Development of augmented reality system for servicing electromechanical equipment

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Abstract. Electromechanical equipment is widely used. It is used in industrial enterprises, in the spheres of public services, in everyday life, etc. Maintenance servicing of electromechanical equipment is an important part of its life cycle. High-quality and timely service can extend the life of the electromechanical equipment. The creation of special systems that simplify the process of servicing electromechanical equipment is an urgent task. Such systems can shorten the time for maintenance of electrical equipment, and, therefore, reduce the cost of maintenance in general. This article presents an analysis of information on the operation of service services for maintenance and repair of electromechanical equipment, identifies the list of services, and estimates the time required to perform basic service operations. The structure of the augmented reality system is presented, the ways of interaction of the augmented reality system with the automated control systems working at the enterprise are presented.

1. Introduction

The number of electromechanical equipment used at mining plants is significant. Maintenance of the electromechanical equipment is a main factor of costs. In the struggle for a competitive advantage, plants are looking for various ways to improve production efficiency [1, 2, 3]. One of the ways can be a decrease of the cost of maintenance of electrical equipment [4]. Today, there are various systems that simplify the maintenance of electromechanical equipment - remote maintenance systems, a system for predicting the technical condition of electromechanical equipment, the adaptive system of equipment repair planning, etc. [4,5,6]. The augmented reality system is one of the additional tools to improve the efficiency of maintenance of electrical equipment.

The Augmented Reality System is a modern technology and it is already being applied in various areas of human activity [7, 8]. The using of the augmented reality system for servicing electromechanical equipment is an actual task [9,10]. To integrate a system of augmented reality into the work of service services means the solution of the following tasks: identification of the most efficient zones for the realization of the augmented reality system, development of the structure of augmented reality system, the design and development of the system, the introduction of this system into operation [11, 12]. The solution of the task "Identification of the most efficient zones" implies the analysis of the work performed by the service crews, identification of time spent on the performance of these works and the level of their complexity. At the stage «Developing the structure of augmented reality system», the functional and elemental composition of the system is selected and interoperations
of this system with contiguously-allocated automated systems operating in the plant are determined. At the stage "The design and development of the system", the hardware and software are chosen. And the final stage is the introduction of this system into operation. In this article, the implementation of the first two stages of the development of the augmented reality system is considered. Detailed study of the functional possibilities and the structure of the system helps to decrease serious mistakes that may arise during its operation.

2. The basic principle of servicing electromechanical equipment

At a plant of the mining industry, five mobile service crews are used to service the electromechanical equipment. Each team consists of three people. In this research, the special data contain the information about the work of one of such crews.

As a method of analyzing data on the work of the service crew, the method of working time photography was used. According to this method, the workers of this crew realize 28 functions during servicing electromechanical equipment. Five of them are the most suitable for implementation in the augmented reality system. These functions are: information search, diagnosing of defects, collaboration with other specialists, collecting additional information, adding information about service works. On average, 1 to 3 hours were spent by the crew to perform these functions, which is about 35% of the time spent by the crew at one zone. After identifying the functions that are possible to implement in the augmented reality system, time calculations spent on performing the same operations only using the system are performed. The results of the comparing are shown in Figure 1.

As a result of comparing of execution time of functions with the Augmented Reality System and without one, the average time for maintenance of electrical equipment by a crew was reduced by 68%. This result was achieved mainly due to the shortening of the time of this function: collecting additional information, searching for additional information, collaboration with other specialists and adding information about service works.
3. The augmented reality system for servicing electromechanical equipment

Possible areas of application of the augmented reality system are very diverse. The system can provide access to maintenance instructions, historical data on the operation of the equipment, information about predicted defects on different parts of the machines.

When access to the maintenance instructions of the equipment is provided using the Augmented Reality system, the details of maintenance and the additional information about the current step, the next step and the previous step, the instruction list of maintenance are visualized. In addition, the time allocated for the current, the next and previous maintenance steps are displayed. The presence of links to the next and previous step is mandatory, since the specialist can go back one step or plan the time and actions necessary to perform the list of steps for servicing electromechanical equipment.

When the mode "Access to historical data on the operation of equipment" is selected, the information about the values of the various parameters of the electrical equipment at different points in time appears before the servicing personnel. A specialist can view the electrical parameters (current, voltage, power, etc.), parameters of technological processes (capacity of the technological complex, pressure, temperature and other parameters characterizing the process change), and diagnostic parameters (parameters of vibration analysis, thermal analysis, etc.). Data can be selected independently: in the form of pop-up values, in the form of tables, graphs, etc.

If one selects the mode «The information about predictable defects on different parts of machines», the following information is displayed before the user: determining the position of the equipment's life cycle, the forecast of a state of electrical equipment for different periods: day, month, year, etc. The length of the period can be changed by the user independently. In addition, information on recommended actions that can extend the life cycle of equipment is displayed.

During maintenance, information and service status are constantly displayed to the user. The status changes in real time. Information about the repairs carried out is recorded in the system.

In the augmented reality system, voice control is provided. Voice control helps to speed up the process of switching to different modes of the system, searching for necessary information, etc.

Implementation of the described functional is impossible without the collaboration of the augmented reality system with the existing automation systems in the plant. To work together augmented reality system and related automated control systems, it is necessary to organize a special private cloud data space at the plant level. At least in the zone of this private cloud space, one needs to place an analytical server and a data storage server. The function of the storage server is to collect information about the operation of the plant. The analytical server communicates with the data storage server and performs various analytical functions (determining the optimal modes of operation of the equipment, predicting defects, etc.).

To conduct analysis and perform tasks to determine the defects of electrical equipment, the private cloud space of a plant is linked with a global cloud space, in which global information on the use of electromechanical equipment of this and similar types is accumulated and analyzed. In this case, only certain knowledge is recorded from the global cloud space, which is stored as information in the private cloud space of the plant.

Special services of the augmented reality system interact with adjacent automated control systems through private cloud space, mainly using an analytical server. Such organization gives a number of advantages, the most important of which are - fast access to data, redistribution of computing power to the cloud platform, ensuring information security, etc.

One of the most difficult tasks for implementing augmented reality system is the correct choice of a special mark. In this research, the RFID tag and GPS coordinates were chosen in the capacity of a marker. At the first stage, the RFID tag allows finding a complex of electromechanical equipment, at the second stage the GPS coordinate will allow one to select the necessary equipment from the equipment included in the complex. The use of RFID + GPS will allow the flexible identification of real-world objects in a virtual reality of augmented reality.

The structural circuit of the augmented reality system is shown in figure 2. It contains two service buses – the plant service bus and the AR-system service bus. The AR-system exchanges the
information through the plant private space. It is a cloud platform. It contains the analytic and data storage server, used during communicating between the AR-system and sensors.

![Diagram of the augmented reality system](image)

**Figure 2.** Structural circuit of the augmented reality system

4. **Conclusions**

A large amount of electromechanical equipment that is used at plants is serviced according to the schedule compiled on the basis of technological maps and programs of preventive maintenance. Often, information about the condition of the equipment and the prediction of its residual life is outside the field of view of repair personnel, especially when the equipment is maintained under contract with the repair company.

Integration of the augmented reality system usually consists of providing interactive access to the documentation databases and step-by-step instructing and monitoring systems. The use of augmented reality in integration with automation systems will allow integration of predicting services based on "Big data" technologies, multifactor diagnostic systems and expert evaluations of a specialist directly at the workplace. Increasing the efficiency and capacity to determine the state of equipment and its repair is based on the provision of timely, full and veracity information and predicting results. Instant analysis and visualization of data without additional tools allow one to achieve high productivity and reduce the costs of performing operations to search and analyze information.
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