

Advanced driver assistance system (ADAS) and machine learning (ML): The dynamic duo revolutionizing the automotive industry

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Abstract: This work aims to build a comprehensive and effective fire emergency management system based on the Internet of Things (IoT) and achieve an actual intelligent fire rescue. A smart fire protection information system was designed based on the IoT. A detailed analysis was conducted on the problem of rescue vehicle scheduling and the evacuation of trapped persons in the process of fire rescue. Methods The intelligent fire visualization platform based on the three-dimensional (3D) Geographic Information Science (GIS) covers project overview, equipment status, equipment classification, equipment alarm information, alarm classification, alarm statistics, equipment account information, and other modules. The live video accessed through the visual interface can clearly identify the stage of the fire, which facilitates the arrangement of rescue equipment and personnel. The vehicle scheduling model in the system primarily used two objective functions to solve the Pareto Non-Dominated Solution Set Optimization: emergency rescue time and the number of vehicles. In addition, an evacuation path optimization method based on the Improved Ant Colony (IAC) algorithm was designed to realize the dynamic optimization of building fire evacuation paths. Results The experimental results indicate that all the values of detection signals were significantly larger in the smoldering fire scene at $t=17s$ than the initial value. In addition, the probability of smoldering fire and the probability of open fire were relatively large according to the probability function of the corresponding fire situation, demonstrating that this model could detect fire. Conclusions The IAC algorithm reported here avoided the passages near the fire and spreading areas as much as possible and took the safety of the trapped persons as the premise when planning the evacuation route. Therefore, the IoT-based fire information system has important value for ensuring fire safety and carrying out emergency rescue and is worthy of popularization and application.

Keywords: Smart fire protection information system; Internet of things; Rescue vehicle scheduling; Optimal evacuation routes

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1 Introduction

The SFP came into being in the context of FP needs in the new era. SFP is an integral part of SC construction, mainly reflected in four aspects: smart prevention and control, smart management, smart operations, and smart command [1]. Its application field covers all scenarios requiring FPC, such as public buildings, commercial buildings, real estate communities, and entertainment venues, especially in production enterprises with high risks, including factories of petroleum, chemical, flammable, and explosive materials. Entering the BD era, the continuous development of the computer technology revolution has significantly impacted the operation mode of each industry and provided technical support for the innovation of FP business [2]. Menon and Vishnu-Menon [3] pointed out that the intelligent FM system applies high-end technologies such as GIS, Wireless Communication Technology, Global Positioning System (GPS), and IoT terminals to the management, supervision, collection, and monitoring services of FP. These functions are reflected as the platform presentation in FM work, such as real-time updates and dynamic monitoring of various data, closed-loop management of inspection operation and maintenance work, and online display of personnel work conditions. The system integrates all elements and links in FP, breaks the barriers of information transmission, combines matches, and optimizes the online monitoring data and FP content, making the process of each link of FP management clearer. Alqourabah et al. implemented an intelligent fire detection system to detect fires using integrated sensors and alert homeowners and local fire departments to protect lives and assets [4]. This system collects signals from different integrated detectors to forecast the probability of a fire and broadcast the prediction to all parties using the Global System for Mobile Communication modulator-demodulator associated with the system.

2 Related work

2.1 Small form-factor pluggable information system

The SFP came into being in the context of FP needs in the new era. SFP is an integral part of SC construction, mainly reflected in four aspects: smart prevention and control, smart management, smart operations, and smart command [5]. Its application field covers all scenarios requiring FPC, such as public buildings, commercial buildings, real estate communities, and entertainment venues Table 1, especially in production enterprises with high risks, including factories of petroleum, chemical, flammable, and explosive materials. Entering the BD era, the continuous development of the computer technology revolution has significantly impacted the operation mode of each industry and provided technical support for the innovation of FP business [6]. Menon and Vishnu-Menon [7] pointed out that the intelligent FM system applies high-end technologies such as GIS, Wireless Communication Technology, Global Positioning System (GPS), and IoT terminals to the management, supervision, collection, and monitoring services of FP. These functions are reflected as the platform presentation in FM work, such as real-time updates and dynamic monitoring of various data, closed-loop management of inspection operation and maintenance work, and online display of personnel work conditions. The system integrates all elements and links in FP, breaks the barriers of information transmission, combines matches, and optimizes the online monitoring data and FP content, making the process of each link of FP management clearer. Alqourabah et al. implemented an intelligent fire detection system to detect fires using integrated sensors and alert homeowners and local fire departments to protect lives and assets [8]. This system collects signals from different integrated detectors to forecast the probability of a fire and broadcast the prediction to all parties using the Global System for Mobile Communication modulator-demodulator associated with the system.

Table 1 table PRA

t	0	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9	1.0
e^{-t^2}	1.000000	0.990050	0.960789	0.913931	0.852144	0.778801	0.697675	0.612626	0.527292	0.444858	0.367879

2.2 Emergency rescue

EM is a system process problem, including information collection, transportation, emergency response, and material distribution. Wang et al. put forward the idea of active disaster relief in response to the ER of sudden fires, that is, the coordinated, centralized control of ventilation, air exhaust, smoke blocking, smoke exhausting, and other facilities to assist passengers in evacuation and firefighting [9]. The authors analyzed complex subway's ventilation and smoke exhaust methods at multi-layer intersections, selected a typical transfer station, and established a numerical model. Besides, the combined control of fire smoke was analyzed using six ventilation modes, and several numerical simulations were carried out using the fire dynamics simulator software. Then, according to the characteristics of different fire sources and smoke control scenarios, a multi-element information fusion RM model was established, such as ventilation paths, fan characteristics, smoke exhaust channels, and smoke blocking facilities. The author finally proved that the ER platform is conducive to efficient fire rescue and the safe escape of personnel in emergencies. Tang et al. established a timely and effective Satellite Remote Sensing Emergency Monitoring Information Service (SRSEMIS) framework as a vital part of the natural disaster ER [10]. It focuses on key technologies such as comprehensive data management, multi-source data processing, disaster response information analysis, and rapid release of information services. Meanwhile, the SRSEMIS framework realized the real-time transmission of disaster data before and after the disaster through the specific application in the emergency remote sensing monitoring of the 3.30 Forest fire in Muli County, Sichuan. In the ER process, it is imperative to release remote sensing interpretation images of disaster areas promptly and improve comprehensive information services such as 3D terrain characterization, rescue accessibility prediction, and fire change analysis.

$$D_M(z) = \frac{1}{H_0 \sqrt{|\Omega_{k0}|}} \text{sinn} \left[\sqrt{|\Omega_{k0}|} \int_0^z \frac{dx}{E(x)} \right], \quad (1)$$

where $H_0 = H(z = 0)$ is the Hubble constant, $E(z) = H(z)/H_0$ is the dimensionless Hubble parameter, and $\text{sinn}(\sqrt{|\Omega_{k0}|}x)/\sqrt{|\Omega_{k0}|} = \sinh(\sqrt{|\Omega_{k0}|}x)/\sqrt{|\Omega_{k0}|}$, x and $\sin(\sqrt{|\Omega_{k0}|}x)/\sqrt{|\Omega_{k0}|}$ for $\Omega_{k0} > 0$, $\Omega_{k0} = 0$ and $\Omega_{k0} < 0$, respectively. For a spatially flat universe, $\Omega_{k0} = 0$,

$$D_M(z) = \frac{1}{H_0} \int_0^z \frac{dx}{E(x)}. \quad (2)$$

2.3 Intelligent fire evacuation path

When a fire occurs, the intelligent fire evacuation system implements fire evacuation guidance in the form of optical ground flow according to the fire alarm information of the fire alarm system and the direction of the spread of smoke. It can accurately give Evacuation Paths (EPs) instructions, help people in the building choose the escape route, guide the safe escape direction, and ensure the personal safety of the masses [11]. After a fire, an AI application can guide occupants to secure evacuation routes while helping rescuers enter the building. Gomaa et al. proposed an integrated trained AI and sensor-based data collection system for the short-term prediction of fire occurrence behavior, structural integrity, and optimal escape paths. It can also issue escape instructions to users via mobile devices or public address systems [12]. Cao et al. proposed an intelligent EP optimization scheme for dense crowds in buildings [13]. First, they used an artificial Fish Swarm Algorithm-based agglomeration model without the help of an instructor. Second, a single-layer evacuation model based on the improved K-Nearest Neighbors algorithm was used to classify individuals. This model could help individuals choose the nearest stairs, saving escape time.

Existing studies have systematically discussed the design of SFP systems and the application of critical technologies. This work built an SFP information system based on visualization technology and combined it with IoT technology to achieve high application value in FMDM. In addition, in-depth research was carried out on the most critical RV scheduling and personnel escape path optimization in the SFP information system.



Figure 1 The architecture of the IFFV platform.

3 Traffic information processing and task scheduling in digital twins scenarios

3.1 Smart fire visualization information platform based on the three-dimensional geographic information science

At present, the main problem with fire rescue is that the arrangement of rescue resources is not systematic enough. Most SFP systems in operation or under research are developed based on two-dimensional (2D) geographic information systems. The 2D geographic information system can only display the plane information of buildings and structures but cannot display the 3D geographic data. The new large-scale and low-cost 3D modeling technology is gradually maturing [14], which has significant practical value for the critical units of FP, FM, information entry, firefighting plan, and on-site command of key monitoring areas of FP [15]. The 3D trend for the SFP platform has become unstoppable. Therefore, it is imminent to design and implement a high-load, high-integration SFP information platform based on 3D GIS. Figure 1 shows the architecture of the IFFV platform designed here. After successfully logging in to the platform, users will see the main content displayed on the home page, including project overview, device status, device classification, device alarm information, alarm classification, alarm statistics, and device account information. Users can select the map as a Building Information Modeling model to display warnings from any sensors. Hidden hazard management includes hazard inspection, hazard treatment, and hazard records. The purpose of hidden danger inspection is to enable the system to distribute work orders to engineering personnel after an alarm or a hidden danger occurs. After processing, engineers fill in relevant work order task records in the system for the historical query.

Declaration of competing interest

The authors declare that they have no conflict of interest.

CRediT author statement

Shengqing GAO: Conceptualization, Writing“Original draft. **Qing GAO:** Writing“Creview & editing. **Yungui GONG:** Data curation, Methodology. **Xuchen LU:** Validation.

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