim 22, wherein the number of sensors each of whose individual field of view is redirected at least in part by a reflective area is at least three.

24. The viewing apparatus of claim 22, wherein the number of sensors each of whose individual field of view is redirected at least in part by a reflective area is at least five.

25. A composite image produce with a plurality of sensors each having an individual field of view, by following the method of:

for at least one of the plurality of sensors, redirecting at least a portion of its individual field of view with a reflective area; and

merging images corresponding to the individual fields of view to produce the composite image having a corresponding field of view, wherein each one of at least two fields of view corresponding to images that are merged has a portion, where the images are merged, that has viewing directions that are substantially similar to the viewing directions of the other portion, and wherein the viewing directions within each one of such two portions appear to originate substantially from a point that is offset from the point for the other one of such two portions.

26. The composite image of claim **25**, wherein the field of view corresponding to the composite image has at least one blind region that encompasses at least a portion of an edge of a reflective area and that lies between the two portions of the two individual fields of view.

27. The method of claim **26** wherein the number of sensors each of whose field of view is redirected at least in part by a reflective area is at least three.

28. The method of claim **26** wherein the number of sensors each of whose field of view is redirected at least in part by a reflective area is at least five.

29. The composite image of claim **25**, wherein images corresponding to the individual fields of view are merged electronically by merging data representative of the fields of view to produce data representative of the composite image and data representative of the composite image is stored by electron means.

30. The composite image of claim **29**, wherein a portion of the composite image is displayed selectively using a control means to select the portion of the composite image to be displayed.

31. The method of claim **30** wherein the number of sensors each of whose field of view is redirected at least in part by a reflective area is at least three.

32. The method of claim **30** wherein the number of sensors each of whose field of view is redirected at least in part by a reflective area is at least five.

33. The composite image of claim **29**, wherein at least a portion of the composite image is displayed remotely after this portion is transmitted over a communication network.

34. The method of claim **33** wherein the number of sensors each of whose field of view is redirected at least in part by a reflective area is at least three.

35. The method of claim **33** wherein the number of sensors each of whose field of view is redirected at least in part by a reflective area is at least five.

36. The method of claim **29** wherein the number of sensors each of whose field of view is redirected at least in part by a reflective area is at least three.

37. The method of claim **29** wherein the number of sensors each of whose field of view is redirected at least in part by a reflective area is at least five.

38. The method of claim **25**, wherein the number of sensors each of whose field of view is redirected at least in part by a reflective area is at least three.

39. The method of claim **25**, wherein the number of sensors each of whose field of view is redirected at least in part by a reflective area is at least five.

* * * * *

EXHIBIT B:

US Patent 6,128,143

(Panoramic viewing system with support stand)

US006128143A

United States Patent [19]

Nalwa

[11] **Patent Number:** 6,128,143

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

[54] **PANORAMIC VIEWING SYSTEM WITH SUPPORT STAND**

[75] Inventor: **Vishvjit Singh Nalwa**, Middletown, N.J.

[73] Assignee: **Lucent Technologies Inc.**, Murray Hill, N.J.

[21] Appl. No.: **09/141,883**

[22] Filed: **Aug. 28, 1998**

[51] **Int. Cl.**[7] **G02B 13/06**; G03B 37/04; H04N 7/00

[52] **U.S. Cl.** **359/725**; 359/363; 359/403; 353/94; 348/39

[58] **Field of Search** 359/363–367, 359/402–406, 431, 618, 627, 629, 725–731, 831, 834–836; 348/14–15, 36, 218, 264, 39; 353/30, 37, 94, 98–99

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Primary Examiner—Thong Nguyen
Attorney, Agent, or Firm—Christopher N. Malvone

[57] **ABSTRACT**

A compact high resolution omnidirectional or panoramic viewer has several cameras with a common virtual optical center. The field of view of each of the cameras is arranged to form a continuous 360 degree view of an area when taken as a whole. The cameras are positioned so that they each views a different reflective surface of a polyhedron such as a pyramid. This results in each camera having a virtual optical center positioned within the pyramid. The cameras may be positioned so that their virtual optical centers are offset from each other. The offsets produce narrow blind regions that remove image distortions received from the edges of the pyramid's reflective surfaces. The reflective pyramids may be stacked base to base or nested within each other to produce a more compact panoramic viewer. Using two or more reflective pyramids in such close proximity permits using many cameras with the same virtual optical center. Using many cameras divides a large viewing area into many smaller areas where an individual camera views each smaller area. Since each camera views a smaller area, increased resolution is provided to the user. The pyramids are mounted to a post that passes through their vertices, and the cameras are secured to the portion of the post extending out of the vertices.

18 Claims, 12 Drawing Sheets

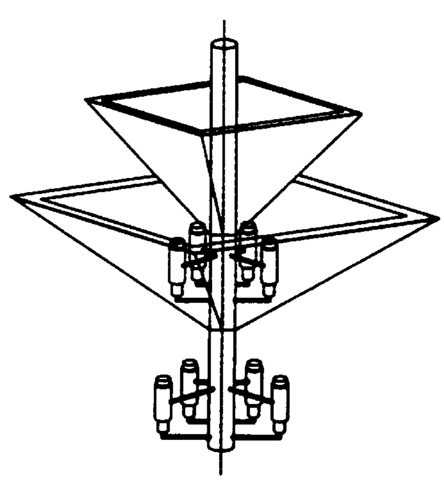

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FIG. 1

PRIOR ART

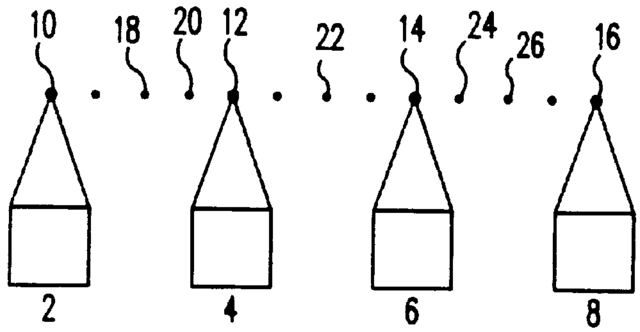


FIG. 2

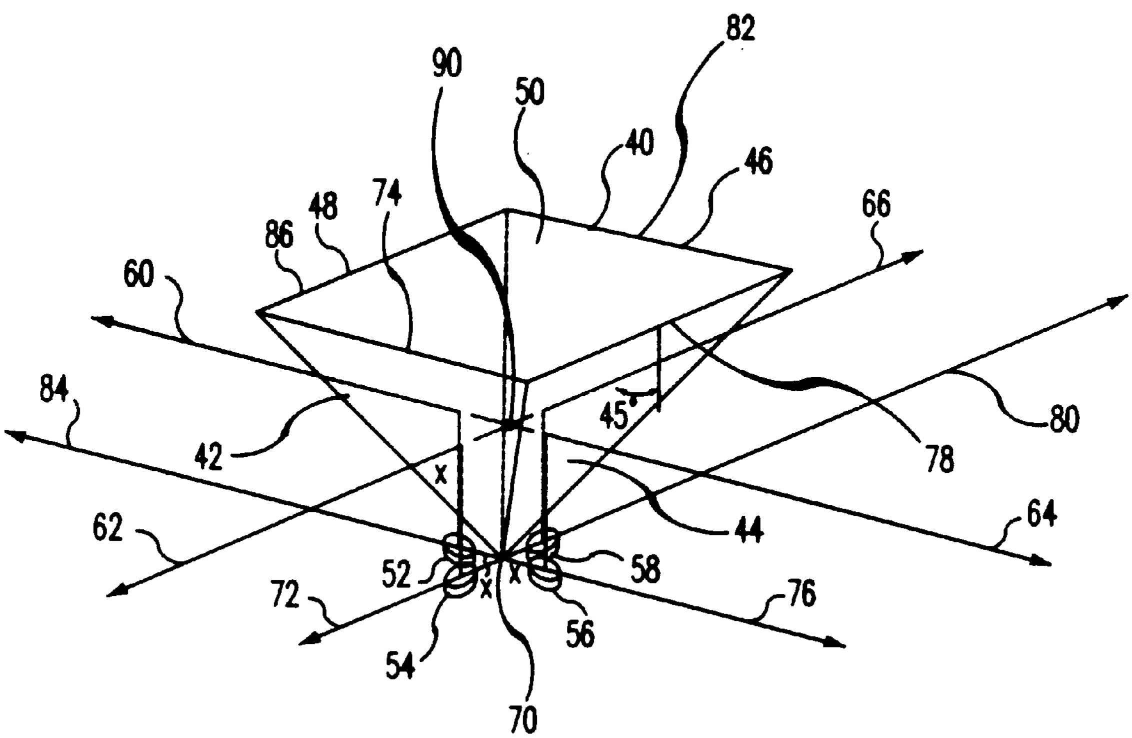


FIG. 3

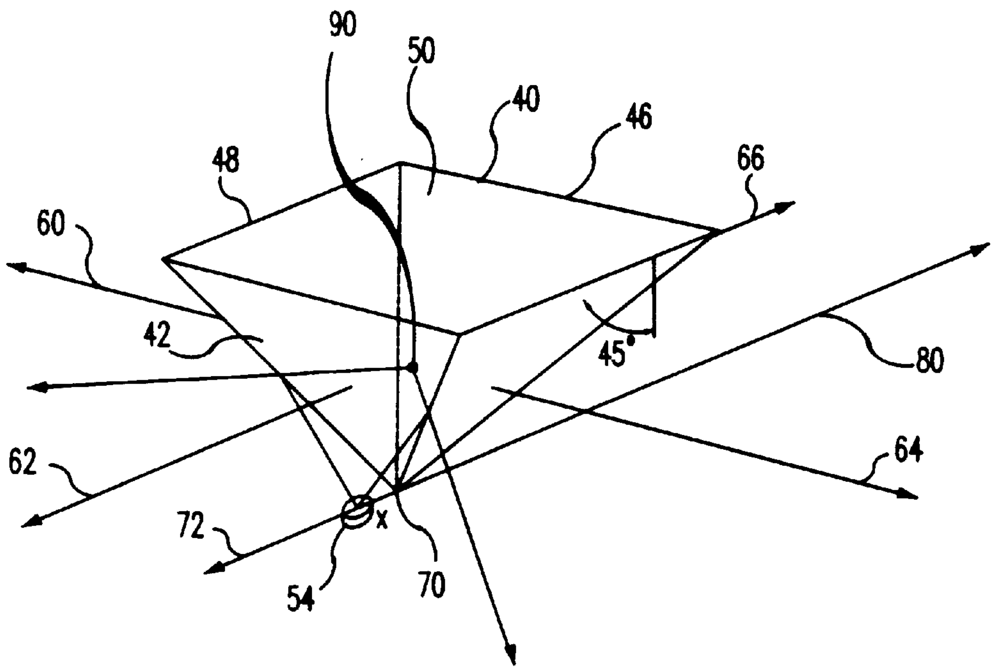


FIG. 4

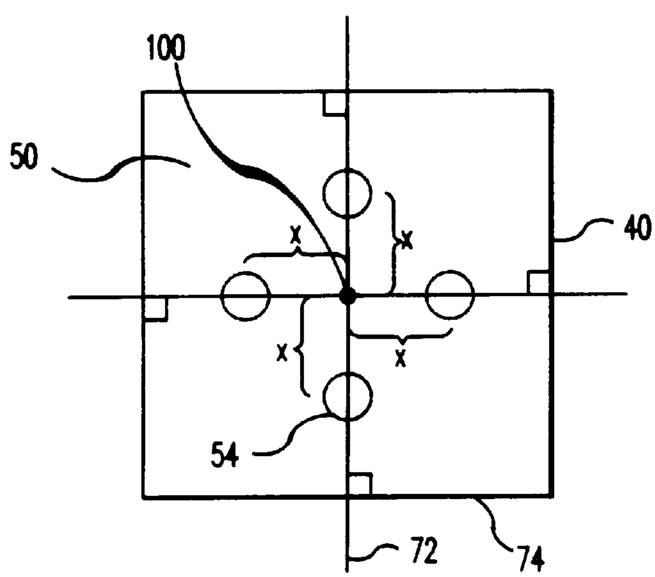


FIG. 5

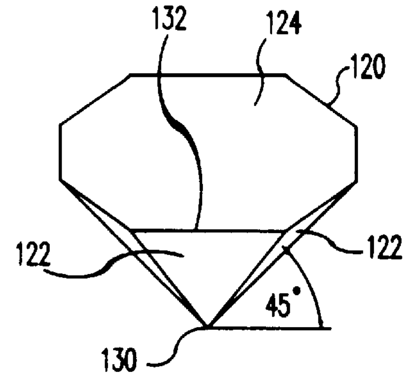


FIG. 6

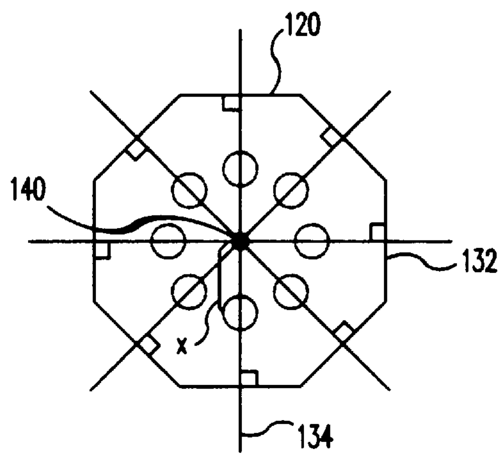


FIG. 7

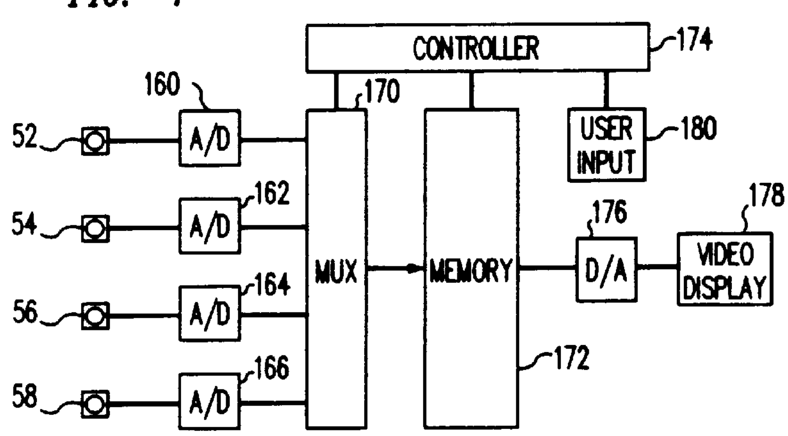


FIG. 8

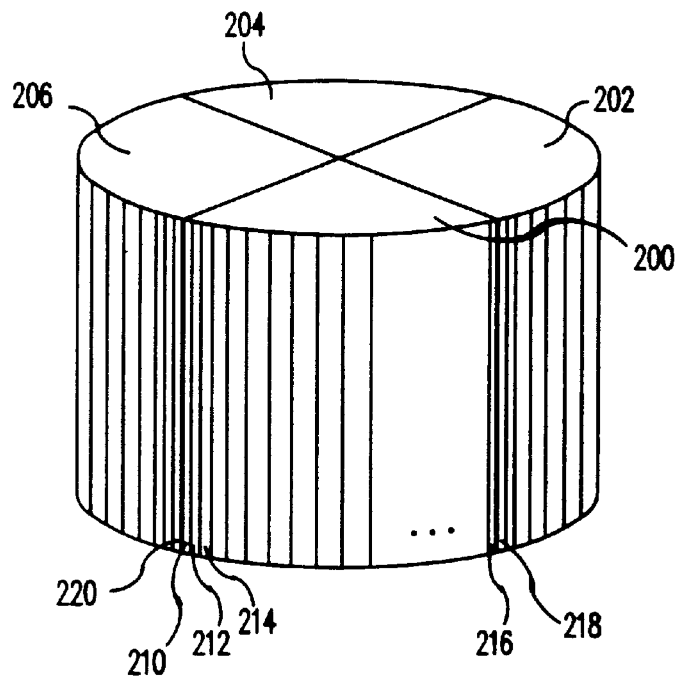

204
206
202
200
220
210
212
214
216
218

FIG. 9

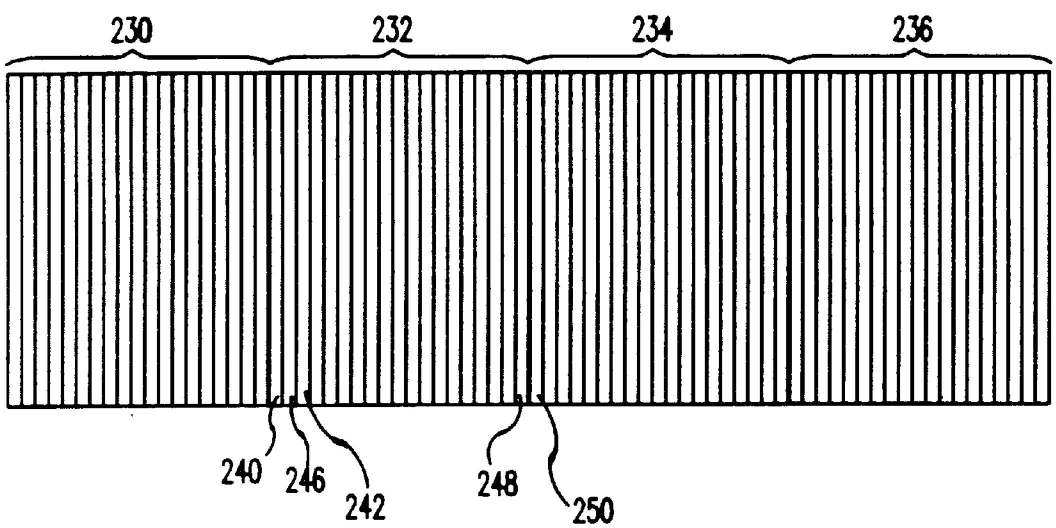
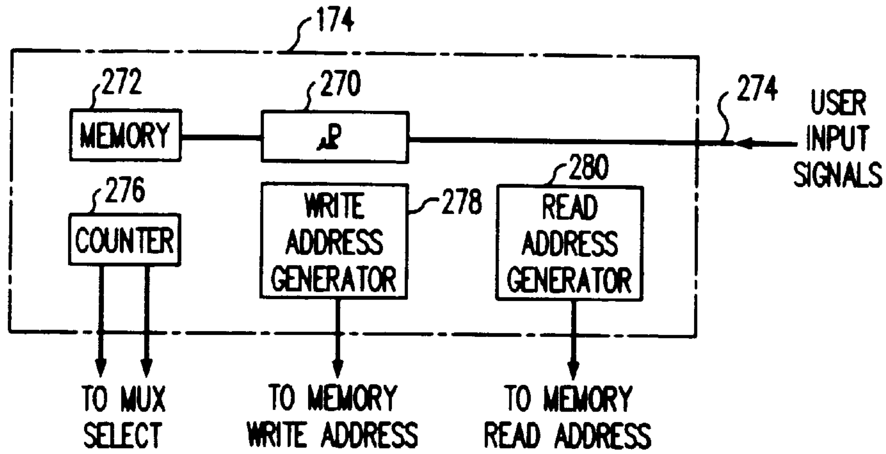
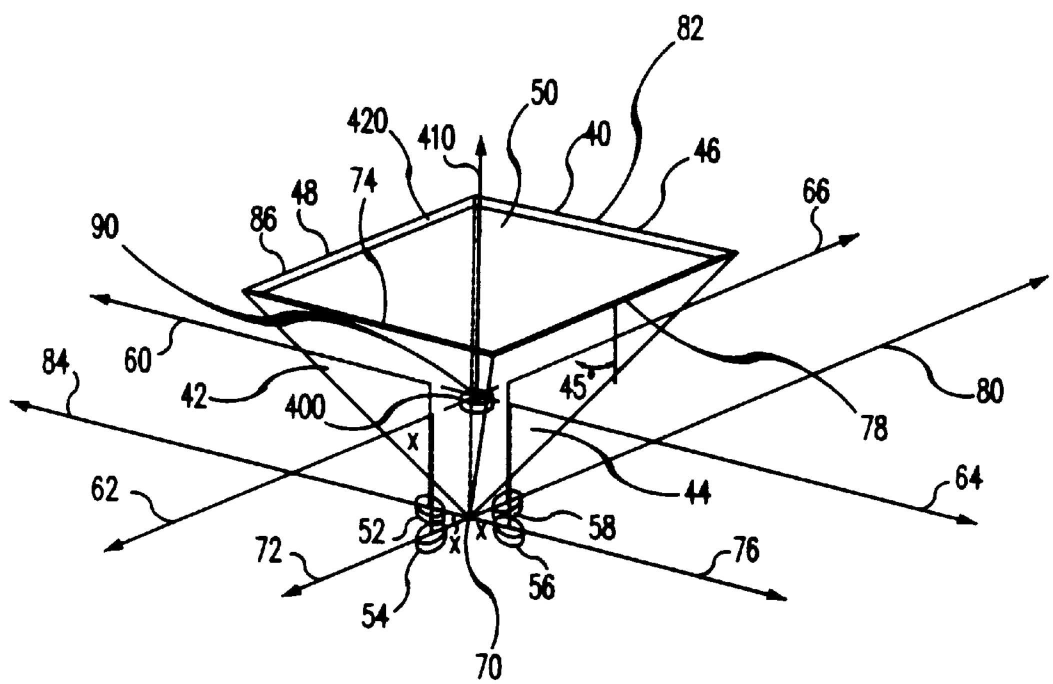

230
232
234
236
240
246
242
248
250

FIG. 10



174
272
MEMORY
270
μP
274
USER INPUT SIGNALS
276
COUNTER
WRITE ADDRESS GENERATOR
278
280
READ ADDRESS GENERATOR
TO MUX SELECT
TO MEMORY WRITE ADDRESS
TO MEMORY READ ADDRESS

FIG. 11



82
50
420
410
40
46
66
90
86
48
74
84
60
42
400
45°
78
80
62
X
44
64
52
58
72
X
X
76
56
54
70

FIG. 12

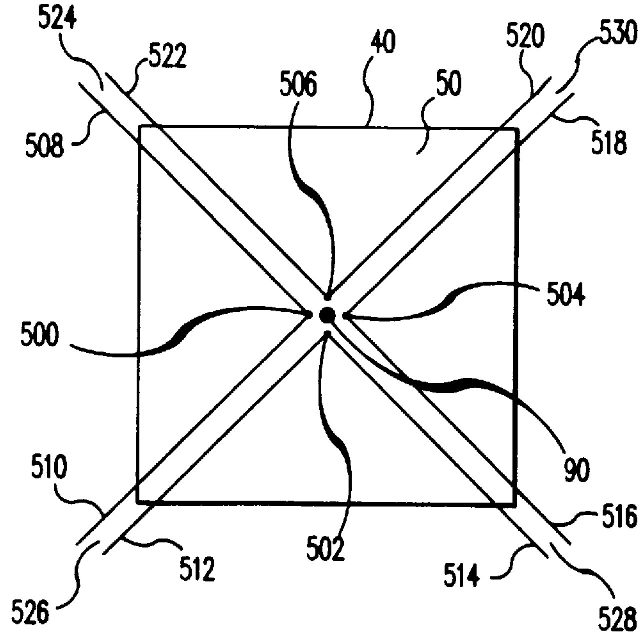

524
522
40
520
530
506
50
508
518
504
500
90
510
516
512
502
514
526
528

FIG. 13

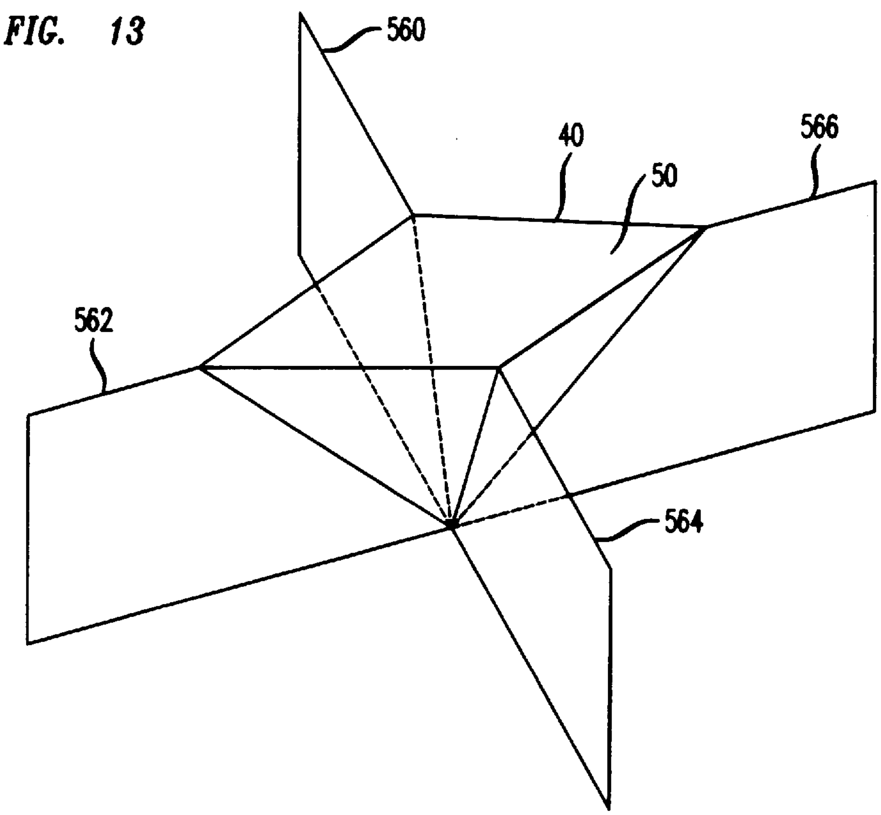

560
40
566
50
562
564

FIG. 14

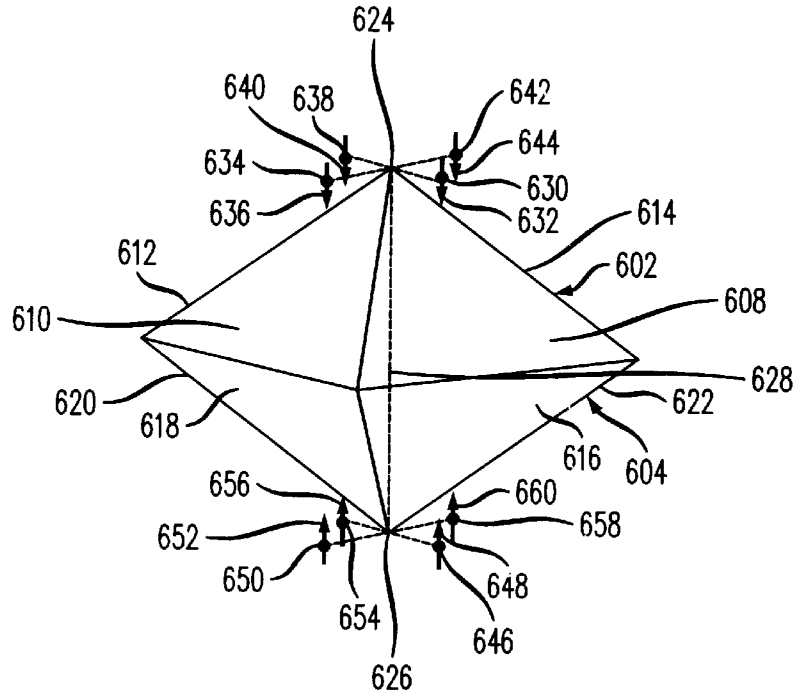

624
640
638
642
644
634
630
636
632
614
612
602
610
608
628
620
622
618
616
604
656
660
652
658
650
648
654
646
626

FIG. 15

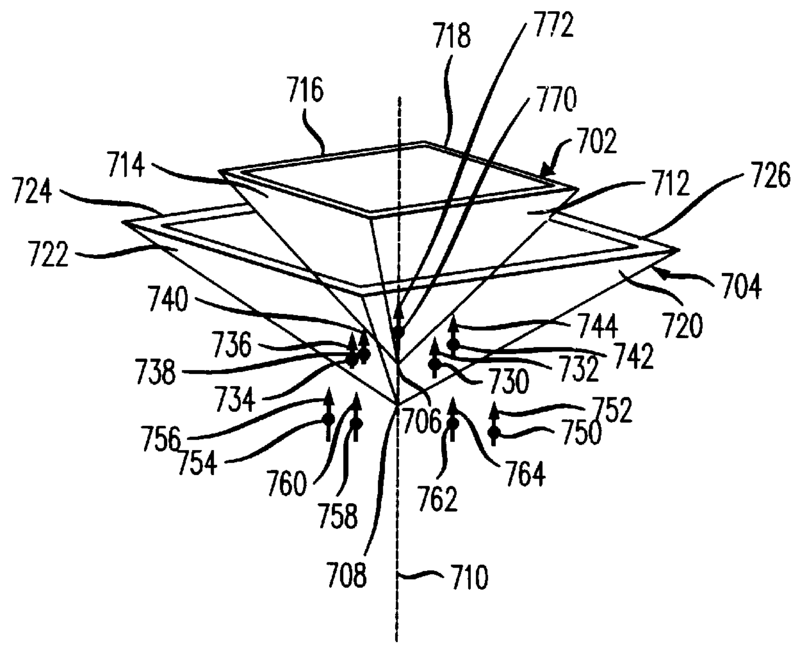
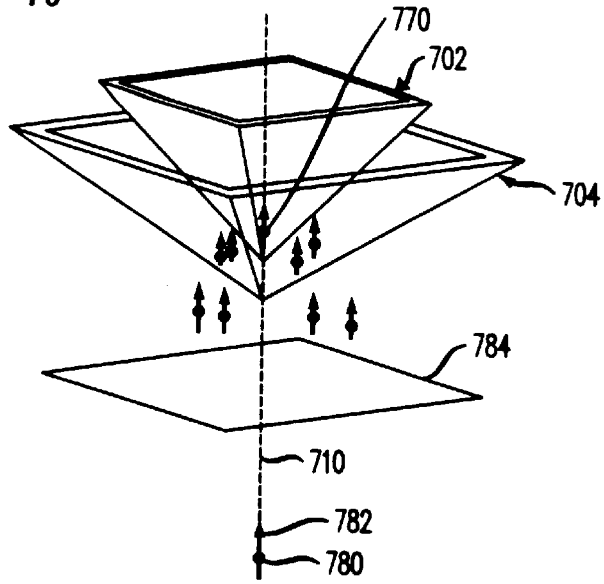
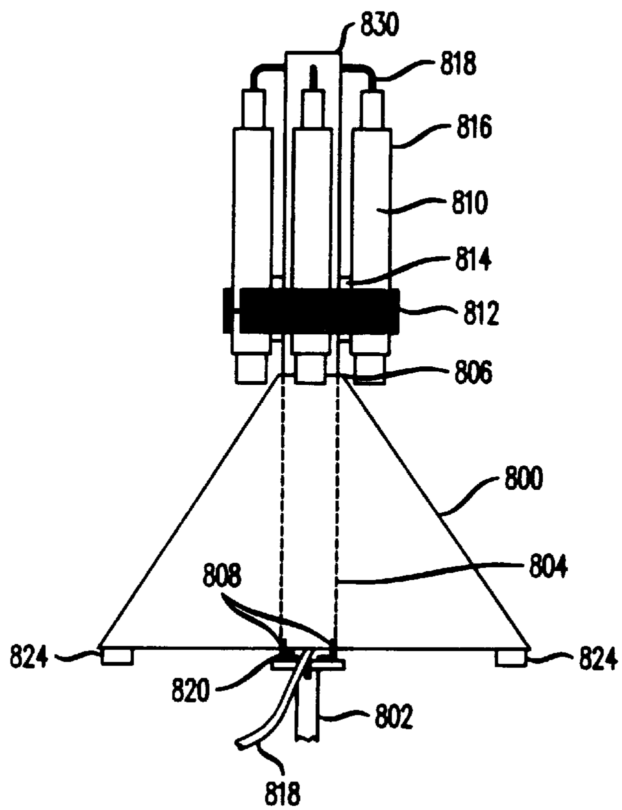

772
718
716
770
702
714
724
712
726
722
704
740
744
720
736
742
738
732
730
734
752
706
756
750
754
760
764
758
762
708
710

FIG. 16



770
702
704
784
710
782
780

FIG. 17



830
818
816
810
814
812
806
800
804
808
824
824
820
802
818

FIG. 18

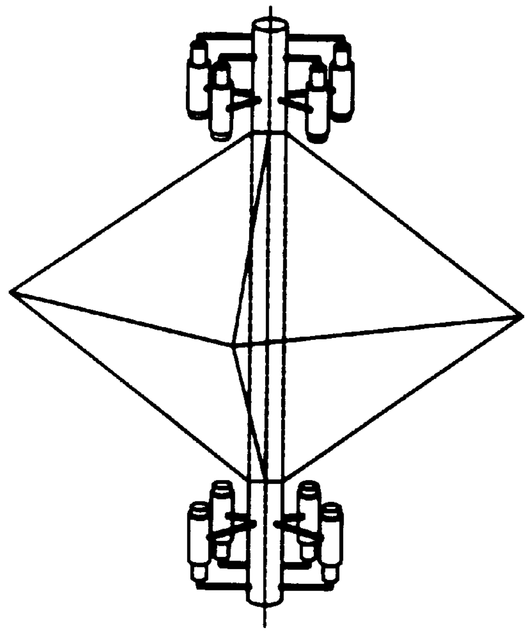


FIG. 19

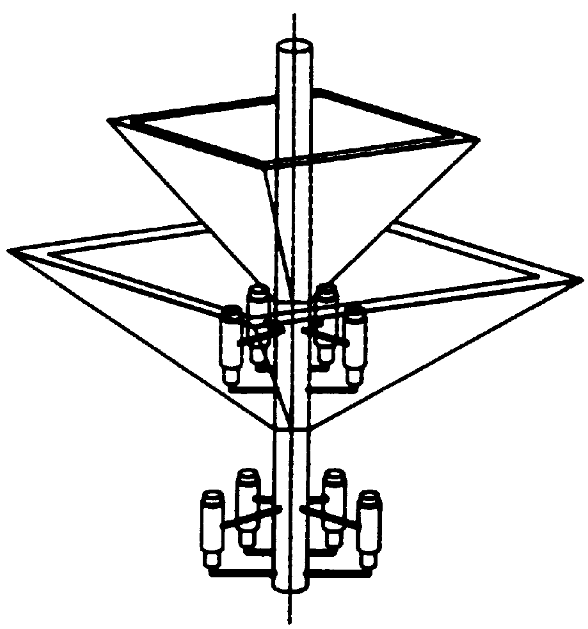


FIG. 20

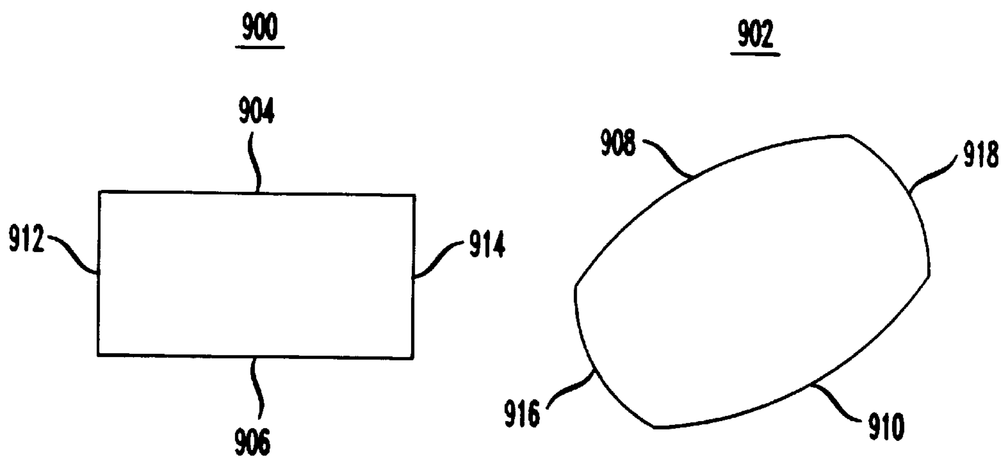


FIG. 21

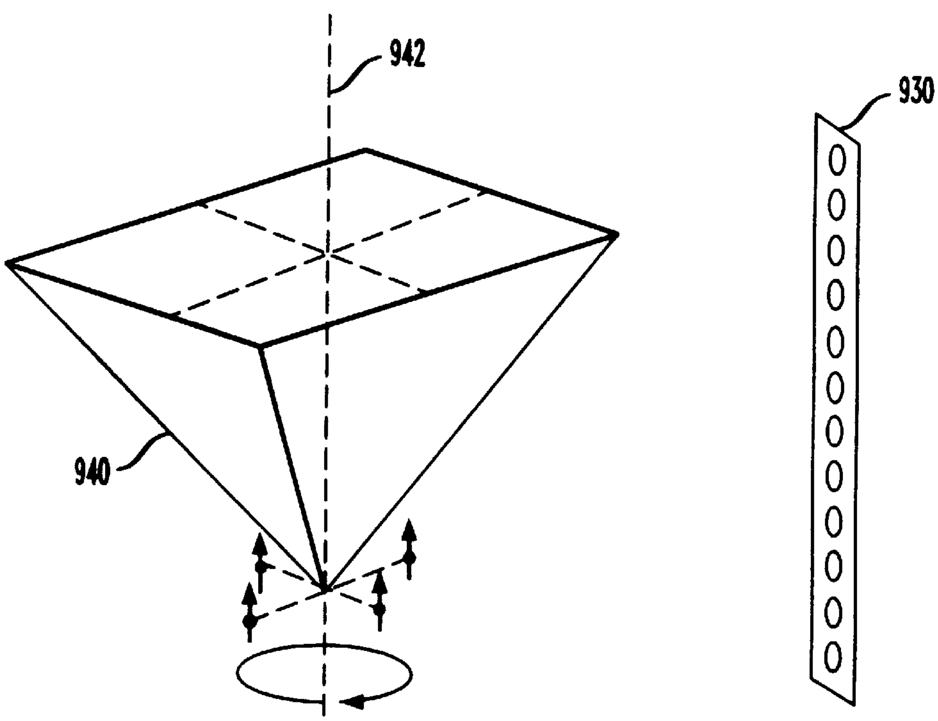


FIG. 22

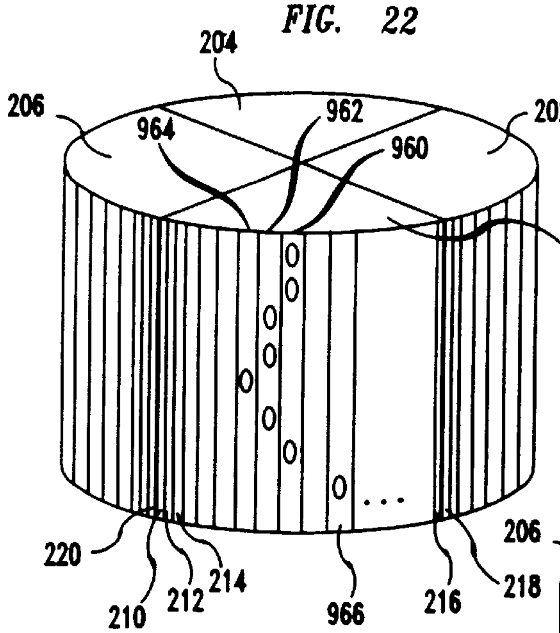


FIG. 24

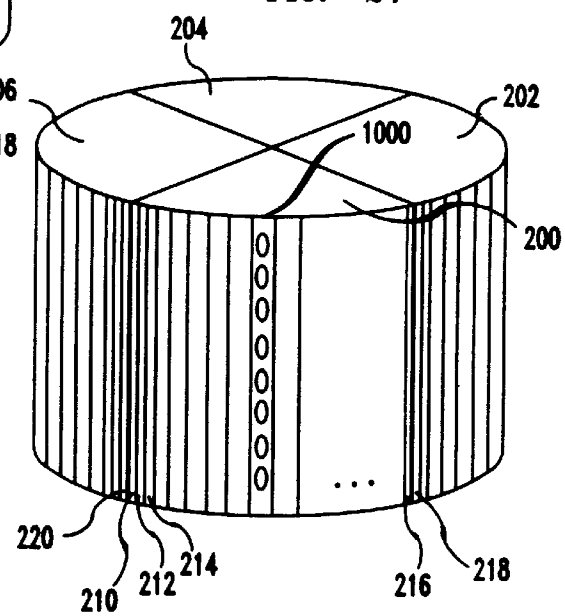


FIG. 23

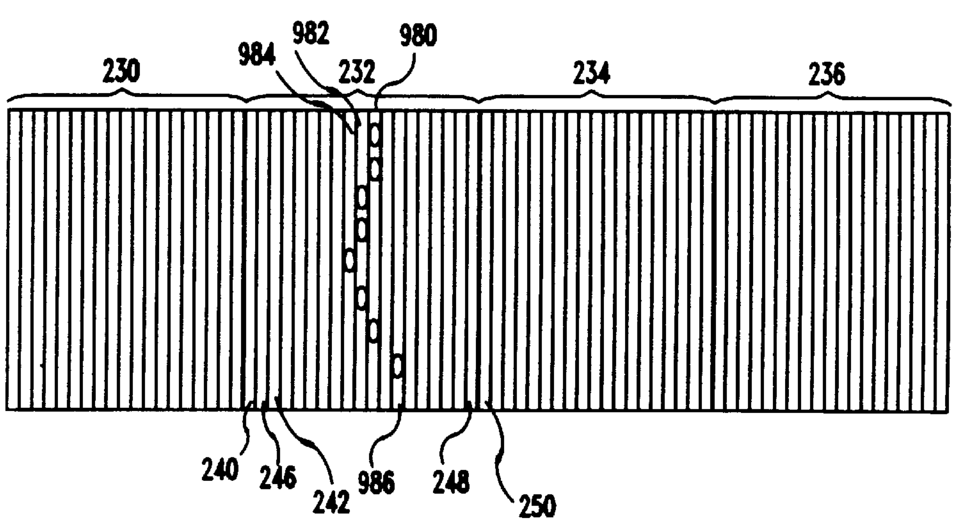
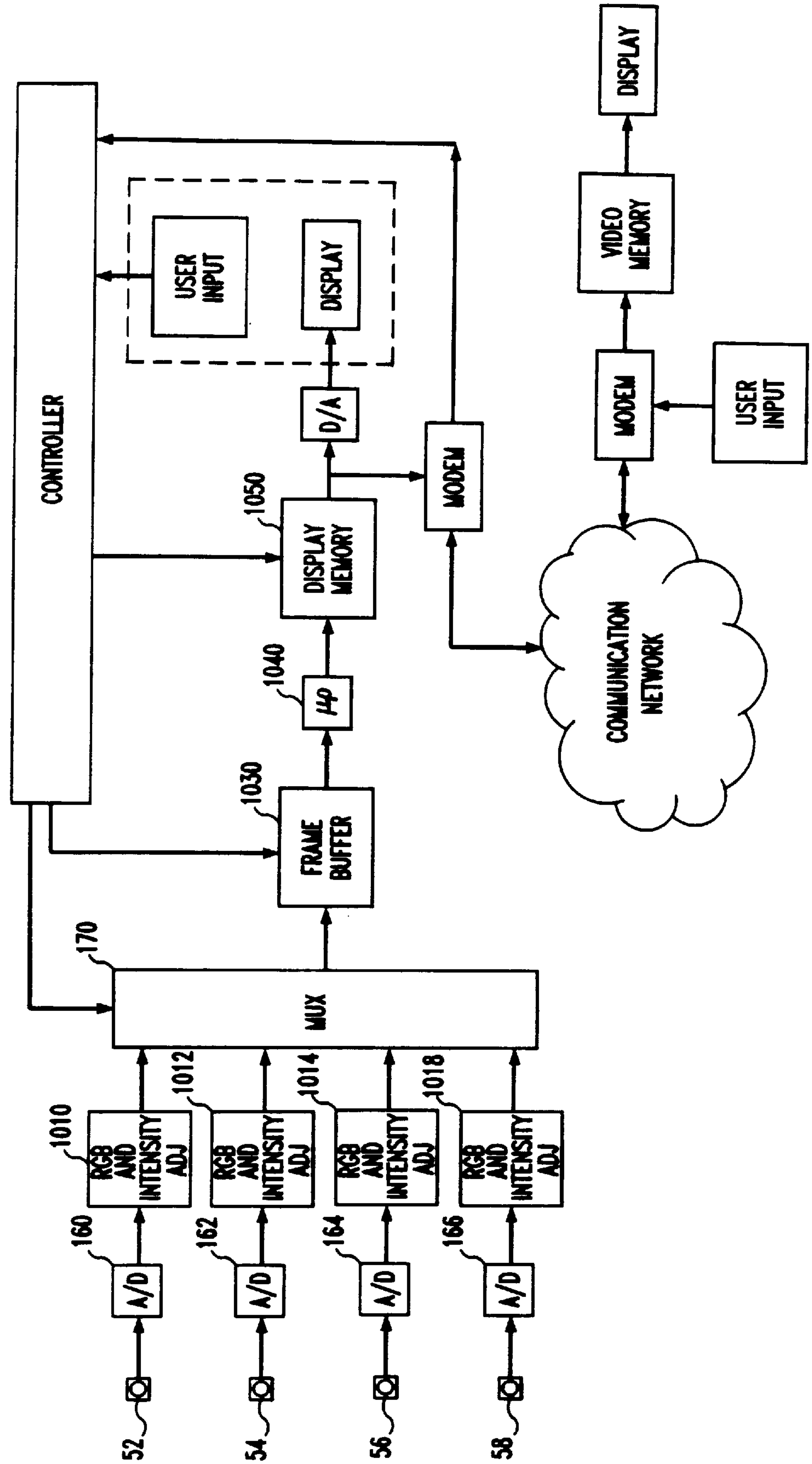


FIG. 25


CONTROLLER
USER INPUT
DISPLAY
D/A
MODEM
DISPLAY MEMORY
1050
1040
μp
1030
FRAME BUFFER
170
MUX
1010
1012
1014
1018
RGB AND INTENSITY ADJ
160
162
164
166
A/D
52
54
56
58
COMMUNICATION NETWORK
MODEM
USER INPUT
VIDEO MEMORY
DISPLAY

PANORAMIC VIEWING SYSTEM WITH SUPPORT STAND

CROSS REFERENCE TO RELATED INVENTIONS

This application is related to the following commonly assigned US Patent Applications: "Panoramic Viewing Apparatus", Ser. No. 08/431,356 which issued as U.S. Pat. No. 5,745,305; "Method And System For Panoramic Viewing", filed Apr. 28, 1995, Ser. No. 08/43135; "High Resolution Viewing System", Ser. No. 08/497673, which issued as U.S. Pat. No. 5,793,527; "Panoramic Projection Apparatus", Ser. No. 08/497341, which issued as U.S. Pat. No. 5,539,483; "Spherical Viewing/Projection Apparatus", filed Nov. 30, 1995, Ser. No. 08/565501; "Panoramic Viewing System With Offset Virtual Optical Center", filed Oct. 7, 1997, Ser. No. 08/946443; commonly assigned and concurrently filed US Patent Application entitled "Compact High Resolution Panoramic Viewing System"; and commonly assigned and concurrently filed US Patent Application entitled "Stereo Panoramic Viewing System", filed Aug. 28, 1998, Ser. No. 09/141,867.

BACKGROUND OF THE INVENTION

1. Field of the Invention

The present invention relates to a viewing system; more particularly, a panoramic viewing system.

2. Description of the Related Art

In an effort to operate more efficiently, it is desirable to perform some tasks using telepresence. Telepresence refers to providing visual or other types of sensory information from a device at a remote site to a user that makes the user feel as if he/she is present at the remote site. For example, many businesses now hold meetings using telepresence. Telepresence is also useful for distance learning and remote viewing of events such as concerts and sporting events. A more realistic telepresence is provided to a user by providing the user with the capability to switch between views, and thereby mimic, for example, looking around a meeting room.

In the past, when several views were made available to a user, several cameras with different optical centers were used. Such a situation is illustrated in FIG. **1**. FIG. **1** illustrates cameras **2**, **4**, **6**, and **8** with optical centers **10**, **12**, **14**, and **16**, respectively. When the user decided to change views, he or she simply switched between cameras. In more sophisticated systems, when a user decided to change views, he or she was able to obtain a view from optical centers **10**, **12**, **14**, or **16** as well as from additional optical centers **18**, **20**, **22**, **24**, or **26**. Views associated with optical centers such as **18**, **20**, **22**, **24**, and **26** were obtained by using views from the two cameras nearest to the selected optical center. For example, a view from optical center **18** was obtained by using the views from cameras **2** and **4** and interpolating between the two views so as to simulate a view from optical center **18**. Such procedures introduced irregularities into views. In addition, forming these interpolated views required a large amount of computational power and time, and thereby made this technique expensive and slow to respond to a user's commands. This computational overhead also limited the number of users that could simultaneously use the system.

SUMMARY OF THE INVENTION

One embodiment of the present invention provides an omnidirectional or panoramic viewer in which multiple cameras effectively have a common optical center at least one of these cameras having its field of view redirected by a planar mirror. The field of view of each of the cameras is arranged to form a continuous 360 degree view of an area when taken as a whole. The user can sweep through 360 degrees of viewing, where each view has the same or nearly the same optical center, by simply using the output of one camera, more than one or the combination of cameras without requiring the computational overhead of interpolation used in the prior art. Such an arrangement may be used to enhance use of virtual meeting rooms by allowing a viewer to see the meeting room in a more natural format. This format corresponds closely to a person sitting in the actual meeting who simply turns his or her head to change the view at a particular time.

In another embodiment of the invention, the cameras are positioned so that they each views a different reflective surface of a solid or hollow polyhedron such as a solid or hollow pyramid. This results in each camera having a virtual optical center positioned within the pyramid. The cameras are positioned so that their virtual optical centers are offset from each other. The offsets produce narrow blind regions that remove image distortions received from the edges of the pyramid's reflective surfaces. A pyramid is supported by a post that passes through the vertex of the pyramid. Small cameras are then mounted to the post to provide a panoramic viewer with a mounting structure and a structure for supporting individual cameras.

In still another embodiment of the invention, a stereo panoramic view is provided through the use of multiple virtual optical centers. A reflective polyhedral element, such as a pyramid, redirects the field of view of each camera in a first set of cameras to form a group of substantially co-located virtual optical centers at a first location within the pyramid. The pyramid also redirects the field of view of each camera in a second set of cameras to form a group of substantially co-located virtual optical centers at a second location within the pyramid. Panoramic images from the first and second virtual optical centers provide a stereo panoramic view when one panoramic image is provided to a user's left eye and the other panoramic image is provided to the user's right eye.

In yet another embodiment of the present invention, polyhedrons such as pyramids having reflective surfaces are stacked base to base or nested within each other to produce a compact panoramic viewer. Using multiple reflective polyhedrons in such a manner permits using many cameras with the same or nearly the same virtual optical center. Using many cameras divides a large viewing area into many smaller areas where an individual camera views each smaller area. Since each camera views a smaller area, increased resolution is provided to the user. The pyramids are supported by a post that passes through their vertices. Cameras are then mounted to the post to provide a panoramic viewer with a mounting structure and a structure for supporting individual cameras.

In yet another embodiment of the present invention, the viewing device may include any type of image processing device. If the image processing device is a camera or other type of image capture device, a panoramic image is captured for the user, and if the image processing device is a projector or other type of image producing device, a panoramic image is produced for the user.

BRIEF DESCRIPTION OF THE DRAWING

FIG. **1** illustrates a prior art multiple camera viewing system;

FIG. **2** illustrates a four camera omnidirectional or panoramic viewing system using a four-sided pyramid with reflective surfaces;

FIG. **3** illustrates how a reflective surface of the pyramid is used to provide each camera with a common optical center;

FIG. **4** illustrates the top view of the pyramid illustrating the camera positions;

FIG. **5** illustrates an eight-sided pyramid with reflective side surfaces;

FIG. **6** is a top view of the pyramid of FIG. **5**;

FIG. **7** is a block diagram of a system to control data produced by the cameras;

FIG. **8** illustrates the association between the data received from the cameras and the view presented to a user;

FIG. **9** illustrates an addressing scheme for the memory of FIG. **7**;

FIG. **10** is a block diagram of the controller of FIG. **7**;

FIG. **11** illustrates the viewing system of FIG. **2** with a fifth camera;

FIG. **12** illustrates a top view of the pyramid of FIG. **2** with displaced virtual optical centers;

FIG. **13** illustrates the pyramid of FIG. **12** with shades positioned in blind regions;

FIG. **14** illustrates a panoramic viewer using pyramids stacked base to base;

FIG. **15** illustrates a panoramic viewer using nested pyramids;

FIG. **16** illustrates a spherical viewer using nested pyramids;

FIG. **17** illustrates a stand used to support a panoramic;

FIG. **18** illustrates the viewer of FIG. **14** with a support stand;

FIG. **19** illustrates the view of FIG. **15** with a support stand;

FIG. **20** illustrate two types of distortion;

FIG. **21** illustrates a calibration process;

FIG. **22** illustrates the association between data received from the cameras and the view presented to the user with distortion;

FIG. **23** illustrates how distorted image data is stored;

FIG. **24** illustrates how mapped image data is stored; and

FIG. **25** is a block diagram of a panoramic camera system where image mapping is used.

DESCRIPTION OF THE PREFERRED EMBODIMENT

FIG. **2** illustrates a four camera system for providing a 360 degree view to a user, where the cameras each have a common or nearly common virtual optical center within the pyramid. Pyramid **40** has reflective sides **42**, **44**, **46**, and **48** and may be a hollow, solid or truncated structure. In a preferred embodiment, each of the reflective sides forms a 45 degree angle with a plane parallel to base **50** and passing through the vertex of pyramid **40**. Cameras **52**, **54**, **56**, and **58** are associated with pyramid reflective surfaces **48**, **42**, **44**, and **46**, respectively. The cameras may be image gathering devices such as an optical scanner. As a result, camera **52** views a reflection from surface **48** to enable it to view objects in the direction of arrow **60**. Camera **54** views a reflection from surface **42** to view objects in the direction of arrow **62**. Camera **56** views a reflection from surface **44** to view objects in the direction of arrow **64**, and camera **58** views a reflection from surface **46** to view objects in the direction of arrow **66**. Each camera has a 90 degree field of view; however, larger fields of view may be used and the overlapping portion of the images may be removed by deleting or combining the pixels associated with the overlapping views. The combination of the four cameras viewing reflections from their associated reflective surfaces on pyramid **40**, produce a 360 degree view of the area surrounding pyramid **40**. When the mirrors are at 45 degree with respect to the pyramid base, it is desirable to locate the optical center of each camera on a plane that is parallel to base **50** and intersects vertex **70** of pyramid **40**. Each camera's optical center should also be located on a line that passes through vertex **70** and is perpendicular to the base line of the camera's associated reflective surface. For example, the optical center of camera **54** is located on line **72**. Line **72** is perpendicular to base line **74** of reflective surface **42**. Line **72** is in a plane that passes through vertex **70** and is parallel to base **50**. Likewise, the optical center of camera **56** is positioned on line **76** which is perpendicular to baseline **78**, the optical center of camera **58** is positioned on line **80** which is perpendicular to base line **82**, and the optical center of camera **52** is positioned on base line **84** which is perpendicular to base line **86**.

Each camera optical center is positioned on one of the above described lines at a distance X from vertex **70** and each camera has its optical axes or direction of view pointing perpendicular to base **50**. (The distance X should be such that the reflective surface reflects as much of the camera's field of view as desired; however, the defects in the reflective surface become more visible when the camera is moved closer to the reflective surface.) This positioning of optical centers results in the cameras sharing a virtual optical center located at, or substantially at, position **90**. Virtual optical center **90** is located a distance X from the vertex **70** on a line that passes through vertex **70** and is perpendicular to base **50**.

Although a pyramid configuration has been discussed in this example, different planar mirror geometries may be used to redirect fields of view so that the cameras have virtual optical centers that are substantially co-located. For example, solid, hollow or partial polyhedrons may be used. Additionally, in the case of a pyramid configuration the base and vertex do not have to be physically present and can be thought of as conceptual aids such as a base plane or end and vertex point or end.

FIG. **3** illustrates another view of pyramid **40** where only camera **54** is shown for the sake of simplicity. Camera **54** is positioned on line **72** so as to have a virtual optical center at, or nearly at, position **90** within pyramid **40**. If camera **54** has a 90 degree field of view in the direction perpendicular to base **50**, and if the optical center of camera **54** is at a distance of X from vertex **70** along line **72**, camera **54** has a 90 degree view in the direction of arrow **62**. In similar fashion, cameras **56**, **58**, and **52** have 90 degree views in the direction of arrows **64**, **66**, and **60**, respectively. This arrangement inexpensively produces a **360** degree field of view of an area because cameras with a 90 degree field of view have relatively inexpensive optics.

FIG. **4** is a top view of pyramid **40**. FIG. **4** illustrates the placement of the optical center of camera **54** along line **72**. Line **72** should be in a plane passing through vertex **70** and is parallel to base **50**. The line should also be perpendicular to base line **74** of pyramid **40**. The camera's optical center should be positioned a distance X, or a distance substantially equal to X, from vertex **70** along line **72**. Point **100** is located on base **50** at a position where a line from vertex **70** perpendicularly intersects base **50**. In a similar fashion, the optical centers of cameras **56**, **58** and **52** are positioned the distance X, or a distance substantially equal to X, along lines **76**, **80** and **84**, respectively.

FIG. **5** illustrates an eight-sided pyramid **120**. Pyramid **120** has reflective surfaces **122** where each of surfaces **122** forms a 45 degree angle with a plane that passes through vertex **130** and is parallel to base **124**. As with the four-sided pyramid of FIG. **2**, each reflective surface of FIG. **5** may have a camera associated with it. Each camera's optical center is positioned on a line that is in a plane that passes through vertex **130** and is parallel to base **124**. The line is perpendicular to base line **132** of the reflective surface associated with the camera to be positioned. Using an eight-sided pyramid offers the advantage of using cameras with only a 45 degree horizontal field of view to obtain a 360 degree view. Cameras with only a 45 degree field of view have inexpensive optics and enable a 360 degree view to be constructed using relatively inexpensive components.

FIG. **6** is a top view of pyramid **120**. As discussed with regard to FIG. **5**, each camera's optical center is positioned along a line **134** which is in a plane that passes through vertex **130** and is parallel to base **124**. The optical centers are positioned a distance X, or a distance substantially equal to X, along line **134** which is perpendicular to the appropriate base line **132**. Point **140** is on base **124** at the point of intersection between base **124** and a line that passes through vertex **130** and is perpendicular to base **124**.

Polyhedrons or pyramids having more or less reflective sides may be used. The advantage of using pyramids having a large number of sides is that cameras with moderate to small fields of view may be used. Cameras with moderate fields of view have relatively inexpensive optics. The number of sides used in a pyramid is somewhat limited by the cost of providing a large number of cameras. A 360 degree view of a scene may be provided using a pyramid having three reflective sides. It may be expensive to use only a three-sided pyramid in order to provide a 360 degree field of view. This embodiment of the invention uses three cameras each with a 120 degree field of view, and cameras with such a wide field of view use relatively expensive optical components.

In applications where a full 360 degree view is not desired, it is possible to build a viewer that does not have a camera associated with each reflective surface of the pyramid. In addition to eliminating an unnecessary camera, it is also possible to eliminate an unnecessary pyramid polyhedron surface by using reflective elements that are partial pyramids or partial polyhedrons.

Although a pyramid configuration has been discussed in this example, different planar mirror geometries may be used to redirect fields of view so that the cameras have virtual optical centers that are substantially co-located. For example, solid, hollow or partial polyhedrons may be used. Additionally, in the case of a pyramid configuration the base and vertex do not have to be physically present and can be thought of as conceptual aids such as a base plane or end and vertex point or end.

FIG. **7** illustrates a block diagram of a system for controlling data produced by the cameras of a viewing device such as the viewing device described in FIGS. **2** through **4**. Cameras **52**, **54**, **56** and **58** obtain a 360 degree view of an area via their associated reflective surfaces of pyramid **40**. The image signal or output signal of cameras **52**, **54**, **56** and **58** are passed through analog to digital converters (A/D)

160, **162**, **164**, and **166**, respectively. The output of the cameras can be thought of as a stream of pixels and the output of the A/Ds can be thought of as data representative of the pixels from the cameras. The output of the A/Ds are passed through mux **170**. Mux **170** allows the pixel data from each of the A/Ds to reach memory **172**. Controller **174** cycles the select lines of mux **170** so that the outputs of all of the A/Ds are stored in memory **172**. Mux **170** is switched at a rate that is four times the pixel rate of the cameras. If more or less cameras are used, the rate at which mux **170** is switched will be increased or slowed accordingly. It is also possible to eliminate mux **170** and to store the output of each A/D in a separate memory. Controller **174** is implemented using a microprocessor which provides control signals to counters that control the switching of mux **170** and counters used to provide addressing to memory **172**. The control signals to the counters include reset, enable and a starting offset.

As a result of the pixel information being passed to memory **172**, memory **172** contains a 360 degree view of a scene. Pixel information stored in memory **172** is passed through digital to analog converter (D/A) **176** and to video display **178**. The actual portion of memory **172** that is passed to video display **178** via D/A **176** is controlled via user input device **180**. User input device **180** may be a common device such as a mouse, joystick, or keyboard. The user may simply lean ajoystick to the right to shift his view to the right, lean the joystick to the left to shift the view to the left, or leave the joystick in the center to keep the view unchanged. Based on the input from user device **180**, controller **174** varies offsets and starting addresses that are used to provide addressing to memory **172**.

FIG. **8** illustrates the relationship between the data provided by the cameras and the view available to the user. Since the cameras share a virtual optical center, the view can be thought of as a cylindrical view. Sector **200** can be thought of as representing the information provided by camera **52**, sector **202** can be thought of as representing the information provided by camera **54**, sector **204** can be thought of as representing the information provided by camera **56**, and sector **206** can be thought of as representing the information provided by camera **58**. The surface of the cylinder in each sector can be thought of as a collection of columns, where each column is composed of pixels. For example, sector **200** can be thought of as a collection of columns including columns **210**, **212**, **214**, and **216**. Likewise, the output produced by camera **54** can be thought of as a collection of columns which include column **218** in sector **202** and the output of camera **58** can include columns such as column **220** in sector **206**.

FIG. **9** illustrates how memory **172** is divided to provide easy access to different views based on signals from user input device **180**. Sections **230**, **232**, **234**, and **236** correspond to sectors **206**, **200**, **202**, and **204**, respectively. Each of sections **230**, **232**, **234**, and **236** can be thought of as a block within memory **172**. The blocks in memory **172** are broken into columns of sequential addresses. The first column of memory segment **230** corresponds to the first column of pixels of sector **206**. The number of memory positions associated with a column should be at least sufficient to have one location for each pixel in a particular column. For example, if a column of pixels from FIG. **8** includes 1000 pixels, each column associated with the memory segments of FIG. **9** should have at least 1000 locations. The number of columns associated with a particular memory segment should be at least equal to the number of columns associated with a particular section of the cylinder of FIG. **8**.

If a camera scans in a horizontal direction, sequential pixels are written in adjacent columns, but possibly different rows, of a particular memory segment by simply changing an offset to a counter generated address. The overall write address is generated by adding the offset to the counter's output. This offset is changed at the rate in which the horizontally scanned pixels are received. After a horizontal scan is completed, the counter is incremented and once again the offsets are changed at the horizontal scan rate. As a result, when addressing a particular segment of memory during a write cycle, the columns are addressed by changing the offset at the horizontal pixel scan rate, and incrementing the counter at the vertical scan rate. This type of addressing scheme is used for accessing columns within each memory segment. When addressing different memory segments during a write cycle, a write segment offset is added to the sum of the counter output and the column offset. The write segment offset permits addressing memory segments **230**, **232**, **234**, and **236**. The segment offset is changed at the same rate as mux **170** is switched.

Pixel data is read from memory **172** in a similar fashion. The sum of a counter output and two sets of offsets are used to generate a read address. Once an initial starting column has been picked, the read address is generated by switching a read column offset at a rate that is equal to the horizontal scan rate of a video display. After reading one horizontal scans worth of data, the read counter is incremented and the read column offsets are changed at a rate equal to the horizontal scan rate of the display. As a result, the offset addresses are changing at the display's horizontal display rate and the counter is incremented at a rate equal to the vertical scan rate of a display. It is possible to read data out at a rate faster or slower than required by the video display; however, if read out faster, a buffer memory should be used, if read out slower the video display may appear choppy to the viewer.

It should be noted that the cylindrical arrangement of pixels of FIG. **8** is typically displayed on a flat or nearly flat display. As a result, the image may be displayed by compensating for converting between a cylindrical surface and a flat surface. This may be carried out using a simple conversion algorithm within a common digital signal processing integrated circuit. Methods for these types of conversions are well known in the art and can be found in "A Guided Tour of Computer Vision, Vishvjit S. Nalwa, Addison-Wesley Publishing Co., Reading, Mass., 1993." It is also possible to carry out the conversion using a very high resolution display.

It should be noted that if the view selected by a user corresponds exactly to the view of a particular camera, such as camera **52**, columns **240–248** are read from memory **170**. Column **240** is the first column in segment **232** and column **248** is the last column in segment **232**. If the user decides to move the view in a counter-clockwise direction, the start column will shift to the right so that the read operation begins at column **246** and ends at column **250**. It should be noted that column **246** is the second column associated with memory segment **232** which has the pixel data from camera **52**, and that column **250** is the first column of pixel data associated with camera **56**. As the user shifts the view, the starting column shifts in relationship to the user's commands. For example, if the user indicates that the view should shift in a counter-clockwise direction, the start column of FIG. **9** moves to the right, similarly, if the viewer indicates that the view should shift in a clockwise direction, the start column shifts to the left. As before, columns are addressed by using offsets, if the offsets involve moving between memory segments, a read segment offset is added to the sum of the column offset and counter output.

FIG. **10** illustrates a block diagram of controller **174**. Controller **174** includes microprocessor **270** and memory **272**. Memory **272** includes RAM and ROM. Processor **270** receives commands on line **274** from user input device **180**. Microprocessor **270** controls start, stop and reset of counter **276**. Counter **276** controls the select lines of mux **170**. Counter **276** counts at a rate that is four times the horizontal scan rate of the cameras. Write address generator **278** provides write addressing for memory **172**. Write address generator **278** includes a counter, register for storing offsets and adder for adding the offsets and counter output. Microprocessor **270** controls the offset selection and the counters used by write address generator **278**. The write addresses are formed as described with regard to FIG. **9**. Read address generator **280** provides read addresses to memory **172**. Read address generator **280** includes a counter, register for storing offsets and adder for adding the offsets and counter output. As with write address generator **278**, microprocessor **270** controls the offset selection and the counters of read address generator **280**. Microprocessor **270** also controls the starting column used by the counters based on inputs provided on line **274** from user input **180**.

The write and read addresses are provided to memory **172** separately if memory **172** is implemented using a two port memory. If memory **172** is implemented with a single port memory, the write and read addresses are multiplexed to memory **172**.

FIG. **11** illustrates the viewing system of FIG. **2** with a fifth camera. Camera or image gathering device **400** is located in pyramid **40** with the optical center of camera **400** located at, or nearly at, virtual optical center **90**. Camera **400** views objects in the direction of arrow **410**. The resulting view coupled with the views of the remaining four cameras, provides a nearly spherical view. If the cameras of FIG. **11** are replaced with image producing devices, the nearly spherical viewing system becomes a nearly spherical projection system. It should be noted, that a camera or projection device, may be placed at the virtual optical center of viewing/projection devices having pyramids with three, four or more sides. It should also be noted that base edges **420** of the reflective surfaces should be beveled to avoid undesirable obstruction of camera **400**'s field of view. It is also possible to avoid undesirable image artifacts from base edges **420** by moving camera or image processing device **400**. Device **400** should be moved so that device **400**'s optical center is positioned away from virtual optical center **90** in the direction of arrow **410**. Device **400**'s optical center should be positioned so that the device's field of view does not include edges **420**.

FIG. **12** illustrates a top view of the pyramid of FIG. **2**. In reference to FIG. **2**, camera **52**, **54**, **56**, and **58** have been moved upward in the direction of base **50**. As a result, virtual optical centers **500**, **502**, **504** and **506**, which correspond to cameras **52**, **54**, **56** and **58**, respectively, are moved away from virtual optical center **90**. It is desirable to move the virtual optical centers so that camera **52** captures an image between lines **508** and **510** that are unaffected by an edge of the pyramid, camera **54** captures an image between lines **512** and **514** that are unaffected by an edge of the pyramid, camera **56** captures an image between lines **516** and **518** that are unaffected by an edge of the pyramid, and camera **58** captures an image between lines **520** and **522** that are unaffected by an edge of the pyramid. This results in the cameras not capturing images distorted by edges of the pyramid from narrow planar shaped regions. In particular, planar regions **524**, **526**, **528**, and **530** are not used and form blind regions. This offers the advantage of removing image regions that are distorted by the edges of the reflective pyramid. Eliminating these portions of the fields of view alleviates the need to provide image processing that compensates for image artifacts at the edges. It is desirable to keep virtual optical centers **500**, **502**, **504**, and **506** closely clustered so that planes **524**, **526**, **528**, and **530** are only as thin as necessary to avoid edge artifacts. By maintaining such thin planes, the need to process the images at their common boundaries is removed while minimizing the noticeable effect seen by a user.

FIG. **13** illustrates the pyramid of FIG. **12** with shades **560**, **562**, **564**, and **566** positioned in planar regions **524**, **526**, **528**, and **530**, respectively. The shades reduce the amount of unwanted light that enters the cameras. Similar shades may be placed in blind regions between device **400** and one or more of the other image processing devices. It is also possible to place a shade on base **50** with the edges of the shade extending beyond the edges of the base to reduce the amount of unwanted light that enters cameras **52**, **54**, **56**, and **58** from sources behind base **50**.

FIG. **14** illustrates reflective pyramids **602** and **604** arranged in a base-to-base configuration. The bases may be in contact with each other or spaced apart. Reflected pyramids **602** and **604** each have four reflective side facets. Pyramid **602** has reflective side facets **608**, **610**, **612**, and **614**. Reflective pyramid **604** has reflective sides **616**, **618**, **620**, and **622**. Pyramid **602** includes vertex **624** and pyramid **604** includes vertex **626**. Vertices **624** and **626** are on a line **628** that is perpendicular to the base of each pyramid. Each pyramid has four image processing devices such as cameras with a field of view being redirected by a reflective surface. With regard to pyramid **602**, a camera with an optical center positioned at point **630** has a field of view in the direction of arrow **632** where that field of view is redirected by reflective surface **608**. A second camera with an optical center at point **634** has a field of view in the direction of arrow **636** which is redirected by reflective surface **610**. A third camera with an optical center at point **638** has a field of view in the direction of arrow **640** which is redirected by reflective surface **612**. A fourth camera with an optical center at point **642** has a field of view in the direction of arrow **644** which is redirected by reflective surface **614**. Regarding reflective pyramid **604**, a first camera with an optical center at point **646** has a field of view in the direction of arrow **648** which is redirected by reflective surface **616**. A second camera with an optical center at point **650** has a field of view in the direction of arrow **652** which is redirected by surface **618**. A third camera with an optical center at point **654** has a field of view in the direction of arrow **656** which is redirected by reflective surface **620**. A fourth camera with an optical center at point **658** has a field of view in the direction of arrow **660** which is redirected by reflective surface **622**. The cameras associated with each of the pyramids are positioned in a way similar to how the cameras were positioned with regard to FIGS. **2**, **3**, **4**, **11**, and **12** so that each set of four cameras shares a common virtual optical center or have closely clustered virtual optical centers within their associated pyramid. Each set of cameras may also have offset virtual optical centers within their associated pyramid. The cameras may be positioned so that the cameras associated with each pyramid share a common virtual optical center along line **628** where the bases of the two pyramids meet. It is also possible to position the cameras so that their offset virtual optical center are clustered about a point on line **628** where the bases of the two pyramids meet.

The structure of FIG. **14** increases the vertical field of view as compared to the viewers discussed with regard to FIGS. **2**, **3** and **4**. The viewer of FIG. **14** increases the vertical field of view by using two cameras rather than one camera for the same or nearly the same horizontal field of view. It should be noted that a projector may be constructed by replacing the cameras with image producing devices. It should also be noted that reflective pyramids **602** and **604** may be rotationally misaligned with respect to each other. This misaligned relationship is obtained by rotating one or both of the pyramids about an axis that passes through the vertices of both pyramids. For example, the axis may be co-linear with line **628**. As a result of this rotation, the side edges of the reflective side facets of pyramid **602** will not align with the side edges of the reflective side facets of pyramid **604**.

Although a pyramid configuration has been discussed in this example, different planar mirror geometries may be used to redirect fields of view so that the cameras have virtual optical centers that are substantially co-located. For example, solid, hollow or partial polyhedrons may be used. Additionally, in the case of a pyramid configuration the base and vertex do not have to be physically present and can be thought of as conceptual aids such as a base plane or end and vertex point or end.

FIG. **15** illustrates two reflective pyramids. Reflective pyramid **702** is nested within reflective pyramid **704**. It should be noted that more than two reflective pyramids may be nested. For example, another reflective pyramid may be nested within reflective pyramid **702** and yet another reflective pyramid may be nested within the pyramid that is nested within pyramid **702**. Vertex **706** of pyramid **702** and vertex **708** of pyramid **704** are on a line **710** which is perpendicular to the bases of both pyramids. Once again, each pyramid includes four image processing devices such as cameras each with a field of view that is redirected by a reflective surface of their associated pyramid. Pyramid **702** includes reflective side facets **712**, **714**, **716**, and **718**. Reflective pyramid **704** includes reflective side facets **720**, **722**, **724**, and **726**. Four cameras are positioned so that their field of view is redirected by the reflective surfaces of pyramid **702**. A first camera with an optical center at point **730** and a field of view in direction of arrow **732** has its field of view redirected by reflective surface **712**. A second camera with an optical center at point **734** and a field of view in the direction of arrow **736** has its field of view redirected by reflective surface **714**. A third camera with an optical center at point **738** and a field of view in the direction of arrow **740** has its field of view redirected by reflective surface **716**. A fourth camera with an optical center at point **742** and a field of view in the direction of arrow **744** has its field of view redirected by reflective surface **718**. It should be noted that pyramid **702** and its associated cameras are positioned so that the field of view of the cameras is not obstructed by pyramid **704**. This is accomplished by allowing pyramid **702** to extend beyond the base of pyramid **704**. Regarding pyramid **704**, a first camera with an optical center at point **750** and a field of view in the direction of arrow **752** has its field of view redirected by reflective surface **720**. A second camera with an optical center at point **754** and a field of view in the direction of arrow **756** has its field of view redirected by reflective surface **722**. A third camera with an optical center at point **758** and a field of view in the direction of arrow **760** has its field of view redirected by reflective surface **724**. A fourth camera with an optical center at point **762** and a field of view in the direction of arrow **764** has its field of view redirected by reflective surface **726**. The cameras associated with each of the pyramids are positioned in accordance with the positioning illustrated with FIGS. **2**, **3**, **4**, **11**, and **12** so that the eight cameras share a virtual optical center at position **770** or have closely clustered virtual optical centers within pyramid **702**. Each set of cameras may also have offset virtual optical centers within pyramid **702**.

The panoramic viewer of FIG. **15** can be provided with a ninth camera having an optical center at point **770** and a field of view in the direction of arrow **772** to provide a viewer with a partially-spherical view. The camera having an optical center at position **770** may use a wide-angle lens to provide a broader view.

FIG. **16** illustrates the partially-spherical viewer of FIG. **15** with an additional camera having an optical center at point **780** and a field of view in the direction of arrow **782** where that field of view is redirected by planar mirror **784**. It should be noted that optical center **780** is on line **710** which passes through the vertices of pyramid **702** and **704** as well as virtual optical center **770**. It should also be noted that point **780** is placed a distance away from planar mirror **784** that is equal or nearly equal to the distance between planar mirror **784** and virtual optical center **770**. By placing a camera with an optical center at point **780** and having the field of view redirected by planar mirror **784**, the partially-spherical viewer of FIG. **15** becomes a spherical viewer. In order to increase the field of view of the camera positioned with an optical center at point **780**, the camera may be provided with a wide-angle lens. It should also be noted that planar mirror **784** may be replaced with a curved mirror to provide a wider field of view for the camera positioned at point **780** and minimize the need for a wide-angle lens.

Although a pyramid configuration has been discussed in this example, different planar mirror geometries may be used to redirect fields of view so that the cameras have virtual optical centers that are substantially co-located. For example, solid, hollow or partial polyhedrons may be used. Additionally, in the case of a pyramid configuration the base and vertex do not have to be physically present and can be thought of as conceptual aids such as a base plane or end and vertex point or end.

Regarding FIGS. **15** and **16**, it should be noted that a projector may be constructed by replacing the cameras with image producing devices. It should also be noted that reflective pyramids **702** and **704** may be rotationally misaligned with respect to each other. This misaligned relationship is obtained by rotating one or both of the pyramids about an axis that passes through the vertices of both pyramids. For example, the axis may be co-linear with line **710**. As a result of this rotation, the side edges of the reflective side facets of pyramid **702** will not align with the side edges of the reflective side facets of pyramid **704**.

FIG. **17** illustrates a stand used to support a panoramic viewer. Reflective pyramid **800** is mounted to stand or post **802** using a support member such as hollow tube **804**. The pyramid is secured to hollow tube **804** at vertex end **806**. The hollow tube is secured to stand **802** by angle brackets **808**. Hollow tube **804** extends beyond vertex end **806** so that cameras **810** may be supported by tube **804**. The cameras are mounted to tube **804** by strap or belt **812** which presses cameras **810** against spacer **814**. The pressure provided by clamp or strap **812** provides friction between camera **810**, spacer **814**, and the outer surface of tube **804** and thereby mounts cameras **810** to tube **804** in a secure fashion. It is also possible to provide a second strap and associated spacers at end-section **816** of cameras **810**. Video and power connections to cameras **810** are provided by cables **818** which are fed through hollow tube **804** and out through space **820** which is between post **802** and the base of pyramid **800**. It should be noted that hollow tube **804** may be replaced with a solid support member; however, a hollow support member provides a convenient path for routing cables. Feeding the cables through tube **804** prevents the cables from entering the field of view of cameras **810**. Rubber stands or feet **824** are provided at the base end of pyramid **800**. These stands may be used in place of post **802** to provide flexibility in application where the user does not want to use post **802**.

It is also possible to invert the viewer of FIG. **17** so that the viewer is supported by end **830** of tube **804**. In this configuration cables **818** will simply be passed out through an opening at end **830** of tube **804**. In this configuration tube **804** is mounted to post **802** at end **830** using angle brackets similar to angle brackets **808**. It is also possible to mount end **830** to any convenient structure to support the panoramic viewer.

The stand of FIG. **17** is applicable to the viewer of FIGS. **14**, **15**, and **16**. As discussed with regard to FIG. **17**, the viewer is mounted to a hollow tube passing through the vertices or vertex ends of both pyramids. FIG. **18** illustrates the viewer of FIG. **14** mounted to the stand of FIG. **17** and FIG. **19** illustrates the viewer of FIG. **15** mounted to the stand of FIG. **17**.

Calibration

A higher quality image may be produced by calibrating the camera system. Calibration may be used to determine image mapping functions (which may be implemented as look up tables) that compensate for different types of image distortion. For example, the mapping functions may be used to correct barrel distortion which is a distortion introduced by a wide-angle lens. Mapping functions may also be used to correct other types of distortions such as a rotational distortion resulting from misaligned charged coupled devices within the cameras. FIG. **20** illustrates a combination of barrel distortion and rotational distortion, where the distortion results in rectangular object **900** appearing as distorted image **902**. Distorted image **902** is rotated with respect to undistorted object **900** and a barrel distortion is seen where edges **904** and **906** of rectangular object **900** appear as edges **908** and **910** of image **902**, and where edges **912** and **914** appear as edges **916** and **918**, respectively. This distortion may be corrected using mapping functions that are determined by calibrating the camera system.

FIG. **21** illustrates a process for calibrating the camera system. A vertical column of equally spaced elliptical dots **930** is placed in a fixed position. The dots are white on a black background where the major axis of the elliptical dot is in the vertical direction. Panoramic camera **940** is then rotated in small discrete steps about an axis **942** passing through the virtual optical center of the panoramic camera. At each step, the distorted image of the column of elliptical dots is viewed and a mapping function for that data is determined to remove the distortion. This function maps the image such that the distorted image of each vertical column of equally spaced dots is a vertical column of equally spaced dots in the mapped image. Note that although the images of the white dots have black gaps between them, the mapping function is computed to apply to every image pixel (including the pixels between the white dots) through interpolation. An image mapping function is determined at each of the discrete steps as the camera is rotated, the union of these mapping functions is combinable into a 2-D to 2-D mapping that ensures not only that each vertical column of equally spaced dots appears as a vertical column of equally spaced dots in the image, but also that these columns are spaced horizontally in proportion to the angular rotation between their image acquisitions, the latter providing a cylindrical (rather than flat) image of the scene.

FIGS. **22** and **23** illustrate how the data representative of the vertical column of elliptical dots is represented as a result of distortion. FIG. **22** is similar to FIG. **8** in that it illustrates the relationship between the data provided by the cameras and the view available to the user. It should be noted that the vertical column of dots is not in a single column of FIG. **22** as a result of the distortion. The distortion has caused the dots to occupy columns **960**, **962**, **964** and **966**, rather than just a single column. FIG. **23** is similar to FIG. **9** in that it illustrates how image data is stored. When the distorted image data is stored in memory as represented in FIG. **23**, the data representative of the dots also occupies several columns where columns **980**, **982**, **984** and **986** correspond to the columns **960**, **962**, **964** and **966** of FIG. **22**, respectively. The image mapping function determined during the calibration phase is used to correct for this distortion when the data is read from the memory represented in FIG. **23**. The corrected or undistorted image data may then be displayed to the user or written to a memory used to store data representative of the undistorted image. FIG. **24** illustrates the relationship between the data read from the memory of FIG. **23** and the undistorted view made available to a user. For example, the mapping function associated with column **1000** specifies that when reading data for use in the uppermost portion of column **1000**, data is read from column **980** and when reading data for use in the portion of column **1000** just below, data is read from column **982**. The mapping function also specifies that when reading data for use in the middle portion of column **1000**, data is read from column **984**. Moving further down column **1000**, data is then read from column **982**, then column **980**, and eventually from column **986** when data for use at the bottom of column **1000** is retrieved. As a result of reading data, as specified by the mapping function, the column of data will appear vertical to a user viewing a display. FIG. **24** illustrates that the data retrieved from the memory of FIG. **23** now appears as a vertical column where the distortion is no longer evident. A similar mapping function, as determined during calibration, is used for each column of FIG. **24** to produce an undistorted image for display. It should be noted that multiple discrete rotational steps used to calibrate the panoramic camera could be substituted by a group of several columns illustrated in FIG. **24**.

Color and intensity calibration may also be carried out using a procedure similar to the procedure illustrated in FIG. **21**. In this case, column **930** of elliptical dots is replaced by a known color pattern. The panoramic camera is then rotated so that each camera captures an image of the color pattern. Several color patterns (such as various shades of red, green, blue, and gray) could be used one by one. Then on a pixel-by-pixel basis, the data from each camera is adjusted to correct any red, green, or blue distortion so that the produced image has a color pattern that closely matches the calibration color pattern. Additionally, the intensity of each pixel from each camera is adjusted so that there is relatively uniform intensity and color within a single camera's image and between the images of the multiple cameras when viewing a scene with constant color and brightness. As discussed with regard to the mapping function, the pixel-by-pixel adjustment may be stored in a table. A less precise, but simpler method of color and intensity calculation may be used. This method simply involves manually adjusting the color and intensity controls of each camera to get correct

color and intensity when viewing a scene with a particular color and intensity. It should be noted that by using this method, all of the pixels of a particular camera receive the same adjustments.

FIG. **25** illustrates a panoramic camera system where calibration based image mapping correction is used. FIG. **25** is similar to FIG. **7**; however, it should be noted that a frame buffer memory and an additional microprocessor have been included. Cameras **52**, **54**, **56**, and **58** gather image data and then pass the data to analog-to-digital converters **160**, **162**, **164**, and **166**, respectively. The output of the analog-to-digital converters are then passed through red, green, blue, and intensity adjustment units **1010**, **1012**, **1014**, and **1018**. It is possible to place these units before the analog/digital converters, if the adjustment units are analog units. Additionally, it is also possible to use cameras that have the adjustment units built into each camera. In any case, the adjustment units are programmed or set to adjust the color and intensity as determined by the calculation procedures. Each of these units adjust the red, green, and blue levels and the overall levels of the signals from the analog-to-digital converter. It should be noted that if cameras **52** through **58** are color cameras, analog-to-digital converters **160** to **166** typically receive three signals and output three signals, where each pair of input and output signals corresponds to one of the colors red, green, and blue. Units **1010** through **1016** simply adjust the relative amplitudes of the red, green, and blue signals in accordance with the settings determined during the calibration procedure. Each of units **1010** through **1018** also adjust the overall amplitude of the red, green, and blue signals in accordance with the overall intensity calibration settings. The outputs of the red, green, and blue intensity adjustments are then passed through a multiplexer as discussed in FIG. **7**, and are passed to frame buffer memory **1030**. It is also possible to replace frame buffer **1030** with an individual frame buffer for each of red, green, blue and intensity units **1010**, **1012**, **1014**, and **1018**. The outputs of each of the individual frame buffer may then be passed to microprocessor **1030** via multiplexer **170**.

Frame buffer memory **1030** is operated in a fashion similar to memory **172** of FIG. **7** and stores the data representing the distorted images as was discussed in reference to FIG. **23**. Microprocessor **1040** then reads the data from frame buffer memory **1030** using the mapping functions determined during the calibration procedure and then writes the data into display memory **1050**. Recalling the discussion associated with FIG. **24**, the data representing undistorted images is then stored in memory **1050** for retrieval by the users. The users can retrieve the data as is discussed in reference to FIG. **7** where the data read out is determined based on a user's input. It is also possible for the entire contents of display memory to be made available to each user. The data may be communicated to each user through a communication network such as a telephone network or a data network, or it may be directly communicated to the user via a dedicated wired or wireless communication path. The user then may use a digital-to-analog converter to convert the data into an analog format that may be displayed for the user or the user may use the digital data directly and forego the use of a digital-to-analog converter.

The invention claimed is:

1. A panoramic viewing apparatus, comprising:

a plurality of image processing devices, each having an optical center and a field of view;

a reflective element being at least partially polyhedral having a plurality of reflective facets facing in different directions, each of at least two of the plurality of reflective facets redirecting a field of view of one of the plurality of image processing devices to create a plurality of virtual optical centers; and

a support member intersecting an inner volume of the reflective element, the reflective element being secured to the support member and the plurality of image processing devices being secured to the support member.

2. The panoramic viewing apparatus of claim **1**, wherein the plurality of image processing devices are secured to a portion of the support member extending out from the reflective element.

3. The panoramic viewing apparatus of claim **1**, wherein the support member is hollow.

4. A panoramic viewing apparatus, comprising:

a plurality of first image processing devices, each having an optical center and a field of view;

a plurality of second image processing devices, each having an optical center and a field of view;

a first and a second reflective element each being at least partially polyhedral arranged adjacent to each other, the first reflective element having a plurality of first reflective facets facing in different directions, each of at least two of the plurality of first reflective facets redirecting a field of view of one of the plurality of first image processing devices to create a plurality of first virtual optical centers, and the second reflective element having a plurality of second reflective facets facing in different directions, each of at least two of the plurality of second reflective facets redirecting a field of view of one of the plurality of second image processing devices to create a plurality of second virtual optical centers; and

a support member intersecting an inner volume of at least one reflective element, at least one of the reflective elements being secured to the support member and at least one of the plurality of first or second image processing devices being secured to the support member.

5. The panoramic viewing apparatus of claim **4**, wherein the plurality of first image processing devices are secured to a first portion of the support member extending out from the first reflective element, and the plurality of second image processing devices are secured to a second portion of the support member extending out from the second reflective element.

6. The panoramic viewing apparatus of claim **4**, wherein the support member is hollow.

7. A panoramic viewing apparatus, comprising:

a plurality of first image processing devices, each having an optical center and a field of view;

a plurality of second image processing devices, each having an optical center and a field of view;

a first reflective element being at least partially polyhedral;

a second reflective element being at least partially polyhedral with at least a portion of the second reflective element being positioned within the first reflective element, the first reflective element having a plurality of first reflective facets facing in different directions, each of at least two of the plurality of first reflective facets redirecting a field of view of one of the plurality of first image processing devices to create a plurality of first virtual optical centers, and the second reflective element having a plurality of second reflective facets facing in different directions, each of at least two of the

plurality of second reflective facets redirecting a field of view of one of the plurality of second image processing devices to create a plurality of second virtual optical centers; and

a support member intersecting an inner volume of at least one reflective element, at least one of the reflective elements being secured to the support member and at least one of the plurality of first or second image processing devices being secured to the support member.

8. The panoramic viewing apparatus of claim **7**, wherein the plurality of first image processing devices are secured to a first portion of the support member extending out from the first reflective element, and the plurality of second image processing devices are secured to a second portion of the support member extending out from of the reflective element.

9. The panoramic viewing apparatus of claim **7**, wherein the support member is hollow.

10. A panoramic viewing apparatus, comprising:

plurality of image processing devices, each having an optical center and a field of view;

a pyramid shaped element having a plurality of reflective side facets facing in different directions, each of at least two of the plurality of reflective side facets redirecting a field of view of one of the plurality of image processing devices to create a plurality of virtual optical centers; and

a support member intersecting an inner volume of the pyramid shaped element, the pyramid shaped element being secured to the support member and the plurality of image processing devices being secured to the support member.

11. The panoramic viewing apparatus of claim **10**, wherein the plurality of image processing devices are secured to a portion of the support member extending out from the pyramid shaped element.

12. The panoramic viewing apparatus of claim **10**, wherein the support member is hollow.

13. A panoramic viewing apparatus, comprising:

a plurality of first image processing devices, each having an optical center and a field of view;

a plurality of second image processing devices, each having an optical center and a field of view;

a first and a second pyramid shaped element arranged base end to base end, the first pyramid shaped element having a plurality of first reflective side facets facing in different directions, each of at least two of the plurality of first reflective side facets redirecting a field of view of one of the plurality of first image processing devices to create a plurality of first virtual optical centers, and the second pyramid shaped element having a plurality of second reflective side facets facing in different directions, each of at least two of the plurality of second reflective side facets redirecting a field of view of one of the plurality of second image processing devices to create a plurality of second virtual optical centers; and

a support member intersecting an inner volume of at least one of the pyramid shaped elements, at least one of the pyramid shaped elements being secured to the support member and at least one of the plurality of first or second image processing devices being secured to the support member.

14. The panoramic viewing apparatus of claim **13**, wherein the plurality of first image processing devices are secured to a first portion of the support member extending out from the first pyramid shaped element, and the plurality of second image processing devices are secured to a second portion of the support member extending out from the second pyramid shaped element.

15. The panoramic viewing apparatus of claim **13**, wherein the support member is hollow.

16. A panoramic viewing apparatus, comprising:

plurality of first image processing devices, each having an optical center and a field of view;

a plurality of second image processing devices, each having an optical center and a field of view;

a first pyramid shaped element having a first vertex end and a first base end;

a second pyramid shaped element having a second vertex end and a second base end with at least a portion of the second pyramid shaped element being positioned within the first pyramid shaped element so that the first and second vertex ends point in the same direction, the first pyramid shaped element having a plurality of first reflective side facets facing in different directions, each of at least two of the plurality of first reflective side facets redirecting a field of view of one of the plurality of first image processing devices to create a plurality of

first virtual optical centers, and the second pyramid shaped element having a plurality of second reflective side facets facing in different directions, each of at least two of the plurality of second reflective side facets redirecting a field of view of one of the plurality of second image processing devices to create a plurality of second virtual optical centers; and

a support member intersecting an inner volume of at least one of the pyramid shaped elements, at least one of the pyramid shaped element being secured to the support member and at least one of the plurality of first or second image processing devices being secured to the support member.

17. The panoramic viewing apparatus of claim **16**, wherein the plurality of first image processing devices are secured to a first portion of the support member extending out from the first pyramid shaped element, and the plurality of second image processing devices are secured to a second portion of the support member extending out from the second pyramid shaped element.

18. The panoramic viewing apparatus of claim **16**, wherein the support member is hollow.

* * * * *

EXHIBIT C:

Microsoft RoundTable camera head, assembled and disassembled

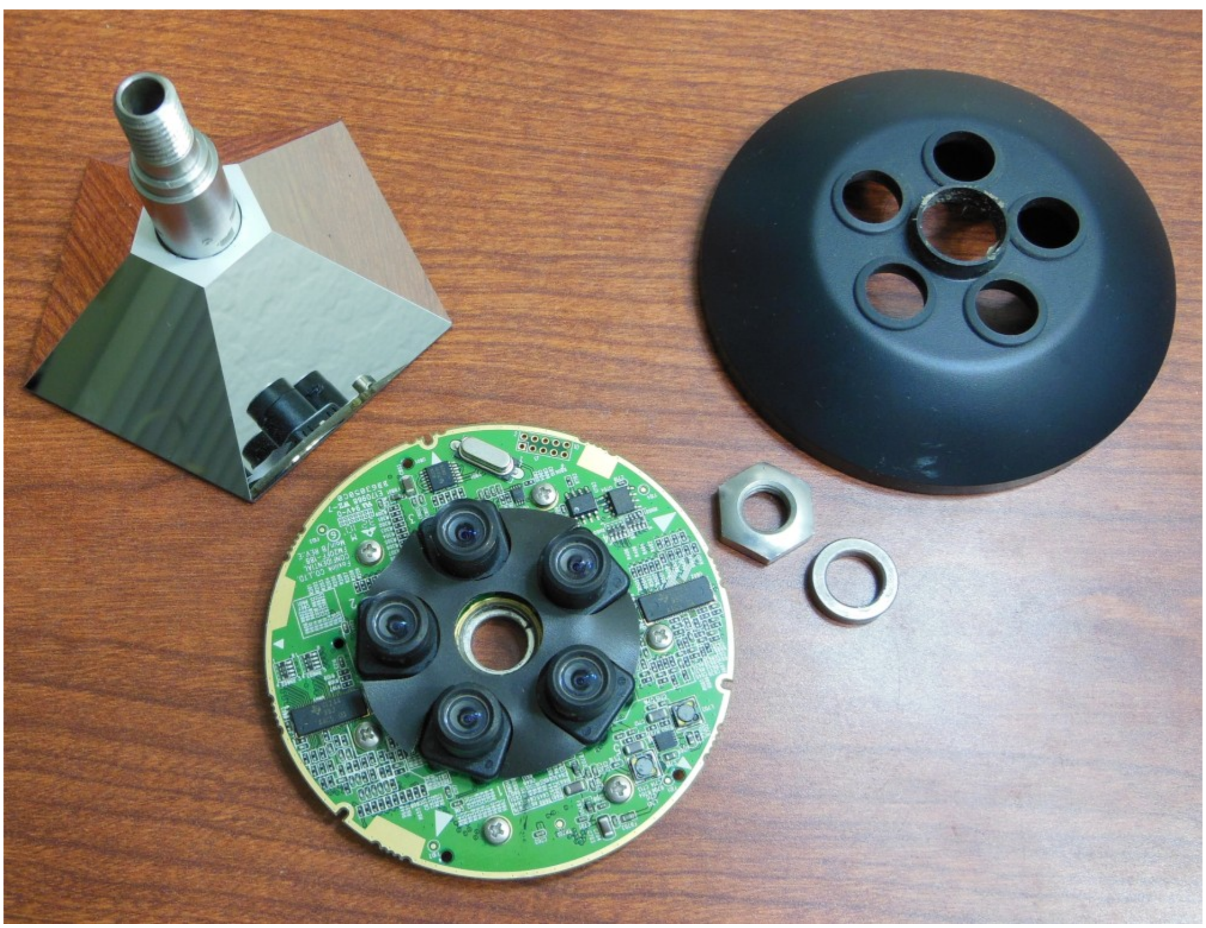
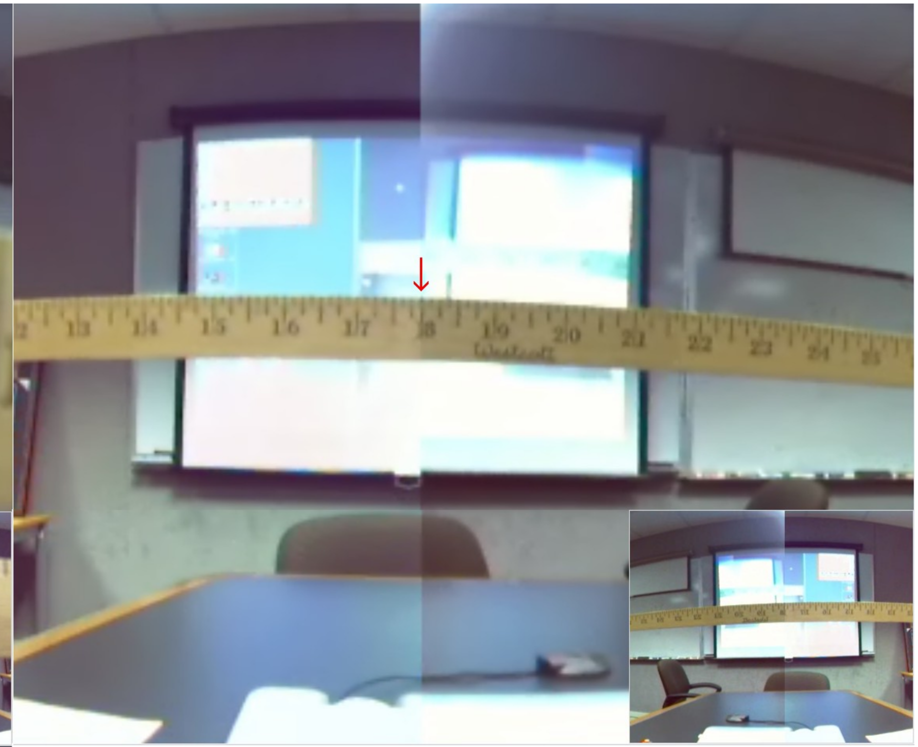


EXHIBIT D:

Two sets of a RoundTable's composite images of a yardstick positioned across the RoundTable's mirrored pyramid's side edge at three different distances

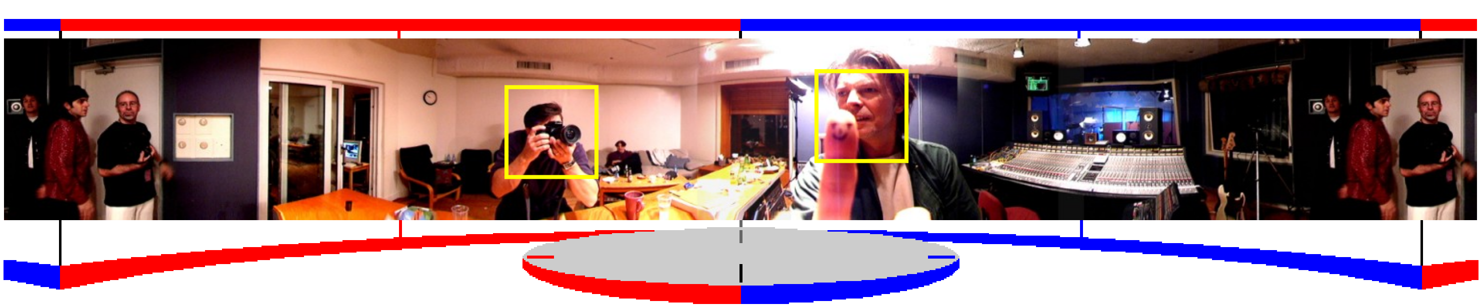
September 17, 2008



April 15, 2009

EXHIBIT E:

FullView's Bowie Prototype used to webcast a live performance by Mr. David Bowie in New York City in 1999, above a 360° composite image from that webcast (with ends repeated for continuity) along with two sample subviews that a remote user could view in different directions at a higher resolution



May 24, 1999

EXHIBIT F:

For several years until 2002, Microsoft had been pursuing its RingCam design, in which multiple cameras looked out directly, rather than off mirrors


MS Research

EXHIBIT G:

Central to Polycom's CX5000 and CX5000 Successor Products is the RoundTable design that Microsoft licensed from FullView — this design with 5 cameras looking up and off a 5-sided mirrored pyramid from "offset" viewpoints to provide apparently seamless 360° composite images with "blind regions," just as in FullView's Bowie Prototype

FullView's Bowie Prototype from 1999

Polycom CX5000: CX5000 HD is similar to CX5000

Polycom CX5100: CX5500 and CX8000 360º are similar to CX5100

Polycom RealPresence Centro

EXHIBIT H:

Microsoft and Polycom's announcement of March 30, 2009 that the Microsoft RoundTable would be *distributed* by Polycom as the Polycom CX5000

Microsoft and Polycom Expand Their Relationship to Enhance Unified Communications and Collaboration Solutions

March 30, 2009 |

PLEASANTON, Calif., REDMOND, Wash., and VoiceCon Orlando 2009, Booth No. 309 — March 30, 2009 — Polycom, Inc. [Nasdaq: PLCM], and Microsoft Corp. [Nasdaq: MSFT] today announced that the two companies are deepening their strategic relationship to deliver one of the broadest and most powerful sets of voice and video solutions for unified communications and collaboration. As part of Microsoft's vision to broaden the availability of Microsoft RoundTable, Polycom has licensed the right to distribute RoundTable, effective April 13, 2009. The product, renamed the Polycom CX5000 Unified Conference Station, will be available through Polycom and its extensive channel network.

Known respectively for innovative collaboration solutions, Microsoft and Polycom are working together to help customers enhance team communication and collaboration with voice and video conferencing. As a leader in telepresence, video and voice communications solutions, Polycom continues to expand the market for visual communication with a range of new solutions that will put video conferencing and collaboration capabilities into general purpose, point-to-point, and multipoint environments.

The CX5000 adds to Polycom's broad portfolio and enables it to address the video collaboration needs of organizations that rely on Microsoft Office Communications Server 2007 and Microsoft Office Live Meeting service.

Originally launched by Microsoft in October 2007, the CX5000 is a plug-and-play device that connects to a PC through a USB connection, so no extra provisioning or configuration is needed; any user can walk into a conference room, plug in a laptop, and start a meeting. The CX5000 is designed for enterprises that use Microsoft Office Live Meeting 2007 or Office Communications Server 2007 and want a simple way to add audio and visual communication to an Office Live Meeting or Office Communications Server 2007 session. When used with Office Live Meeting service or as part of Office Communications Server 2007, the CX5000 combines content, a panoramic 360-degree view of the entire meeting room, and a separate view of the active speaker for a unique and engaging voice and video experience.

"Microsoft and Polycom share a long-standing, strategic relationship in the unified communications space, and we are confident in Polycom's depth of experience and customer support in the conferencing market," said Gurdeep Singh Pall, corporate vice president in the Unified Communications Group at Microsoft. "Our vision to make RoundTable available to more people in more countries has been realized with the introduction of the Polycom CX5000 Unified Conferencing Station, and shows further evidence of Microsoft's commitment to a software platform that enables device innovation."

"Our collaboration with Microsoft is a key component of Polycom's vision to provide our customers with unified communications endpoints that embody the high quality for which Polycom is known," said Sunil Bhalla, senior vice president and general manager of Voice Communications Solutions at Polycom. "With our expertise in enterprise collaboration and our broad distribution network, it makes perfect sense for us to incorporate the CX5000 into our family of devices optimized for Microsoft UC solutions. We look forward to our continued relationship with Microsoft and the benefits this will bring our joint customers."

Customers using the device report better daily interaction with colleagues, as well as significant operational benefits.

"The University of Kentucky has a very robust IP-based voice and video network, and Microsoft and Polycom are integral to our communications strategy," said Doyle Friskney, chief Technology officer. "We've been using RoundTable for real-time communications and information-rich virtual meetings, and it has helped us streamline operations, improve productivity, and reduce travel costs significantly and encourage improved productivity. As we continue to enhance our UC platform, it gives us great confidence knowing two companies with innovative technologies and high-quality products that truly make a difference in our daily interactions are deepening their partnership in this way."

"IDC's 2009 Top 10 list for Enterprise Networking includes the prediction that 2009 will become the year of the great enterprise video experiment which will help businesses do more with less," said Nora Freedman, senior analyst, Unified Communications Infrastructure, IDC. "The ability for partners to cross-sell video and voice solutions, as well as leverage their respective distribution channels, can help to lower the barriers to entry in an enterprise, which is especially advantageous in this economy."

Polycom offers a full suite of devices that integrate with Office Communications Server 2007. Polycom's series of CX phones optimized for Office Communications Server 2007 includes the CX700 IP telephone, CX200 desktop USB phone and CX100 personal speakerphone. These phones deliver crystal-clear, wideband audio and provide full, convenient access to the advanced presence-enabled features of Office Communications Server 2007. For versatile video communications, Polycom's HDX video endpoints register, authenticate and share presence information with Office Communications Server 2007, making it simple for users to launch video calls by clicking on presence-enabled contacts to see the availability status of Polycom video and telepresence users. Additionally, Polycom's RMX 2000 real-time media conferencing platform works with Microsoft Office Communications Server 2007 R2, allowing users to launch on-demand voice, video and unified (voice and video) conferences with other standards-based video and voice endpoints.

Availability and Pricing

The Polycom CX5000 will be available beginning April 13, 2009, at a list price of U.S. $4,300. The CX5000 will be available in 27 countries through Polycom's extensive channel partner network and will be available for shipment in late April. Once the Polycom CX5000 is available, RoundTable will no longer be sold. Microsoft will continue to support all RoundTable devices already sold, while Polycom will provide front-line customer support for CX5000 units sold beginning April13. More information about the Polycom CX5000 can be found online at http://www.polycom.com/cx5000.

About Polycom

Polycom, Inc. (Nasdaq: PLCM) is the global leader in telepresence, video, and voice solutions and a visionary in communications that empower people to connect and collaborate everywhere. Please visit www.polycom.com for more information.

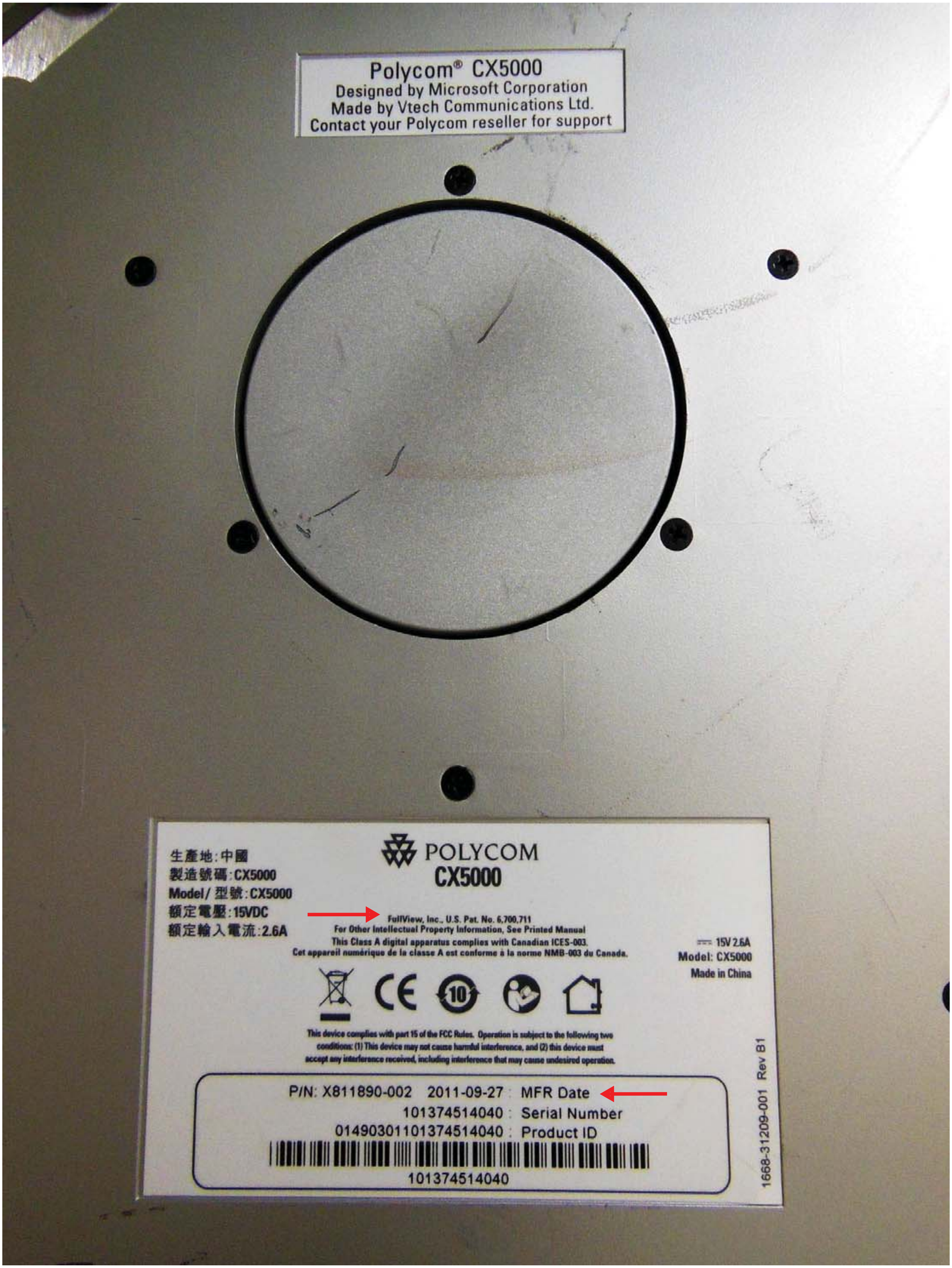
About Microsoft

Founded in 1975, Microsoft (Nasdaq "MSFT") is the worldwide leader in software, services and solutions that help people and businesses realize their full potential.

Note to editors: If you are interested in viewing additional information on Microsoft, please visit the Microsoft Web page athttp://www.microsoft.com/presspass on Microsoft's corporate information pages. Web links, telephone numbers and titles were correct at time of publication, but may since have changed. For additional assistance, journalists and analysts may contact Microsoft's Rapid Response Team or other appropriate contacts listed at http://www.microsoft.com/presspass/contactpr.mspx.

EXHIBIT I:

Product Labels affixed to the Polycom CX5000 product over the course of the IPA


Polycom® CX5000
Designed by Microsoft Corporation
Made by Vtech Communications Ltd.
Contact your Polycom reseller for support
生產地:中國
製造號碼:CX5000
Model/ 型號:CX5000
額定電壓:15VDC
額定輸入電流:2.6A
POLYCOM
CX5000
FullView, Inc., U.S. Pat. No. 6,700,711
For Other Intellectual Property Information, See Printed Manual
This Class A digital apparatus complies with Canadian ICES-003.
Cet appareil numérique de la classe A est conforme à la norme NMB-003 du Canada.
15V 2.6A
Model: CX5000
Made in China
10
This device complies with part 15 of the FCC Rules. Operation is subject to the following two conditions: (1) This device may not cause harmful interference, and (2) this device must accept any interference received, including interference that may cause undesired operation.
P/N: X811890-002 2011-09-27 : MFR Date
101374514040 : Serial Number
014903011101374514040 : Product ID
101374514040
1668-31209-001 Rev B1