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Original Research Article

AIoT-based indoor fire inspection and early warning system

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Abstract: This paper analyzes an AIoT-based indoor fire inspection and early warning system that utilizes a layered architecture to achieve multi-source data collection and fusion. The system integrates IoT technology, big data analysis, and artificial intelligence algorithms to build an intelligent fire warning model. Through three major functional modules - real-time monitoring, intelligent analysis, and remote management - the system achieves precise identification and early warning of fire risks, providing reliable theoretical support for indoor fire safety.

Keywords: AIoT; Fire Warning; IoT Technology; Big Data Analysis; Deep Learning

1. Introduction

Fire, as a disaster with high suddenness and destructive power, poses a serious threat to public safety. Traditional fire alarm systems mostly rely on smoke detectors or temperature sensors, which may have false positives or missed detections in complex indoor environments[1]. The integration of AIoT technology provides a new solution for fire warning, enabling more precise and real-time fire monitoring.

2. System architecture

The AIoT-based indoor fire inspection and early warning system adopts a layered architecture design, building a complete fire warning solution through the organic combination of perception layer, network layer, platform layer, and application layer[2]. The perception layer deploys various types of detection devices such as smoke detectors, infrared thermal imagers, and gas sensors, which can comprehensively collect indoor environmental data, laying a solid data foundation for fire warning. The network layer utilizes diverse wireless communication technologies including Wi-Fi, Zigbee, and LoRa to ensure real-time and reliable data transmission, efficiently transmitting frontend environmental data to the cloud platform for processing[3]. As the core of the system, the platform layer integrates big data analysis and machine learning algorithms to conduct deep mining and analysis of massive environmental data, achieving intelligent identification and risk assessment of fire hazards. The application layer faces end users, providing an intuitive visualization interface that allows users to conveniently view fire warning information while supporting remote monitoring and emergency command functions, realizing intelligent management of fire prevention and control[4]. This architecture design with clear layers and complementary functions effectively ensures the stability and reliability of system operation.

3. Key technologies

3.1. IoT technology

IoT technology plays a key role in the indoor fire inspection and early warning system, achieving comprehensive interconnection of fire detection devices through the construction of a complete IoT architecture. Various sensor devices deployed in the system establish reliable connections with gateway devices through

standardized communication protocols, forming a highly integrated IoT sensing network. Smart gateway devices, based on edge computing technology, can perform preliminary processing and filtering of collected sensor data, effectively reducing data transmission load[5]. The IoT platform adopts a distributed architecture design with powerful device access and data processing capabilities, capable of simultaneously managing massive terminal devices and processing complex data streams, ensuring system operation stability and scalability. By adopting lightweight IoT protocols such as MQTT and CoAP, low-latency and efficient data transmission between devices and platforms is achieved. The deep application of IoT technology enables the system to obtain real-time multi-dimensional data of indoor environment such as temperature, humidity, and gas concentration, providing comprehensive and reliable data support for fire warning.

3.2. Big data analysis

Big data analysis technology plays a core role in the fire warning system, constructing accurate fire risk assessment models through deep mining and analysis of massive historical fire data[6]. The system uses distributed computing frameworks to process heterogeneous data from different sources, including real-time sensor data, historical fire records, and building structure information. Through data cleaning, feature extraction, and other preprocessing steps, data quality and analysis accuracy are ensured. Based on time series data analysis methods, the system can identify abnormal patterns in environmental parameter changes and discover potential fire risk factors through correlation analysis. Machine learning algorithms are used to model historical fire cases, establishing accurate fire risk prediction models through multi-dimensional feature analysis[7]. The big data analysis platform supports both real-time stream processing and offline batch processing modes, enabling both quick analysis of real-time data and continuous optimization of warning models through periodic offline analysis, improving the warning accuracy and reliability of the system.

3.3. Artificial intelligence algorithms

Artificial intelligence algorithms realize intelligent data analysis and decision support in the fire warning system, significantly improving fire detection accuracy through deep learning and computer vision technology. The system uses convolutional neural networks to analyze real-time images and video data collected by surveillance cameras, establishing high-precision flame and smoke recognition models. Combined with object detection algorithms, it can accurately locate fire occurrence positions and track fire spread trends[8]. Time series prediction models based on recurrent neural networks conduct intelligent analysis of sensor data, achieving early identification of abnormal states by learning environmental parameter variation patterns. Deep learning models integrating multi-source data can comprehensively analyze multi-dimensional data such as video and sensors, providing more comprehensive fire risk assessment results. The application of artificial intelligence algorithms greatly reduces the system's false alarm rate while improving the timeliness of fire warning, providing strong technical support for fire prevention and control.

4. System functions

4.1. Real-time monitoring and warning

The AIoT-based indoor fire inspection and early warning system achieves round-the-clock continuous environmental monitoring through distributedly deployed multiple types of sensor devices. The system adopts

a multi-level warning mechanism, automatically triggering different levels of warning responses based on the degree of environmental parameter abnormality. When minor abnormalities are detected, warning prompts are issued; when serious abnormalities are found, emergency plans are immediately activated. Warning information is pushed through multiple channels, including SMS, APP push notifications, and emails, ensuring relevant personnel can receive warning information in time[9]. The intelligent warning algorithm can adaptively adjust warning thresholds by analyzing historical data and environmental change patterns, dynamically optimizing warning parameters to effectively reduce false alarm rates. The system supports hierarchical and classified management of warning information, with different types of abnormal situations being notified to corresponding responsible personnel, achieving precise push of warning information. The implementation of real-time monitoring and warning functions provides timely and reliable information support for fire prevention and control.

4.2. Intelligent analysis and decision support

The intelligent analysis and decision support module provides comprehensive analysis results and decision recommendations for fire prevention and control through the fusion of multi-source data. The risk assessment model built based on deep learning algorithms can analyze indoor environmental states in real-time and identify potential fire risk factors. Through mining and analysis of historical data, it summarizes typical characteristics and evolution patterns of fire occurrence, providing data support for risk prevention and control[10]. The decision support system uses knowledge graph technology, combining expert experience with data analysis results to provide optimal decision solutions for emergency response in different scenarios. The system has self-learning capabilities, continuously improving decision models through accumulation and analysis of actual cases. The intelligent analysis platform provides visualization analysis reports, including risk trend graphs, heat distribution maps, and other intuitive display methods, helping management personnel quickly grasp fire risk situations and formulate scientific and reasonable prevention and control measures.

4.3. Remote monitoring and management

The remote monitoring and management function provides system maintenance personnel with convenient management approaches through a unified Web management platform and mobile APP. The management platform adopts responsive design, supporting multi-terminal access, allowing management personnel to check system operation status anytime through PC, mobile phone, tablet, and other devices. The real-time monitoring interface displays indoor environmental parameter change trends in a graphical way, supporting real-time viewing and historical playback of video monitoring footage[11]. The system provides a complete permission management mechanism, assigning different operation permissions according to user roles to ensure system security. Remote management functions support device parameter configuration, warning rule settings, system maintenance, and other operations, improving system maintenance efficiency. The mobile APP has functions such as message push, real-time viewing, and remote control, enabling management personnel to grasp system operation situations anytime, achieving mobile office work.

5. Conclusion

The AIoT-based indoor fire inspection and early warning system achieves organic integration of perception, network, platform, and application layers through layered architecture design. It builds a complete data collection

network through IoT technology, establishes accurate risk assessment models using big data analysis, and improves fire identification accuracy by incorporating artificial intelligence algorithms. The system forms a complete functional system in aspects such as real-time monitoring, intelligent analysis, and remote management, providing strong support for enhancing indoor fire prevention and control capabilities.

About the author

Li Yan: born in 1986, female,native of Yangzhou, Jiangsu province, Han nationality, undergraduate, research interests: senior engineer, big data, artificial intelligence, cloud computing, Java.

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