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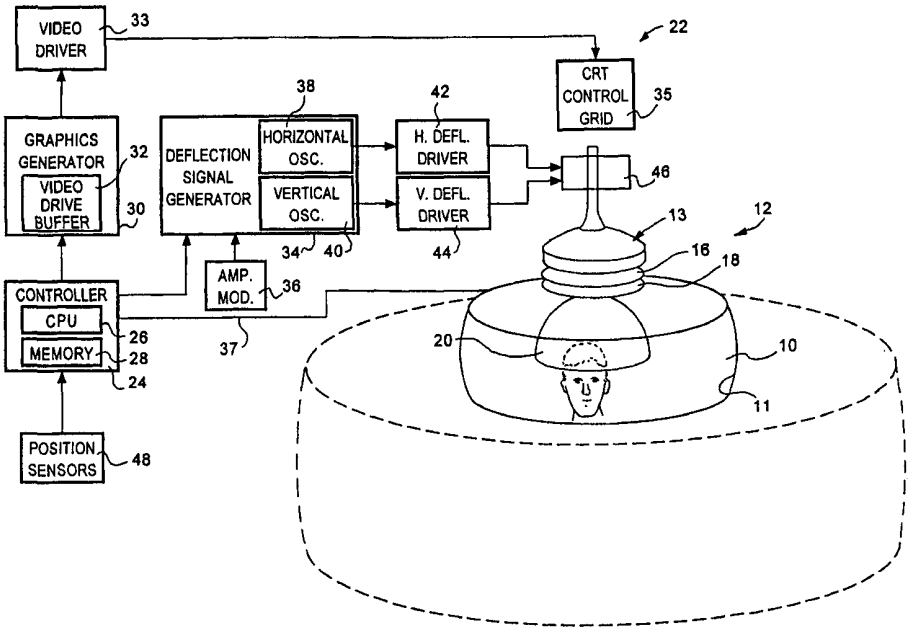

(57) Abstract

A halo display system generates a panoramic virtual image and includes an optical element (10) that surrounds a user's head by 360° degrees to project an annular virtual image or a portion thereof that appears to completely surround the user.

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A HALO DISPLAY SYSTEM GENERATING A PANORAMIC VIRTUAL IMAGE SURROUNDING THE USE

TECHNICAL FIELD

The present invention is directed to a virtual image display system and more particularly to a display system having an optical element that surrounds a user's head and is capable of projecting a panoramic virtual image that appears to surround the user, i.e., a Halo display system, so that as the user moves his head through 360°, he sees a continuous virtual image throughout the 360°.

BACKGROUND OF THE INVENTION

Binocular virtual image display systems have included one set of optics positioned in front of the user' right eye and a second set of optics positioned in front of the user's left eye in order to project a virtual image that appears directly in front of the user and is viewed by both eyes. With these known systems, it is extremely difficult to generate a virtual image that is large enough to take up the user's entire horizontal field of view. Typically, the virtual image generated by known systems is bounded on the right and left sides thereof. Because the user perceives the boundaries of the virtual image, he feels as if he is looking at a picture as opposed to being totally immersed in a virtual environment. Further, the optics of these known systems are typically supported or mounted on a user's head because the optics must be position in close proximity to each of the user's eyes in order to generate the desired virtual image. However, there are applications, such as location based entertainment systems, military command and control

systems and virtual environment systems for which it is undesirable to have the user wear head gear.

SUMMARY OF THE INVENTION

In accordance with the present invention, the disadvantages of prior virtual image display systems have been overcome. The virtual image display system of the present invention includes a single optical element that is viewable by both of the user's eyes. The optical element surrounds the user's head through 360° and is shaped so as to project an enlarged virtual image that surrounds or appears to surround the user so that as the user turns his head through 360°, he sees a continuous virtual image throughout the 360°. Because the optical element completely surrounds the user's head and is capable of generating a virtual image that also completely surrounds the user, no boundaries in the horizontal field of view of the virtual image are perceived by the user so that he can become totally immersed in the virtual environment created by the projected virtual image.

More particularly, the Halo display system of the present invention includes a video generator for generating a circular video image that is preferably in the shape of an annulus or a portion thereof. The optical element is annular and suspended so as to surround the user's head. The annular optical element receives the video image from the video generator either directly or via intervening optics including reflective elements so as to project a virtual image that appears to surround the user. The optical element is further shaped so that the virtual image projected is enlarged and appears to be at a distance from the user that is greater than the distance

of the optical element from the user and preferably at optical infinity.

In one embodiment of the present invention, the video generator is controllable to generate a video image in only a sector of the circular video image, the sector preferably being greater than 180°. In this embodiment, the system also includes one or more position sensors for sensing the position of a user's head. A controller is responsive to the position sensors to control the video generator to generate the video image in a particular sector so that it is received by a portion of the annular optical element that is in front of the user. The bandwidth of the system is thereby substantially reduced without affecting the visual presentation perceived by the user. This is because the remaining portion of the circular video image which is not generated and is blanked is positioned in back of the user's head and is therefore not viewable by the user. As the user turns his head, the controller is responsive to the output of the position sensors for moving the sector of the video image generated so that it is received by the portion of the annular optical element that is in front of the user's face as he moves.

The video generator of one embodiment of the present invention may include a cathode ray tube display having a spiral raster scan that is preferably interleaved with one or more additional spiral scans so as to further reduce the bandwidth of the system. In another embodiment of the present invention, the video generator may include a rotatable disc shaped support member having mounted thereon a number of linear arrays of light emitting diodes (LEDs) including a linear array of red LEDs, a linear

array of green LEDs and a linear array of blue LEDs. Each of the linear arrays of LEDs is aligned on a radius of the disc-shaped support. The disc is controlled to rotate or spin while the light emitting diodes are modulated with respective red, green and blue video information so as to scan a circular video image that is preferably in the shape of an annulus. In this embodiment, light sensing devices such as Charge Coupled Devices (CCD) may be disposed in arrays between each pair of adjacent linear arrays of LEDs. The light sensitive devices are used to sense the position of a user's head for feedback to the controller.

These and other objects, advantages and novel features of the present invention as well a details of an illustrated embodiment thereof will be more fully understood from the following description and the drawing.

BRIEF DESCRIPTION OF THE DRAWING

Fig. 1 is a perspective view of the virtual image display system of the present invention illustrated with a block diagram of the control system therefor;

Fig. 2 is an illustration of the spiral raster scan of the CRT depicted in Fig. 1, the scan generating a video image in the shape of an annulus;

Fig. 3 is a second embodiment of a video generator for the virtual image display system depicted in Fig. 1;

Fig. 4 is a perspective view of another embodiment of the virtual image display system of the present invention; and

Fig. 5 is a perspective view of a further embodiment of the virtual image display system of the present invention.

DESCRIPTION OF THE PREFERRED EMBODIMENT

The Halo display system of the present invention as shown in Fig. 1 includes an annular optical element 10 that surrounds the user such that the optical element 10 extends 360° about the user's head. The optical element 10 is a reflective lens preferably having a toroidal reflective inner surface 11. The reflective inner surface 11 is toroidal in shape so as to project an enlarged annular virtual image 14 of video information received from a video generator 12 with minimal distortion wherein the annular virtual image 14 appears to be at a distance from the user that is greater than the distance of the optical element from the user. Preferably, the annular virtual image is projected at optical infinity so that the user perceives a natural representation of the virtual image which may depict a virtual environment in which the user is to be immersed. The optical element 10 may be formed of lightweight acrylic or a polycarbonate material having a reflective coating.

In one embodiment of the present invention, as shown in Fig. 1, the image generator 12 includes a cathode ray tube (CRT) display 13 suspended above the user. The CRT 13 is controlled to generate a generally circular or 360° video image preferably in the shape of an annulus as described below. The image may be scanned on the CRT using white phosphor. The light from the phosphor is passed through a collimating lens 16 and from there through a liquid crystal color filter 18 that is positioned in front of the face of the cathode ray tube display 13. The liquid crystal color filter 18 is such that by varying a drive voltage applied to the filter, the color of the filter 18 changes. The color filtered light

impinges on a spherical reflective lens 20 that is suspended about the user's head above his eyes. The reflective lens 20 reflects the color filtered light onto the toroidal inner-surface of the optical element 10 which in turn projects the color filtered light as a virtual image that appears to completely surround the user.

Preferably, the reflective lens 20 is made of a lightweight acrylic or polycarbonate material with a reflective coating. It is noted that the reflective lens 20 need not be spherical. In particular the reflective lens 20 preferably has a parabolic outer reflective surface so as to improve the quality of the virtual image 14 projected. It is further noted that the reflective lens 20 and the optical element 10 may have reflective surfaces shaped otherwise, for example, one of the lenses 10 or 20 or both lenses may be aspheric, so as to generate a virtual image with minimal distortions as will be apparent to one of ordinary skill in the art. The use of multiple optical surfaces i.e., lens 10 and lens 20 allows distortions to more easily be corrected for a high resolution image as compared to other embodiments in which the image is projected directly onto the lens 10.

Preferably, the cathode ray tube 13 is controlled to generate the circular or 360° video image utilizing a spiral raster scan 53 as depicted in Fig. 2. A circular portion at the center of the scanned image may be blanked so as to generate the video image in the shape of an annulus. The center of the video image is blanked since it coincides with the top of the user's head and is not perceivable by the user.

The CRT 13 is controlled by a video generation control system 22. The video generation control system 22

includes a controller 24 having a central processing unit 26 that operates in accordance with software and data stored in a memory 28. The controller 24 controls a deflection signal generator 34 to generate the spiral raster scan 53. The deflection signal generator 34 includes a horizontal oscillator that generates a first modulated sine wave that is applied to a horizontal deflection driver 42 and a vertical oscillator 40 that generates a second modulated sine wave that is applied to a vertical deflection driver 44 such that the sine wave applied to the horizontal deflection driver 42 is shifted 90° from the sine wave applied to the vertical deflection driver 44. The outputs of the horizontal and vertical deflection drivers 42 and 44 are respectively coupled to the horizontal and vertical deflection coils 46 of the CRT 13 so as to generate the spiral raster scan 53. An amplitude modulator 36 generates a ramp signal or the like to provide a control for the instantaneous radius of the spiral raster scan 53 on the CRT and to control flyback of the spiral raster scan 53. It is noted that in order to further reduce the bandwidth of the system, the CRT 13 preferably includes two or more interleaved spiral raster scans.

The controller 24 also controls a graphics generator 30 that stores in a video drive buffer 32 video information representing the image to be generated by the image generator 12. The video information contained in the video drive buffer 32 for a given pixel is coupled to a video driver 33 to provide a signal for modulating a CRT control grid 35. More particularly, the video drive signal output from the driver 33 is fed to the control grid 35 to modulate the electron beam of the CRT to

control the light intensity on the CRT face plate at each pixel position within the spiral scan 53. The controller 24 synchronizes the timing of the output of the video pixel information from the buffer 32 to the driver 33 with the timing of the horizontal and vertical oscillator output signals coupled to the deflection drivers 42 and 44 to modulate each pixel of the spiral scan with the correct video information.

The controller 24 also controls a drive voltage applied on line 37 to the color filter 18 to sequentially switch at a fast rate the color of the filter 18 between red, green and blue to provide sequential color fields. The controller 24 synchronizes the drive voltage on line 37 for the field sequential color with the video information coupled to the video driver 33 and the horizontal and vertical deflection signals so that the user perceives a color virtual image. As discussed above, the center of the circular video image depicted on the face of the cathode ray tube display 13 may be blanked so as to generate a video image in the shape of an annulus. In order to further reduce the bandwidth requirements of the system, only one sector of the video image annulus need be generated such that only a corresponding sector of the spiral raster scan is modulated with video information. In this embodiment, therefore, the image depicted on the face of the CRT 13 is in the shape of a sector of an annulus. This sector of the video image annulus is preferably greater than 180° such as on the order of 200°. The remaining 160° sector of the raster scan is blanked. One or more position sensors 48 are preferably employed when only a sector of the circular video image is generated. These position sensors

may be mounted on the user or on a chair or the like supporting the user so as to sense the position of the user and most importantly the position of the user's head with respect to the annular optical element 10 so that the portion or sector of the annular optical element 10 that the user is facing can be determined. The position sensors 48 are coupled to the controller 24 so as to control the graphics generator 30 to couple video information for the sector of the video image annulus to be presented on the CRT 13 such that it is received by the portion of the optical element 10 that is in front of the user and extends partially about the user. The blanked portion of the video image annulus is therefore positioned directly in back of the user's head and is not viewable by the user.

As shown in Fig. 2, the sector A of the spiral raster scan 53 forming the video image annulus 51 may be modulated with video information whereas the sector B may be blanked. As the user moves his head through 360°, the position sensors 48 detect the head movement. The controller 24 is responsive to the head movement signal from the sensors 48 to control the graphic generator 30 to change the content of the video image in the video image modulated sector A of the annulus 51 and to also change or rotate the angular position of the video containing sector A as well as the blanked sector B so that as the user moves or rotates through 360° he sees a continuous virtual image through the 360°. Preferably, the projected virtual image is centered in front of the user and extends partially about the user so that the blanked portion is positioned directly in back of the user's head so as not to be perceivable.

In a second embodiment of the virtual image display system of the present invention, as shown in Fig. 3, the video generator 12 may take the form of a rotatable or spinning disc support member 60 on which a number of linear arrays of light emitting diodes (LEDs) are radially disposed. Preferably, this video generator includes at least one linear array of red LEDs 62 disposed along a radius of the disc or circular support member 60 from a central area 64 to an outer periphery 66 of the disc. The video generator also includes a linear array of green LEDs 68 and a linear array 70 of blue LEDs similarly disposed along a respective radius of the disc 60. Each of the LEDs of the red, green and blue linear arrays 62, 68 and 70 is modulated with respective red, green and blue video information coupled to the LEDs from respective sources 72, 74 and 76 in response to respective outputs from a controller 80. The controller 80 also controls a disc drive 82 to spin the rotatable disc 60 while the LEDs of the arrays 62, 68 and 70 are modulated with the video information so that a video image is scanned by the video generator in the shape of an annulus. It is noted that although only three linear arrays of light emitting diodes are depicted in Fig. 3, the video generator in accordance with this embodiment may have more than one linear array of light emitting diodes of a particular color mounted on the spinning disc 60. Preferably, disposed between each adjacent pair of linear arrays is an array of light sensitive devices such as Charged Coupled Devices (CCD) as depicted at 84, 86 and 88. The outputs of the CCDs arrays 84, 86 and 88 are coupled to the controller 80 to sense the position of the user's head. The controller 80 is responsive to the outputs from the CCD arrays 84, 86 and

88 to control the video information applied from each of the sources 72, 74 and 76 to the linear arrays of LEDs 62, 68 and 70 so as to generate only a sector of the video image annulus if desired. As discussed above, this sector of the video image annulus is preferably greater than 180° and on the order of 200°, the sector being such that it is received by a portion of the optical element 10 that it is centered in front of the user's face and extends partially about the user's head. The blanked remainder of the video image annulus is received by that portion of the optical element 10 that is in back of the user's head so as not to be viewable by the user.

The spinning disc 60 may be generally planar. Alternatively, the disc may be non-planar such that it has the general shape of a cone as depicted in Figs. 4 and 5. In Fig. 4, the cone-shaped spinning disc 90 has a conical side wall 92 with an inner surface 94 on which the linear arrays of LEDs 62, 68 and 70 are mounted in a radial pattern as shown for the arrays 62 and 68. More particularly, the linear arrays 62, 68 and 70 extend from a central area 96 of the disc along a line extending from an apparent vertex of the cone 96 to the outer peripheral edge 98 thereof. The annulus video image generated by the spinning disc 90 is reflected by a spherical or parabolic reflective lens 20 onto the optical element 10. The optical element 10 in turn projects an enlarged annular virtual image that surrounds the user, or appears to surround the user, if only a sector of the image is generated as described above. As shown in Fig. 4, the optical element 10 as well as the reflective lens 20 and spinning disc 90 are supported on a hood support 100 that is suspended from a frame or the like (not shown).

Preferably the hood support 100 is vertically adjustable to accommodate users of various heights. The disc drive 82 is also supported by the hood 100; however, the controller 80 may be disposed remotely therefrom as will be apparent to one of ordinary skill in the art. In Fig. 5, the spinning disc 112 is also generally cone-shaped being shown as a truncated cone, however, the LEDs are disposed on an outer, conical side wall 110 as opposed to an inner side wall as shown in Fig. 4. The cone-shaped disc 112 is also in an inverted position such that the top portion 114 of the cone -shaped disc 112 is larger than the bottom portion 116 thereof which is adjacent to the user's head. In this embodiment, the LED arrays 62, 68 and 70 are mounted on the side wall 110 so as to project the annulus video image directly onto the optical element 10.

Many modifications and variations of the present invention are possible in light of the above teachings. Thus, it is to be understood that, within the scope of the appended claims, the invention may be practiced otherwise than as described hereinabove.

What is claimed and desired to be secured by Letters Patent is:

CLAIMS

1. A panoramic virtual image display system comprising:

a video generator for generating video information; and

an annular optical element surrounding a user's head, said optical element receiving the video information from the video generator and being shaped so as to project an enlarged virtual image of said video information from the video generator so that the virtual image appears to surround the user.

2. A panoramic virtual image display system as recited in claim 1 wherein said video generator generates said image with at least one spiral raster scan.

3. A panoramic virtual image display system as recited in claim 1 wherein said video generator generates the image with at least two interleaved spiral raster scans.

4. A panoramic virtual image display system as recited in claim 1 wherein said video information is a generally circular video image with a centrally located blanked area therein so as to form an annulus video image.

5. A panoramic virtual image display system as recited in claim 4 wherein at least one sector of said annulus video image is blanked.

6. A panoramic virtual image display system as recited in claim 5 wherein said blanked sector is less than or equal to 180°.

7. A panoramic virtual image display system as

recited in claim 6 including a position sensor to sense the position of a user's head; and a controller for controlling said blanked sector of said video image to move in response to movement of the user's head so as to substantially maintain said blanked sector in back of the user's head.

8. A panoramic virtual image display system as recited in claim 1 wherein said optical element has a toroidal reflective surface.

9. A panoramic virtual image display system as recited in claim 8 wherein said optical element is fully reflective.

10. A panoramic virtual image display system as recited in claim 8 wherein said optical element is partially reflective.

11. A panoramic virtual image display system as recited in claim 1 including at least one reflective lens for reflecting said video image onto said optical element.

12. A panoramic virtual image display system as recited in claim 11 wherein said reflective lens is spherical.

13. A panoramic virtual image display system as recited in claim 11 wherein said reflective lens is a parabolic lens.

14. A panoramic virtual image display system as recited in claim 1 wherein said video generator includes a cathode ray tube with a spiral raster scan and at least one blanking period for scanning an annulus.

15. A panoramic virtual image display system as recited in claim 14 including a position sensor to detect a direction in which said user is facing and a controller responsive to said position sensor to modulate said scan with video information to generate a video image in a sector of said annulus to project only a portion of said annular virtual image said projected portion surrounding the user's face.

16. A panoramic virtual image display system as recited in claim 15 including a second blanking period to blank said spiral scan in the area of said annulus other than said sector.

17. A panoramic virtual image display system as recited in claim 14 wherein said cathode ray tube has white phosphor and said system includes a liquid crystal color filter for receiving light from the cathode ray tube, said color filter being controllable to sequentially change the color thereof for providing a color virtual image.

18. A panoramic virtual image display system as recited in claim 1 wherein said video generator includes a rotatable generally circular support and a plurality of linear arrays of light emitting diodes including a linear array of red light emitting diodes, a linear array of green light emitting diodes and a linear array of blue light emitting diodes each of said linear arrays being aligned on a radius of said circular support, said red, green and blue light emitting diodes being modulated with red, green and blue video information as said circular support is controlled to spin to scan a color video image in the shape of at least one sector of an annulus.

19. A panoramic virtual image display system as recited in claim 18 wherein said color video image is in the shape of a 360° annulus.

20. A panoramic virtual image display system as recited in claim 18 wherein said support is generally planar in the shape of a disc.

21. A panoramic virtual image display system as recited in claim 18 wherein said support is non-planar in the general shape of a cone, said linear arrays being mounted on a side wall of said cone in a radial pattern extending from a central area towards an outer peripheral edge of said support.

22. A panoramic virtual image display system as recited in claim 18 wherein said linear arrays are mounted on an inner surface of said support side wall.

23. A panoramic virtual image display system as recited in claim 18 wherein said linear arrays are mounted on an outer surface of said support side wall.

24. A panoramic virtual image display system as recited in claim 18 including an array of light sensitive devices disposed between each pair of adjacent linear arrays of light emitting diodes for sensing the position of a user's head.

25. A panoramic virtual image display system as recited in claim 24 wherein said light sensitive devices are Charged Coupled Devices.

26. A panoramic virtual image display system comprising:

a video generator for generating a generally circular video image; and

an annular optical element surrounding a user's head, said optical element receiving said video image and being shaped so as to project an enlarged annular virtual image of said video image that surrounds the user and appears to be at a distance from the user that is greater than the distance of said optical element from the user.

27. A panoramic virtual image display system as recited in claim 26 wherein said video generator includes a cathode ray tube with a spiral raster scan and at least one blanking period for scanning an annulus video image.

28. A panoramic virtual image display system as recited in claim 27 including a position sensor to detect a direction in which said user is facing and a controller responsive to said position sensor to modulate said scan with video information to generate a video image in only a sector of said annulus to project only a portion of said annular virtual image said projected portion surrounding the user's face.

29. A panoramic virtual image display system as recited in claim 28 including a second blanking period to blank said spiral scan in the area of said annulus other than said sector.

30. A panoramic virtual image display system as recited in claim 27 wherein said cathode ray tube has white phosphor and said system includes a liquid crystal color filter for receiving light from the cathode ray tube, said color filter being controllable to sequentially change the color thereof for providing a color virtual

image.

31. A panoramic virtual image display system as recited in claim 26 wherein said video generator includes a rotatable generally circular support and a plurality of linear arrays of light emitting diodes including a linear array of red light emitting diodes, a linear array of green light emitting diodes and a linear array of blue light emitting diodes each of said linear arrays being aligned on a radius of said circular support, said red, green and blue light emitting diodes being modulated with red, green and blue video information as said circular support is controlled to spin to scan at least one sector of a color circular video image in the shape of an annulus.

32. A panoramic virtual image display system as recited in claim 31 wherein said support is generally planar in the shape of a disc.

33. A panoramic virtual image display system as recited in claim 31 wherein said support is non-planar in the general shape of a cone, said linear arrays being mounted on a side wall of said cone in a radial pattern extending from a central area towards an outer peripheral edge thereof.

34. A panoramic virtual image display system as recited in claim 31 wherein said linear arrays are mounted on an inner surface of said support side wall.

35. A panoramic virtual image display system as recited in claim 31 wherein said linear arrays are mounted on an outer surface of said support side wall.

36. A panoramic virtual image display system as recited in claim 31 including an array of light sensitive devices disposed between each pair of adjacent linear arrays of light emitting diodes for sensing the position of a user's head.

37. A panoramic virtual image display system as recited in claim 36 wherein said light sensitive devices are Charged Coupled Devices.

38. A panoramic virtual image display system as recited in claim 26 wherein said optical element has a toroidal reflective surface.

39. A panoramic virtual image display system as recited in claim 38 wherein said optical element is fully reflective.

40. A panoramic virtual image display system as recited in claim 38 wherein said optical element is partially reflective.

41. A panoramic virtual image display system as recited in claim 26 including a reflective lens for reflecting said video image onto said optical element.

42. A panoramic virtual image display system as recited in claim 41 wherein said reflective lens is spherical.

43. A panoramic virtual image display system as recited in claim 41 wherein said reflective lens is a parabolic lens.

44. A panoramic virtual image generator comprising:

a cathode ray tube display;

a color filter controllable to provide sequential color fields and positioned with respect to the cathode ray tube display to receive light therefrom;

a source of video information coupled to the cathode ray tube display and controllable to provide video information to modulate the light intensity of a beam of the display at a plurality of pixel positions;

a beam deflection driver system coupled to the cathode ray tube display for controlling the beam of the display to scan in a spiral;

a controller for synchronizing the video information with the spiral scan and the sequential color fields to provide at least a portion of a generally circular color image; and

an optical system including an annular optical element that surrounds a user's head, the optical system receiving the color image and directing it to the annular optical element so that the image is perceivable by the user as surrounding the user.

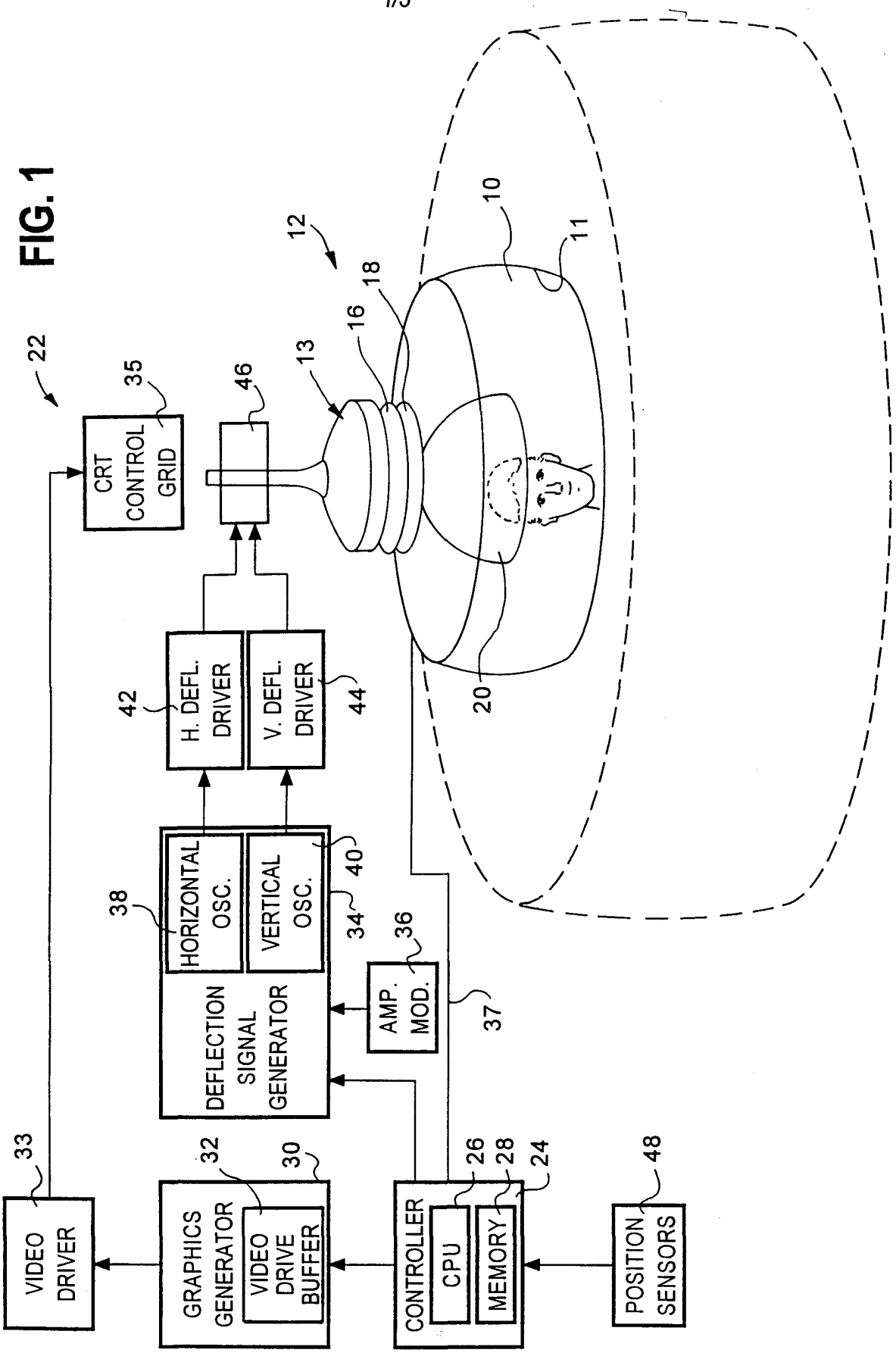
45. A panoramic virtual image generator, comprising:

a rotatable generally circular support and a plurality of linear arrays of light emitting diodes mounted on the support, each array being of a different color;

a source of video information coupled to said diodes to modulate the light emitting diodes with video information to scan at least a portion of a generally circular color image as said support is rotated; and

an optical system including an annular optical element that surrounds a user's head, the annular optical element receiving the color image so that the image is perceivable by the user as surrounding the user.

FIG. 1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VERTICAL OSC.
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AMP. MOD.
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DEFLECTION SIGNAL GENERATOR
33
32
30
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24
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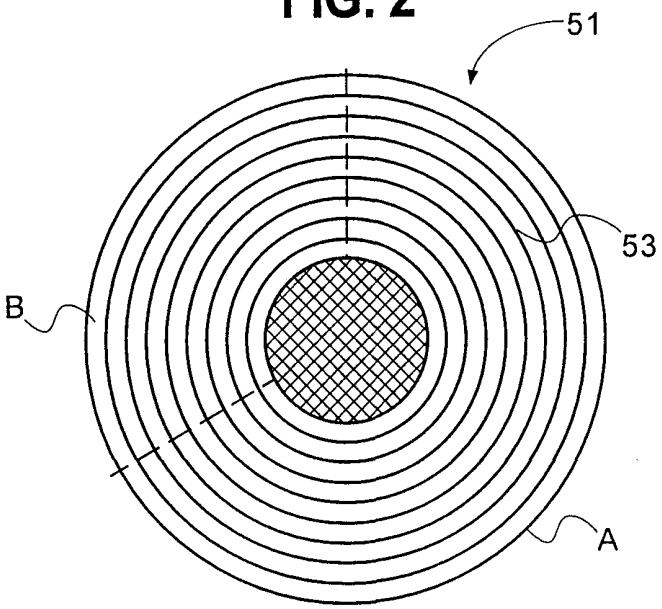
VIDEO DRIVER
GRAPHICS GENERATOR
VIDEO DRIVE BUFFER
CONTROLLER
CPU
MEMORY
POSITION SENSORS

FIG. 2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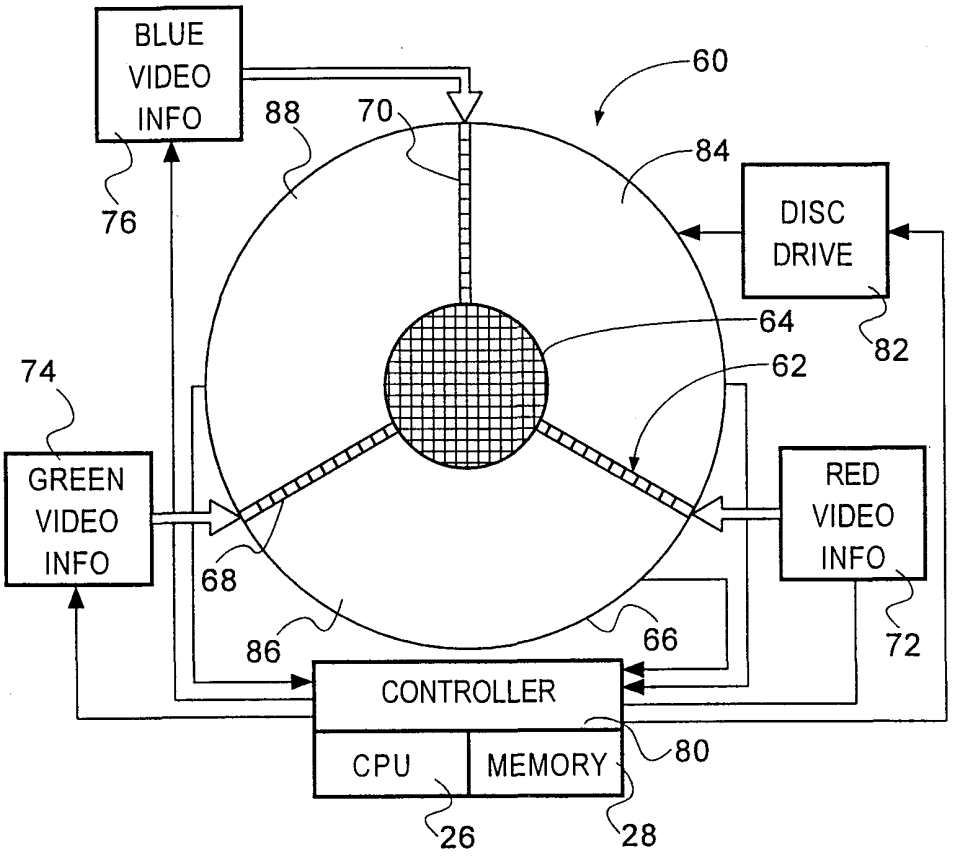
A

FIG. 3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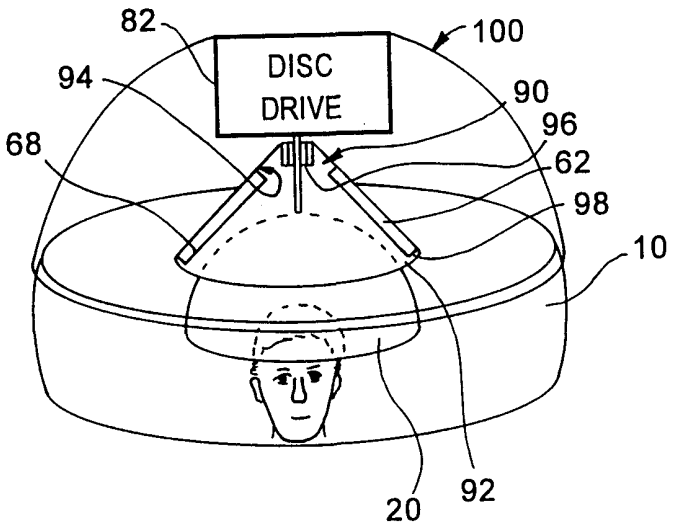
76
88
70
60
84
DISC DRIVE
82
64
62
74
GREEN VIDEO INFO
68
RED VIDEO INFO
72
86
66
CONTROLLER
80
CPU
MEMORY
26
28

FIG. 4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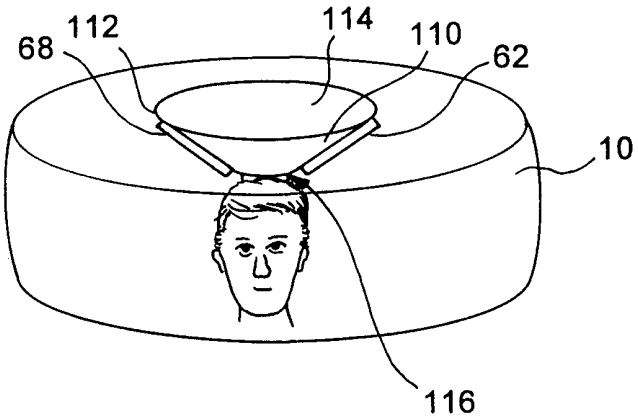
100
DISC
DRIVE
94
90
96
68
62
98
10
20
92

FIG. 5


68
112
114
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62
10
116

INTERNATIONAL SEARCH REPORT

International application No.
PCT/US00/03751

A. CLASSIFICATION OF SUBJECT MATTER

IPC(7) :H 04 N 7/00
US CL :348/36

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)

U.S. : 348/36, 37, 38, 39
IPC(7): H 04 N 7/00

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

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

EAST

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	US 5,130,794 A (RITCHEY) 14 JULY 1992, FIGS. 7-10, 15-18, 24-26, AND 55.	1-45
Y	US 5,023,725 A (MCCUTCHEN) 11 JUNE 1991, FIGS. 1-9, 18-26, AND 31.	1-45
Y	US 5,721,585 A (KEAST ET AL) 24 FEBRUARY 1998, FIGS. 1-8.	1-45
Y	US 4,656,506 A (RITCHEY) 07 APRIL 1987, FIGS. 2-5, 11, AND 14-18.	1-45

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

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

Date of the actual completion of the international search	Date of mailing of the international search report
20 APRIL 2000	05 MAY 2000

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