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Practical Application of Artificial Intelligence Technology in Safety Management of Instrument/Electrical Laboratories in Universities

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Abstract: The safety management of instrument and electrical laboratories in universities is very important. This paper focuses on the application of artificial intelligence (AI) technology in this field. Firstly, the related theories and technical foundations are expounded, covering machine learning, deep learning and sensor technology, which constitute the cornerstone of application. Then, a variety of application strategies are put forward, such as monitoring equipment and personnel by image recognition, monitoring environment and equipment status by sensors, implementing predictive maintenance by means of data analysis, and building an intelligent early warning and emergency response system to improve the efficiency of safety management in multiple dimensions. Futhermore, the challenges faced by the application are analyzed, including data quality and algorithm efficiency at the technical level, data security and privacy risks, and personnel and management problems. In view of the challenges, this paper gives corresponding solutions, including establishing data quality monitoring, optimizing algorithms, strengthening data encryption and access control, carrying out personnel training and combing management processes. The research shows that the rational use of AI technology and effective response to challenges can build a more intelligent, efficient and safe safety management system for instrument and electrical laboratories in universities, and provide a strong guarantee for the safe operation of laboratories in universities.

Keywords: AI Technology; University Laboratory; Safety Management; Application Strategy; Challenge Response.

1. Introduction

In the field of higher education, instrument and electrical laboratories in universities, as important places for teaching and scientific research, shoulder the heavy responsibility of cultivating professional talents and promoting academic innovation [1]. However, this kind of laboratory is difficult to manage safely because of its complicated instruments and equipment and numerous electrical systems, and its potential risks cannot be ignored [2]. The traditional laboratory safety management mode relies on manual inspection and experience judgment, which is not only inefficient, but also prone to omissions, and it is difficult to meet the growing safety management needs of modern university laboratories [3]. With the rapid development of information technology, AI technology gradually shows great application potential in various fields. Its powerful data analysis, pattern recognition and intelligent decision-making ability provide new ideas and methods for the safety management of instrument and electrical laboratories in universities [4]. Introducing AI technology into laboratory safety management is expected to realize real-time monitoring, accurate early warning and intelligent disposal of potential safety hazards, thus significantly improving the scientificity and effectiveness of safety management.

At present, some research work has been carried out on AI technology in laboratory safety management in universities [5]. Some researches focus on monitoring the running state of laboratory equipment by using image recognition technology, while others explore the real-time perception of laboratory environmental parameters by using sensor networks [6]. However, the existing research focuses on the application of a single technology, lacking systematicness and comprehensiveness, and has not yet formed a mature theoretical and practical system on how to deeply integrate multiple AI technologies into the laboratory safety management process.

Based on this background, this study aims to explore the practical application of AI technology in the safety management of instrument and electrical laboratories in universities. By combing the relevant theoretical and technical basis, this paper analyzes its application scenarios, strategies and possible challenges in laboratory safety management, and puts forward targeted countermeasures. This study is expected to provide theoretical support and practical guidance for improving the level of laboratory safety management in universities, and promote the wide application and innovative development of AI technology in this field.

2. Related Theoretical and Technical Basis

As a frontier discipline, AI covers many theories and technologies, which provides a solid support for the safety management of instrument and electrical laboratories in universities. Machine learning theory is one of the cores of AI, which is dedicated to making computers learn patterns and laws through data, thus realizing the prediction and decision of unknown data [7]. As a branch of machine learning, deep learning is based on deep neural network and can automatically extract advanced features from a large number of data [8]. In laboratory safety management, convolutional neural network (CNN) is often used for image recognition tasks, such as identifying whether the equipment is running normally and whether the personnel follow the safety operation rules by analyzing the laboratory monitoring video. Recurrent Neural Network (RNN) and its variant Long-term and Short-term Memory Network (LSTM) are good at processing time series data, and can analyze the time series of

laboratory environmental parameters and predict the changing trend of environmental safety.

Sensor technology is the key to obtain laboratory safety-related data. Various sensors, such as temperature sensor, humidity sensor and smoke sensor, can collect laboratory environmental parameters in real time; Current sensors and voltage sensors can monitor the operating state data of electrical equipment [9]. The data collected by these sensors provide a rich source of information for AI algorithm, which enables it to make accurate safety judgments and decisions based on actual data.

3. Application Strategy of AI Technology in Laboratory Safety Management

In the safety management of instrument and electrical laboratories in universities, with the help of AI technology, a more perfect safety management system can be constructed from multiple dimensions, which can effectively improve the management efficiency and accuracy [10]. Image recognition technology plays a key role in laboratory safety management. With the help of cameras and other equipment to collect image information, CNN and other algorithms can be used to monitor the status of laboratory equipment and personnel behavior in real time. For personnel, it can monitor whether they wear protective equipment correctly, such as safety helmet and goggles, and whether there are illegal operations. Taking the electrical laboratory as an example, if the staff does not wear insulating gloves as required, the image recognition system can quickly capture and give an alarm. Sensor technology can sense the laboratory environment and equipment running status in real time. Various sensors, such as temperature and humidity sensors, smoke sensors and gas concentration sensors, are arranged in the laboratory, which can collect environmental parameters in real time. Once the environmental parameters exceed the safety threshold, the system will issue an early warning immediately. For instruments and equipment, by installing sensors such as current, voltage and vibration, the running status of the equipment can be monitored in real time. When the current of electrical equipment fluctuates abnormally, which may indicate that there is a fault inside the equipment, the sensor transmits data to the analysis system so that managers can deal with it in time and avoid accidents.

In-depth analysis of a large number of collected data by using AI algorithm can mine potential security risks and realize predictive maintenance. Through the comprehensive analysis of historical operation data, fault records and environmental data of equipment, a prediction model is constructed. Table 1 shows an example of predictive maintenance cycle based on data analysis for some equipment in instrument laboratories:

Table 1. Predictive Maintenance Schedule for Some Equipment in Instrument-type Laboratories

Equipment Name	Key Operating Parameters	Predictive Maintenance Cycle Based on Data Analysis
High-precision Spectrum Analyzer	Optical Signal Intensity, Wavelength Stability	Every 6 months
Intelligent Electronic Load	Current Carrying Capacity, Temperature Variation	Every 4 months
High-speed Centrifuge	Rotational Speed Stability, Vibration Amplitude	Every 3 months

When the AI system detects a security risk, it can quickly issue an intelligent early warning. Early warning methods include sound alarm, SMS notification, APP push, etc., to ensure that relevant personnel can obtain information in time. Futhermore, according to the preset emergency plan, the system automatically starts emergency response measures. In case of fire, after the smoke sensor and temperature sensor trigger the alarm, the system will automatically turn off the power supply of related electrical equipment, start the fire sprinkler system, and notify the laboratory management and the campus fire department to minimize the accident loss. The safety analysis of instrumental analytical chemistry laboratory is shown in Figure 1:

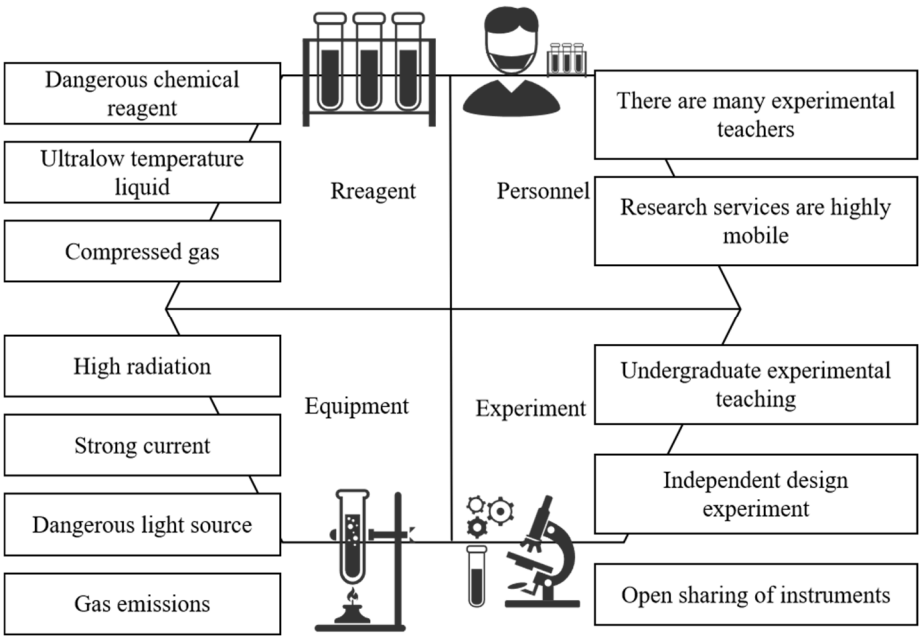

Figure 1. Safety analysis of instrumental analytical chemistry laboratory

Through the above comprehensive application strategies of various AI technologies, an all-round and intelligent safety management system for instrument and electrical laboratories in universities can be constructed, which can effectively guarantee the safe operation of the laboratories.

4. Challenges and Countermeasures of Application

4.1. Technical Challenges and Countermeasures

Although AI technology has significantly improved the safety management of instrument and electrical laboratories in universities, it still faces many challenges in practical application and needs to put forward corresponding measures. AI relies on a large amount of accurate data for learning and decision-making. However, the laboratory environment is complex, sensors may fail, and data transmission may be lost, resulting in data loss or errors. The countermeasures include establishing a data quality monitoring mechanism and regularly calibrating and maintaining data acquisition equipment such as sensors. Using data cleaning and repair algorithm, the abnormal data are identified and corrected.

Although advanced AI algorithm can improve the accuracy of safety management, it is often complex and requires a lot of computing resources, which leads to slow processing speed. In the real-time monitoring scene, such as the sudden fire in the laboratory, if the algorithm can't respond quickly, it will delay the emergency treatment. Relevant personnel should optimize the algorithm structure and adopt lightweight model or model compression technology to improve the calculation efficiency on the premise of ensuring accuracy. Futhermore, using cloud computing, edge computing and other technologies, some computing tasks are pre-positioned to edge devices to reduce data transmission delay.

4.2. Data Security and Privacy Challenges and Solutions

Laboratory data contains a lot of sensitive information, such as equipment parameters and scientific research project data. Once the data is leaked, it will not only affect the scientific research work, but also bring security risks. Table 2 below presents the possible consequences of data leakage:

Table 2. Analysis of Consequences of Laboratory Data Leakage

Data Type	Possible Leakage Pathways	Consequences of Leakage	Scope of Impact	Key Points for Response
Instrument and Equipment Parameters	Network attacks, unauthorized operations by internal personnel	Competitors obtain key technical indicators; malicious individuals use parameters to damage equipment	Competitiveness of research achievements, equipment safety	Strengthen network security protection, strictly manage personnel permissions
Experimental Project Data	Loss of data storage media, hacker intrusion	Theft of research achievements, damage to intellectual property rights, leakage of project progress and direction	Overall advancement of research projects, academic reputation	Encrypted storage, regular data backup and security audits
Personnel Information (including experimental personnel, research teams, etc.)	Identity theft, system vulnerabilities	Disclosure of personal privacy, potential harassment or fraud, leakage of team information affecting cooperation	Personal rights and interests, stability of research cooperation	Strict identity authentication, timely repair of system security vulnerabilities
Experimental Operating Procedure Data	Accidental document sharing, external malicious acquisition	Improper use leading to safety accidents or copying of technical know-how	Laboratory safety, technical confidentiality	Standardize document management, restrict access permissions

Relevant personnel should strengthen data access control and adopt technologies such as identity authentication and authority management to ensure that only authorized personnel can access specific data. Futhermore, the data is encrypted, and high-intensity encryption algorithm is adopted in the process of data transmission and storage to prevent data from being stolen or tampered with.

Personal privacy may be involved when image recognition and other technologies collect personnel information. For example, the surveillance video contains information such as the face and behavior of the experimenter, which is easy to invade privacy if it is not handled properly. Therefore, in the data collection stage, we should follow the principle of minimization and only collect the necessary information. Anonymizing data related to personal privacy, such as blurring the face in surveillance video, can protect personal privacy without affecting the security monitoring function. Futhermore, a strict privacy policy is formulated to inform the experimenters of the purpose, usage and protection measures of data collection and obtain their consent.

4.3. People and Management Challenges and Countermeasures

Some laboratory personnel have low acceptance of new technologies, are used to traditional management methods, and are unwilling to change their workflow. Moreover, AI technology is complex, and relevant personnel may lack knowledge of operation and maintenance. In this regard, relevant departments should strengthen publicity and education, show the advantages of AI technology in improving the efficiency and effectiveness of safety management to laboratory personnel, and improve their acceptance. The introduction of AI technology needs to adjust and optimize the existing safety management processes, and

problems such as unclear responsibilities and poor coordination are easy to occur in the process of integrating old and new processes. We can reorganize the safety management process and clarify the responsibilities of various departments and personnel in the new system; Establish an inter-departmental coordination mechanism and strengthen communication and cooperation.

5. Conclusion

In this paper, the application of AI technology in the safety management of instrument and electrical laboratories in universities is comprehensively studied. By combing the relevant theories and technical foundations, the supporting roles of machine learning, deep learning and sensor technology in laboratory safety management are clarified. In terms of application strategy, the strategy construction based on image recognition, sensor monitoring, data analysis and intelligent early warning and emergency response shows the great potential of AI technology in improving the accuracy and efficiency of laboratory safety management. It can realize all-round real-time monitoring and intelligent processing of equipment, personnel and environment, and effectively prevent and deal with potential safety hazards.

However, the application of this technology is not smooth sailing. There are many challenges in technology, data security and privacy, and personnel management. However, these challenges can be effectively overcome through targeted measures, such as ensuring data quality, balancing algorithm complexity and efficiency, strengthening data security protection, and improving personnel acceptance and management process integration.

To sum up, AI technology has brought innovative opportunities for the safety management of instrument and electrical laboratories in universities. As long as we reasonably deal with various problems in the application process and give full play to its technical advantages, we can significantly improve the level of laboratory safety management, create a safer and more reliable environment for the smooth development of teaching and scientific research activities in universities, and have great significance in promoting the modern safety management of laboratories in universities. In the future, with the continuous development of technology, AI is expected to achieve deeper application and breakthrough in the field of laboratory safety management.

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