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Transformation of High-speed Photography in Communication Engineering through the "Cheetah" Photography Glasses

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Abstract: *The "Cheetah" photography glasses are small-sized high-speed photography equipment for use in the field of communication engineering. It employs high-speed photography technology and synchronous data transmission technology to capture target images in real-time through high-speed cameras and transmit them wirelessly using radio energy transmission technology. Meanwhile, under the IEEE1588 PTP precision time protocol, clock signals are transmitted in the form of network packets, achieving high-precision clock synchronization between different terminal devices. After the event ends, the glasses can also be used to replace traditional bulky and inconvenient-to-carry high-speed cameras by utilizing signal processing technology and digital analog technology for fine processing. Moreover, the "Cheetah" photography glasses fully leverage the scalability and adaptability of software, constantly adding new modules and functions to better suit the needs of different consumers.*

Keywords: *Communication Engineering, Clock Synchronization, Signal Processing Technology, Digital Analog Technology*

1. Introduction

With the development of technology, the development of the technology of everything connected, the era of smart home has slowly penetrated into all aspects of life [1]. Life in the household products continue to upgrade and open the intelligent control, to bring consumers a new experience of a better intelligent life [2]. The camera has also become an increasingly common member of family life in the context of the times [3]. With the rapid promotion of cloud services and the Internet of Things, cameras and PCs, tablets, smartphones and other devices are developing closer ties, and the trend of smart interconnection of cameras is unstoppable [4].

"Cheetah" camera glasses is based on high-speed photography technology and synchronous data transmission technology, for the traditional large high-speed camera equipment to miniaturize the processing [5]. The glasses is through the high-speed camera [6] for real-time target capture, rapid recording of images, instant playback [7]; the use of wireless energy transmission technology, the corresponding distance, by the receiving end re-converted into electricity, so as to achieve the goal of wireless transmission [8]; in the IEEE1588 PTP precision time protocol, the use of network data packet form to transmit the clock signal, the terminal equipment through the interaction of clock information to achieve High-precision clock synchronization [9], the large high-speed camera for miniaturization and perfect processing, to achieve the purpose of high-speed camera [10].

The glasses can not only complete the grafted video imaging [11], Bluetooth connection with cell phones after taking pictures and videos and other low-speed photography; can also use its high-speed photography technology and synchronous transmission technology for high-definition recording, the end of the event through the signal processing technology and digital analog technology and other fine processing, and then replace the traditional sense of large, not portable high-speed camera [12]. Fully exploit the scalability and adaptability of the software, and constantly add new modules and functions to better adapt to different consumers [13].

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2. Design Solutions

2.1. High-speed Camera Technology Humanization

Through the new ergonomic design, glasses camera can be integrated with the user's glasses, installed and worn can be synchronized with the human body perspective, recording images and the actual observation of the human eye almost the same, glasses camera can be combined with the head posture to fine-tune the perspective, can adapt to a variety of body postures, such as sitting, standing, or elevation, angle, side view, direct view and other perspective needs [14]. After installation, it can help the wearer to release his hands and quickly and accurately complete the video capture. At the same time glasses camera products can support a variety of connection lines or interface solutions, support 1080P HD video resolution, with dynamic noise reduction microphone, video synchronous recording, low power consumption, clear picture quality, true color, can be widely used in various types of property, medical, after-sales service, technical guidance, equipment maintenance, sports records, work together, video conferencing and other scenarios:

- Ergonomic design: glasses type installation and wear, solid and reliable, safe and practical, synchronized with the human perspective;
- Easy to operate: no handheld recording, reduce operational consumption, easy to focus on;
- Shooting perspective: perspective with the human body linkage, flexible mobility, the first view of the video, live ear synchronization, the same perspective with the human eye, what is seen is recorded, recorded is seen;
- Equipment direct connection: compatible with a variety of recording devices, can be directly connected to law enforcement recorders, police pass, 4G law enforcement terminals, smart phones and other devices;
- Customized multiple interfaces: LG12 interface, M6 interface, Type-C interface, custom interfaces, etc.;

2.2. Synchronized Data Transfer

Using synchronous data transmission technology, each terminal device through the interaction of clock information to achieve high-precision clock synchronization, synchronization accuracy can reach one hundred microseconds, if you increase the hardware to support it can reach nanosecond synchronization accuracy, to achieve simultaneous reception of data in different locations, live or recorded without delay and other effects [15].

2.3. Multi-channel Data Transmission

The use of MIMO technology, through multiple antennas to achieve multiple transmission and multiple reception, without increasing the transmit power of the antenna and spectrum resources, can greatly improve the channel capacity of the system, which shows the obvious advantages of sending signals with the same information through different paths, while obtaining multiple mutually independent fading signals of the same data symbol at the receiver side, thereby improving the reliability of reception.

2.4. Eye Tracking

Eye-tracking is the process of measuring the eye's point of gaze or the movement of the glasses in relation to the head. The eye-tracking measurement technique used in the Cheetah camera glasses is primarily based on image and video measurements, which incorporate a variety of techniques for measuring distinguishable eye movement features such as heterochromatic edges of the sclera and iris, the intensity of light reflected from the cornea, and the shape of the pupil's appearance. Image-based methods that incorporate pupil shape variation as well as corneal reflection are widely used in measuring the focus of the user's vision.

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3. Method

3.1. Technical Features and Principles

The glasses is through the high-speed camera for real-time target capture, image fast recording, instant playback; the use of wireless energy transmission technology, spaced transmission of the corresponding distance, by the receiving end re-converted into electricity, so as to achieve the goal of wireless transmission; in the IEEE1588 PTP precision time protocol, the use of network data packet form to transmit the clock signal, the interaction between the terminal equipment through the clock information to achieve high-precision clock synchronization, through multiple antennas to achieve multiple transmissions, the large high-speed camera for miniaturization and perfect processing, to achieve the purpose of high-speed camera.

3.1.1. High-speed Camera Technology

Here is the translation of the answer:

High-speed photography is a technology that can capture motion images with exposure times less than 1/1000 second or frame rates exceeding 250 frames per second. It is used to record fast-moving objects as photographic images onto storage media. After recording, the images stored on the media can be played back in slow motion. High-speed moving targets are illuminated by natural light or artificial auxiliary lighting, or emit light themselves, and part of these lights pass through the imaging lens of the high-speed imaging system. After being imaged by the lens, according to the energy distribution of the target image on the sensor plane, electric charge packets of response size are generated at each sampling point, that is, pixel point, completing the photoelectric conversion of the image. The electric charge packets with image information are rapidly transferred to the readout register. The readout signal is processed and transmitted to the computer, where the image is read out, displayed, and judged, and the results are output. A complete high-speed imaging system consists of several parts such as optical imaging, photoelectric imaging, signal transmission, control, image storage, and processing.

The process of high-speed image capture can be described by the following mathematical formula. Assuming that the object being photographed is at position $x(t)$ at time t, and its brightness function is $I(x,t)$. Then, in the camera imaging system, a two-dimensional brightness function $I(x,y,t)$ will be obtained through imaging by the lens, where (x,y) represents the point on the imaged object corresponding to x.

The imaging process of the lens can be described by a point spread function (PSF), i.e.,

$$I(x,y,t) = \int_{\Omega} I(x,t)PSF(x-x',y-y',t-t')\,dxdt \quad (1)$$

where (x',y') represents a point on the object, Ω represents the receiving aperture range of the lens, and $PSF(x,y,t)$ represents the value of the point spread function at (x,y,t).

In the imaging device, photons are converted into electrons, generating charge packets (Charge-Coupled Device, CCD) or complementary metal-oxide-semiconductor (CMOS) on the pixels. The size of the charge packets is proportional to the intensity of the brightness at that position, so the output current of the pixel can be regarded as a sampling of the brightness function. Finally, through signal processing and image processing steps, high-speed motion images that have been denoised and enhanced can be obtained.

Through the new ergonomic design, glasses camera can be integrated with the user's glasses, installed and worn can be synchronized with the human body perspective, recording images and the actual observation of the human eye almost the same, glasses camera can be combined with the head posture to fine-tune the perspective, can adapt to a variety of body postures, such as sitting, standing, or elevation, angle, side view, direct view and other perspective needs. After installation, it can help the wearer to release his hands and quickly and accurately complete the video capture. At the same time glasses camera products can support a variety of connection lines or interface solutions, support 1080P HD video resolution, with dynamic noise reduction microphone, video synchronous recording, low power consumption, clear picture quality, true color, can be widely used in various types of property, medical, after-sales service, technical guidance, equipment maintenance, sports records, work together, video conferencing and other scenarios.

3.1.2. Precision Time Protocol IEEE1588 PTP

IEEE1588 defines a precision time protocol (PTP for short) that can synchronize the clock phase and

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frequency of Ethernet terminal devices. In the standard Ethernet, it uses the form of network packets to transmit the clock signal, each terminal device through the interaction of clock information to achieve high-precision clock synchronization. IEEE 1588 clock synchronization in two parts, one is to establish the synchronization system; two is to complete the synchronization process.

Establishment of synchronization system

PTP network can be a very large architecture of the network system, can contain multiple PTP subsystems, each subsystem can contain multiple clock nodes. In order to achieve the time synchronization of each node, it is necessary to achieve unified management of all clock nodes in the system, to build an orderly synchronization system. The establishment of the synchronization system is that, before the clock nodes for clock synchronization, from all the clock nodes in the PTP network to select a time property of the best as the source of time synchronization, the source clock is also called the master clock, other nodes as from the clock to synchronize the time to the master clock, so as to achieve the master-slave division of the clock nodes.

Under the synchronization system, all the clock nodes in the PTP network can only be uniquely in a master-slave clock state, and in the entire network at the same time only one clock node is the master clock. The establishment of the synchronization system for the next step in clock synchronization to lay a good foundation.

Synchronization process

Audio synchronous transmission is both the realization of master and slave devices between the use of phase frequency strictly the same clock on the audio signal for real-time sampling and transmission, which requires the completion of the time between the devices consistent. In this paper, the time offset and network delay are calculated through the interaction of PTP messages with time stamps between master and slave devices, and the local time is synchronized to the master clock according to this calculation result. The whole synchronization process is divided into two stages: offset measurement and network delay measurement, as shown in Figure 1.

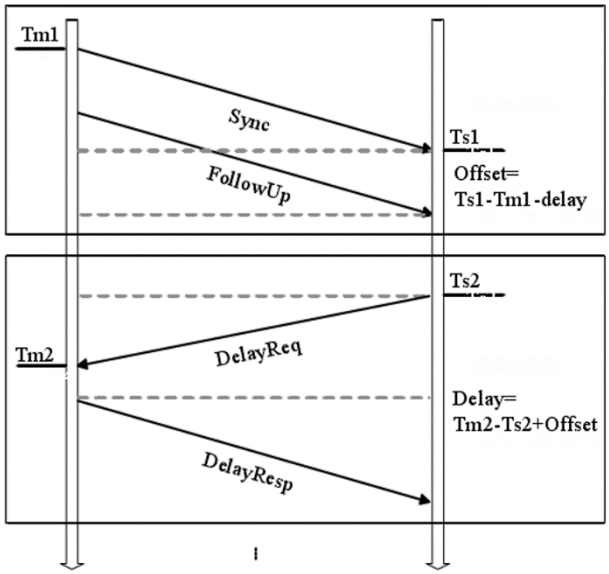

Figure 1: Clock synchronization process diagram

3.1.3. Wireless Energy Transmission Technology

Wireless Power Transmission (WPT) technology can be described by the following mathematical formula. First, assuming that the electromagnetic field intensity generated by the transmitting end is $E_s(t)$, it propagates to the surrounding area, and when it encounters the receiving end, it induces an electromotive force $E_r(t)$ .The electromagnetic field attenuates during transmission, so the effect of transmission distance r on signal attenuation is considered.

According to the basic physical laws of electric field propagation, the attenuation coefficient of the electric field signal when the transmission distance is r is $\alpha = 20\log_{10}(r) - 20\log_{10}(d) - 32.44$, where d is the reference distance and α is the attenuation coefficient, measured in decibels (dB).

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Assuming that the distance between the transmitting end and the receiving end is r, the electric field signal strength received by the receiving end is:

$$E_r(t) = \sqrt{P_t}\frac{E_s(t)e^{-jkr}}{4\pi r} \tag{2}$$

where P_t is the transmission power of the transmitting end, k is the wave number, and j is the imaginary unit.

After receiving the signal using an antenna, we can obtain the received power P_r:

$$P_r = \frac{1}{2}\mathrm{Re}\left(E_r(t)\cdot H_r^*(t)\right) \tag{3}$$

where $H_r(t)$ is the magnetic field intensity at the receiving end. After reverse propagation and power adjustment, we can obtain the final output power P_o:

$$P_o = \frac{\eta_s\cdot\eta_t\cdot A_r\cdot P_r}{4\pi r^2} \tag{4}$$

where η_s is the antenna efficiency of the transmitting end, η_t is the antenna efficiency of the receiving end, and A_r is the effective area of the receiving end antenna.

The above are some basic mathematical formulas for wireless power transmission, which can be used to describe and calculate the signal transmission and power transmission process in WPT technology.

Wireless Power Transmission (WPT), also known as wireless energy transmission or non-contact energy transmission, mainly uses special devices to convert electrical energy into energy that can be transmitted wirelessly (such as electromagnetic field energy, laser, microwaves, etc.), transmit the corresponding distance across space, and then convert it back into electrical energy at the receiving end, thus achieving the goal of wireless transmission. WPT completely overcomes the constraints of electrical engineering equipment relying on line bundles, reduces the complexity of circuit structure, and truly achieves a "tailless" energy transmission method. Nowadays, with the rapid development of technology, wireless terminal technology represented by household appliances, implanted medical devices, wearable devices, and electric vehicles has become a new direction of technological development. However, WPT technology can break the mechanical connection shackles, achieve wireless devices to directly ignore spatial restrictions to meet energy supply needs, and eliminate risks such as fire/electric shock and conductor exposure, which plays a huge role in maintaining device life and system functionality, and has positive and far-reaching effects. Therefore, the appearance of WPT technology has attracted high attention from people, and scholars from various countries have carried out corresponding analysis and exploration. So far, it is still a core subject of the electrical engineering discipline. The topology of FM and tuned signal and power synchronization transmission is shown in Figure 2 and Figure 3.

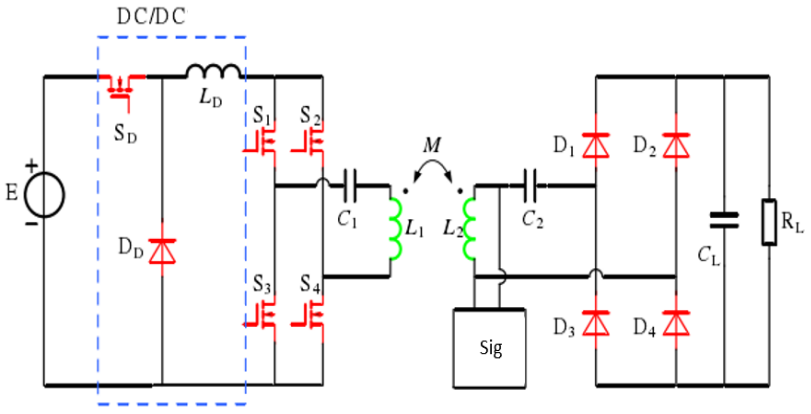

Figure 2: Amplitude modulated signal and power synchronous transmission system schematic

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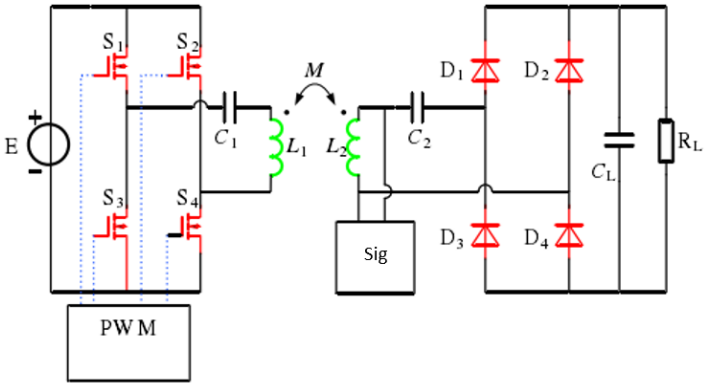

Figure 3: Topology diagram of tuned signal and power synchronous transmission

3.1.4. MIMO Technology

Multiple input multiple output technology (MIMO) refers to the use of multiple transmit antennas and multiple receive antennas at the transmitter and receiver ends, respectively, so that signals are transmitted and received through multiple antennas between channels, thus achieving improved communication quality. It can make full use of space resources to achieve multiple transmission and reception through multiple antennas, which can greatly improve the channel capacity of the system without increasing the transmit power of the antennas as well as the spectrum resources, and it shows obvious advantages, so MIMO is regarded as the core technology of next-generation mobile communication.

The transmitter first maps the data signal to be transmitted to multiple antennas through space-time mapping, and then sends it out, and the receiver performs space-time decoding of the signals received by each antenna, and then recovers the original data signal sent by the transmitter. According to the different methods of space-time mapping, MIMO technology can be broadly divided into two categories: spatial diversity and spatial multiplexing. Spatial diversity refers to the use of multiple transmitting antennas, the signal with the same information sent through different paths, while at the receiver side to obtain the same data symbol of multiple mutually independent fading signal, thereby improving the reliability of reception. For transmit diversity technology, the same is the use of multiple path gain to achieve the purpose of improving the reliability of the system. Currently in the MIMO system commonly used spatial diversity techniques are mainly airtime grouping codes and beamforming techniques. When the signal sent by the radio is reflected, multiple groups of signals are generated. Each group of signals is a spatial stream. Systems using single input single output (SISO) can only send or receive one spatial stream at a time. mimo allows multiple antennas to send and receive multiple spatial streams simultaneously and can distinguish between signals sent to or from different spatial orientations. The application of mimo technology makes space a resource that can be used to improve performance and can increase the coverage of a wireless system.

There are two main advantages of MIMO technology:

Increased channel capacity

Between the MIMO access point and the MIMO client, multiple spatial streams can be sent and received simultaneously. The channel capacity can be increased linearly with the number of antennas, so the MIMO channel can be used to increase the wireless channel capacity exponentially, and the spectrum utilization can be greatly improved without increasing the bandwidth and antenna transmission power.

Improved channel reliability

Using the spatial multiplexing gain and spatial diversity gain provided by the MIMO channel, channel fading can be suppressed using multiple antenna techniques. The application of multi-antenna system allows parallel data streams to be transmitted simultaneously, which can significantly overcome the effect of channel fading and reduce the BER.

3.1.5. Eye Tracking Technology

Eye tracking is the process of measuring the operation of the eye. Image processing techniques are performed through instrumentation to locate the pupil position, obtain coordinates, and through certain algorithms, calculate the point at which the eye gazes or stares. The orientation of the user's gaze is

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tracked at all times to reduce omissions and delays in the shooting process.

3.1.6. Holographic Imaging Technology

Combining holographic imaging with other imaging technologies is one of the current development trends. By combining holographic imaging technology and high-speed camera technology, we can make full use of the advantages of both, not only record the image of the object quickly, but also record the three-dimensional information of the object dynamically; embed the hologram of the information to be encrypted into the carrier image as the secret information to achieve information hiding, use the propagation law and structural geometric parameters as the key, and design multiple "locks". By designing multiple "locks" and multiple "keys", we can achieve high-security data encryption and protect user privacy.

3.1.7. Fresnel Lenses

In order to perfect the user's wearing experience and to achieve the above mentioned technology, the product needs to be small and light. If the size is to be small, then the focal length of the lens must be as short as possible; if the weight is to be light, then the thickness of the lens must be as thin as possible. For traditional lenses, small focal length and thin lenses are not compatible, so new technology is needed to solve this contradiction. In addition to ordinary lens imaging, there are two other means, Fresnel lens imaging and folded optical path image imaging. Fresnel lens is the mainstream device using solutions, well-known Pico neo3 and Oculus Quest 2 and so on. Its focal length is slightly reduced, the mass is lighter, the production cost is smaller than the ordinary lens, but due to the curvature discontinuity, affecting the image quality. Short focal length system by folding the optical path (composite lens) way, the lens will be thinner so as to greatly reduce the weight of the device, is the future direction of VR equipment development. Due to the complex design of the optical path, and the need to go through multiple reflections and refraction, the optical path loss is large, the coating technology, optical path design capabilities require high. The evolution of the Fresnel lens is shown in Figure 4.

Refractive optical path (short focus system) mainly consists of reflective polarizer, complex optical components and display screen. The reflective polarizer only allows the light path of a specific polarization direction to pass. The design of the optical assembly is more flexible, and consists of a combination of Bragg grating, polarizer, quarter wave sheet and other optical components to change the direction of polarization, reflection and refraction of the optical path. Specifically, light is emitted from the display, passed through the beamsplitter, reflected on the polarizer, reflected again through the beamsplitter to realize the optical path folding, and then shot into the human eye through the polarizer. However, due to its complex optical path design, multiple reflection and refraction, the light loss is large, the process manufacturing and easy to appear stray light problems.

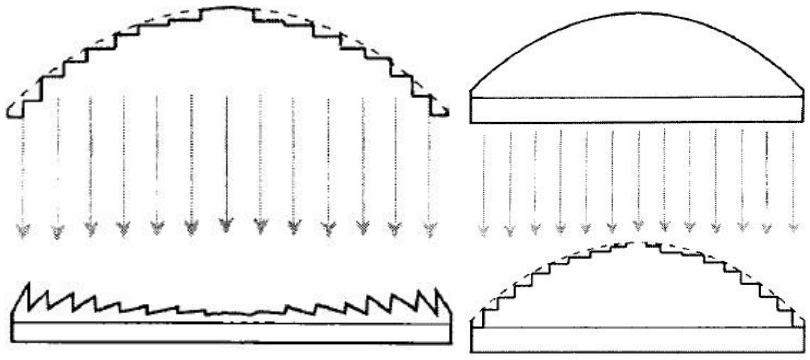

Figure 4: Fresnel lens evolution principle diagram

3.2. Product Composition

The product includes a hanging ear glasses, charging compartment, charging cable, manual, professional care solution. The use of the product also needs to be combined with the company's APP, the download method is attached to the first page of the manual. The frame can choose its own color, the color classification includes sunset brown, red birch brown, smoky black, brown gray gold, caramel crystal calm, cherry soft pink, glacier lake blue, morning fog gray, turquoise Mori green, etc.

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3.3. Use and operation

Before wearing this product, you need to wipe the lens clean and adjust the two frames to a distance suitable for yourself. If you are a first time wearer, you should practice under the guidance of a professional, as it is easy to damage your eyes if you don't wear them well. After wearing the glasses, you need to look around in an open outdoor environment for ten minutes to ensure that you are comfortable with wearing them and that they do not damage your eyes. The company will record a video for each buyer to learn how to wear and operate the glasses, so the buyer can watch the video to get a preliminary understanding of some common functions of the product. At the same time, purchasers can also purchase online teaching to learn, the company is fully committed to achieving the perfect product experience for the purchaser and efforts.

3.4. Failure Analysis and Troubleshooting

If you find that the brightness or light is very dark during use, it is possible that the battery is low, if the brightness is normal after charging, it means that the product functions normally, if it is still not bright after charging, it is possible that the line is faulty and can be repaired at the company's own expense.

3.5. System Design Model

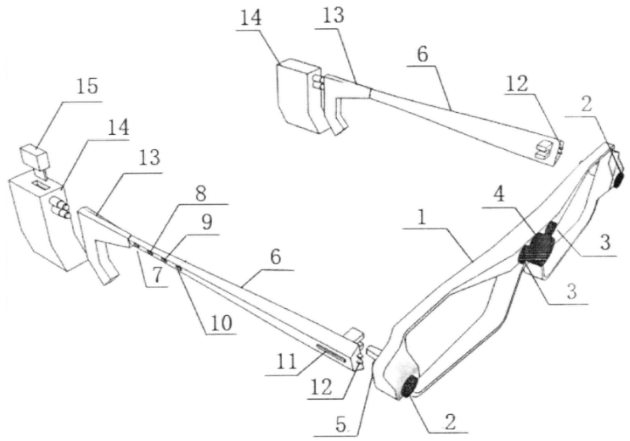

Figure 5: Physical model diagram

Figure 5 shows the physical model drawing. "Cheetah" camera glasses design model diagram as shown in the figure, the system includes a frame (1), lighting (2), flash (3), camera (4), plug bad (5), glasses frame (6), light intensity adjustment switch (7), video switch (8), photo switch (9), flash switch (10), lighting switch (11), plug (12), non-slip ear cover (13), power data integrator (14), data transceiver (15).

The eyeglass frame (1) is equipped with two lights (2) located at the ends of the frame (1); the camera (4) is located in the middle of the frame (1); two flash lights (3) are located in the middle of the frame (1) and on both sides of the camera (4); the plug bad (5) is located at both ends of the frame (1); one of the switch buttons attached to the outside of the frame (6) are the light intensity adjustment switch (7), the video switch (8), photo switch (9), flash switch (10), illumination switch (11); plug (12) is located at the front of the eyeglass frame (6); power data integrator (14) is located at the end of the eyeglass frame (6); power data integrator (14) is integrated by power supply, signal processor, and data memory; non-slip ear sleeve (13) is located between the eyeglass frame (6) and power data integrator (14); a data transceiver (15) is located above a power data integrator (14).

4. Conclusions

In today's society, whenever large social events and news reports or even program recording, the photographer will shoulder the "heavy" responsibility. The traditional sense of the camera not only has a large size, not easy to carry, easy to be destroyed in the process of transportation and other objective defects, but also easy to lose audio photography data, the photographer also need to spend a lot of time and cost to export the camera material after the end of photography. Its innovative performance for the

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following points:

(1) High-speed camera miniaturization: based on high-speed camera technology, high-speed motion target by natural light or artificial auxiliary lighting illumination differential reflected light, part of this light through the high-speed imaging system imaging objective lens. After the objective lens imaging, falling on the image sensing surface of the photoelectric imaging device, the photoelectric device controlled by the drive circuit, will respond quickly to the target image on the image sensing surface, that is, according to the distribution of the target image light energy on the image sensing surface, in each sampling point that is the pixel point to produce a response size of the charge packet, to complete the image of the photoelectric conversion. The glasses on the large camera miniaturization, to a certain extent can replace the use of large high-speed camera, easy to carry, free your hands, what you see is what you get; high transmission capacity, low power consumption, wireless energy transmission technology to solve the problem of inconvenient battery carrying;

(2) Glasses chip and the human eye, brain wave synchronous induction: "cheetah" camera glasses is based on the eyes and brain wave synchronous induction, based on the addition of the chip in the glasses to make it synchronized with the human body, the human eye to see things through the brain waves launched to the chip synchronous output, replacing the traditional external large camera equipment, so that it and the human body induction synchronization, controlled by the subjective consciousness of the human body;

(3) High image stability: digital image ingestion target can be converted into image signals first, and then transmitted to a dedicated image processing system; strong anti-interference ability, MIMO technology to achieve multiple transmission and reception, set photoelectric conversion, charge storage, charge transfer and signal reading in one, will not be easily affected by external environmental factors, the user can reduce a lot of unwanted trouble in the process of use;

(4) High-speed camera humanization: through the new ergonomic design, glasses camera can be integrated with the user's glasses, installation and wear can be synchronized with the human body perspective, recording images and the actual observation of the human eye almost the same, glasses camera can be combined with the head posture to fine-tune the perspective, can adapt to a variety of body postures, such as sitting, standing, or elevation, pitch, side view, direct view and other perspectives It can be adapted to a variety of body postures such as sitting, standing, elevation, tilt, side view, direct view, etc. After installation, it can help the wearer to release his hands and quickly and accurately complete the video capture. Specifically reflected in the following aspects:

① Ergonomic design: glasses type installation and wearing, solid and reliable, safe and practical, synchronization of human perspective;

② Easy to operate: no handheld recording, reduce operational consumption, easy to focus on;

③ Shooting perspective: perspective with the human body linkage, flexible mobility, the first view of the video, the scene of the ear synchronization, the same perspective with the human eye, what is seen is recorded, what is recorded is seen;

④ Equipment direct connection: compatible with a variety of recording equipment, can be directly connected to law enforcement recorders, police pass, 4G law enforcement terminal, smart phones and other devices;

⑤ Customized multiple interfaces: LG12 interface, M6 interface, Type-C interface, custom interfaces, etc;

(5) High-speed multi-port synchronous transmission: under IEEE1588 PTP precise time protocol, using synchronous data transmission technology, each terminal device through the interaction of clock information to achieve high-precision clock synchronization, synchronization accuracy can reach one hundred microseconds, if the hardware to support it can reach nanosecond synchronization accuracy, and through the front-end part of the special equipment to convert electrical energy into wireless Transmission energy (such as electromagnetic field energy, laser, microwave, etc.), the corresponding distance, the receiving end reconverted into electricity, so as to achieve the goal of wireless transmission, greatly saving time and labor costs; and then rely on MIMO technology, through multiple antennas to achieve multiple transmission and reception, without increasing the antenna transmission power and spectrum resources, can greatly improve the channel capacity of the system, which shows the obvious advantage of sending signals with the same information through different paths, while obtaining multiple mutually independent fading signals of the same data symbol at the receiver side, thus improving the

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reliability of reception;

(6) Security: breaking the traditional photography technology for space and geographical restrictions, while achieving synchronous data transmission between master and slave devices, meeting the needs of data collection in different environments and various types of high-speed photography, while reducing the risk of network infringement, getting rid of the risk of loss and physical factors in traditional printing to obtain data and transmit data;

(7) Fault tolerance: the project simulates real-world 3D interactive scenes with the help of virtual reality technology, enabling the operation process to simulate more operation scenarios and analyze the feasibility of each scenario and the final presentation effect, improving the fault tolerance of the project and the accuracy of the printing process;

(8) applicability and and scalability: with the development and upgrading of technology synchronously optimize the technology and human behavior adaptability, give full play to the scalability and adaptability of the software, and constantly add new modules and functions to better adapt to different consumers; can be used in the field of scientific research, industrial manufacturing, aerospace, sports, life entertainment, etc.

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