THREE DIMENSIONAL DISPLAY APPARATUS

This invention relates to a three dimensional display apparatus.

Display apparatus are in common use, e.g. in television receivers, computer interfaces, instrumentation and visual display units. Generally these are two dimensional display apparatus, in that they display only a two-dimensional picture.

A variety of cues are present in the picture provided by a two dimensional display, which provide the observer with a perception of depth. Such cues include shadow, size, perspective and obscuration of far objects by close ones. However, two of the most important depth cues which are used by human vision are missing in a conventional two dimensional display. These are the difference between the views seen by the two eyes, and the continuous change of view which an observer would expect if he were moving his head with respect to a true three dimensional image. These two cues are necessary if the observer is to be given a proper perception of three dimensions.

Various display systems have been made which require the user to wear spectacles so that different views of a scene are presented to each eye. These provide human vision with stereoscopic information, but not with

the information or cue expected from movement of the head. Further, such spectacles are inconvenient to wear.

Some attempts have been made to construct three dimensional display apparatus which do not require the user to wear spectacles. In many of these apparatus the picture seen on the screen depends on the direction from which the screen is viewed. The picture seen on the screen is that which would be seen of the three dimensional image from the same direction of observation if the three dimensional image were present in place of the display apparatus. The image presented by these apparatus provides all of the information needed by human vision to perceive depth, so is apparently three dimensional. Most of these apparatus have moving parts which make them expensive and delicate.

For a conventional display such as a television screen, a picture of an object is assembled from a two dimensional array of pixels. In a similar way a three dimensional image of an object might be assembled form a three dimensional array of pixels but such an apparatus would be complicated and expensive.

I have now devised a three dimensional display apparatus which overcomes the drawbacks noted above.

In accordance with this invention as seen from one aspect, there is provided a three dimensional display apparatus, comprising a spatial light modulator, a control system controlling said spatial light modulator for causing a plurality of different images of a subject to be formed in succession on said spatial light modulator, each different image being a view of said subject from a different angle, a two dimensional display device controlled by said control system to emit a spot of light at selected locations thereon, and a lens system for forming a beam of light from said spot and projecting said beam through the spatial light modulator at angles dependent upon the locations of said spot so that the different images formed on the spatial light modulator are visible from different directions.

A spatial light modulator is a device whose optical

transparency or optical reflectivity can be electronically controlled. Such devices can be divided into arrays in which the transparency or reflectivity of each element of the array can be individually controlled. Consequently they can be used to present a picture comprised of many pixels. An example of a spatial light modulator is a liquid crystal display (LCD).

The apparatus in accordance with this invention in effect utilises both lateral multiplexing and time multiplexing. Lateral multiplexing is a technique by which a two dimensional display presents not just one but several pictures in such a way that each picture is visible from a different position of observation. Each picture is a different view of the same solid object, and the positions from which the views are visible correspond to the angles from which the views were imaged. The result is an image which appears three dimensional. The two eyes of an observer see different views because each eye observes from a separate position, and the views seen by the observer change as he moves his head round the display.

In the apparatus in accordance with this invention, instead of presenting several views simultaneously as with conventional lateral multiplexing, the views are presented in sequence while the position from which the display is visible is adjusted. Provided the angle between views is sufficiently fine and the sequence of views is repeated at sufficiently short intervals, the image displayed by the apparatus will appear smooth and three dimensional.

Also in accordance with this invention there is provided a three dimensional display apparatus, comprising a two dimensional display device, a control system controlling said two dimensional display device for causing a plurality of different images of a subject to be formed in succession on said two dimensional display device, each different image being a view of said subject from a different angle, a lens system and a spatial light modulator positioned in front of the two dimensional display device, the spatial light modulator being a device whose optical transparency is electronically controlled, and the control system being coupled to the spatial light modulator to cause the spatial light modulator to be

transparent at a spot the position of which is selectable, the different images formed on the two dimensional display device being visible from different directions dependent upon the location of said spot on the spatial light modulator.

Embodiments of the invention will now be described by way of examples only and with reference to the accompanying drawings, in which:

FIGURE 1 is a diagrammatic section through a three dimensional display apparatus in accordance with the invention;

FIGURE 2 is a ray diagram which demonstrates how a view is displayed by the apparatus of Figure 1;

FIGURE 3 is a diagrammatic plan of a dimensional display apparatus used in a three dimensional television system;

FIGURE 4 is a diagrammatic section through a second embodiment of three dimensional display apparatus where the lens system comprises a lenticular array;

FIGURE 5 is a ray diagram for the apparatus shown in Figure 4;

FIGURE 6 is a diagrammatic section through a third embodiment of three dimensional visual display apparatus where the two dimensional device comprises a lenticular array scanned by a ray of coherent light;

FIGURE 7 is a ray diagram showing use of the apparatus shown in Figure 6 to make a hologram; and

FIGURE 8 is a diagrammatic section through an embodiment of three dimensional display apparatus using a cathode ray tube to provide the views and a liquid crystal display to determine the direction in which each view is projected.

Referring to the apparatus shown in Figures 1 and 2, a lens 1 is placed face to face against a spatial light modulator 2. The screen 3 of a two dimensional display device 4 is placed in the focal plane 5 of the lens 1. An opaque box 6 is fitted round the rear and sides of the assembly to exclude extraneous light.

A succession of two dimensional pictures of the three dimensional image are displayed by the spatial light modulator. Each picture portrays what would be seen of the image from a specified point of view, and is hereafter referred to as a "view". Simultaneous to the display of a view, a spot of light 7 is displayed on the screen 3 of the two dimensional display device 4. When light from the spot 7 passes through the lens 1, it is converted into

parallel rays of light 8 whose direction depends on the position of the spot 7 in the screen 3 of the two dimensional display device 4. The position of the spot 7 is so controlled that light passes through the spatial light modulator 2 only to that view point 9 from which the view on the spatial light modulator 2 is supposed to be seen. The width of the spot 7 determines the arc of view points within which the view is visible. The display of each view is to be repeated sufficiently quickly for the intervening dark periods not to be noticeable by the human eye. Consequently an image which is apparently three dimensional is perceived.

Among the possible types of two dimensional display devices 4 are cathode ray tubes, electro-luminescent displays, arrays of light emitting diodes, spatial light modulators with background illumination, and screens illuminated by a scanned ray of light.

Among the possible types of lens 1 are lenses with spherical surfaces, lenticular arrays of many spherical or cylindrical lenses, Fresnel lenses and holographic optical elements.

Among the possible types of three dimensional image which might be displayed by a three dimensional display device are stereoscopic images, multiplexed images, images in parallax, fully three dimensional images, and images in colour, as follows.

For stereoscopic images, only two views of the image need be presented: one for each eye of the observer.

In certain instances it might be desirable to project the same view or set of views to several different observers. This could be done by having not one but several spots 7 of light on the two dimensional display device 4 simultaneous to the display of each view on the spatial light modulator 2.

For an image in parallax, only views from a single plane round an image need be provided.

For colour images, each view comprises a red, a blue and a green picture. The pictures may be presented in succession on the spatial light modulator 2 and the colour of the light from the screen 3 of the two dimensional display device 4 varied as appropriate for the picture. Alternatively coloured filters may be placed over pixel positions on the spatial light modulator 2 and the two dimensional display device 4 made to emit white light. The three pictures are presented simultaneously on the spatial light modulator 2 so that the pixels of each picture are displayed at a pixel position covered in a filter of the appropriate colour.

As shown in Figure 3, the three dimensional display apparatus may be used as the screen 13 for a three dimensional television system. The scene to be televised 10 is surrounded by a set of conventional television cameras 11, each of which would record a corresponding view. The views would then be transmitted, e.g. via an optical fibre link 12, to the screen 13. Data compression techniques may be used to reduce the information transmission rate if required.

Referring to Figures 4 and 5, a succession of views are displayed by the spatial light modulator 2. Simultaneous to the display of a view, spots 7 of light are displayed on the screen 3 of the two dimensional display device 4. When light from each spot 7 passes through the nearest lens 1 of the lenticular array, it is converted into parallel rays of light 8 whose direction depends on the position of the spot 7 in the screen 3 of the two dimensional display device 4. The positions of the spots 7 are so controlled that light passes through the spatial light modulator 2 only to that view point 9 from which

the view on the spatial light modulator 2 is supposed to be seen. The display of each view is to be repeated sufficiently quickly for the intervening dark periods not to be noticeable by the human eye. Consequently an image which is apparently three dimensional is perceived. The advantage of this embodiment is that the thickness of the three dimensional display device is much less than in the first embodiment.

Referring to the apparatus shown in Figure 6, the three dimensional image is displayed as in the first embodiment with the refinement that the two dimensional display device emits coherent light. A ray of light 14 from a laser 15 passes through a beam scanner 16 which is a device that can control the position to which the ray of light travels. Simultaneous to the display of a view on the spatial light modulator 2 the ray of light is directed by the beam scanner 16 to a selected lens 17 in the lenticular array 3 from which light must be emitted if the view is to be seen only from the appropriate viewpoint 9. The lenticular array 3 forms the screen of the two dimensional display device. The lens 17 defocuses the ray so that it emits light just as the spot 7 in the first embodiment with the exception that, in this third embodiment, light from the spot 7 is coherent. This makes it possible to record holograms from the screen.

Referring to Figure 7, a hologram can be recorded by placing a photographic plate 18 against the screen and illuminating the photographic plate with a coherent optical reference ray 19 simultaneous to the three dimensional image being displayed on the three dimensional display device 13. The optical reference 19 is created by splitting part of the ray of light 14 from the laser 15 with a beam splitter 20. The redirected light 21 is

reflected by mirrors 22 and the beam widened by lenses 23 so that the optical reference 19 illuminates the whole of the photographic plate 18.

A basic three dimensional display apparatus in accordance with the embodiment of Figures 1 and 2 may comprise a cathode ray tube for the two dimensional display device and a liquid crystal display (LCD) for the spatial light modulator. It will be appreciated that, the cathode ray tube being positioned in the focal plane of the lens so that the spot of light emitted at any instant by the cathode ray tube is collimated into a parallel beam projecting the image on the LCD in one direction only, the action of the lens may be described mathematically as a Fourier transform. Thus, the spatial distribution of amplitude as light passes through one focal plane of a lens is the Fourier transform of the spatial distribution of amplitude as light passes through the other focal plane of the lens.

The frame rate with LCD's is less than that available at present with cathode ray tubes.

An alternative embodiment is shown in Figure 8 which uses a cathode ray tube to present views and can present more views without flicker than the one using an LCD. The cathode ray tube 2 can be made visible from discrete positions 9 by use of two lenses 1a, 1b and a LCD 4. The two lenses are placed face to face with one each of their focal planes coplanar. The LCD is placed in the focal plane between the lenses, and the CRT is placed in the other focal plane of the outer lens 1b.

The first lens 1a images the Fourier transform of the image on the CRT onto the LCD. The second lens also performs a Fourier transform, but except for a sign change this is equivalent to an inverse Fourier transform, so effectively the second lens reproduces the original picture.

A single spot is made transparent on the LCD, the remainder of the LCD being left opaque. Because the LCD is in the Fourier transform plane, its effect is to control the position 9 from which the CRT image is visible, and since only a single spot is transparent on the LCD and CRT image becomes visible from only a single position 9.

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CLAIMS

1) A three dimensional display apparatus, comprising a spatial light modulator, a control system controlling said spatial light modulator for causing a plurality of different images of a subject to be formed in succession on said spatial light modulator, each different image being a view of said subject from a different angle, a two dimensional display device controlled by said control system to emit a spot of light at selected locations thereon, and a lens system for forming a beam of light from said spot and projecting said beam through the spatial light modulator at angles dependent upon the locations of said spot so that the different images formed on the spatial light modulator are visible from different directions.

2) A three dimensional display apparatus as claimed in claim 1, in which said lens system comprises a lenticular array and the control system controls the two dimensional display to emit light from a plurality of spots corresponding to the respective lens of the array and such that a corresponding plurality of parallel beams of light emerge from the array in a common direction for each image provided on the spatial light modulator.

3) A three dimensional display apparatus as claimed in claim 1, in which the two dimensional display device comprises a lenticular array positioned in the focal plane of the lens system and a light source and a beam scanning means disposed behind the lenticular array to direct light from the light source to selected lens on the array, the spatial light modulator being positioned in front of the lens system to project each view formed on the spatial light modulator in a direction dependent upon the selected lens of said array to which the beam scanning means directs the beam of light from the light source.

4) A three dimensional display apparatus, comprising a two dimensional display device, a control system controlling said two dimensional display device for causing a plurality of

different images of a subject to be formed in succession on said two dimensional display device, each different image being a view of said subject from a different angle, a lens system and a spatial light modulator positioned in front of the two dimensional display device, the spatial light modulator being a device whose optical transparency is electronically controlled, and the control system being coupled to the spatial light modulator to cause the spatial light modulator to be transparent at a spot the position of which is selectable, the different images formed on the two dimensional display device being visible from different directions dependent upon the location of said spot on the spatial light modulator.

5) A three dimensional display apparatus substantially as herein described with reference to Figures 1 and 2, Figures 4 and 5, Figures 6 and 7 or Figure 8 of the accompanying drawings.