Design of Intelligent Firefighter Helmet Based on AR Technology

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Abstract. Traditional firefighter helmet has the disadvantages of poor shading and lack of flexibility. AR is the process of computing 3d coordinate points according to the image points of real objects, and then superimposing “virtual + real” surreal scenes based on real scenery through the calculation simulation of the processor. The AR firefighter helmet is a new type of firefighting protective that uses AR technology in traditional firefighter helmet. Intelligent firefighter helmet based on AR technology uses 3D simulation imaging technology, thermal camera tracking technology, human-computer interaction technology, and code recognition technology to maximize the effect of realistic fire scenes. It can enable firefighters to see the real situation in the scene of heavy smoke and improve the efficiency of rescue. Therefore, firefighter helmets with AR equipment represent the future development trend of firefighter helmet. This paper discusses the theory, value, technical operation, design and development of intelligence. The research on the fireman's helmet based on augmented reality technology has leading advantages and application value.

1. Introduction
As the most used fire-fighting tool, the fire-fighting cap has the important function of protecting the firefighter's head and neck, preventing the impact of falling debris, and seeing the surrounding situation. After investigation, the traditional firefighter helmet has the disadvantages of low visibility, poor flexibility and no smoke prevention [1]. At present, AR technology has gradually matured in recent years, and has achieved results in many fields such as garment fitting, real estate home display, and factory parts renovation. Under the background of the development of AR technology, AR firefighter helmet, which can improve rescue efficiency and reduce the casualty rate of firefighters, emerged at the historic moment. The AR firefighter helmet can use AR technology to enhance the fire scene observation effect and improve the firefighter's mobility flexibility. While improving the rescue efficiency, AR cap provides more protection for the personal safety of firefighters. Therefore, firefighter helmet can escort the fire rescue for the firemen, has a broad development prospect[2].

2. Theory definition

2.1. AR technology
AR technology refers to augmented reality technology, which calculates 3d coordinate points according to the image points of real objects, generates virtual 3d images, and then superimposes "virtual + reality" surreal scenes on the basis of real scenery through computational simulation of the processor[3] The AR technology filters the real scene, leaving only the key frames of the image that
the user needs, making the useful information points more prominent, thus achieving the effect of augmented reality. The AR technology includes three-dimensional modeling technology, real-time image information transmission technology, information point tracking technology, and scene fusion technology. Nowadays, AR technology has gradually developed in many fields such as medical, film and television, and fashion design. On the basis of the use of security technology, the intelligent firefighter helmet combined with AR technology has also emerged.

2.2. Firefighter helmet

The AR firefighter helmet is a new type of protective gear based on the characteristics of a traditional fire hat and incorporating AR technology and systems. The high-speed thermal camera of the AR fire hat is responsible for capturing the picture. The built-in computer module returns the picture data to the terminal controller. After the controller enhances the picture, it is transmitted back to the firefighter helmet. The AR firefighter helmet uses thermal camera tracking technology, human-computer interaction technology, 3D simulation imaging technology, and code recognition technology to complete the conversion and integration of real images and 3D virtual images, so that the firefighter helmet can enhance the perception of the image of the real fire scene to the maximum. The firefighter helmet equipped with AR equipment has the advantages of high technical content, good safety performance, fast rescue speed and high social benefits, which represent the future development trend of firefighter helmets [4]. Through investigation, it is found that the traditional fire hat has the shading property, which leads to the fire relief visibility is relatively low. This can affect firefighters' vision and put pressure on rescue efforts [5].

3. AR technology Application of firefighter helmet

The basic working system for AR Firefighter Helm augmented reality is shown in Figure 1. First of all, images and video information in the real environment are acquired by cameras and sensors and stored in a computer for analysis and pre-processing. Then, according to the real environment identified by the camera, the position of the virtual object is calculated, and its attitude is evaluated, so as to render and transform the corresponding spatial perspective shape of the virtual object. After synthesizing the real environment and the virtual object, the virtual object is output through the display device. Finally, the user sees the enhanced scene content in the display device [6].
3.1. Display technology
Display technology is the cornerstone of the AR Firefighter Helm system. The current header-mounted displays for augmented reality are video mounted displays. The advantages of this technique are greater immersion and less environmental constraints.

3.2. Tracking registration technology
Tracking registration is an essential technology for AR Firefighter Helm system to realize 3D space registration. AR Firefighter Helm USES visual tracking registration technology through a SLAM-based 3d space approach.

3.3. Human-computer interaction technology
AR Firefighter Helm's experience quality is closely related to the use of human-computer interaction technologies. AR Firefighter Helm’s human-computer interaction is characterized by multi-channel integration. In augmented reality scenes, users can control and operate virtual objects through speech recognition, hand and body posture recognition, head tracking, eye movement tracking, face recognition and other ways, which enhances the user’s sense of participation and thus creates a more natural and smooth interaction experience.

4. Design of firefighter helmet

4.1. Foundation design
The AR firefighter helmet is modified on the basis of a traditional fire hat, adding a series of AR technology adaptation equipment. The foundation design of the AR firefighter helmet is as follows:

Firstly, based on the thermal map of the real object taken by the fireman's head thermal sensor, the AR augmented reality of the terminal processor presents an imaging higher than reality. First of all, in the search and rescue process of the fire, the AR fire-fighting cap scans the scene of the smoke-cranked fire in real time through the high-speed thermal sensor. This enables rapid mobilization of on-site resources and timely management of images. The AR firefighter helmet imaging technology enables moving or stationary objects to present a green image outline on the screen even with zero visibility. Secondly, the AR firefighter helmet uses a high-speed thermal sensor to capture the picture, and the computer module built into the fire hat returns the screen data to the “command controller”. After the controller enhances the picture, it is sent back to the special AR display on the firefighter helmet.

Secondly, 3D reconstruction of intelligent helmets. Taking the thermal camera as the origin, the relative position with the actual object becomes the three-dimensional coordinate point. The processor generates a transformation matrix according to the three-dimensional coordinate points, and then draws a virtual scene from the matrix, then merge the virtual 3D image with the real environment into an image and input it to the AR display. The AR firefighter helmet will process the picture through AR technology, which will minimize the visual interference of flame and dense fog. Therefore, the picture seen by the firefighter's firefighters is a picture of the firefighting reality of the computer. However, one thing that needs to be emphasized is that the accurate positioning of the AR fire-fighting cap in the fire field requires a large number of fire field simulations in the early stage, and repeatedly adjusts its positioning data and environmental scene tracking of real objects.[7]

Thirdly, AR technology related equipment still needs continuous optimization. With the rise of the Internet of Things industry, the original objects of the fire field will be networked, and can be directly connected to the terminal processor of the AR firefighter helmet, and share the same set of three-dimensional coordinates to transmit three-dimensional coordinate points to each other. The terminal processor is omitted to calculate a calculation link of the conversion matrix according to the image returned by the thermal sensor. The connection equipment of AR firefighter helmets will continue to innovate with the development of cutting-edge technology. The initial AR firefighter helmet adopting
mode is mainly AR technology + fire cap, and it is likely to grow into AR technology + Internet of Things + firefighter helmet in the future [8].

4.2. Process design
During the fire search and rescue process, the AR firefighter helmet scans the fire scene through a high-speed thermal sensor to make the moving or stationary object present an image. The AR Fire Hat scan image emphasizes the combination of virtual and real. On the one hand, by simulating the real scene landscape, the firefighters can see the outline and texture of the real objects in the fire. On the other hand, through the scanning and recognition of real items, thermal tracking is performed in time, and the rescued person is searched more accurately through the heat map [9]. The computer module built into the fire cap returns the collected image data to the terminal controller. After the terminal controller enhances the picture and reduces the visual interference, it converts into a virtual three-dimensional picture. The virtual 3D image is merged with the real environment to generate an image, which is then passed back to the specially designed AR display on the fire cap. In a word, according to these two principles, the following figure of AR firefighter helmet is formed (see figure 2).

![figure 2. Process design figure of firefighter helmet base on AR](image)

4.3. Structural design
The AR firefighter helmet is designed with a closed helmet and built-in structure including thermal camera, AR display, noise reducer, transmission equipment and other devices. The exterior is equipped with a multi-layer thermal protection layer, a comprehensive gas mask, an insulated helmet, a cover, a thermal imaging device and an audio communication device. The AR firefighter helmet captures the live image through the thermal camera and transmits it to the remote terminal in real time[10]. After the AR technology screen is enhanced, the display is transmitted back to make the fire rescue more accurate and reliable. The AR firefighter helmet is designed as a closed helmet to prevent fire and smoke from entering the helmet and affecting the firefighter's line of sight and breathing. The AR firefighter helmet material uses a high temperature resistant polymeric material that can be directly in contact with an open flame without damage. All protective equipment of AR firefighter helmets, such as gas masks, insulated helmets, inner cushions and outer covers, can be removed and replaced separately. The size, thickness and height can be adjusted according to the fireman's own characteristics [11].

4.4. Supporting product design
Since the AR firefighter helmet is a fully enclosed helmet, it is also very important to have fire protection equipment. AR firefighter helmets need to speed up technological innovations in supporting equipment, including fire suits, fire fighting tools, and fire-fighting shoes. In short, the design of the AR fire-fighting cap should improve the application of the fire-fighting series of auxiliary fire-fighting caps to further improve the fire-fighting efficiency and ensure the safety of firefighters[12].
4.5. Using range design
The core AR technology of the AR firefighter helmet can be mounted on a helmet. At the same time, AR firefighter helmets will continue to develop suitable new products for construction, high-altitude operations, machine operations and other work with higher risk factors.

4.6. R&D process design
R&D is divided into three stages: project start-up, R&D process and test process. During the start-up phase of the project, the design and rectification of the combination of AR technology and traditional firefighter helmets will be carried out. In the R&D process, R&D is carried out for products, tests, and development-confirmed versions. In the process of the test, the test program, the transformation matrix of the real object and the 3D modelling are tested, and the fireman's individual step, pitch, height, angle of view, etc. are tested. It is also necessary to test the functional modules, internal network environment, pre-release environment and formal environment of the product acceptance development output.

To sum up, the following structural design of AR firefighter helmet is formed according to the above description, the structure of the AR firefighter helmet is as follows:
5. CONCLUSION
The AR firefighter helmet designed in this paper solves the problems of low visibility and constant ventilation of traditional firefighter helmets. The AR firefighter helmet is equipped with a thermal augmentation camera, AR display, noise reducer, transmission equipment, etc. It provides real-time backhaul of fire environment data, and the selected terminal and 3D modelling can help firefighters see a clearer thermal image on the AR display. Three-dimensional imaging technology and human-computer interaction technology make firefighters' field rescue in the fire field more efficient. In the research and development stage, the field test of different firefighters' characteristics and the helmet parts that can be disassembled to separately improve the flexibility of the AR firefighter helmet. The combination of the closed helmet design and the fire-fighting boots and other related equipment also ensures the personal safety of the firefighters in the fire. In short, the AR firefighter helmet has the advantages of high technical content, fast rescue speed and good safety performance, and will surely have a broader development market.

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References
[1] Y. Han, T.Li, D.Yang. “Overview of 3D tracking registration technology in augmented reality [J/OL]”, Computer Engineering and Applications: 1-13[2019-09-30].
[2] J.Liu. “Application of augmented reality technology in remote tower control”, Electronic test, No.16, pp.121-122, May 2019.
[3] S.q.Ye, L.Lin. “A review of patented technologies for augmented reality human-computer interaction control”, Science and Technology Economics Guide, 27 No.22, pp.226, Sep 2019.
[4] M.Y.Han. “Augmented Reality and Spatial Turn--The Scene Writing and Aesthetic Change of Network Literature”, Literary Theory Research, No.04, pp. 33-38, Apr 2019.
[5] G. Li. “The Influence of Virtual Reality Technology on the Construction of Training Base”, Information Systems Engineering, No.07, pp.157, Jul 2019.
[6] J.Li, S.L.Wang, H. Pan, Y.R.Ma. ”Augmented Reality Underground Pipeline Visualization Technology Based on Mobile Terminal”, Journal of Zhengzhou University, No.03, pp.115-119, Mar 2019.
[7] X.Y.Ge, H.M.Bao, M.Feng. “Design of Remote Augmented Reality Interactive System”, Design, No.14, pp.137-139, May 2019.
[8] L.W.Ma, R.Deng, Z.X.Bao, D.Shi. “Design of Outdoor Exploration Concept Product Based on Augmented Reality Technology”, Creativity and Design, No.03, pp.98, Mar 2019.
[9] F.G.Peng, Y. Liu. “Research on Key Technologies of Mobile Augmented Reality System”, Surveying and Spatial Geography Information, No.06, pp. 145-148, Jun 2019.
[10] S.Zhang, Z.L.Ji, W.H.Wang. “Application of Augmented Reality Technology on the Battlefield”, Military Abstracts, No.11, pp.54-57, Nov 2019.
[11] C.L.Xu. “Research on Augmented Reality Technology for Digital Workshop”, University of Chinese Academy of Sciences No. Institute of Computing Technology, Chinese Academy of Sciences, 2019.
[12] J.Y.Zhang, D.H.Chen, T.Y.Yi. “Research and development of intelligent beehives and intelligent bee yards based on Internet of Things technology”, Science and Technology Innovation, No.3, pp.102-103, Mar 2019