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Research on the Application of Intelligent Interconnection Technology in Fire Safety Supervision and Management

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Abstract: This paper discusses the application of intelligent interconnection technology in fire safety supervision and management, analyzes its technical principle, application scenarios, advantages and challenges, and puts forward corresponding optimization strategies and implementation suggestions. Through the integration of Internet of Things (IoT), big data, AI, cloud computing and other cutting-edge technologies, smart internet technology has realized real-time monitoring of fire-fighting facilities and equipment, accurate identification of fire hazards, rapid response to fire accidents and efficient deployment of fire-fighting resources. It shows remarkable advantages in real-time monitoring and remote control of building fire facilities, intelligent management of fire exits, monitoring and early warning of electrical fire hazards, and integration of fire early warning and emergency response. However, the implementation of smart fire supervision system still faces challenges such as data quality and safety risks, shortcomings in grassroots governance capacity, operating costs and sustainability issues, and insufficient public awareness and participation. This paper puts forward some implementation paths, such as building a global IoT sensing network, building a data-driven intelligent decision-making platform, and innovating the "government+market+society" collaborative governance model, and puts forward corresponding solutions to the core challenges, aiming at promoting the transformation of fire control from "post-disposal" to "pre-prevention" and providing strong support for building a safer, more stable and harmonious social environment.

1. Introduction

In today's digital age, intelligent interconnection technology is changing all fields of society at an unprecedented speed, and fire safety supervision and management is no exception. As an important cornerstone to protect people's lives and property and social stability, fire safety is self-evident [1]. However, the traditional fire safety supervision and management mode faces many challenges, such as untimely information transmission, low supervision efficiency, incomplete hidden danger investigation and so on, and it is difficult to meet the high requirements of modern society for fire safety [2-3].

The emergence of intelligent interconnection technology provides new ideas and means to solve these problems. The integrated application of cutting-edge technologies such as Internet of Things (IoT), big data, AI and cloud computing enables fire safety supervision and management to break through the time and space constraints, and realize real-time monitoring of fire facilities and equipment, accurate identification of fire hazards, rapid response to fire accidents and efficient deployment of fire resources [4-5]. Through smart interconnection technology, the fire supervision department can build an all-round, multi-level and dynamic fire safety supervision and management system, and improve the scientificity, accuracy and effectiveness of fire management.

This study delves into the application of intelligent interconnection technology within the realm of fire safety supervision and management. It meticulously examines the technical principles underpinning this technology, explores various application scenarios, highlights its advantages, and candidly addresses the challenges it faces. Furthermore, the study proposes a series of optimized strategies and practical implementation suggestions aimed at fostering a safer, more stable, and harmonious social environment.

2. Theoretical basis and key technologies of smart interconnection technology

IoT is one of the core foundations of smart internet technology. It connects objects with the Internet through various information sensing devices to realize intelligent identification, positioning, tracking, monitoring and management [6]. In the field of fire safety, IoT technology enables various environmental parameters of fire equipment, facilities and fire scene to be sensed and collected in real time. For example, smoke sensors and temperature sensors installed in buildings can monitor the signs of fire in real time and transmit the data to the management platform, providing key information for fire early warning and early disposal [7]. The architecture of IoT includes perception layer, network layer and application layer (Figure 1). The perception layer is responsible for data collection, the network layer ensures the reliable transmission of data, and the application layer analyzes and processes the data and realizes specific application functions, such as remote monitoring and fault diagnosis. This layered architecture provides a clear framework for the construction of fire safety supervision and management system.

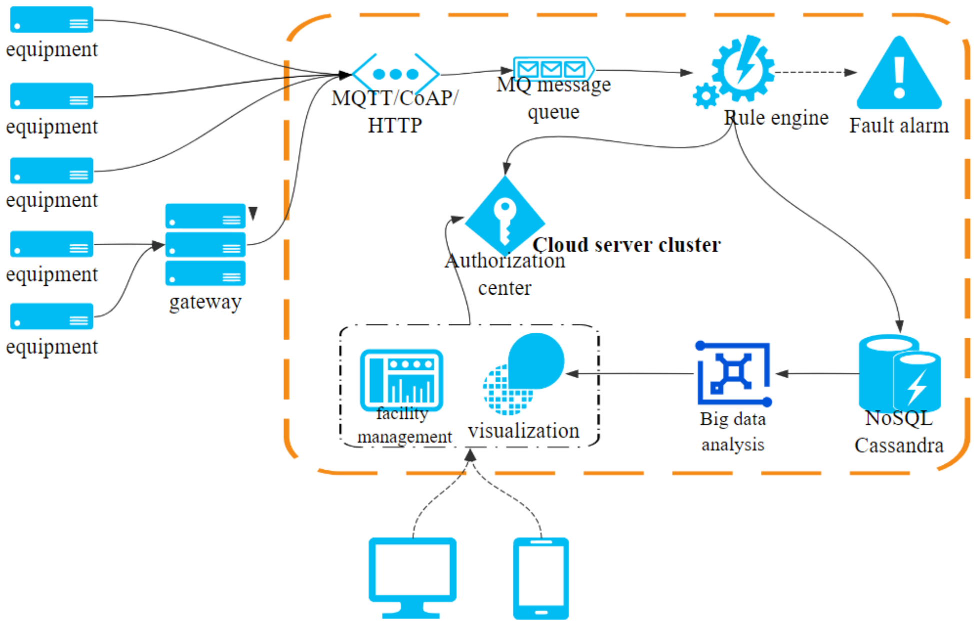

Figure 1 IoT technology architecture

The application of intelligent interconnection technology in fire safety supervision and management is a complex system engineering, which needs to follow the system theory and synergy theory. The system theory emphasizes that fire safety supervision and management should be regarded as a whole composed of interrelated and interactive elements, including fire facilities, personnel, management processes and information resources. The elements need to be optimally configured and work together to maximize the overall function of the system. The collaboration theory further expounds how to establish an effective collaboration mechanism among subsystems or elements in the system.

Information theory provides the basic principles of information transmission, processing and storage for the application of intelligent interconnection technology in fire safety. In the process of fire safety supervision and management, a large number of data from IoT devices, monitoring systems, business management systems and other information sources are constantly generated [8]. Information theory focuses on how to transmit these data accurately and efficiently and reduce noise interference and information loss. Data science theory focuses on the mining and analysis of massive, multi-source and heterogeneous data. Through data cleaning, feature extraction, data analysis algorithm and other means, valuable information can be extracted from complex data, such as the construction of fire risk assessment model, fire facilities fault prediction and so on. Machine learning and deep learning methods in data science theory can automatically learn the rules and patterns in data, and provide intelligent support for fire safety decision-making, such as training fire spread prediction model based on historical fire data and formulating coping strategies in advance [9].

The application of intelligent interconnection technology in fire safety involves the collection of multiple data sources. On the one hand, real-time data from IoT devices, such as environmental parameters collected by sensors and state data of fire fighting equipment, are transmitted to the data storage center through wireless or wired communication networks. On the other hand, it is necessary to integrate the internal business data of the fire department, such as fire alarm records, fire inspection records, fire vehicle dispatching records, and other related data from outside, such as meteorological data and geographic information data. For example, through data sharing with meteorological departments, local meteorological forecast information, including temperature, humidity, wind speed and wind direction, is obtained, which is of great significance for fire risk assessment and fire fighting decision [10]. Geographic information data can help to determine the surrounding environment, traffic conditions, fire water source distribution, etc., and provide a basis for the deployment of fire resources. In the process of data collection, it is necessary to establish a unified data format and standard for subsequent data integration and analysis.

3. Typical application scenarios of intelligent interconnection technology in fire supervision

3.1. Real-time monitoring and remote control of building fire control facilities

In high-rise buildings, large commercial complexes and other places, with the help of smart interconnection technology, fire protection facilities can be monitored in all directions. By installing various sensors on key equipment such as fire water tank, fire water pump and sprinkler system, for example, the liquid level sensor monitors the water level of fire water tank, the pressure sensor feeds back the pipeline water pressure, and the flow sensor grasps the water flow situation of sprinkler system. These sensors transmit real-time data to the fire monitoring cloud platform through wireless network. Once the water level is too low, the water pressure is abnormal or the equipment fails, the system can immediately give an alarm and accurately locate the problem equipment. Managers can remotely control fire-fighting facilities through mobile APP or computer, such as remotely starting fire-fighting pumps, to ensure that fire-fighting facilities can be put into use quickly in case of fire.

3.2. Intelligent management of fire escape

The smoothness of fire escape is the key to fire rescue. Using video surveillance combined with intelligent image recognition technology, the state of fire escape can be monitored in real time. High-definition cameras are installed at the entrance and exit of the passage and key positions, and intelligent algorithms can analyze the collected video images, which can quickly identify whether there are traffic jams such as illegal parking and debris accumulation in the passage. Once an abnormality is detected, the system automatically captures a picture or video and sends an early warning message to the property and fire management departments to prompt timely cleanup. Some advanced systems can also integrate with vehicle management systems, enabling them to contact the owners of illegally parked vehicles via license plate recognition and request them to move their vehicles.

3.3. Monitoring and early warning of electrical fire hazards

In factories, shopping malls, office buildings and other places with dense electrical equipment, electrical fire hazards can not be ignored. Smart interconnection technology collects parameters such as current, voltage, temperature, and leakage in lines in real time by installing electrical fire monitoring detectors on distribution boxes, distribution cabinets, and key electrical lines (Figure 2). The detector uses IoT technology to upload data to the cloud, and uses big data analysis and AI algorithm to deeply mine the data. When abnormal current fluctuation, excessive temperature or signs of electric leakage are found, the system immediately issues an early warning, prompting managers to investigate hidden dangers and realize early prevention of electrical fires.

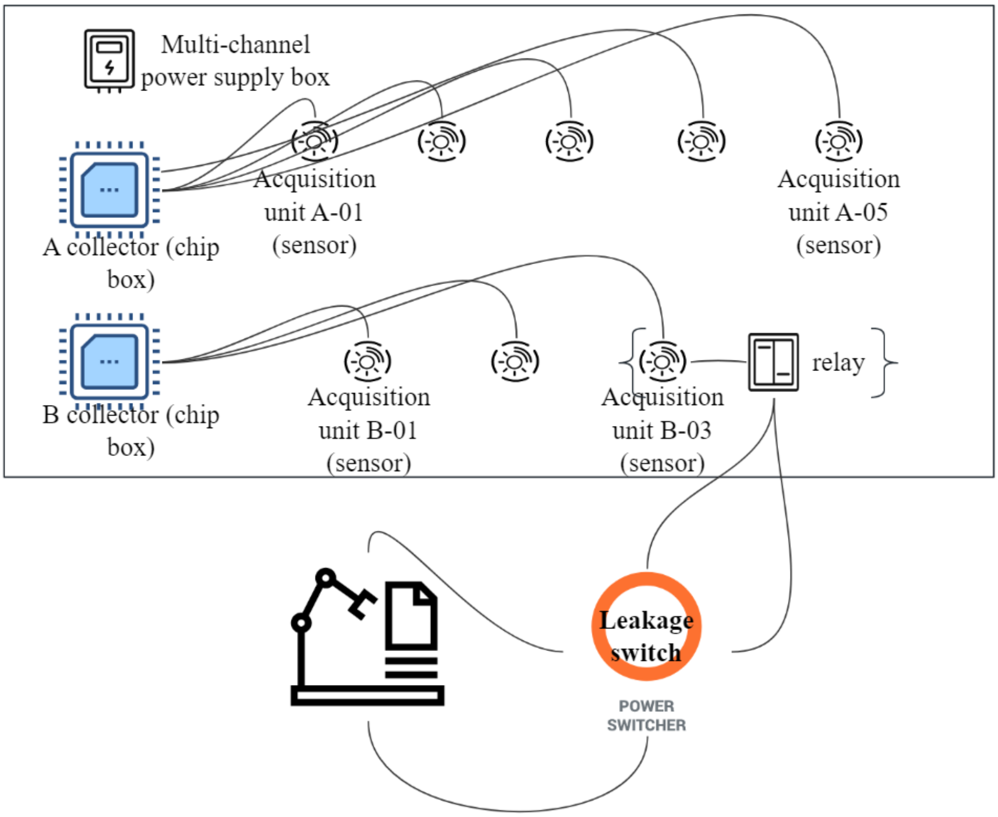

Figure 2 Power detection IoT

3.4. Integration of fire early warning and emergency response

Smart interconnection technology integrates a variety of fire monitoring methods to build a comprehensive fire early warning system. In addition to the traditional smoke and temperature detectors, thermal imaging cameras, gas sensors and other equipment are combined to realize multi-dimensional perception of early fire characteristics. In forests, warehouses and other large-scale places, thermal imaging cameras can monitor temperature changes from a distance and find high-temperature heat sources in advance; The gas sensor can detect the trace combustible gas produced in the early stage of fire. When the fire signs are detected, the system quickly starts the emergency response mechanism, automatically dials the 119 alarm number, sends fire alarm information to the surrounding personnel, and links the surrounding fire control facilities, such as turning on the fire broadcast to guide the evacuation of personnel, and starting the fire shutter to separate the fire zones.

4. The implementation path and challenge of intelligent fire supervision system

4.1. Implementation path

The construction of intelligent fire supervision system needs to be driven by technology empowerment and system innovation, and a closed-loop management system covering the whole chain of "perception-analysis-decision-disposal" should be constructed. Its core path can be summarized as the following three aspects:

(1) Constructing a global IoT sensing network

By deploying terminal equipment such as smoke sensor, temperature sensor, electric fire detector and water pressure level monitor, combined with communication technologies such as 5G and NB-IoT, the real-time dynamic monitoring of the operation state of fire-fighting facilities is realized. For example, Zhenjiang has set up 166,000 terminal points in the whole city, covering 22,000 social units, and built a monitoring system of "terminal perception+cloud analysis" [11]. Aiming at high-risk areas such as high-rise buildings, special equipment such as intelligent power monitoring and combustible gas detection are integrated to form a multi-dimensional risk early warning network.

(2) Building a data-driven intelligent decision-making platform

Relying on big data, cloud computing and other technologies, we will integrate multi-source data such as the status of fire-fighting facilities, hidden danger investigation records and emergency resource distribution to build an "urban fire-fighting brain". Through the "1+2+N" scientific and technological innovation system, the fire department has jointly developed a fire dynamic monitoring and early warning system to realize the functions of early fire identification and rescue path optimization. The database of building fire protection facilities is established through three-dimensional visualization technology, which provides accurate "digital twin" support for law enforcement inspection and emergency disposal [12].

(3) Innovate the "government+market+society" collaborative governance model

As shown in Figure 3, by innovating the "government+market+society" collaborative governance model, the government plays a leading role, formulates technical standards and operational norms, and promotes construction standardization and service standardization; In the market, the government purchases services and enterprises are responsible for their own profits and losses, and the third party is responsible for operation and maintenance and data analysis, and the service quality is guaranteed by KPI assessment; Social forces, through the linkage of fire volunteers and grid workers, build a pattern of group prevention and group governance combining professional forces with mass autonomy, effectively supplementing the grass-roots governance capacity.

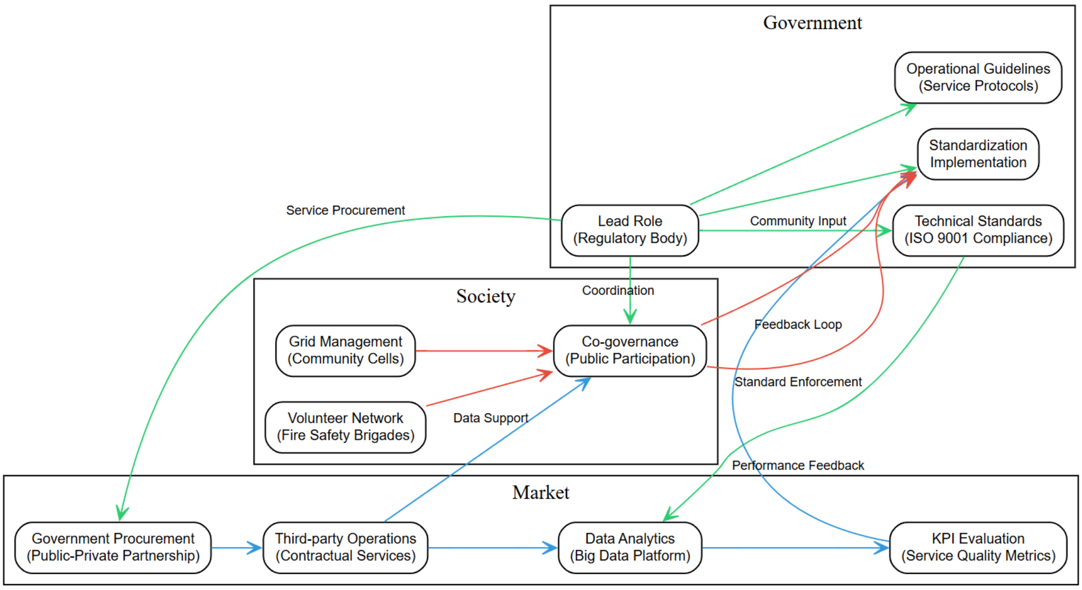

Figure 3 Innovate the "government+market+society" collaborative governance model

4.2. Core challenges

(1) Data quality and security risks

Smart fire protection faces data quality and security risks, including data distortion of old buildings, hidden dangers of privacy leakage, etc. It is necessary to improve data accuracy through the mechanism of equipment self-inspection and manual spot check, and realize data encryption and hierarchical authority management with the help of blockchain technology to ensure the safe operation of the system.

(2) Short board of grassroots governance capacity

Grid workers generally lack professional knowledge of fire protection, and are difficult to be competent for tasks such as equipment maintenance and hidden danger judgment. There are "information islands" among departments such as fire protection, housing construction, and emergency response, leading to a low closed-loop rate in the rectification of hidden dangers. To improve the fire-fighting system, it is necessary to require personnel in fire rescue offices to hold the qualification of registered fire engineers. At the same time, the intelligent fire protection platform will be connected to the "one network unified management" system to realize cross-departmental data interoperability and task distribution.

(3) Operating cost and sustainability

NB-IoT smoke sensor, electrical fire monitoring terminal and other equipment have high unit prices, and large-scale deployment requires huge financial support. In order to reduce the cost and inspection frequency, some service providers lead to the off-line rate of equipment exceeding the standard. Coping strategies: Explore the "insurance at the bottom" model to provide compensation for losses due to fire-fighting equipment failures and fire accidents, thereby reducing the financial risk to the government; Alleviate the initial investment pressure on enterprises through leasing and purchasing options.

(4) Lack of public awareness and participation

Some residents have resistance to smart fire-fighting equipment, such as disassembling smoke detectors by mistake and connecting electrical lines without permission. Most of the existing platforms focus on government supervision and lack of public feedback entrance, which leads to the discovery of hidden dangers relying on top-down inspections. Develop the "National Fire Fighting" app, integrating features like hidden danger reporting and safety knowledge learning, and establish a points-based reward mechanism. At the same time, fire volunteers will be included in the social credit system to enhance their enthusiasm for participation.

4.3. Future prospects

The ultimate goal of the intelligent fire control system is to promote the fire control from "post-disposal" to "pre-prevention" through the deep integration of "data+scenarios". For example, the AI algorithm is used to model historical fire data, predict high-risk areas and time periods, and guide accurate inspections; Additionally, digital twin technology is employed to simulate fire spread paths and optimize emergency plans. With the maturity of fire fighting robots, drones and other technologies, intelligent fire fighting will further evolve to unmanned and intelligent, providing a more solid guarantee for urban safety and resilience.

5. Conclusion

The integrated application of cutting-edge technologies such as IoT, big data, AI and cloud computing can effectively solve the problems of untimely information transmission, low supervision efficiency and incomplete hidden danger investigation in the traditional fire safety supervision and management mode, and realize real-time monitoring of fire facilities and equipment, accurate identification of fire hazards, rapid response to fire accidents and efficient deployment of fire resources. In typical application scenarios, such as real-time monitoring and remote control of building fire protection facilities, intelligent management of fire exits, monitoring and early warning of electrical fire hazards, and integration of fire early warning and emergency response, smart interconnection technology has demonstrated its powerful functions and potential. By building a global IoT sensing network, building a data-driven intelligent decision-making platform and innovating the "government+market+society" collaborative governance model, the intelligent fire supervision system can realize a closed-loop management system covering the whole chain of "perception-analysis-decision-disposal". However, the implementation of smart fire supervision system also faces core challenges such as data quality and security risks, shortcomings in grassroots governance capacity, operating costs and sustainability, and insufficient public awareness and participation. In view of these problems, the study puts forward corresponding countermeasures, such as improving the accuracy of data, ensuring the safe operation of the system, popularizing the fire-fighting system, exploring the "insurance-based" model, and developing the "national fire-fighting" APP. In the future, through the deep integration of "data+scene", the intelligent fire supervision system will promote the fire control from "after-the-fact disposal" to "before-the-fact prevention", further evolve to unmanned and intelligent, and provide a more solid guarantee for urban safety and resilience.

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