Development and application of helmet mounted display

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Abstract: As a kind of input-output device with high immersion and real-time human-computer interaction, the helmet mounted display has good applications in medical, military and entertainment industries. This paper mainly discusses the development history, key technologies, and practical applications of the helmet mounted display, and focuses on its application in the field of virtual reality and augmented reality technology. Finally, we describe its future development trend.

1. Introduction

In 1968, Ivan Sutherland established the sword of Damocles helmet mounted display [1], which was considered to be the world's first HMD and the beginning of the research on HMD technology. Then with the development of virtual reality technology, helmet mounted display (HMD) has been further developed. Today, the helmet mounted display has become an important part of the augmented reality equipment, and the helmet mounted display combined with the spatial tracking locator also realizes the virtual reality output effect. Helmet mounted display is not only widely used in military equipment and modern war, but also widely used in civil equipment.

This paper reviews the development history of HMD, describes its basic principle and key technology, introduces the application fields and development status of HMD, and analyzes its future development prospects.

2. The history of HMD

Since British researcher Gordon Nash put forward the concept of modern helmet in 1950s, the technology of HMD had appeared and developed continuously. In the early development of HMD, its application mainly concentrated in the military field. In the 1960s, the United States Navy developed the first binocular aiming system, VTAS Visual Target Acquisition System [2]. Because the missile control technology was still immature at that time, the helmet aiming system was not applied. In 1968 the world's first helmet mounted display, the sword of Damocles, was introduced. As shown in figure 1, it uses a conventional axisymmetric optical system with a large volume and weight. The user sees only a few lines superimposed on a realistic background, making it less immersive.

In the 1870s, j. h. clark built a curved design interactive environment based on the above research, which was seen as a precursor to 3d interaction technology and a precursor to virtual technology applications. In 1982 Thomas Furness II implemented a helmet mounted display with six degrees of freedom for tracking and positioning. In 1984, Michael McGreevy created a 3D helmet mounted display in NASA Ames. In 1985, Scott Fisher implemented a helmet mounted display system with wide angle, which could be controlled by user's position, voice and so on. In late 1986, NASA's research team integrated a virtual reality 3 D environment that allowed users to initiate real-time human computer interaction using gestures and systems. In 1996, the United States, Britain and Northern Ireland successfully developed a variable field of view helmet mounted display. In 1997, the flat-panel display helmet mounted display appeared, and in the same year, s. uchiyama et al. designed an optical system for helmet realism with a field of view of 80°. To achieve high resolution

imaging with a wide field of view, Michael et al. [3] proposed a method of combining several small field-of-view optical imaging systems. Since then, many new optical systems have been proposed to achieve this goal.

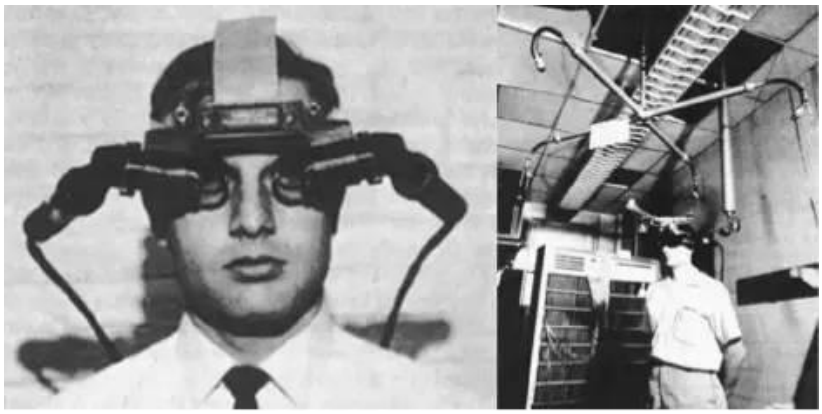

Fig. 1 The first helmet mounted display

3. The development of HMD

3.1 Status of development abroad.

The helmet mounted display has been widely used in the military field of various countries, such as the IHADSS helmet mounted display targeting system developed by the us anti-niver company, which has been deployed in a variety of attack helicopters, and the Russian ZH-3YM-1 helmet sight has been used in the short-range missile launching process.

On the civilian side, eMagin released the world's first 3D enabled helmet mounted display called “eMagin Z800 3D Visor” in 2006 can build a good 3D visual effect, it has since upgraded its display to a SXGA (1280×024) resolution. Sony released "HMZ-T1" in 2011, which provides a realistic and flicker-free 3d display. In January 2015, Microsoft released the first Microsoft Hololens capable of running windows 10.

In addition, researchers in various countries in the field of HMD technology research has also been achieved. For example, optical trackers developed by Kentron improve tracking accuracy and update rate. The new PNVG increases the field of view (Fov) without reducing resolution. WrightPatterson's VCATS system develops day and night conversion interfaces, and realized the panoramic night vision effect and so on.

3.2 Current domestic developments.

In the 1980s, China began to study the helmet mounted display. After more than 30 years of efforts, in the relevant areas have made a lot of research results. Beijing Institute of Technology developed the lightweight large field of view free curved prism HMD [4], and Chinese Academy of Sciences designed the very large field of view HMD [5]. 2013, the Chinese Academy of Sciences has also developed a Holographic waveguide HMD system based on a prism-grating structure [6]. Domestic Research in the field of HMD is still at the initial stage, the related technical research mainly focuses on the transformation of optical system. Due to the low ability to develop high-resolution displays, the domestic production of civil helmet mounted displays is less and the penetration rate of use is lower. In order to shorten the gap with the world advanced level, a lot of research needs to be done to develop the technology of helmet mounted display in China. With the increasing application of virtual reality technology and augmented reality technology, the importance and necessity of helmet mounted display research are increasing day by day.

3. 3 Defects in HMD.

At present, there are still many defects in helmet mounted display. For example, when using helmet mounted display, the time delay caused by data collection, image processing and other

processes will make users feel dizzy. Time lag is the most serious technical flaw in virtual reality systems, as noted by renowned virtual reality expert Frederick e Brooks [7]. Because the traditional three-dimensional helmet is fixed focal plane, which is inconsistent with the visual characteristics of human eyes, it will cause visual fatigue of users. Secondly, the structure of most helmet mounted displays is complex and not light enough, and the man-machine interaction mode is limited, which makes users have a poor sense of use. Moreover, the display effect of the helmet mounted display is also influenced by the surrounding environment such as lighting conditions. To sum up, the research and improvement of optical system of helmet mounted display still has a lot of room for development.

4. The key technology of HMD

4.1 Imaging optical system.

The HMD is mainly composed of micro-image Source Optical System Positioning Sensor System Circuit Control and connection system helmet and counterweight device [8]. The optical system directly affects the final image quality and occupies an important position. The principle of the helmet mounted display is that the two-dimensional image in the display is transmitted through the optical system. After imaging on the focal plane of the eyepiece system, it will become parallel light, and then project to the user's eyes through the optical system in front of the user. The virtual image formed by the optical system is on the same side as the microimage source, and the image becomes larger and further away due to refraction. By using this effect, the near object can be magnified to be viewed at a distance to achieve the so-called holographic vision [9].

The following technical parameters should be considered when designing HMD: Field of view (Fov) resolution, quality of exit pupil distance, diameter of eye pupil and light efficiency of [10].

4.2 Helmet follow-up system.

Helmet follow-up device from the originally relying on mechanical sensor measurement, to electromagnetic measurement, and finally developed based on image processing measurement methods.

Because the sampling rate of Helmet follow-up system is generally not high at present, it is necessary to study how to improve the sampling rate of Helmet follow-up system so that it can adapt to the user's head movement rate. With the increase of the sampling rate, the amount of information to be processed will increase greatly, which requires the researchers to improve the relevant data processing methods and study how to improve the data processing capacity of the system.

4.3 Image rendering.

The early image rendering techniques used in HMD mainly include left and right 3d rendering anti-distortion and anti-dispersion.

In the follow-up study, in order to reduce the display delay, we must increase the refresh rate of the screen, which will compress the rendering time. However, because of the limited processing speed of the GPU, we can not finish the rendering in a short time, so we introduce an Asynchronous time warp algorithm.Secondly, in the existing display technology, double Buffer and multi-Buffer rendering is the mainstream, but in the actual application of this way will increase the display delay, resulting in a bad user experience, so some HMD still using a single Buffer rendering technology. In addition, the helmet mounted display also adopts focus rendering technology combined with eye-tracking technology, which can render only the area of the user's attention with high resolution and blur other areas [11]. This can ensure a good user experience while reducing the GPU processing speed requirements.

With the emergence and development of 5TH GENERATION MOBILE NETWORKS, 5g makes it possible to separate rendering. The complex 3D content is rendered in the cloud, the head control and other movement information is rendered in the virtual reality helmet, and finally connected by

5G Communication [11]. This will make it possible to render images with low latency and high quality, which will drive the development of HMD by leaps and bounds.

5. HMD applications

Virtual Reality (VR) is a simulation system that produces a three-dimensional virtual world by computer simulation and provides an interactive three-dimensional dynamic scene with multi-information fusion and simulates the behavior of entities [12]. Helmet mounted display is the earliest virtual reality display, which USES the helmet mounted display to close people's senses to the outside world and output images on the display. The three dimensional sense is generated in the brain after the human eye acquires the information with the sense of difference, guide the user to the feeling of being in a virtual environment. Virtual Reality Helmet is immersive and interactive. Users wearing virtual reality helmets, which can cover the experience perspective from all angles.

In modern medicine, the use of VR technology with the help of helmet mounted display have achieved good results in clinical surgery, teaching and training, remote treatment, psychological rehabilitation, pain management and other fields. For example, SONY has developed a 3-d, voyeuristic helmet mounted display for medical use that allows doctors to view pathological images of patients in 2D or 3D. The use of panoramic photography and data collection can also realize remote medical treatment, improve treatment efficiency, so that more people get timely medical help. In addition, with the development of industrial production to the intelligent direction, the helmet mounted display (HMD) with VR technology is also gradually applied in the industrial field. This technology can make the industrial production process truly display in front of people's eyes, it is now mainly used in virtual assembly, virtual training, data visualization, and other aspects of production planning.

6. Summary and outlook

This paper mainly discusses the development of HMD technology, briefly describes the principle and key technologies of HMD technology, and finally introduces some practical applications after the combination of helmet mounted display and virtual reality.

At present, helmet mounted display (HMD) still has some problems such as complex structure, difficult to wear and not light enough, which will bring users vertigo and visual fatigue. According to the existing HMD problems, the future research will focus on the following aspects:

1. to further study the HMD optical imaging system with large field of view, large exit pupil distance, high image quality, high resolution and portability;
2. to study more efficient data processing algorithm and image rendering technology to solve the user's Vertigo Problem;
3. development of all-weather helmet mounted Display Technology [13];
4. the combination of gesture recognition and speech recognition technology to achieve better human-computer interaction and sense of use;
5. the integrated development of HMD and 5G technology.

In the future, The main goal of HMD research and development are to achieve better display and use effect. Now, with the gradual maturity of Virtual Reality Augmented Reality Technology and the appearance of 5G technology, it is believed that the helmet mounted display will be further developed and its application fields will continue to expand.

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