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Review of the Development of Several True 3D Display Technology

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***Abstract:** Stereoscopic display technology in television, games, medical, education and other fields has more and more applications, different from the flat image only in the two-dimensional surface through the perspective, shadow and other effects to achieve three-dimensional, three-dimensional display can be from any angle of 360 degrees Watch the different sides of the image, is the real show of 3D. As the ideal three-dimensional display style, holographic three-dimensional technology is a combination of optoelectronic technology, computer graphics technology, sensing technology and display technology and other advanced high technology. In this paper, the advantages and disadvantages of various 3D display technologies are analyzed on the basis of the physiological and psychological mechanism of human eye-based three-dimensional object perception, and the principle and development of holographic three-dimensional display technology are analyzed emphatically and the future research direction is predicted.*

Keywords: 3D display; *Stereoscopic display technology*; depth cue; multi sensor

1 THE CORE ISSUES OF THREE - DIMENSIONAL DISPLAY TECHNOLOGY TO SOLVE

The real world we live in is a three-dimensional world. However, the image presented on the retina of the human eye (a single left eye or right eye) is two-dimensional. The two-dimensional image in the fusion reaction after brain complex, eventually showing a three-dimensional image. Modern psychology believes that the complex process of fusion can be divided into two levels: physiology and psychology, and particularly is divided into 10 types of depth cues. People perceive 3D objects through these depth cues. Among them, the psychological level has 6 main implications for people to perceive three-dimensional objects, and there are 4 kinds of hints that physiology plays a major role in people's perception of three-dimensional objects.

1.1 3D effect image is formed based on mental depth cue

When people look at a two-dimensional image, they tend to judge the distance and depth of objects in the image according to the long-term accumulation of life experience. There are six main psychological cues (Fig.1), which include: (1) linear perspective: According to the human eye habit, when the scenery extends far away, the observed size gradually shrinks. (2) retinal image size: According to the actual size of the object, there is an inherent priori knowledge in the human brain, perceiving the distance of the object through the size of the image. (3) overlap: The overlapping relation between the contours of two objects produces a suggestion that the occluded part is located below or in the distance. (4) Shading and shadowing. (5) structural gradient: Similar to linear perspective, when we look at the uniform gradient of a floor tile or marble pavement, the gradient of its surface roughness gives rise to a depth cue. (6) aerial perspective: When you look at a two-dimensional image, people seem to think that something that looks blurry is in the distance.

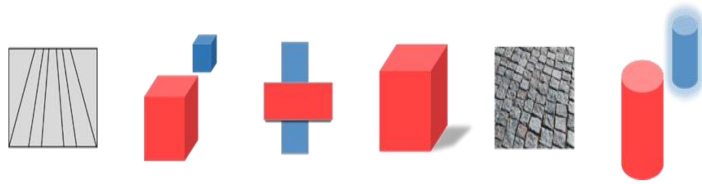

Fig 1: Six kinds of mental depth perception of 3D images (linear perspective, retinal image size, overlap, shading and shadowing, aerial perspective)

1.2 3D effect image is formed based on physiological depth cues

The three-dimensional scene perceived through psychological cues is limited to the two-dimensional level. In the real world, people acquire three-dimensional perception of the real world based on physiological cues such as Monocular Stereo Vision cues and binocular stereoscopic visual cues. There are four main types of physiological depth cues, including:

(1) Accommodation. As shown in Fig. 2, the focal length of the lens of the eye can be adjusted by stretching the muscle of the hair fiber, so that the observer can see the different scenes from different distances or different parts of the same scene.

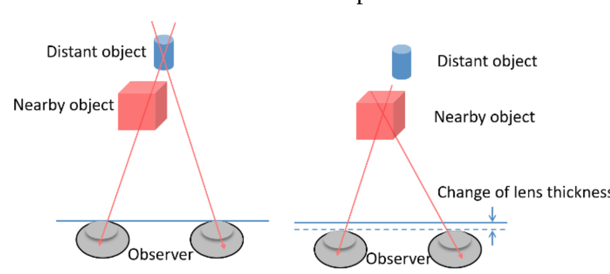

Fig 2: A physiological depth perception of 3D images: Accommodation.

(2) Convergence. As shown in Fig. 3, when the observer's eye muscles are stretched slightly toward the inside of the eye so as to face the 3D object on a point of view, the two eyes of LOS angle is called the convergence angle. Right and left eyes watching two different distances, the convergence angle is not the same, the eye muscles are the tensile strength and the degree of eye rotation is not the same, but the sensory organ can

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compare the intensity and extent of this, so it will have a different sense of depth, which produce three-dimensional sense.

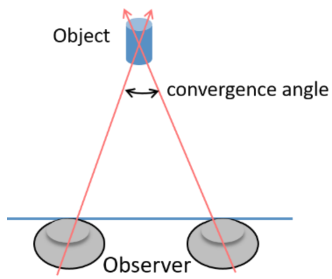


Fig 3: A physiological depth perception of 3D images: Convergence.

(3) Binocular disparity. As shown in Fig.4, binocular parallax is caused by the distance between the eyes of the human eye. The observer watching 3D objects in space, three-dimensional objects light focused on the retina of the eyes, because there is a certain distance between the two eyes (called the pupil spacing, the average value is 6.5 cm), so for the same scene, the left and right eyes relative position is different, it is the binocular disparity, namely the left right eye to see is the image difference.

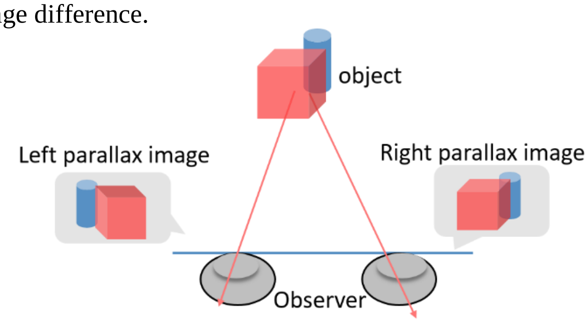


Fig 4: A physiological depth perception of 3D images: Binocular disparity.

(4) Motion parallax. As shown in Fig. 5, if the observer's position changes, the observed three-dimensional object will change accordingly. This effect is called moving parallax.

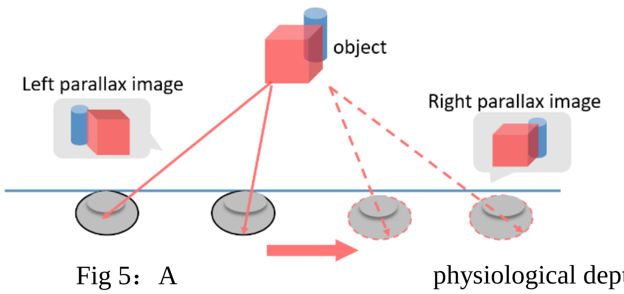


Fig 5：A physiological depth perception of 3D images: Motion parallax.

2 VARIOUS REAL "THREE DIMENSIONAL" DISPLAY TECHNOLOGIES UNDER STUDY AT PRESENT SYSTEM HARDWARE CIRCUIT

A variety of psychological depth in the first part of the implied principle and physiological depth cues based on the true 3D display through a variety of means directly in space, or the object is reproduced in a certain space range, and this and watch things like. Compared with the 3D display technology of binocular disparity depth cues based on the current mainstream, true 3D display technology will not cause visual fatigue of the viewer, the display image can be more real, more in line with people's visual habits.

2.1 Autostereoscopic 3D displays

Autostereoscopic display technology is a kind of true 3D display technology based on multiple depth cues, through the special way to motivate in the transparent display space material, using light scattering or absorption, formation of voxels, and consists of many scattered elements of 3D images, or by two-dimensional display or stacked to form a three-dimensional image rotation. The resulting 3D images as real objects, people can meet almost all the physiological and psychological depth cues, for multi angle viewing naked, meet the people used in visual viewing and depth perception aspects, is a true 3D display technology. Specifically, the method by spatial scanning two-dimensional image or by multilayer planar display static (such as a liquid crystal display panel) superimposed to generate body pixel distribution, thus, there are three main ways: dynamic screen and layer screen display technology.

Based on the dynamic screen of the three-dimensional display rely on the mechanical device to rotate or move the flat screen display, the use of visual effects of the human eye to achieve space stereoscopic display effect. In this regard, in 2007 the University of Southern California Andrew Jones, Ian McDowall, who developed a 360-degree display . The layer screen 3D display using high-speed projector will be displayed the depth of objects projected onto the continuous depth section and display corresponding based on which in short time (1/24 seconds) to complete projection imaging on display, wherein the display body is the distance from the viewer layer at different distances the screen. Using the persistence of vision effect, the viewer can view the three-dimensional image at any position in front of the display. As shown in Fig. 6, the principle of the scanning volumetric 3D display technique is to construct a cylindrical three-dimensional display space by rotating the flat screen around the center. As shown in Fig. 7, the principle of display technology of a static body is to project images onto a layered projection screen through a high-speed projector to form a spatial luminous point distribution.

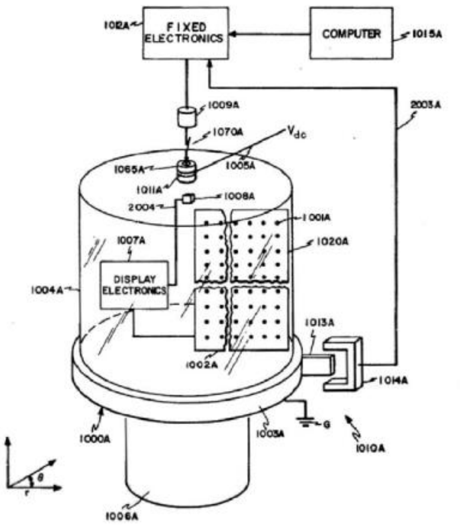


Fig 6: Display that generates volumetric imagery by illuminating LEDs mounted on a rotating panel.

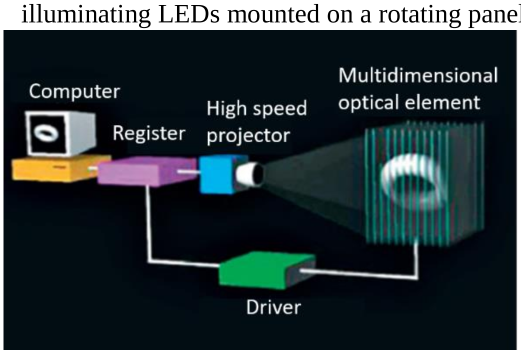


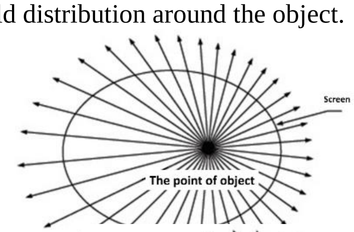
Fig 7: Static volumetric 3D display technique

Therefore, the autostereoscopic 3D display of the object is based on the original light spot of the reconstructed object, and the obtained image is the real image in the corresponding position. When the human eye focuses on the image, there is no focus adjustment conflict. The image has the characteristics of moving parallax, suitable for full field viewing, and the number of observers is unlimited. Therefore, the three-dimensional display of this method is better. The disadvantage is that all the display points can be seen, and there is no space occlusion relation, and it cannot display the surface texture of objects

2.2 Light field three-dimensional display technology

1) The basic principle of light field three-dimensional display technology

As shown in Fig. 8, any object, whether it is self-luminous, or reflect the other light around the light, forms its own unique field distribution around the object.



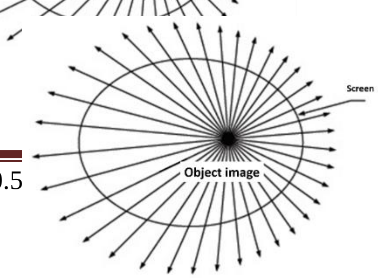


Fig 8: Static volumetric 3D display technique

As shown in Fig. 9, if we can build such a three-dimensional display screen, it can reconstruction the light field of objects (i.e. its emitted light distribution is the same as object before), and human eyes will spontaneously reverse tracing light, makes the observer can feel the 3D object. This is the basic principle of three-dimensional display technology of spatial light field.

Fig 9: DS18B20 interface and STM32 connection circuit diagram

The light field three-dimensional display is to reproduce the light field distribution of three-dimensional objects in the air, thus reproducing the three-dimensional scene. Because the light field contains the light direction of the object, it has the space block effect, and can overcome the shortcoming of volumetric 3D display.

2.3 Realization of light field 3D display

The light field 3D display can be realized either through a high-speed projector and a 360-degree scanning of the screen, or by using a projection array through a three-dimensional light field. The schematic of the former is shown in Fig.10. The high speed projector projects the light in different directions. The schematic diagram of the latter is shown in Fig. 11. The projector projects the light in different directions, and the light of A or B is provided by different projectors. When the projector is sufficiently dense, the three-dimensional image of the space can be constructed.

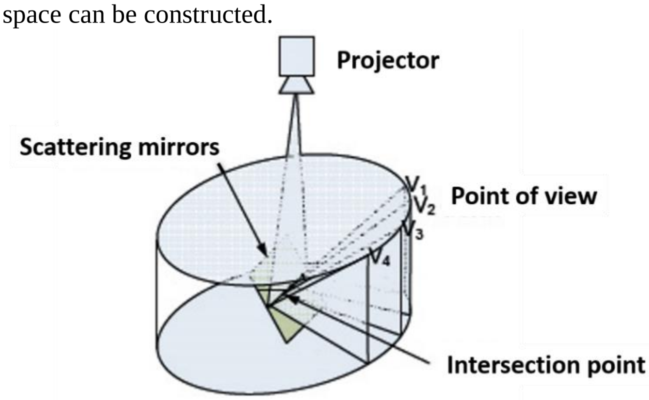


Fig 10: The schematic of high-speed projector and the screen 360-degree scan to achieve light field 3D display

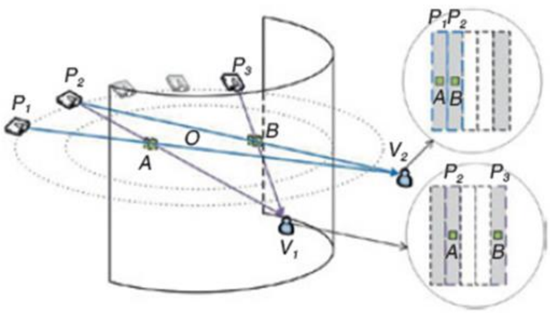


Fig 11: The schematic of realizing light field 3D display light field by projection array stitching

The Q1 amplifier is used to expand the flow, and R38 is a pull-down feedback resistor to avoid MCU reset, so the buzzer may sound phenomenon. The BEEP signal is directly connected to the MCU PB8 above, PB8 can output pulse modulation wave, so if you want to control the alarm buzzer rhythm can be used as a pulse modulated wave output to control the buzzer, rather than simply the use of high and low level.

3 HOLOGRAPHIC THREE DIMENSIONAL DISPLAY TECHNOLOGY

Holography invented in twentieth Century is a three-dimensional display technique based on the principle of physical optics, based on the complete recording and reconstruction of light waves of 3D objects. Because of the holographic reconstruction light retains all the information of the original object wave (amplitude and phase information), so the reconstructed image and the original object has a 3D characteristics of exactly the same, capable of providing full depth perception information required for human visual system. When people look at holographic images, they will have exactly the same visual effects as they do when they look at the original. Therefore, holography has been widely recognized as the most promising 3D display technology.

3.1 The principle of holographic three dimensional display

The theory of holographic technology was first proposed by the British scientist Dennis Gabor in 1948 to improve the resolution of the electron microscope . Holographic imaging has two main processes: the first step is to record the amplitude and phase information of the light wave according to the principle of interference, so that all the information of the light wave can be stored in the recording medium. The second step, according to the diffraction principle, the original light can be reproduced by irradiating the recording medium with the original reference light so as to achieve very realistic three-dimensional images. Three dimensional display based on holography is considered as the most ideal 3D display mode at present. Fig. 12 illustrates the process of holographic recording and reproduction.

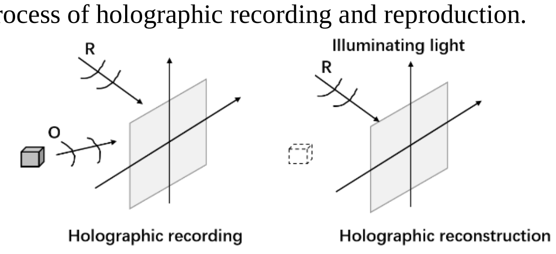


Fig 12: The diagram of holographic process

Since its birth in 1948, with the development of laser, the improvement of photoelectric imaging device performance, the rapid development of computer technology and the continuous improvement of digital image processing technology, holography has developed rapidly. In 1967, The digital holography was proposed by Goodman et al. in 1967. In 1966, B.R. Brown and A.W. Lohman proposed a computational holography based on the research work of Koslns and Kelly , which uses the computer to simulate the whole process of optical hologram formation and calculate the hologram by computer program. Compared with the traditional optical holography, computer-generated 3D projection display with the production of storage and transmission has the advantages of simple, high efficiency, low cost and convenient information, not only can display static objects, but also can display the virtual dynamic objects. The 3D projection display of CGH can completely record and reconstruct the wavefront of 3D objects, and provide all the depth information needed by human visual system. Therefore, it has become the research focus of the naked eye 3D display technology.

The earliest successful implementation of computer-generated hologram, three-dimensional image, and video display was the space optical imaging test team led by Benton, a media laboratory at Massachusetts Institute of Technology. Since 1989, the three generation holographic projection display system with scanning acousto-optic modulator as its core has been developed. Among them, the third generation system can display size of 80mm * 60MM * 80mm, FOV of 24°3D image . But since acousto-optic modulator is a one-dimensional device, it is necessary to obtain horizontal and vertical images by scanning mirror, which is limited in use.

In 2003, the Southwestern University medical center in Texas established a holographic dynamic projection system using digital micro mirror (DMD) chip . The hologram is loaded into the DMD, through the DMD modulation of the incident light field, 3D projection and variable distance, the image generated by gel media reception, virtual image can directly observe the eyes. However, because of the small number of DMD pixels, the size and resolution of the reconstructed image are low, which restricts its application in the holographic projection display system.

Sato et al of Hyogo University in Japan realized the true color holographic display of single LCD by time division method in 2006 . In 2004, Ito applications such as red green blue (RGB) LED photosource synthesis of polychromatic light, also use a single LCD to realize 3D true color holographic display . 2009, they realized the 3D true color hologram display using three RGB LCDs. This method needs to reproduce the three primary colors very closely together, need fine calibration, and require high experimental requirements.

In 2004, the United Kingdom Qinetiq and Advanced Photonics and electronic technology center of the University of Cambridge developed a digital holographic projection display system using electronic addressed liquid crystal SLM and optically addressed bistable liquid crystal SLM . The area of the aperture of hologram diffraction window is 136mm * 34mm, and the number of pixels exceeds 100M. With the 30Hz frame refresh, we can display the full parallax 3D color image whose

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width is greater than 300mm. But the system is complex and expensive.

3.2 Technical improvement and development direction of holographic 3D display

The 3D display of CGH has been developed so far, although progress has been made in various fields. But there are always two problems that restrict its subsequent development. On the one hand, the computing speed of the hologram is not up to the requirements of real-time dynamic display; on the other hand, the development of the photoelectric display cannot obtain three-dimensional images of large size and wide field angle.

Due to the complex spatial structure of three-dimensional objects, it is difficult to use specific mathematical function to represent its light distribution. The three-dimensional information ambassador has to compute the hologram rapidly under the existing computer force level. The point source method, stereo projection method and tomography method are usually used to simplify the calculation of holograms. From the data compression point of view, reducing the amount of data acquisition of three-dimensional objects is also a feasible research direction. In 2011, Yair, Rivenson, Ben-Gurion, et al. Combined with nearly perceptual theory and holography, greatly reduced the acquisition of 3D objects when generating holograms, and achieved data compression.

4 CONCLUSION

This paper summarizes several common 3D display technology solutions, to meet the people's psychological and physiological depth cues on the level of analysis of various modes, and points out that the calculation of three-dimensional holographic display is more in line with the actual experience of 3D display technology. The 3D technology of CGH can be further studied in terms of computing speed, imaging field of view, and remote rendering of 3D information.

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