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- (71) **Applicant (for all designated States except US):** SHARP KABUSHIKI KAISHA [JP/JP]; 22-22, Nagaike-cho, Abeno-ku, Osaka-shi, Osaka, 5458522 (JP).
- (72) **Inventor; and**
- (71) **Applicant (for US only):** YUAN, Chang.
- (74) **Agent:** HARAKENZO WORLD PATENT & TRADE-MARK; Daiwa Minamimorimachi Building, 2-6, Tenjin-bashi 2-chome Kita, Kita-ku, Osaka-shi, Osaka, 5300041 (JP).

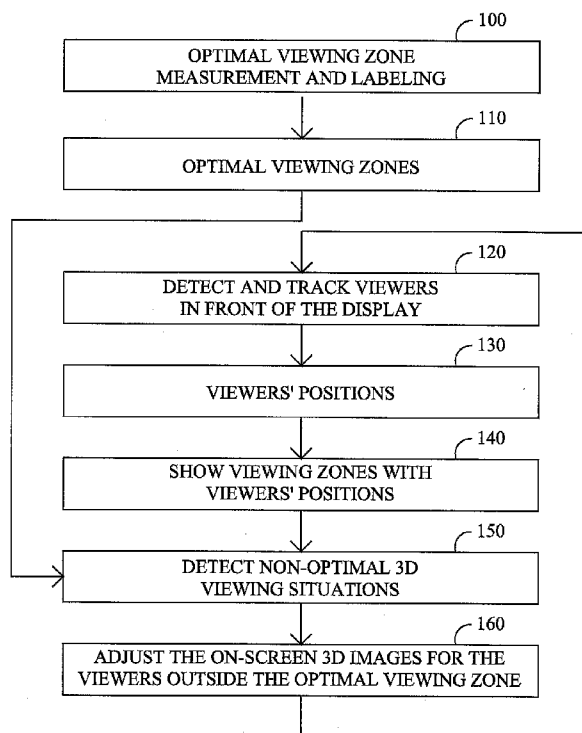
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(54) **Title:** VIEWER REACTIVE AUTO STEREOSCOPIC DISPLAY



(57) **Abstract:** An auto stereoscopic display includes a plurality of views thereby providing a perceived three dimensional image to a viewer. The display includes a sensor that determines the position of the viewer with respect to the display and modifies the plurality of views to provide an improved perceived three dimensional image to the viewer.

Description

Title of Invention: VIEWER REACTIVE AUTO STEREOSCOPIC DISPLAY

Technical Field

[0001] The present invention relates to auto stereoscopic displays.

Background Art

[0002] Auto-stereoscopic (AS) three dimensional (3D) displays are increasing in popularity together with the growth of available three dimensional content. Auto stereoscopic displays present stereoscopic images by adding the perception of three dimensional depth without the use of special headgear or glasses on the part of the viewer. Because headgear is not required, it is also sometimes referred to as "glasses-free 3D" or "glasses-less 3D". Since they do not require the viewers to wear glasses and they generate multiple (usually more than two) views for viewers' left and right eyes, this results in three dimensional human depth perception. They are suited for various applications, including digital signage, televisions, monitors, and public information. Some auto stereoscopic displays include parallax barrier type displays, lenticular type displays, volumetric type displays, electro-holographic type displays, and light field type displays.

Summary of Invention

Technical Problem

[0003] One of the challenges of existing auto stereoscopic displays is achieving high quality three dimensional images for the viewer. There are certain areas in the viewing space in front of an auto stereoscopic display that are optimal for three dimensional depth perception, generally referred to as "optimal viewing zones" or "sweet spots." Viewers outside sweet spots, however, will observe sub-optimal-quality three dimensional images. In some cases, the three dimensional images may appear to have reversed views (namely the viewer's left eye sees the right view and the right eye sees the left view). If the viewers are not at the optimal viewing distance (e.g., too close to the display), the three dimensional images may also contain multiple views that generates blurry or tearing images. In addition, the level of cross talk (one view leaking into another view) also varies when viewers move in front of the display. What makes such issues even more problematic is the limited flexibility of human visual system, especially the stereoscopic vision system, that viewers may not notice the problems in the three dimensional images right away. Thus, viewers tend to stay in a wrong position for an extended period of time and may or may not realize that the image is incorrect. During this process, however, viewers may already experience visual

discomfort and fatigue, due to the sub-optimal three dimensional viewing experience.

Solution to Problem

[0004] According to the present invention, there is provided an auto stereoscopic display comprising:

[0005] (a) said auto stereoscopic display including a plurality of views thereby providing a perceived three dimensional image to a viewer;

[0006] (b) said display including a sensor that determines the position of said viewer with respect to said display;

[0007] (c) modifying said plurality of views to provide an improved said perceived three dimensional image to said viewer.

Advantageous Effects of Invention

[0008] The foregoing and other objectives, features, and advantages of the invention will be more readily understood upon consideration of the following detailed description of the invention, taken in conjunction with the accompanying drawings.

Brief Description of Drawings

[0009] [fig.1]FIG. 1 illustrates a technique for viewer reactive displays.

[fig.2]FIG. 2 illustrates multiple cone-shape views from a display.

[fig.3A]FIG. 3A illustrates original viewing zones and optimal viewing zones.

[fig.3B]FIG. 3B illustrates original viewing zones and optimal viewing zones.

[fig.4]FIG. 4 illustrates a technique for measuring viewing zones of the display.

[fig.5]FIG. 5 illustrates images with individual viewing zone numbers.

[fig.6]FIG. 6 illustrates a final multi-view calibration pattern image.

[fig.7]FIG. 7 illustrates a process for viewing zone measurement.

[fig.8]FIG. 8 illustrates labeled optimal viewing zones for a display.

[fig.9]FIG. 9 illustrates a process for viewer detection and tracking.

[fig.10]FIG. 10 illustrates reversed viewing on a display.

[fig.11A]FIG. 11A illustrates optimal single viewing zone and mixed viewing zones.

[fig.11B]FIG. 11B illustrates optimal single viewing zone and mixed viewing zones.

[fig.12]FIG. 12 illustrates adjusting multi-view images to improve three dimensional viewing.

[fig.13]FIG. 13 illustrates switching views to solve the reversed viewing on auto stereoscopic displays.

[fig.14]FIG. 14 illustrates instructing viewers to move to an improved viewing position.

Description of Embodiments

[0010] Referring to FIG. 1, it is desirable to improve the ability of the viewer to be in the sweet spot by including reactive capabilities with an auto stereoscopic display. A

display measurement process 100 may be conducted to characterize the viewing zones 110 in front of the display. In particular, the display measurement process 100 may evaluate the perceived multiple views at different positions in front of the display by moving a camera in front of the display and labeling optimal viewing zones for the display. This process may be done before the viewer uses the display.

[0011] While the viewer is viewing the display, a viewer detection and tracking process 120 may be used to determine the location of one or more viewers in front of the display. The viewer detection and tracking process 120 may generate a depth map by using a three dimensional sensor associated with the display. Preferably the three dimensional sensor is integrated with the display or otherwise maintained in a fixed position with respect to the display. The viewer detection and tracking process 120 provides the location(s) of one or more of the viewer's positions 130. The display may show the optional viewing zones on the display together with an indication of the viewer's position(s) 140 and/or where to relocate to. In this manner, the viewer may be directed to relocate themselves from a non-optimal viewing zone to a more optimal viewing zone. The detected viewer positions 130 are compared 150 to the optimal viewing zones 110 in front of the display. If one or more viewers is determined to be in a sub-optimal zone, the display reacts to this situation by adjusting the on-screen images to provide more optimal three dimensional images for one or more viewers. For example, if a particular viewer occupies a zone by himself, the display may adjust the views so that the two views the viewer sees are corrected and lead to a more optimal three dimensional depth perception. For example, if two or more viewers occupy different zones, the display may adjust the views so that the two views that each of the viewer sees are corrected and lead to a more optimal three dimensional depth perception. For example, if the viewer shares one or more viewing zones with other viewers, the display may not be capable of adjusting the image without adversely affecting the other viewers. In this case, the display preferably shows a visual message 140 to notify one or more viewers to move to a nearby unoccupied position in order to achieve an improved viewing experience or otherwise reverts to showing a two dimensional image.

[0012] The display measurement process 100 estimates the visible viewing zones at a plurality of locations in front of the display. Many auto stereoscopic displays generate multiple cone-shaped views in the three dimensional space in front of the display. Referring to FIG. 2, the three dimensional display ideally generates clearly separated views for each eye, which leads to ideal three dimensional vision when the viewer is in the appropriate position. Unfortunately, actual auto stereoscopic displays do not generate such a simplistic viewing layout. Instead, the cone for each view tends to intersect with all the other ones and generates a common area where viewers can see

multiple views from their eyes.

- [0013] Referring to FIG. 3A, each viewing zone may contain 1, 2, 3 or more views. For example, location 120 includes primarily view number 6. For example location 122 includes primarily views 5 and 6. For example, location 124 primarily includes views 4, 5, and 6. To provide a more pleasant viewing experience, the viewers should be in a location where each eye can only see a single view. Referring to FIG. 3B, the viewer's left eye observes view 4 and the viewer's right eye observes view 5. View 4 is intended for the observer's left eye and view 5 is intended for the observer's right eye. The two views are different from one another and therefore viewers can obtain a three dimensional depth perception. The preferable optical viewing zones are those zones across the center of the region with a single view contained therein. Typically, the views for each eye are spaced apart from one another by the distance between the eyes.
- [0014] Referring to FIG. 4, one technique to characterize the viewing zones in front of the display is to show calibration patterns on the display 200. The pattern may consist of multiple views (e.g., in total 8 views), each of which is rendered with the view number by a computer. For example, FIG. 5 illustrates a number of images that are shown with their viewing zone numbers. For example, FIG. 6 illustrates a resulting final composite pattern image.
- [0015] The display may capture three dimensional images of the viewing space and two dimensional images of the viewing space 210. Based upon these captured images of the viewing space 210, the system may determine a three dimensional depth map of the viewing space 220 and a two dimensional color image of the viewing space 230. Based upon the three dimensional depth map 220 and the two dimensional color image 230 the system may determine the three dimensional camera position 240 as the camera is moved in front of the display. The system may recognize the viewing zone number(s) in the captured images 250 and equate that to the location of the camera. Based upon the recognized numbers the system may label the viewing zone at each position in the three dimensional viewing space 260. The camera is moved to all desired sampling positions until the entire space is sufficiently measured 270.
- [0016] When the camera is moved in front of the display, the images captured by the camera are preferably analyzed by an image pattern matching process. The process, as illustrated in FIG. 7, includes template matching over the captured images and determines matches of the computer generated numerical patterns. In other words, the process first recognizes the visible viewing zone numbers in the captured images 300. The set of viewing zone numbers is searched and the possibility of each number pattern being visible at a certain position is summarized. The process may determine if only one viewing zone number is visible for a particular location 310. Those locations that only include a single zone number are labeled as optimal viewing zones 320.

Those locations that include more than a single zone number are labeled as non-optimal viewing zones 330. In this manner, those locations with preferred views and those locations with non-preferred views are identified. The system may further characterize the viewing zones as having two or more zone numbers and the numbers therein. Referring to FIG. 8, a set of exemplary optical viewing zones are illustrated. Typically, the optical viewing zones are in the middle range of the viewing space in front of the display. Viewers are then recommended to stay within this zone in order to perceive improved three dimensional images.

- [0017] During the tracking process for one or more of the viewers, the display may capture three dimensional images of the viewing space and two dimensional images of the viewing space 400. Other image capture techniques may be used, as desired. Based upon these captured images of the viewing space 400, the system provides a three dimensional depth image of the viewing space 410 and a two dimensional color image of the viewing space 420. Based upon the three dimensional depth image 410 and the two dimensional color image 420, the system detects viewer faces (and/or heads and/or locations) 430. The result of detecting the viewer faces 430 is a three dimensional position and/or orientation of the viewer faces 440. Based upon the position and/or orientation of the viewer faces 440, the process may locate the viewer's eyes 450 and provide the location of the viewer's eye positions 460. Over time the process may track the viewers' eye positions 470 and provide an output of the tracked viewers' eye positions 480. Tracking the viewer's positions over time results in additional robustness of the location determination process. In this manner, the system may determine the location of the eyes (or other suitable characteristic) of one or more viewers in front of the display.
- [0018] Once the viewing zone and viewers' eye positions are determined, the system may determine if the viewers are within a sufficiently optimal viewing zone or not. There are several sources for sub-optimal three dimensional viewing zones, which depending on the source of the limitation, may be reduced by modification of the images provided to one or more viewers.
- [0019] In many cases, the eyes of the viewer are aligned with the left eye observing the left view and the right eye observing the right view. Referring to FIG. 10, in the region of adjoining sets of eight views the left eyes observes the image intended for the right eye and the right eyes observes the image indeed for the left eye. This reversal of images results in visual discomfort and fatigue. For example, if the viewer's left eye sees view #8 and the right eye sees view #1 from an eight view display, the viewer will observe a reversed depth.
- [0020] FIG. 11A and FIG. 11B illustrate an example of mixed viewing zones. FIG. 11A shows the situation where each eye only observes one zone intended for that eye, and

tends to lead to a preferred three dimensional perception. FIG. 11B shows the situation where each eye observes multiple zones: e.g., the left eye observes zones 4 and 5, and the right eye observes zones 5 and 6. The images observed by the viewer will contain different parts from different views which leads to degraded three dimensional depth perception.

- [0021] Displays usually generate cross talk between the adjacent views. The cross talk, however, can be spatially varying. For example, the cross talk may be more visible if the three dimensional image is viewed off-angle. If the viewers happen to stand in such positions, they will observe lower-quality images. Cross talk correction processes may be applied to reduce the crosstalk before applying view adjustment techniques.
- [0022] If one or more viewers are not properly located to view optimal three dimensional images, the auto stereoscopic display will determine a suitable modification to the images and/or direct the viewers to move to a more suitable position.
- [0023] Referring to FIG. 12, the display may determine if one of the same views is shared among multiple viewers. In the case that multiple viewers are observing one of the same views, then the display may notify one or more of the viewers to move to another position 510 so as to not share a view.
- [0024] The display may also determine if one of the same views is shared among multiple viewers. In the case that multiple viewers are observing one of the same views, the system may update the on screen three dimensional images on the display 520 by suitably replacing the shared view with different non-shared views to improve the three dimensional viewing characteristics.
- [0025] In the case that multiple viewers are not observing one of the same views, then the display may replace one or more of the existing views with one or more other views 530 to improve the three dimensional viewing experience for the viewers. In this case, the system may determine which of the views to be replaced with another view in a manner suitable to improve the viewing characteristic for one or more viewers.
- [0026] In the case that multiple viewers are observing one of the same views, then the display may be capable of replacing the other non-matching view in a manner to improve the three dimensional viewing experience for at least one of the viewers, and preferably all of the viewers.
- [0027] In the case that multiple viewers are observing one of the same views, then the display may be capable of replacing the matching view in a manner to improve the three dimensional viewing experience for at least one of the viewers, and preferably all of the viewers.
- [0028] In the case that multiple viewers are observing one of the same views, then the display may be capable of replacing both of the views in a manner to improve the three dimensional viewing experience for at least one of the viewers, and preferably all of

the viewers.

- [0029] The different sources of sub-optimal image quality may result in different image adjustments for a more suitable viewing experience. By way of example, in the case that the views are reversed, the two reversed views may be reversed so that the viewer's eyes see the three dimensional images in the proper left eye and right eye. This is especially suitable when the switching of the two views does not impact any other viewers. By way of example, if a viewer observes reversed views #8 and #1, the system may check if there exist other viewers seeing either of the same two views (#1 and #8). This assists in ensuring that any adjustment to views #1 and #8 do not adversely affect other viewers who are already having optimal three dimensional viewing. If there is no adverse impact on other viewers, the system may switch view #1 with view #8 so that the viewer observes a more optimal three dimensional viewing experience.
- [0030] Referring to FIG. 13, the display may temporally switch views #1 and #8 so that the viewer will not see the reversed image. If the viewer moves away from this position, the original views #1 and #8 may be restored to their original arrangement.
- [0031] As previously discussed, in the case of a mixed viewing zone situation, the zones that appear to the viewers' eyes may be replaced by a single viewing zone. For example, a zone that includes a plurality of different views may be replaced by a single view. Referring to FIG. 11B, by way of example, the viewer original sees views #45 in his left eye and #56 in his right eye. The system may apply a replacement of the original #3 as new #4, the original #4 as new #5, and the original #4 as new #6. As a result the viewer then observes #3 in his left eye and #4 in his right eye, which improves the three dimensional viewing experience.
- [0032] In the case of cross talk between adjacent views, cross talk reduction techniques may be applied to reduce the leakage of one view into the adjacent view.
- [0033] If the viewer with sub-optimal viewing shares the same views with other viewers, the above viewer replacement technique may not be suitable. In this case, the technique may show the current viewing zone with viewers' positions and instructs the viewer to move to a better position.
- [0034] If the viewer with sub-optimal viewing shares the same views with other viewers, the above viewer replacement technique may not be suitable. In this case, the technique may replace the three dimensional display technique with a two dimensional display.
- [0035] If the viewer with sub-optimal viewing shares the same views with other viewers, the above viewer replacement technique may not be suitable. In this case, the technique may replace the three dimensional display technique for one or more viewers with a two dimensional display and maintain three dimensional display for other viewers. In this manner, the display may have a mixed mode two dimensional and three di-

mensional content simultaneously presented to a plurality of viewers.

[0036] The terms and expressions which have been employed in the foregoing specification are used therein as terms of description and not of limitation, and there is no intention, in the use of such terms and expressions, of excluding equivalents of the features shown and described or portions thereof, it being recognized that the scope of the invention is defined and limited only by the claims which follow.

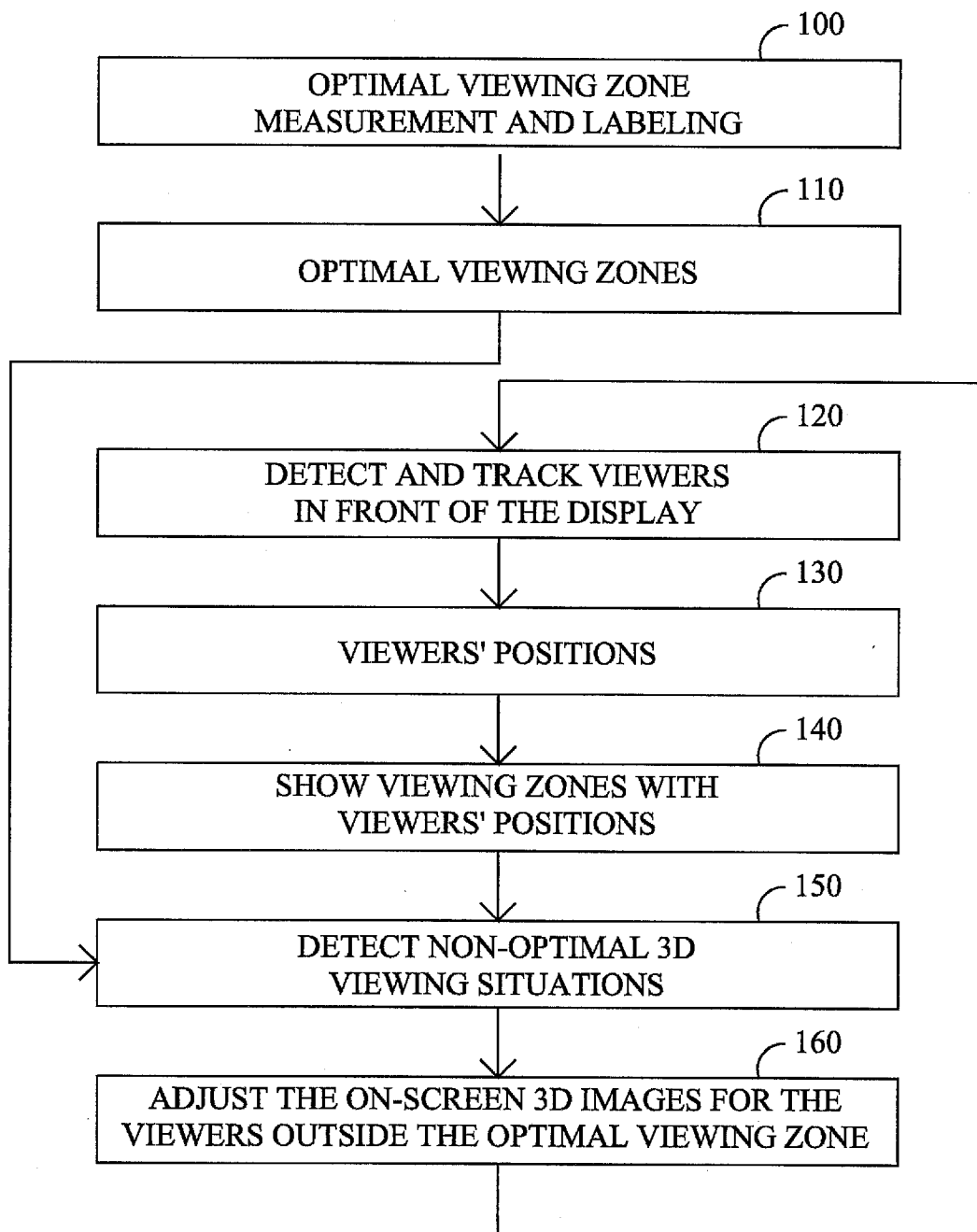
Claims

- [Claim 1] An auto stereoscopic display comprising:
(a) said auto stereoscopic display including a plurality of views thereby providing a perceived three dimensional image to a viewer;
(b) said display including a sensor that determines the position of said viewer with respect to said display;
(c) modifying said plurality of views to provide an improved said perceived three dimensional image to said viewer.
- [Claim 2] The display of claim 1 wherein said sensor obtains a two dimensional color image.
- [Claim 3] The display of claim 1 wherein said sensor obtains a three dimensional image.
- [Claim 4] The display of claim 1 wherein said sensor obtains both a two dimensional color image and a three dimensional image.
- [Claim 5] The display of claim 1 including presenting an image to said viewer indicating a desirability to relocate based upon said sensing said position of said viewer.
- [Claim 6] The system of claim 1 wherein said display temporally tracks said position of said viewer.
- [Claim 7] The display of claim 5 wherein said relocate is to a position of improved perceived three dimensional image.
- [Claim 8] The display of claim 1 wherein said sensor determines a position of a plurality of viewers with respect to said display.
- [Claim 9] The display of claim 8 wherein said display modifies said plurality of views to provide an improved said perceived three dimensional image to a plurality of said viewers.
- [Claim 10] The display of claim 1 wherein said modifying is a switching of a pair of said plurality of views.
- [Claim 11] The display of claim 9 wherein said modify of said plurality of views is the replacement of one view not shared among said plurality of viewers with another one of said plurality of views.
- [Claim 12] The display of claim 9 wherein said modify of said plurality of views is the replacement of one view shared among said plurality of viewers with another one of said plurality of views.
- [Claim 13] The display of claim 8 wherein said display modifies said plurality of views to provide a two dimensional view to said viewers.
- [Claim 14] The display of claim 8 wherein said display modifies said plurality of

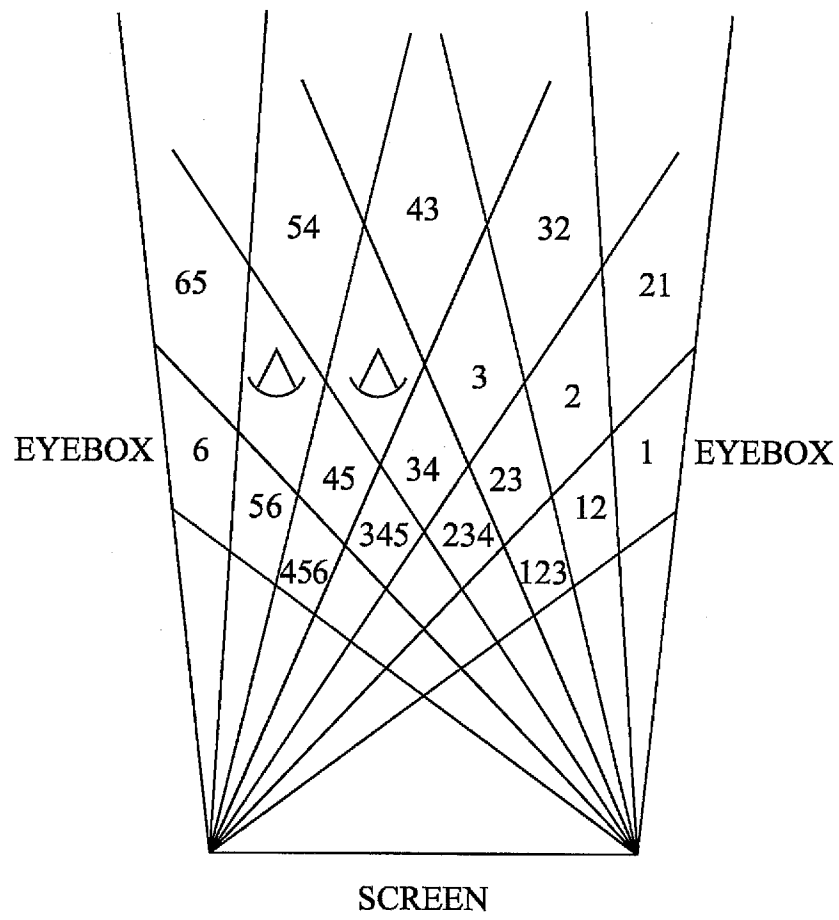
views in a manner to provide both a two dimensional view to at least one viewer and a three dimensional view to at least one other viewer.

[Claim 15] The display of claim 1 wherein said display also modifies said views in a manner to reduce cross talk.

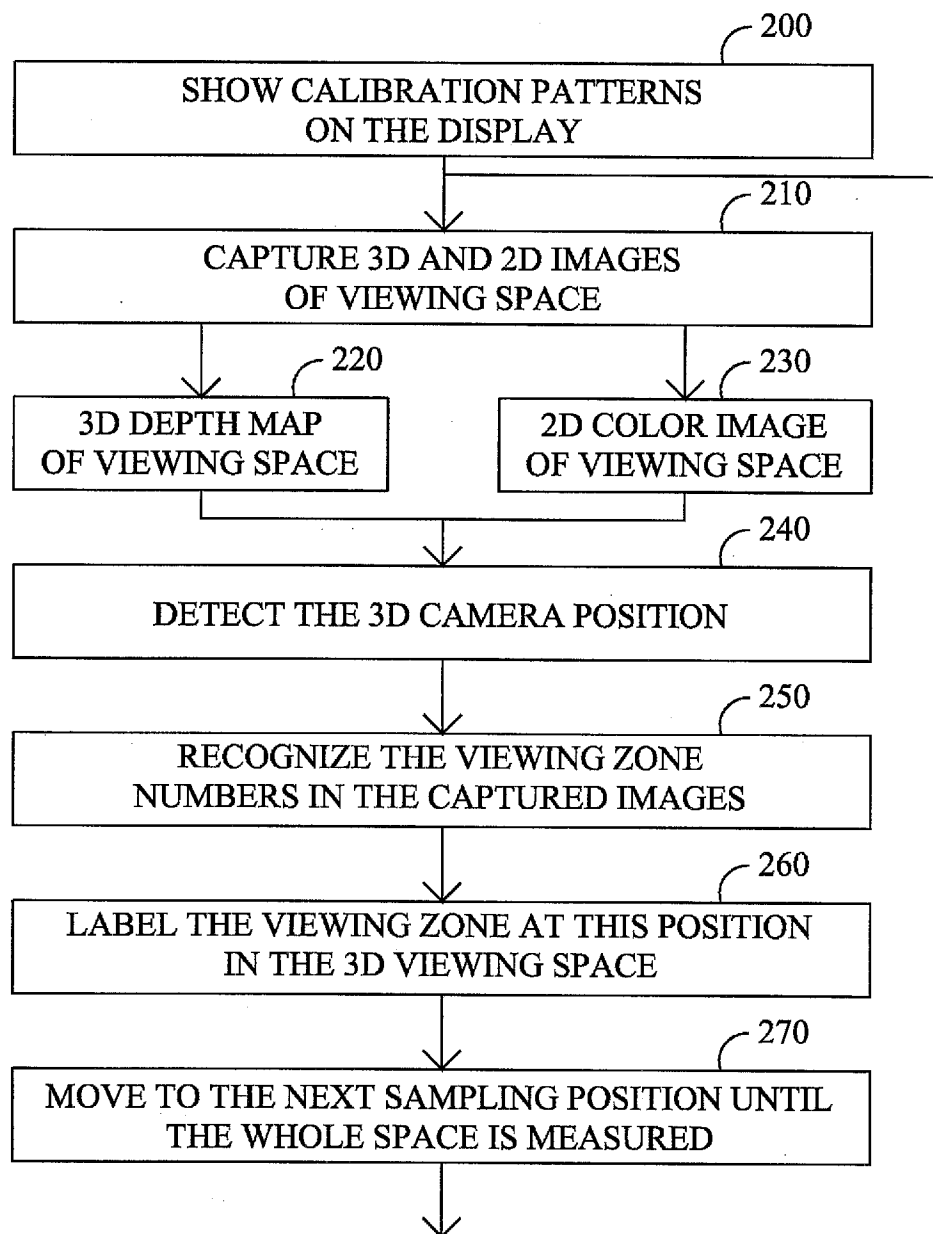
[Fig. 1]

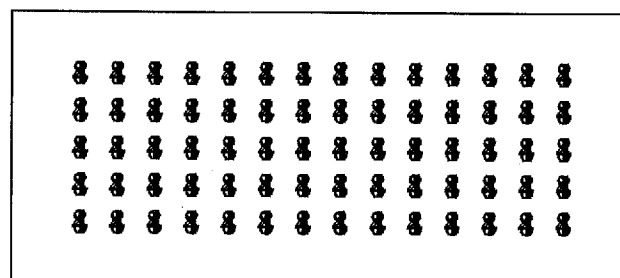
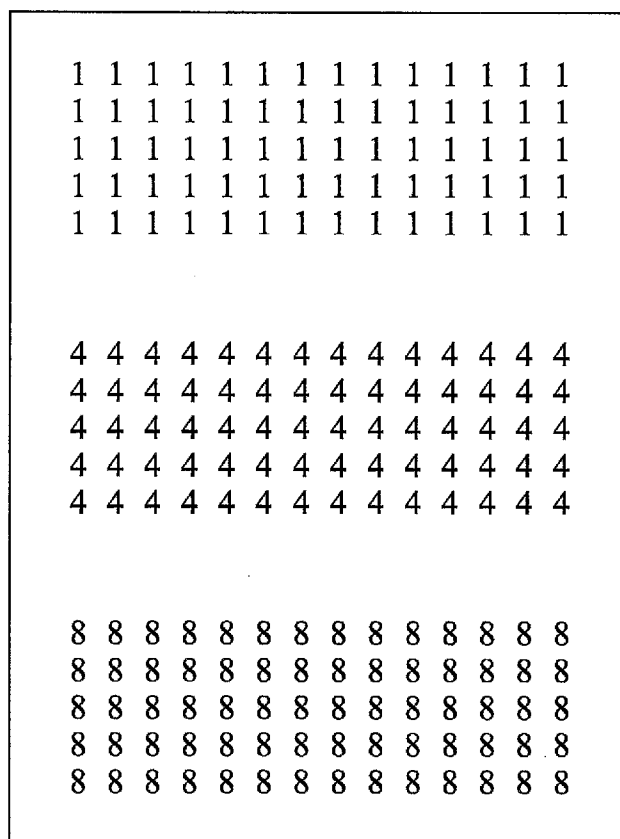


[Fig. 3B]

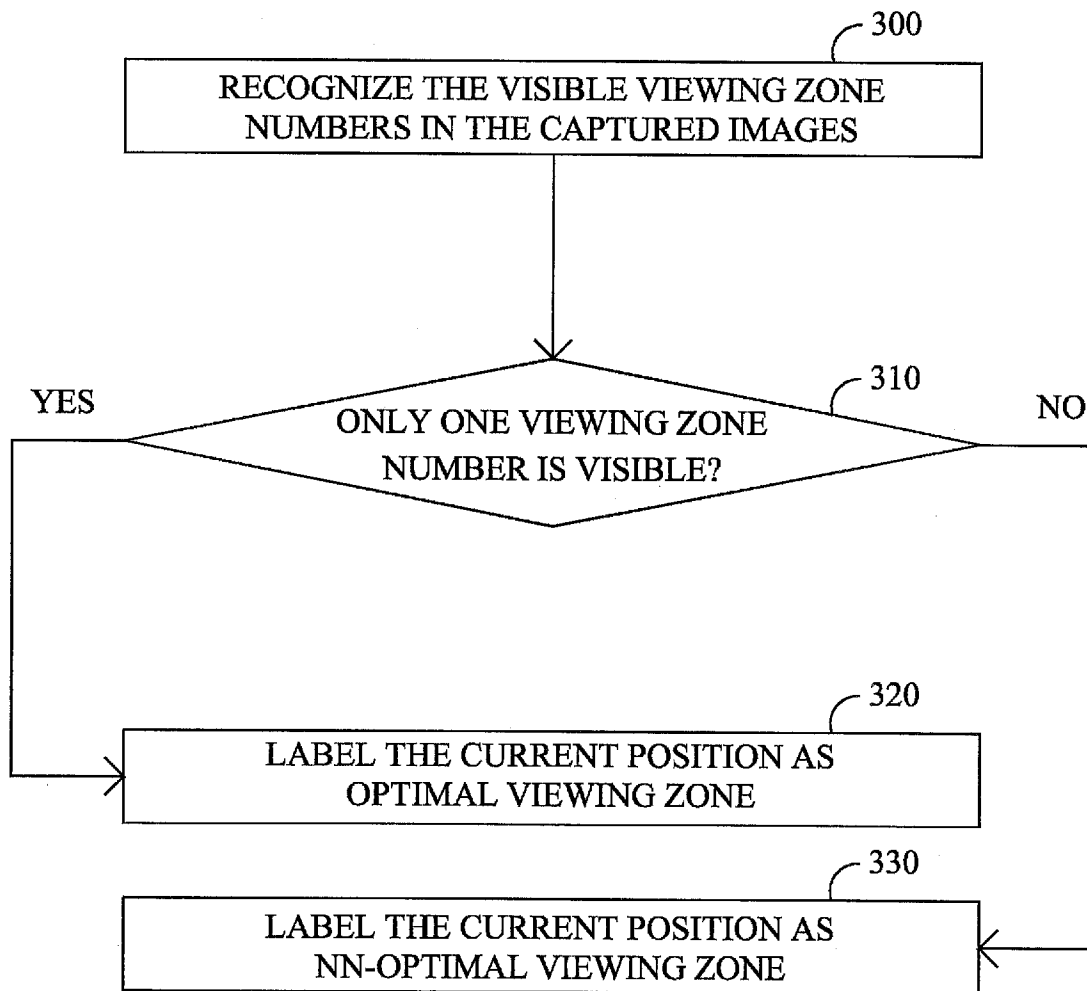


[Fig. 4]

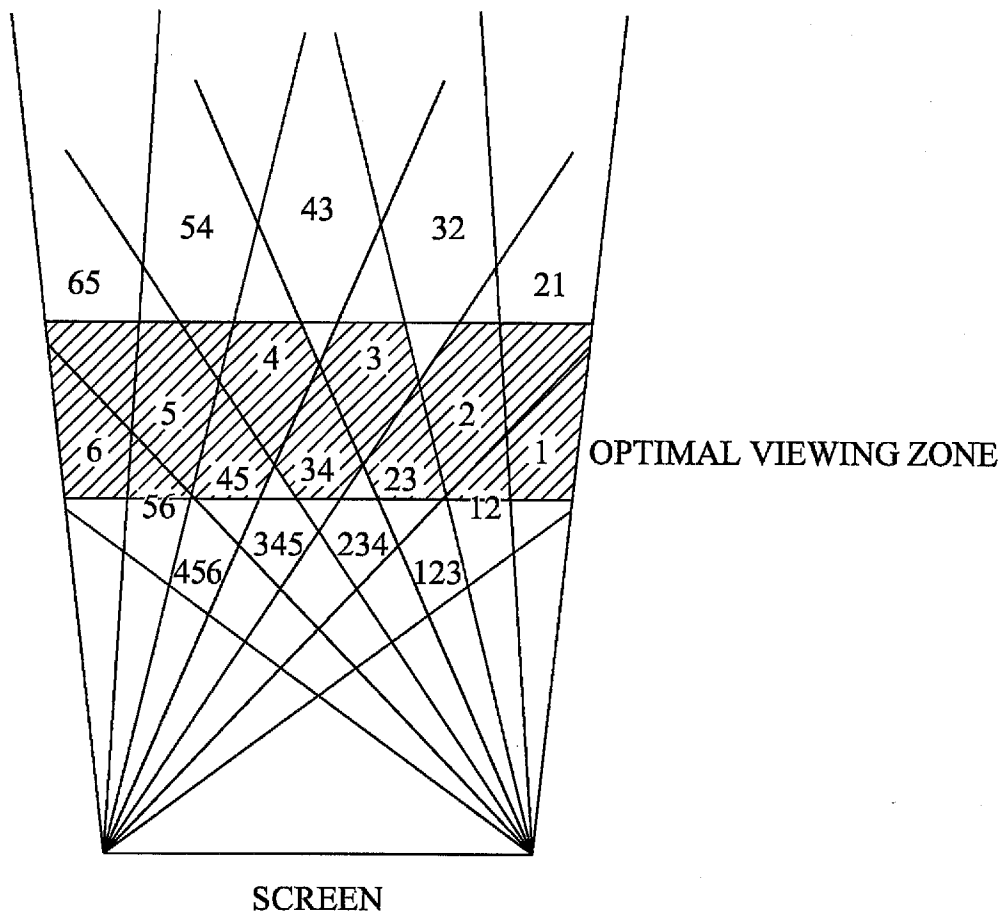




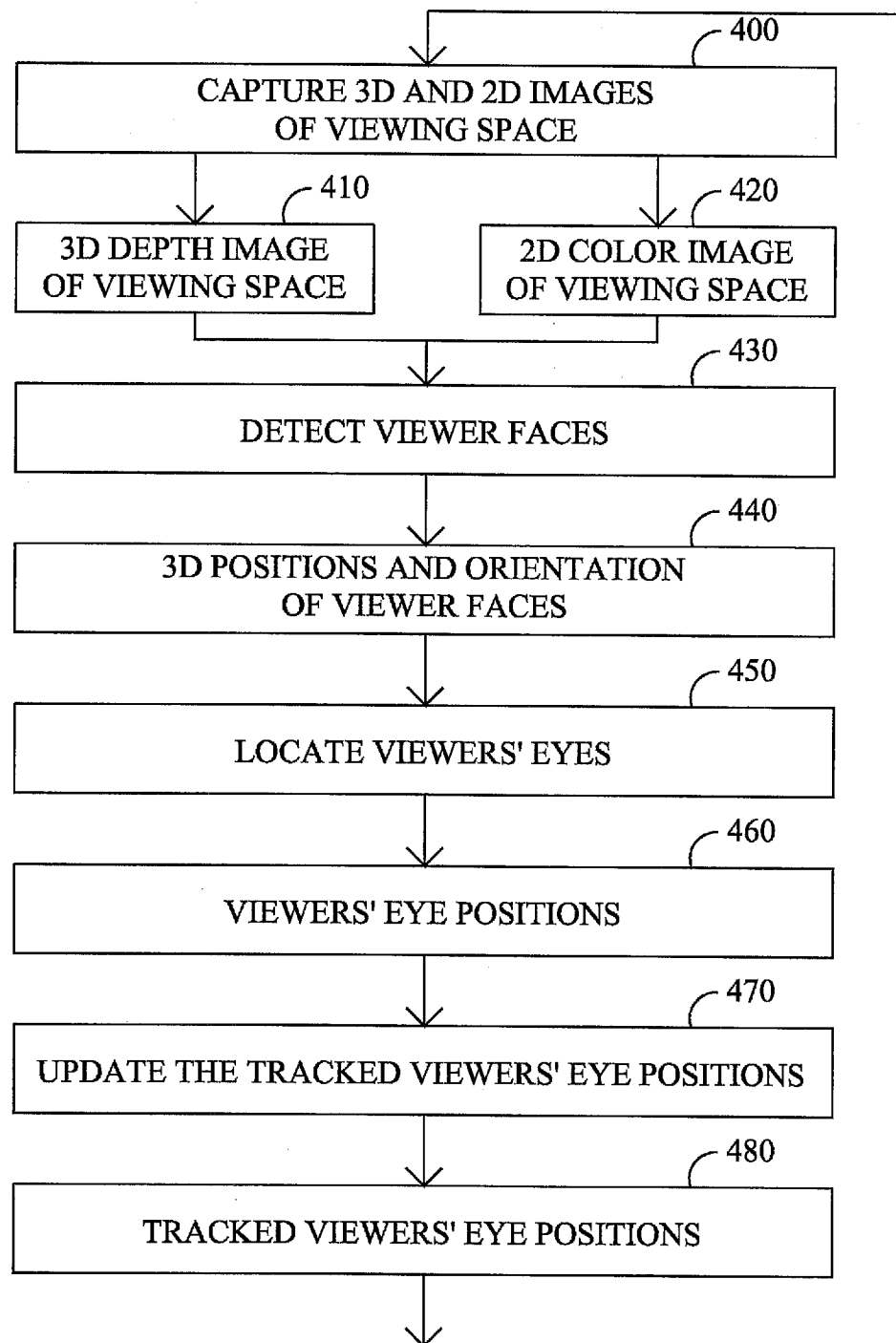
[Fig. 7]



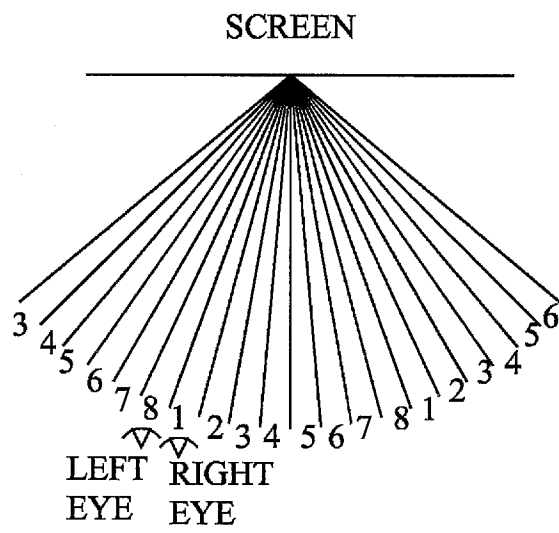
[Fig. 8]



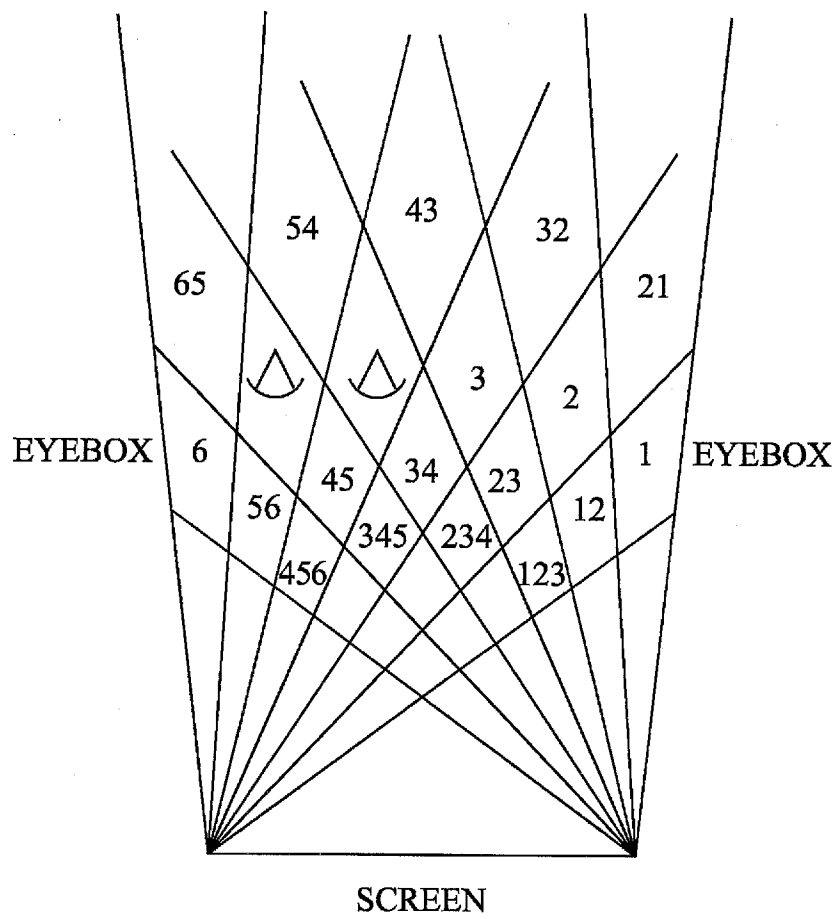
[Fig. 9]



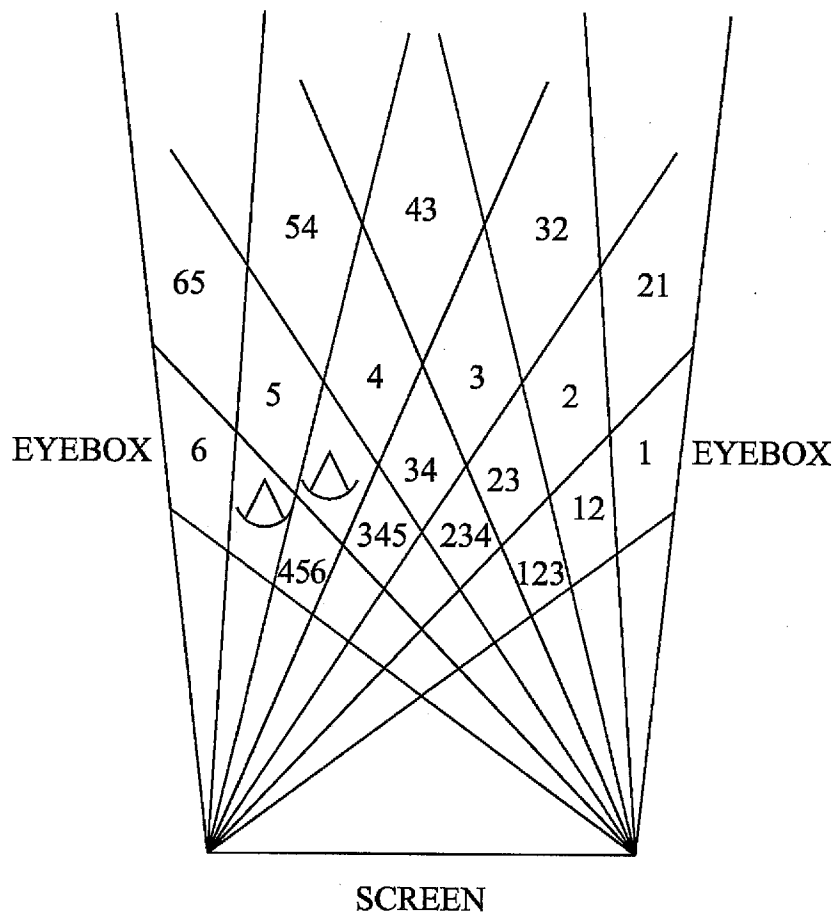
[Fig. 10]



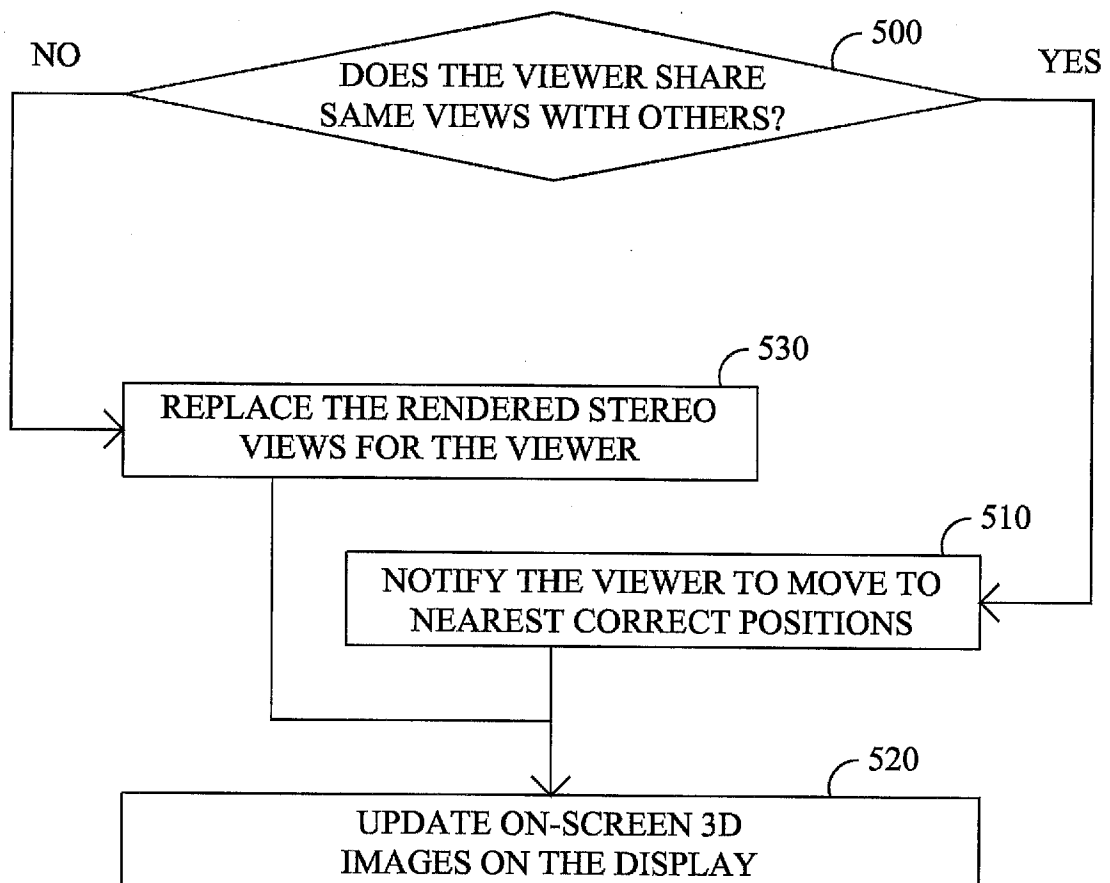
[Fig. 11A]



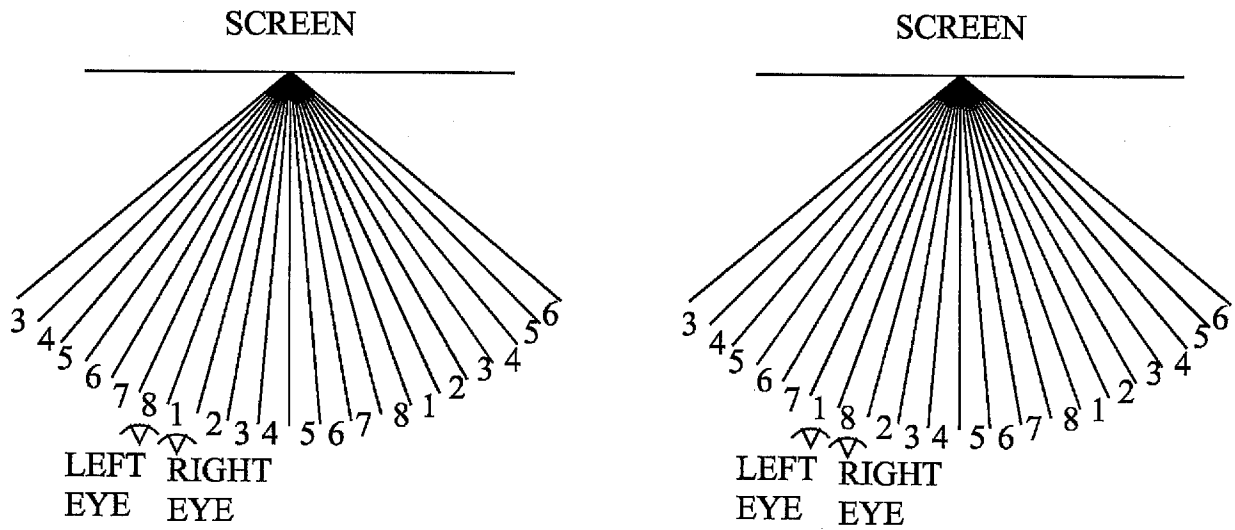
[Fig. 11B]



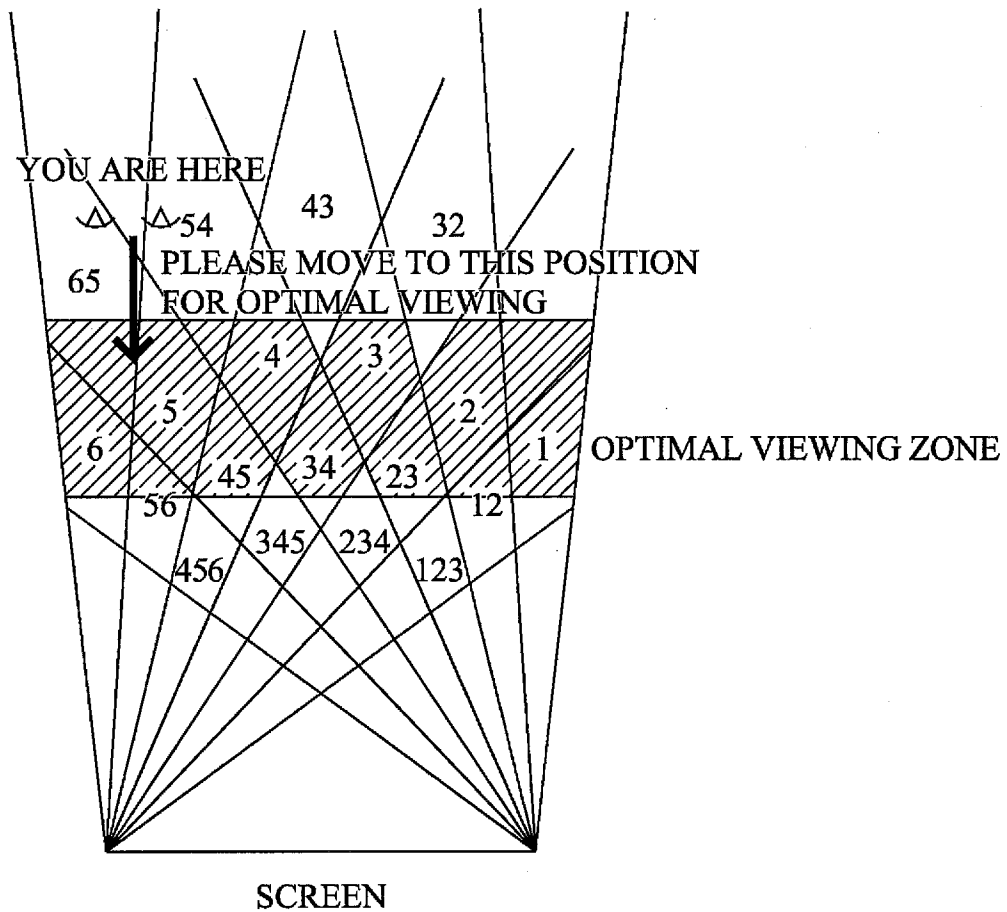
[Fig. 12]



[Fig. 13]



[Fig. 14]



INTERNATIONAL SEARCH REPORT

International application No.

PCT/JP2012/006573

A. CLASSIFICATION OF SUBJECT MATTER

Int.Cl. H04N13/04 (2006.01) i, G02B27/22 (2006.01) i

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

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

Int.Cl. H04N13/04, G02B27/22

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

Published examined utility model applications of Japan 1922-1996
 Published unexamined utility model applications of Japan 1971-2012
 Registered utility model specifications of Japan 1996-2012
 Published registered utility model applications of Japan 1994-2012

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

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	JP 10-174127 A (SANYO ELECTRIC Co., Ltd.) 1998.06.26, Paragraphs [0001]-[0055], Figs. 1-15	1, 3, 5-12
Y	(Family: none)	2, 4, 13-15
Y	JP 2006-72506 A (NORITSU KOKI Co., Ltd.) 2006.03.16, Paragraph [0004] (Family: none)	2, 4
Y	JP 2002-182154 A (MIXED REALITY SYSTEMS LABORATORY INC.) 2002.06.26, Paragraphs [0023]-[0125], Figs. 1-19 (Family: none)	13, 14

☒ Further documents are listed in the continuation of Box C.
 ☐ See patent family annex.

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Date of the actual completion of the international search

25.12.2012

Date of mailing of the international search report

08.01.2013

Name and mailing address of the ISA/JP

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5P

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INTERNATIONAL SEARCH REPORT

International application No.

PCT/JP2012/006573

C (Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT		
Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	JP 11-88914 A (SANYO ELECTRIC Co., Ltd.) 1999.03.30, Paragraph [0036] (Family: none)	15