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Wearable Device-Based Intelligent Patrol Inspection System Design and Implementation

Chengming Jin, Liaoning Power Development Group Co., Ltd., China*
Donghui Tong, Liaoning Power Development Group Co., Ltd., China

ABSTRACT

The traditional on-site operation of power stations includes inspection and maintenance. However, it heavily relies on experience for maintenance. Most on-site operation and maintenance data are text records. On the one hand, the data processing is tedious for experience to affect the safe on-site operation. On the other hand, we usually cannot give full consideration to the value of maintenance experience, so that the corresponding efficiency is very low. Therefore, this paper proposes a wearable device based remote and intelligent patrol inspection system that uses the cloud video transmission mode of both public and private clouds to realize the video connection between the power stations and the remote diagnosis center and uses the wearable devices for real experience. In this way, the authors can simulate real operation guidance and safety supervision, etc. so as to realize the remote management patrol operations, improve the fault detection efficiency, and improve equipment reliability.

KEYWORDS

Intelligent, On-Site, Patrol Inspection, Wearable Device

1. INTRODUCTION

During the on-site operation, the production personnel can realize the ledger, fixed value and drawing inspection through the intelligent glasses voice control, liberate their hands and improve the work quality and efficiency. The technicians of the remote diagnosis center can mark the video content on the PC side, which is convenient for the on-site personnel to understand (Nwaogu et al. 2021). In addition, the on-site homework can be recorded through smart glasses, which can be used for retrospective and training. It can better adapt to the development needs of industrial field operation to standardization, intelligence and safety, and better meet the remote technical support to overseas power stations (Bergman et al. 2005). It has great technical superiority and broad application space, which represents the development direction of intelligent wearable + cloud video technology in industrial application (Ahmad et al. 2012).

Power stations have the natural properties of intensive equipment and high degree of automation. The inspection of power station operation requires a lot of data monitoring of the field equipment to ensure that the equipment is in good condition (Brayne et al. 2017). When the equipment is overhauled, the operator needs to operate the equipment, put the equipment into the state of maintenance, and the maintenance personnel carry out maintenance according to the data such as drawing paper and maintenance process. At the same time, the on-site operation has the characteristics of complex working

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environment, many working sites and wide areas, frequent high-risk operations, such as high-altitude operation, live working, cross-working and so on (Carlucci et al. 2015). There are many unsafe factors of man-made unsafe behavior and environment in the process of production operation (Zhang et al. 2020).

According to the characteristics of the field operation of the power station, the intelligent wearable equipment can solve the above problems through the functions of calculation, monitoring, video communication and so on (Feng et al. 2021). Because there are many functions to be integrated, it tends to use large helmet-type or helmet-based smart glasses in power generation enterprises to meet the needs of daily on-site operations. At the same time, according to the business requirements of remote technical support, a remote technical support service system is built (Luo et al. 2021). Based on the same platform, realize the functions of remote technical support, operation and maintenance guidance, video communication and so on. In network applications, it should be divided into data transmission construction mode through public cloud and hybrid cloud according to demand, that is, audio and video communication uses public cloud, and file transfer uses hybrid cloud for data transmission (Talaat et al. 2020).

Through this study, a set of intelligent inspection systems (for example, the drone inspection system, where drones are equipped with AI models (Zhu et al. 2021a; Zhu et al. 2022) and intelligent image recognition models (Gao et al. 2022)) based on MR technology (including intelligent inspection terminal and intelligent safety operation production management platform) is built to realize the full-line implementation of safety supervision, the standardization, digitization and networking of the on-site construction process. In particular, these systems greatly reduce the attendance cost and invalid working hours of experts and safety management personnel, and at the same time relatively improves the work efficiency of workers. At the same time, the networking and digital implementation of full-flow operations also contribute to the deep docking of the group's parent system, provide the data cornerstone for the next construction of ubiquitous power Internet of things, and realize the concept of deep service integration at the arrival of the 5G era. to build an integrated intelligent operation and maintenance of the national power grid system. In order to realize the construction of intelligent inspection system and solve the existing problems of field equipment inspection in power system, the main objectives of this study are as follows:

- Intelligent inspection terminal based on MR (mixed reality) and small proprietary wireless network are adopted to realize real-time communication and data exchange between foreground and background, and to improve the control depth of foreground work and on-site work in the background.
- Through the introduction of all kinds of sensors and new IoT (Internet of things) equipment, it can improve the real-time data collection and storage ability of business process, and provide quantitative basis for business process optimization and management improvement through data archiving and mining.
- Through the introduction of three-dimensional interactive equipment, we can improve the practicality and depth of training. Via the digital modeling of the actual working environment or scene, we can realize the dynamic interaction between the real scene and the digital model, and improve the friendliness and effect of the training, as well as promote the rapid cultivation of personnel's professional quality.

Through the construction and application of the intelligent safety operation production management platform, we can further improve the overall work efficiency of inspection and maintenance, simplify the management process, and open up the data flow of different links such as operation site, logistics, transportation management and so on. achieve the dynamic and fine management of the whole process of the operation, so as to better achieve the ultimate goal of reducing cost and increasing efficiency, and ensuring the stable operation of the equipment.

The rest of this work are summarized as follows. Section 2 summarizes the related work. Section 3 introduces the designed patrol system. Section 4 evaluates the proposed system comprehensively. Section 5 concludes this work.

2. RELATED WORK

The safe and stable operation of the power system is the most important task, and in order to ensure the safe and stable operation of the system, we must first ensure the state of the equipment. A large number of failures and problems will occur in the daily operation of electric power and communication equipment, and the maintenance and maintenance of these equipment is the focus of the operation and guarantee work (Zhao et al. 2020). The traditional maintenance method is usually in the form of manual maintenance tickets, which has the advantages of low inspection efficiency and high safety risk. In order to solve the above problems, it is particularly prominent and important to study the intelligent inspection and maintenance system which has certain commonness and detects the operation of the equipment in the power industry. At present, many domestic power units have put forward solutions to the above problems, especially in colleges and universities, which have made achievements in related technologies (Tao et al. 2010; Zhu et al. 2021b).

The Southern Power Grid Peak Regulation and Frequency Modulation Power Generation Company published "Application of Intelligent Patrol system (Huang et al. 2017) in Secondary Hydropower Station" and proposed an intelligent patrol system based on handheld terminal. The purpose of this system is to combine radio frequency identification technology (RFID) (Li et al. 2018) with IPAD to standardize the inspection line and cycle of power plant, standardize the inspection task and intelligentize the analysis of patrol data, and provide support and guarantee for the reliable operation of power equipment (Zhang et al. 2022). The Automation Department of Tsinghua University extends the application research of MR to the maintenance process of nuclear power equipment, and uses mixed reality technology to build a set of nuclear power plant equipment maintenance auxiliary system, including interface, simulation, comprehensive analysis, guidance and supervision (Szakas et al. 2008). The system can guide the maintenance personnel to go to the correct position and carry out scientific and reasonable maintenance operation, and at the same time monitor in real time, once the maintenance personnel have the wrong operation to issue a warning and guide them to correct the error, so as to fundamentally improve the maintenance efficiency (Hui et al. 2012).

The Security Engineering Department of Sichuan normal University puts forward the design of intelligent substation maintenance safety measures assistant decision-making system, which completes the collection of digital information in the substation based on the IEC61850 rules (Deng et al. 2019) followed by the intelligent substation, focuses on the realization of the automatic generation technology of intelligent substation maintenance measures, constructs the online auxiliary platform monitoring data and updates the maintenance status in real time. Display maintenance safety measures in the way of graphics combined with text, and provide correct safety information for maintenance operators, so as to ensure the correctness, reliability, safety and timeliness of maintenance operations (Zhang et al. 2019). The China Electric Power Research Institute has customized a set of wearable device solutions for typical power operation scenarios, including smart safety caps, smartwatches and supporting monitoring systems (Zhang et al. 2018). The research results improve the work efficiency of workers, assist in solving operators' personal safety monitoring questions, and fully illustrate the advantages of wearable results in electric power inspection operations (Yi et al. 2022). North China Electric Power University even put forward the optimization research of intelligent operation and inspection of substation based on patrol robot, using patrol robot to completely replace the patrol work of human workers (Han et al. 2018).

The ThyssenKrupp of Germany developed its own intelligent inspection platform combined with the latest MR technology (Zacharie et al. 2009). Maintenance inspection workers wearing customized intelligent terminals can access the task target on the spot and view the three-dimensional disassembly diagram of the target workpiece at any time. Through real-time initiating to share pictures with background experts for barrier-free communication, problems can be solved quickly and neatly. According to statistical estimates, the application of this system has improved the operation and maintenance business efficiency of Tyson Knoop by more than 60% (Zhao et al. 2011).

3. INTELLIGENT PATROL INSPECTION PLATFORM DESIGN AND IMPLEMENTATION

The intelligent inspection terminal based on MR (mixed reality) (Zhou et al. 2017) is considered in this project, which is based on virtual visualization technology. Virtual visualization technology is the use of computer graphics and image processing technology, the virtual ring. The theory, method and technology of the integration of environment and real environment, and then interactive processing (Ma et al. 2022). There are three main technologies: VR (virtual reality), AR (augmented reality) and MR (mixed reality technology) (Sale et al. 2012), which can be used in the field of power system inspection. As a collection of virtual visualization technology and holographic technology, the development of MR technology has made a breakthrough in the past two years. Because of the rapid modeling, positioning, gesture speech recognition and interaction of indoor space scanning, as well as the function of cooperation and sharing of multiple devices, VR and AR have more advantages as daily tools to be used by employees in the whole process of construction to solve all kinds of business problems. Combined with the actual business needs, this study selected Hololens as the intelligent inspection terminal equipment, and we develop and build intelligent building system based on Hololens and its service platform.

In addition, the computer room intelligent inspection platform based on wearable technology is a set of hardware and software products tailor-made for the inspection business of machine room in electric power enterprises. The department integrates many advanced technologies, such as identity identification (Miscenko et al. 2016), wireless communication GPRS (Vejlggard et al. 2017), wearable glasses (Hong et al. 2016) and so on. Based on the concept of "mobile information platform", it changes the traditional working mode of computer room inspection, and actively explores a new way and new mode of computer room inspection management, which can minimize missed detection and wrong detection. Avoiding the situation that the quality of inspection is not high and the means are backward, and organically combine the information such as the operating status, operating parameters, maintenance and management of the equipment in the computer room, so as to prevent the equipment from over-maintenance (Ruigendijk et al. 2014) and under-maintenance, and reduce the occurrence rate of obstacles, to finally achieve the goal of safe, economic, scientific and effective equipment management.

4. WEARABLE GLASS BASED INTELLIGENT FRAMEWORK

The system can realize the infrastructure of front-end and back-end communication with the help of cloud computing. Like application services, this technology is designed to support scalable, reliable, and low-cost applications. Application services are hosted on a virtual machine (VM). You can access them remotely by installing your own software on VM that uses cloud services. In the future, you can also choose to deploy the server locally offline to ensure security and stability.

On the basic software platform, the social communication function module is integrated to realize the real-time video / audio function of the front and rear end, as well as the audio and video online recording and uploading function. As a result, the front-end and back-end real-time video call connection can be realized, at the same time, audio and video can be recorded, the security check of the scene can be realized in the background, and the front can ask the rear experts for help when necessary. For the 3D object in the project, the 3D model can be moved, rotated, scaled and so on in the terminal. Most engineering projects will create Revit models in advance, which can be imported into Unity and compiled into terminal equipment to realize the viewing of 3D models. Then the model can be located by the way of image recognition, the relative position of the model and the image can be identified and adjusted, the model can be located by the positioning function of the terminal itself and fine-tuning, and the direction of the model can be determined by turning the head. the position of the model is controlled by the eye point. It can also connect multiple MR devices under the wide area network to operate and view the model in a cooperative state. By setting the server to transmit

the anchor points scanned by one MR device to the other, the two sets with the same anchor points can realize multi-machine interconnection, and multiple people roam and operate in a large space. The marking operation in the background can be deployed through cloud services, so as to achieve multi-computer interconnection not only between the front end, but also between the front end and the background. This ability of multi-computer interconnection allows the front and rear personnel to monitor the same content at the same time, especially the three-dimensional model of the maintenance object and its related static and dynamic data records, which can greatly facilitate the operation of the field personnel and liberate their hands. Improve the efficiency of front and rear communication.

The design structure of the wearable glasses developed in this project is to make use of the optical reflection projection principle (Zhang et al. 2021), that is, the miniature projector first projects light on a reflective screen, and then refracts it to the human eye through a convex lens to achieve the so-called "primary magnification". Form a large enough virtual screen in front of people to display simple text messages and all kinds of data. The application software part is based on the Android (Gilski et al. 2015) operation system of wearable smart glasses to develop the related business of computer room inspection management to realize the combination of software and hardware. Generally speaking, the wearable glasses used in this item are the combination of micro projector, camera, sensor, storage transmission and control device. The small lens of the right eye includes a miniature projector and a camera, the projector is used to display data, the camera is used to capture video and images, and the storage and transmission module is used to store and output data. the control device can be controlled by voice, touch and automatic modes.

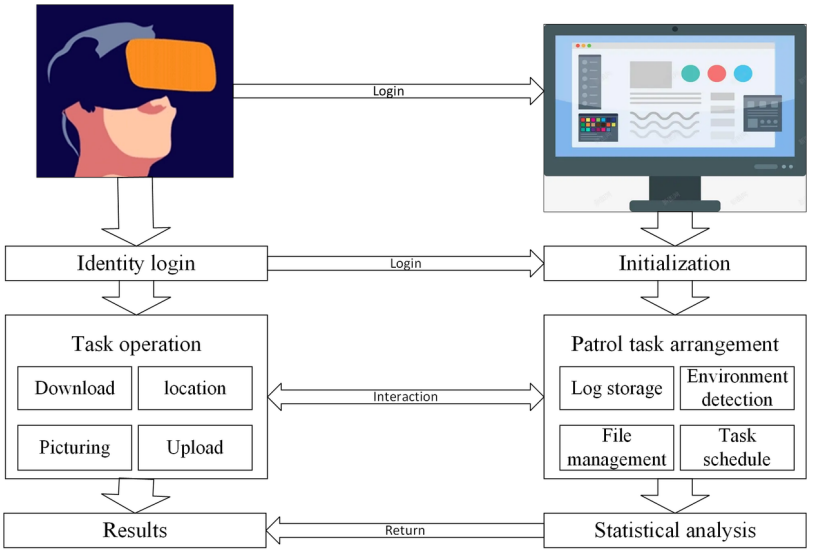
The wearable smart glasses used in this item show that the glasses are mainly composed of frames, cameras, prisms, CPU, batteries, etc. When the glasses are working, they are first captured and changed by the camera, and then through a miniature projector and a semi-transparent prism. The image is projected onto the human retina.

5. INTELLIGENT INSPECTION PLATFORM

The intelligent inspection system includes the intelligent inspection terminal based on MR (mixed reality) and the intelligent safety production management platform. System preset equipment and site 3D model, patrol task information and patrol operation. The manual will facilitate the on-site operation of the inspector at the terminal. At the same time, the system obtains the field operation image, influence and equipment data through the intelligent inspection terminal to record the whole operation process. The field personnel can connect the background technical force in real time through the system to assist the decision-making of unexpected situations and difficult points on the spot. At the same time, the intelligent safe operation production management platform provides real-time monitoring and guidance platform for managers and technical experts, and can update the field equipment and site model through the background management platform, and carry on the online digital management to the operation data.

As shown in figure 1, this project establishes a unified computer room inspection and management platform (top right side) based on wearable intellectual glasses (top left side), which includes the foreground intelligent eye mirror system and the rear management machine subsystem. The foreground intelligent glasses system realizes task download query, inspection standard query, equipment identification and location, scene shooting and remote live broadcast, and upload inspection records. The subsystem of the back-stage management machine realizes the management of equipment files in the computer room, the establishment of inspection standard system, the generation of inspection tasks, the management of inspection records, the management of situation and the statistical analysis of inspection. The platform architecture is shown in the following figure.

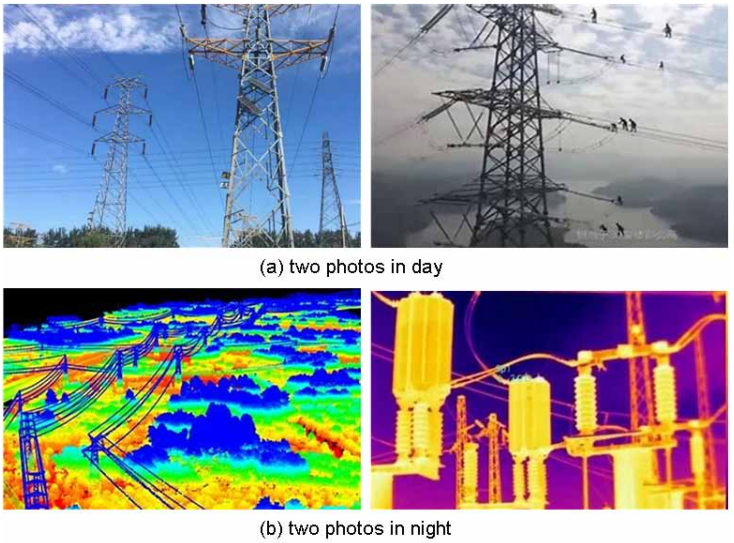
Figure 1. Platform structure



6. EVALUATION

The intelligent inspection platform based on wearable technology proposed in this paper has achieved good application results. It brings convenience to the modern computer room inspection and management business with the benefits of paperless, efficient, accurate, transparent information, simple management and intelligent analysis. The first view shot by the inspector in the control room can truly restore the scene picture of the inspection. In particular, the front camera with 8 million pixels can focus accurately and quickly; and the depth optimizes the quality and size of the photos. The patrol inspection photos captured by these cameras are shown in figure 2 as follows:

Figure 2. Patrolling photos with the first view camera

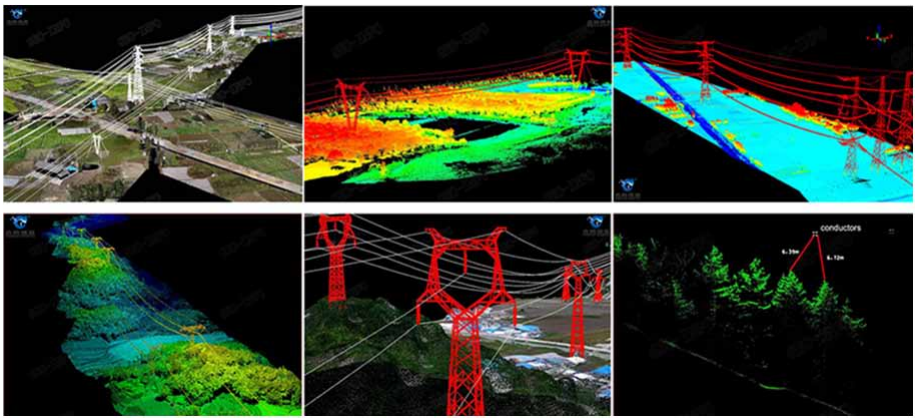


Specifically, we need to notice that: (1) When the inspection personnel in the computer room need to share the data such as painting, sound and location with the back-end management system through WIFI or 5G network, the traditional users use mobile phones, iPAD, peeping cameras, etc., but when the user's hands are occupied. Wearable smart glasses can still output the field data to the server at the first corner of view. (2) About the on-site safety operation instruction, after wearing the patrol inspection and setting up the standby landing system, the on-site operators can obtain the detailed operation flow of the equipment, and the system will automatically distribute the task information of the current operation, provide the three-dimensional model of the equipment and related information, and assist the on-site personnel in safe operation. (3) At the same time, through the image, image recording and real-time return of the on-the-spot operation flow and the real-time examination and approval of the safety control points, we can fully supervise and control the operation flow to avoid the safety risk operation of the operators.

Apart from this, the proposed system also supports the security surveillance. Through the intelligent safe operation production management platform, the background managers can view the task distribution on the GIS map, carry out real-time GPS positioning of the operators, and assist the operators in attendance. By establishing a video connection with the intelligent inspection terminal, the background management personnel can remotely examine and approve the security control points to ensure that the safe operation flow can be carried out in an orderly manner; at the same time, managers can establish a real-time video connection with the operation site to conduct security spot checks, detect site violations in a timely manner, and provide guidance and corrective suggestions for on-site safety operations. The system assists the safety management and control of the operation site, in view of the power equipment to avoid the emergence of dangerous behaviors such as self-test and self-inspection, to achieve full coverage of field quality and safety acceptance, and reduce the possibility of safety risk accidents.

Moreover, the inspector in the computer room can scan the code through wearable smart glasses to obtain relevant information, and can also identify images such as pictures. AR wearable glasses can quickly and correctly identify scenes and superimpose virtual objects, scenes, videos, or prompts into the real scene, for example, we capture the view from wearable glasses and show them in figure 3. Apparently, we can see that the wearable glass provided pictures can also show the details of the environment. Particularly, there are also some noticed information with the help of MR. Hence, we can get more information with this kind of technology.

Figure 3. Remote patrolling view with wearable devices



Now, comparing the views from the cameras and the view from the wearable devices, we can summarize the analysis results in Table 1, where we can see that the view from real cameras can reflect the real world accurately and correctly. For example, the recognition rate can reach 100%, while the view from the wearable devices reaches 98%, which is approaching to the target. For the other metrics, the wearable devices can also achieve similar results, for example, the captured light is good. The only limitation is that the pixel of the wearable devices is lower than that from the real cameras, in about half the percentage. Moreover, we can see more results bout the expert remote diagnosis. It provides a set of efficient and accurate solutions to the complex situations such as emergencies, difficult faults and so on. The on-site operator sends a video request to the technical expert through the intelligent device and gives real-time feedback on the scene. Technical experts can obtain on-site data and equipment information through the intelligent safe operation production management platform, such as three-dimensional decomposition model, basic properties of equipment, inspection records, maintenance records, etc., to assist experts and operators to study and judge the problems. At the same time, the specialist can mark the video picture and guide the operators accurately. In addition to realizing the digital preservation of job tasks and operation results, the information of job objects (load switches, etc.) can also be completely digitized. Such as three-dimensional models of switches, models of different levels. The proposed system can also deal with different scenarios, the basic three-dimensional model can be used to identify the fault point of maintenance, and the more responsible model with operation time flow can be used in training and other occasions, realizing the comprehensive application of full-professional and full-process data.

Table 1. The comparison results

	Recognition	Accuracy	Pixel (million)	Light (color)
View from real cameras	100%	99.999%	800	good
View from wearable devices	98%	99.9%	400	good

7. CONCLUSION

Combined with the mix reality code scanning technology of intellectual glasses, this item realizes the integrated intelligent inspection and supervision of the equipment in the computer room of the power industry, connects with the back-end equipment supervision system information, and scans the QR code through the front-end intellectual glasses. Back desk automatic push equipment historical attributes and status information to assist workers to maintain equipment. And through the technology, in the equipment maintenance, can intelligently push the maintenance guide picture, superimposed with the real equipment, to help the front-end construction personnel to complete the inspection task more efficiently. At the same time, intelligent glasses as an information concentration platform, through the construction of IoT network, push the sensor data of on-site equipment to the eyes of workers, provide workers with safety early warning and equipment status judgment, and truly realize intelligent power and intelligent work.

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