The Safety Training System Based on AR Cloud in Metallurgical Enterprises

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***Abstract*—Metallurgical enterprises are important for the production industry. The safety accidents occurred frequently as the complex production processes and severe work environment. The safety training of employees can improve their safety awareness and ability. It is one of the most important ways to reduce personal injury and property loss. This paper analyzed the existing training methods according to the needs of the employees of metallurgical enterprises. To address these drawbacks, this paper proposed a safety training framework based on Augmented Reality (AR) and cloud platform (CC). Several modules are designed in this framework, which including basic knowledge module, equipment cognition module, intelligent maintenance module, standardized operation module, accident emergency module, remote assistance module, training evaluation module, to achieve basic knowledge training, practical training based on augmented reality, evaluation of training efficiency, question answering, etc. This framework breaks through the limitations of existing training system and increases the proportion of operational skills in training. It can be applied not only to potential employees but also to experienced employees.**

***Index Terms*—safety training, augmented reality, cloud platform, metallurgical safety**

I. Introduction

China is a major metallurgical country in the world. Based on the statistical data from the World Steel Association, The crude steel production in China accounts for 49.19% of the world total production in 2017 [1]. At a global level, the per capita steel consumption in 2016 was 225kg, which shows that steel plays a crucial role in people's production and daily living [1]. The safety accidents are characterized by large-scale and high-loss with the development of industrial technology in metallurgical enterprises production [2]. As a result, people's attention has been aroused by this kind of accident in 2014, the metallurgical industry is clearly listed in key high risk industries in the new safety production law [3]. Up to 70%-80% of industrial accidents are caused by human risky behaviors [4].Training staff can improve their abilities and the capacities of handling accidents in daily work. It can minimize the possibility of production safety accidents and reduce casualties and accidental property losses.

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Staff training is one of the important ways to cultivate high-quality skilled workers. Its importance has been recognized by more and more companies [5]. The current training methods mainly have the following drawbacks [6], [7]. Firstly, the training is mostly fragmented teaching, which subject to funding, location, time and so on. Secondly, the training is mainly centralized teaching, so it cannot meet the needs of all workers who are in different position at the same time. Thirdly, the content of training deviates from reality and emphasizes on theoretical knowledge. However, the flexible application of these theories still requires much practice. In order to solve these drawbacks, many scholars introduced augmented reality technology in training. Augmented reality have already found preliminary study on learning tool, the staff training and auxiliary maintenance [8], [9]. However, researches in the field of metallurgy still need to be further strengthened.

In order to improve training efficiency and make up the lack of on-site training in current training, this paper proposed a safe production training framework based on augmented reality and cloud platform. The framework combines augmented reality with metallurgical companies, designing functional modules such as basic knowledge, equipment cognition, intelligent maintenance, standardized operation, training evaluation, remote assistance, and accident emergency.

II. AR Cloud Processing System

Metallurgical enterprises occupy a large area and production process is complex. From iron works to continuous casting, high temperature liquid runs through it all the time. Therefore, employees need to master the knowledge and standard operating skills in order to reduce the rate of accidents and ensuing losses. The regular concentrated teaching has failed to meet the needs of metallurgical enterprises. Against this phenomenon, AR cloud processing system was introduced in the paper. It is made up of augmented reality and cloud platform.

Augmented reality is to superimpose computer-generated information such as text and virtual objects in real scenes for realizing the combination of virtual environment and real scene mainly by means of computer graphics, visualization, photoelectric imaging and so on[10]. Augmented reality is developed on the basis of virtual reality. It can supplement information to real scenes and form a training environment in which operational

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guidelines and real scenes exist at the same time [11]. Cloud computing is a supercomputing model based on virtualization technology. It can integrate large-scale and scalable computing, storage, data, applications, and other distributed computing resources and make them work together, terminal users can access any applications they need at any time and any place [12]. Based on the advantages of augmented reality and cloud computing, the concept of AR cloud processing system is proposed as shown in Fig. 1.

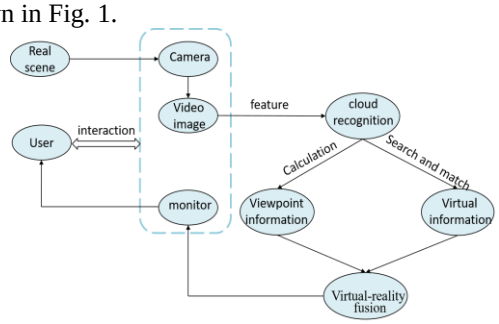

Figure 1. AR Note how the caption is centered in the column.

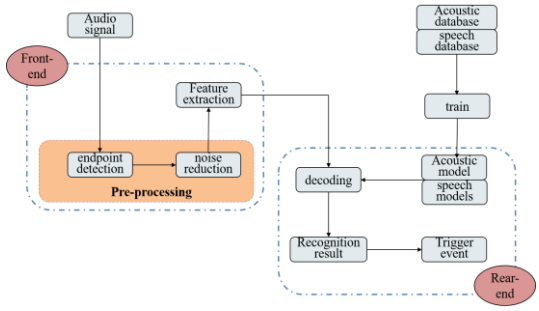

Figure 2. Voice interaction technology process.

The AR cloud processing system realizes the superposition feedback of virtual information in a real scene through five parts of real-scene capture, cloud recognition, virtual-reality fusion, augmented display, and real-time interaction (Fig. 1) [13]. The purpose of real-time scene capture is to get the video information of the device through the camera and upload it to the cloud. Cloud recognition is mainly used to identify the object in the real scene and calculate the spatial position of virtual information. Cloud server can store data and models of metallurgical enterprises. After identifying the device submitted by the terminal, the cloud will search the auxiliary information related to the device, calculate the viewpoint information of the user relative to the target object, and determine the content and space position of the virtual information. The spatial spot of the virtual information changes with the user's spatial spot. Virtual-reality fusion is the core part of augmented reality which can realize the seamless connection between words, pictures and other auxiliary information and real scenes. The main purpose of the augmented display is to present the augmented reality effect to the user, it plays a decisive role in the enhancement effect received by the user. The purpose of real-time interaction is to improve the user's perceptual experience. The current interaction ways mainly cover gesture interaction, speech interaction and so on. Generally, the choice of interaction depends on the nature and needs of employees in different enterprises. Therefore, voice interaction is chosen according to the poor lighting status and frequently hands-on operation in metallurgical enterprises. The principle of voice interaction is shown as Fig. 2.

Voice interaction is the process by which commands issued by employees are captured and executed by the system. The system captures audio signals. Firstly, the preprocessing process such as endpoint detection and noise reduction is performed to minimize the interference to the subsequent steps. Secondly, the audio features are extracted. Finally, the audio feature is matched with the trained acoustic and speech models in the acoustic and speech databases to find the best one and trigger the results.

III. System Framework Design

In order to standardize employee operations and reduce the risks posed by unsafe behavior, a framework for a safety training system for metallurgical enterprises is proposed in this paper. The framework covers the resources needed for staff pre-job training and on-job training. The following describes the functions of the system in terms of data support layer, processing layer, application layer and client. The relationship between them is shown in Fig. 3.

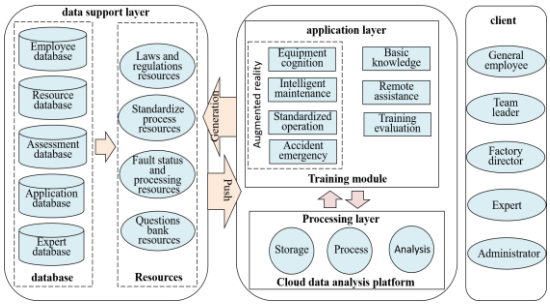

Figure 3. Voice interaction technology process.

The data support layer is the basis of the training system. It includes employee database, resource database, assessment database, application database, and expert database. The employee database covers the information of all employees in metallurgical enterprises and provides the basis for the establishment of permission setting in the course of staff training. For example, the hearth worker can only look up information related to the operation of equipment such as converter and ladle; the maintenance man responsible for the circuit will only see circuit experts. The resource database is the core part of the training system. It covers the laws and regulations required to be followed by different types of work, the overview of the production environment, the construction of equipment, the operation procedures, troubleshooting and other information which lays a solid foundation for the staff's working. The assessment database is dedicated to assessing the effectiveness of staff training, including the bank of questions and the corresponding evaluation criteria. The application database is mainly used to record

and analyze the training of employees in order to know the training situation of a single person or a whole workshop. Expert database is the information of experts in various industries who cooperate with metallurgical enterprises. These experts are classified according to their professional fields. When employees encounter problems in the training process, they can turn to experts for help through video or message. The application layer includes basic knowledge, equipment cognition, intelligent maintenance, standardized operation, accident emergency, remote assistance, training evaluation and other training modules. Equipment cognition, intelligent maintenance, standardized operation and other modules are combined with AR augmented reality. In addition, the evaluation module is set up to evaluate the training effect of employees. The system is mainly for general employees, team leaders, factory directors, experts and administrators. Employees invoke the corresponding resources through the cloud platform and their training process is stored in the database in the opposite path through the processing layer.

IV. System Function Module

A. Basic Knowledge Module

This module mainly carries out the pre-job training for employees in metallurgical enterprises. The system in advance stored the basic knowledge of metallurgical production process, main equipment, safety education, workshop layout, regulations and rules and so on. Employees can learn through the electronic resources to control the functions and organizational structures of different workshops like ironworks, steelworks, continuous casting, as well as the operation status of blast furnace, converter, travelling crane and so on.

B. Practical Training Module

The groups of metallurgical enterprises are mostly skilled workers. The main purpose of practical training is to improve their hands-on ability. Given the personnel safety and economy condition, theory learning and practical operation are usually taught separately in existing training. However, this teaching mode is not conducive to the flexible application of theoretical knowledge in practical operation. In view of this situation, the introduction of augmented reality has created conditions for the integration between on-site and theoretical.

Augmented reality overlays the operation processes, precautions, equipment structures and other information required by metallurgical enterprises in the real training scene, and devotes to the realization of the synchronous training mode of virtual information guiding and physical operation. In the augmented reality training mode, the auxiliary information changes with the spatial position of the person so that the auxiliary information within the view of the employee is seamlessly connected with the real scene. Employees wearing the interactive device achieve the real-time interaction with the work scene. Different augmented reality operation processes are designed for equipment cognition, standardized operation and intelligent maintenance module. The specific process is shown in Fig. 4.

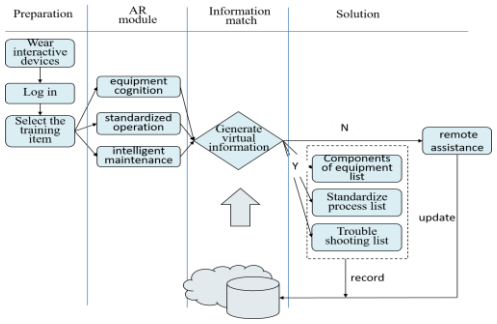

Figure 4. Training flow chart based on field equipment AR.

Job skill training is essential in metallurgy industry production. There are significant differences in operating equipment and job requirements among various posts. Workers need to be explicit about the aim and choose the corresponding training module. The system will filtrate auxiliary information from previous materials based on workers' needs, and transform them into virtual lists. The concrete instructions of three modules above are as follows.

1) Equipment cognition module

The amount of workers in metallurgical enterprise is enormous, and the tasks are heavy as well. So being familiar with the devices is the first step of achieving safe production. Only if the workers master the function, principle and construction of the devices, can they operate them better in the future. Augmented reality changes the way of device learning. Workers could learn knowledge of devices from e-resources or on-site training. There are not only text resources, but also labels that stand for matched videos and models. By recognizing those labels, workers can see the described scenes, 3D model, risk information and the functions of the operation buttons of the device. In the on-site training, workers recognize objects by wearing an interactive device. The system will search for the corresponding auxiliary information and cover them on the device, so that those workers can see them at the same time. Meanwhile, it will generate a virtual list, on which those workers can label and record through voice interaction once they finish one item. The introduction of augmented reality gives stuff an experience combined virtual with reality, which helps them have a deeper understanding of the devices as well as lay the foundation of standardized operation.

2) Standardized operation module

Technical, equipment and job skills desire in metallurgy industry are multi-layered now, but standardized operation is the precondition of achieving safety production in all types of works [14]. Not only spot check, routing inspection and group management, but also converter, steel ladle and slag ladle, all of these have a series of standardized code of conduct. Standardization training promotes staff to form safety awareness and standard operation.

Different jobs have different production tasks, so standardization training should formulate reasonable content in accordance with job category. For example, converter steelmaking workers have intense continuity producing, thus the training could include molten iron measurement, blowing oxygen time, catch carbon frequency, oxygen usage, terminus temperature control, production quality, steel consuming, etc. [14]. The employees can wear interactive device to scan for the equipment that they need to learn. After analyzing, the system will show an instruction list which includes the device operating points, steps, demonstration actions and other information need to be learn by workers. While they are practicing, the system will keep record and give warning once the operation is wrong. Standardization is the core in job skills training, and it can be done combined with equipment acknowledge.

3) Intelligent maintain module

Metallurgy industry has many complex equipment. Any part goes wrong will cause malfunction. Even the same malfunction may due to different reasons. Though fault handling system is gradually being improved, some troubles are beyond maintainers' ability. In order to deal with this phenomenon, the system adds an intelligent maintain module. The module uses the characteristics of real-time interaction and virtual-reality fusion of augmented reality, supplies a training environment of information synchronized with operation for employees [15]. On the one hand, it can help workers obtain solution in real-time, including operating steps and risk reminders. On the other hand, workers can upload new situations they meet during fault treating to cloud platform, so as to perfect resources database.

There are two ways to find fault. First, periodic detection personnel (like spot check or routing inspection staff) finds equipment goes wrong during inspection. Periodic inspection is the key link in daily work in metallurgy industry. This module has the function of reminding maintainers in advance, generating detection list, recording situation and reporting fault automatically. Once a fault is being detected, the system will give corresponding methods based on how severe it is. The other is monitor room or spot operation workers find equipment abnormal thus upload situation to the system. Then the system will inform maintenance workers and give a solution. Workers wear interaction device, operate with the help of instruction given by the system until solve the problems. The detailed process is showed as Fig. 5.

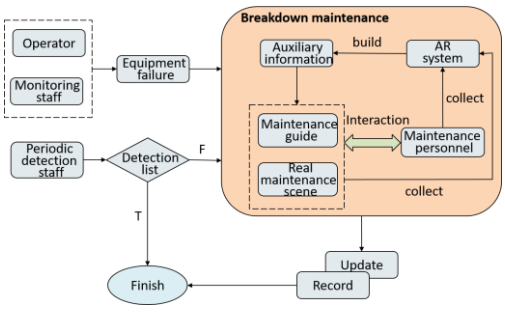

Figure 5. Intelligent maintain module.

4) Accident emergency module

The production environment of metallurgical enterprise is hostile, especially the temperature of liquid steel can even reach to thousand degree. Once there is an accident, it may cause severe consequence. If it happens, it most probably will accompany with dense smoke, which will to a large extent block workers' view. So enhancing the emergency disposal capability and assist evacuation is important in reducing personal injury and property loss.

Accident emergency module should include accident evolution and emergency disposal. When workers learn accident cases, they can see how the accident happens and how to solve different ones. On the practical training, the system should have the function of accident reporting, co-processing, escape assisting. As long as people around site of accident report the situation through the system, leaders will initiate contingency plan at once and give different emergency disposal directions to the people in different areas. Those in dangerous area evacuate, they will wear an interactive glasses, in which forms an escape route synchronous with real scenes within the scope of view.

C. Remote Assistance Module

The training content related to each module of application layer, such as equipment cognition, intelligent maintenance, standardized operation, comes from the resource database. Due to the complexity of the site of the metallurgical enterprise, it is unrealistic for the resource database to cover all the information. When training, employees are likely to encounter problems that the system cannot solve. In the remote assistance module, employees could consult relevant experts through messages, videos, pictures, and other forms. At the same time, the system updates the database to prevent the same problem from occurring later.

D. Training Evaluation Module

The training assessment module is mainly used to examine the training effectiveness of employees. It mainly includes two aspects. One is training performance assessment. The system will give corresponding scores based on the employee's training results, operational standards, proficiency, and completion time. Another is the assessment of training effectiveness. If the employee completes the training, the system will randomly select questions related to his training to assess the employees. When the assessment is completed, the system automatically generates and records the results. The difference between this system and existing assessment is the assessment of hands-on capabilities. The system issues questions randomly according to the nature of the employee's job and training content. These topics may be common theoretical questions, and may require employees to handle a failure or complete a task. Employees need to complete the questions given by the system within the limited time. For example, for maintenance electricians, the key of assessment is the ability of electricians to eliminate accidents and the ability to wire wiring. The system can set faults in the

lanes of crown block and give corresponding scores according to the performance of the employees. The system will give the correct explanation for the missing items in the assessment process. At the same time, these missing items will be recorded as key items, and the frequency of occurrence will increase in the subsequent assessment.

V. Conclusion

Because of the complex production processes and potential safety hazards, safety accidents are easy to burst in metallurgical enterprises. Training employees is an important way to reduce the probability of accidents. First of all, based on the needs of employees, this paper analyzed the current status of the training in the metallurgical industry and figure out its drawbacks. In order to solve the drawbacks in the training process, a novel AR cloud processing system was proposed. Secondly, this paper analyzed the working principle of the AR cloud system and the interaction between employees and the system. Finally, this paper proposed a training framework based on the AR cloud to train employees in the production process in terms of operations, emergency and other aspects. This framework has designed several functional modules such as basic knowledge module, equipment cognition module, intelligent maintenance module, standardized operation module, accident emergency module, remote assistance module, training evaluation module. These modules constitute the main content of staff training in metallurgical enterprises. This framework combines the theoretical knowledge with practical operations and increases the proportion of actual operations in existing training. It can simultaneously meet the needs of employees both on theory and practice leading to the efficient and interactive training. It has a wide range of applications both applying to potential and experienced employees in the metallurgical industry. In addition, the training system can design corresponding systems according to the specific needs of enterprises. It not only can be applied to metallurgical enterprises, but also has an important practical significance and application value for work in other fields.

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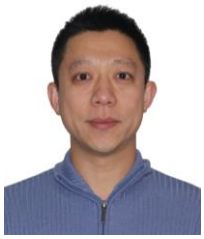

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