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Research Article

Design of Underground Space Intelligent Disaster Prevention System Based on Multisource Data Deep Learning

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With the rapid development of national economy, the population to big cities gathered themselves together, and especially the first-line cities, lead to city continuously extend outward, city scale is more and more big, the surface space is completely unable to meet the needs of urban development and transportation, the demand such as life, development, and use of underground space has become the important way of solving the urban development diameter. With the vigorous development of underground space, many disaster problems, such as fire and flood, have also appeared in many places, which have brought huge human and financial losses to the society. In order to solve the problem of disaster in underground space, this paper summarizes the main disasters, and urban underground space analysis of the different degrees of the risk of disasters; the emergency toughness of disaster prevention concept, combined with intelligent technology application in urban underground space disaster warning and decision-making, according to the requirement of the underground space of disaster prevention wisdom, put forward to underground space disaster, disaster prevention expert database, such as multisource data fusion. Deep learning is used to realize the linkage of disaster rescue and recovery, and an intelligent disaster prevention system based on deep learning of multisource data is established. The results show that the urban underground space disasters mainly include fire, explosion, earthquake, flood, toxic, and combustible gas. Combining with the overlapping characteristics of different disasters and the inability to define the boundaries, the theory of emergency resilience disaster prevention provides effective suggestions and measures for the decision-making and treatment of underground space fires. The intelligent comprehensive disaster prevention system of urban underground space is established from the three aspects of predisaster prevention, rescue in disaster, and reconstruction after disaster, so as to realize the full coverage of intelligent disaster prevention in the whole life cycle of underground space and provide data support for integrated decision-making of disaster prevention and reduction. The research results have important guiding significance for digitization, informationization, and intelligent construction of sudden disaster decision-making in underground space.

1. Introduction

With the rapid rise of China's economy, the process of urbanization has been accelerating, and the scale has been expanding year by year. At the same time, many problems such as shortage of urban land, dense population, and traffic congestion have been gradually exposed. At present, urban planning has been developed by the earth's surface; is given priority to gradually be into underground space development, especially in some big cities; has developed a huge variety of subway, underground mall, underground garage, civil air defense engineering, etc., and obvious solved the problems such as traffic congestion, densely populated, but at the same time compared with the surface buildings exist in the air environment, underground buildings are mostly distributed in rock mass. Such special environment makes

the underground space of the city closed, uncontrollable, sudden disaster, accident difficult to rescue, and other characteristics; these characteristics cause the accident disaster in the underground space will be far greater than the loss caused by the surface disaster, rescue is more difficult, and the consequences are also difficult to recover [1–3]. The underground space disasters such as the subway fire in Daegu in South Korea and the flooding of the London Underground in the UK have brought us a lot of reflection and illustrated the importance and urgency of establishing the underground urban space early warning system. Therefore, it is particularly important to establish intelligent disaster prevention and automatic alarm system in urban underground space [4].

Disasters in underground space have greatly increased the threat to cities and put forward higher requirements for comprehensive disaster prevention system. At the same time, with the emergence of new technologies, such as artificial intelligence, Internet +, big data, and Internet of Things, the concept of smart city has been proposed [5, 6]. Therefore, by taking smart city as an opportunity and making full use of new smart technology and data fusion theory, intelligent disaster prevention in underground space is committed to realize automatic disaster warning in the construction and use of underground engineering, which is conducive to improving the management ability of urban underground space disaster system. At present, scholars at home and abroad have carried out in-depth research on underground space fire, flood, evacuation, and rescue after disaster and achieved rich results [7–9]. Some researchers according to the analysis of current underground space disaster, it is concluded that the underground space and interaction between various disasters associated, with the combination of quantitative and qualitative way, main hazards of underground space, fire, earthquake, flood to build integrated index system, and set up disaster decision-making model based on the fuzzy recognition theory [10, 11]. By summarizing the characteristics of internal and external disasters in underground space, some researchers have established the coping system of internal and external disasters and formed the comprehensive disaster prevention system, put forward the optimization and improvement measures of the system, and integrated the underground comprehensive disaster prevention system with other urban systems. With the help of 3DGIS, BIM, Internet of Things, and other technologies, some researchers have rapidly promoted the construction process of smart cities. Meanwhile, by designing and constructing intelligent warning system for underground space disasters, the comprehensive disaster management level of cities has been improved, and the early warning and forecast of urban disasters have been realized. Some researchers proposed to analyze urban disaster case database and numerical simulation database through fuzzy theory and build intelligent disaster decision-making system [12–15]. Meanwhile, the supervised and unsupervised learning methods were compared to determine which learning method to use by comparing the accuracy and efficiency of the two methods in training set. Some researchers expounded the research of artificial intelligence in smart city planning, intelligent design, construction, maintenance, and disaster prevention and proposed the construction of an integrated smart risk control system to improve the degree of urban intelligence and urban management [16].

Intelligence is the main method of urban underground space disaster warning and decision-making at present. At present, mainstream technologies such as Internet of Things, BIM, and 3Dgis have been applied in the development and utilization of urban underground space intelligent early warning, which has preliminarily achieved the goal of intelligent management of disaster prevention and reduction, but the integrated disaster prevention system of underground space has not been realized yet. This paper summarizes the main disasters and urban underground space to adapt to the need of the underground space of disaster prevention wisdom decision and analyze the present situation of underground space disaster based on the concept of emergency toughness of disaster prevention, disaster in underground space, disaster prevention expert database, such as multisource data fusion, case, and disaster rescue and recovery by using deep learning and linkage, and established the wisdom of multisource data depth study of disaster prevention system. It provides important guiding significance for digitization, informatization, and intelligence of underground space to deal with emergency disaster warning and decision [17, 18].

2. Present Situation of Urban Underground Space Disasters, Evaluation Indexes, and Methods

2.1. Current Situation of Urban Underground Space Disasters. Urban underground space disasters mainly include natural factors and manmade disasters, among which natural factors include earthquake, war, and flood, and manmade disasters include fire, manmade accidents, and terrorist attacks. Compared with the surface of the disaster environment, urban underground space in a relatively closed environment, the rock as protection, can effectively resist the influence of typhoon disasters such as earthquakes, war but in the event of fire, flood, and terrorist attacks would have incalculable consequences, such as these with great difficulty and damage from the disaster and rescue. Through in-depth analysis of urban underground space disaster status, it is helpful to establish urban underground space intelligent disaster prevention evaluation system. The status analysis of urban underground space disasters is shown in Table 1.

2.2. Urban Underground Space Disaster Evaluation Index. There are many types of underground space disasters, and many indexes need to be considered. In order to construct the urban underground space disaster evaluation system, this paper analyzes the influence factors of fire, explosion, earthquake, flood, toxic, and combustible gas, respectively, and selects appropriate indicators to construct the underground space disaster evaluation system, providing the basis for the construction of disaster decision-making. To ensure accuracy and rationality of disaster decision-making model of the building, we fully consider the weights of every index, and to determine index score standard and combining with

Table 1: Current situation of urban underground space disasters.

Disaster type	Disaster status analysis
Fire	It is found that fire is the most frequent and harmful disaster in urban underground space. As the underground space of the city is relatively closed and the ventilation effect is not ideal, mainly artificial lighting, the fire directly leads to traffic paralysis, a large number of casualties, and the destruction of the building structure, resulting in a large number of human and financial losses
The explosion	In the early stage, underground space was mostly civil air defense engineering to prevent air raids. With the continuous improvement of weapon performance and power, the safety of underground space was also threatened. If a war causes an explosion inside the underground space, it will cause huge damage
The earthquake	As a natural disaster, the research on earthquake resistance is focused on the surface buildings, but the research on underground space is less. Under the current large-scale development of the space, the research on earthquake resistance is particularly important. Japan's Hanshin earthquake on the subway and other severe damage
The flood	Statistics shows that most of the cities are located in the coastal areas or along the main roads of rivers, which are prone to floods and typhoons. Once floods occur in cities, urban underground space will cause huge casualties and property losses, and irreparable damage to underground space structure. At the same time, the high groundwater level brings great test to the impermeability of the city
Toxic, flammable gas	In underground space, methane, carbon monoxide, and other toxic and flammable gases are easy to appear because of its sealing. Once leakage or explosion occurs, it will cause a large number of casualties and great harm

overlapping between different disasters caused by the dangerous and not clear boundaries, we build scientific and reasonable evaluation index system of urban underground space disasters such as Table 2.

2.3. Underground Space Disaster Evaluation Method. With the continuous understanding of disasters, people have changed from simple prevention or resistance to prediction, resistance, and planning to solve disasters in advance. At present, resilience disaster prevention has become a hot topic in the prevention and control of underground space disasters. In the face of underground infrastructure facilities such as subway, underground space, and underground parking lot, some functions of the disaster prevention system are out of control or unable to cope with instantaneous explosion disasters. Therefore, the concept of resilience has been transformed from sustainable development to personnel safety protection in emergency situations. Based on the underground space of fire emergency disposal as the research target, using the theory of emergency toughness of disaster prevention, from the early detection, high efficiency, low loss, and rapid recovery of a fire in the early stages of development, rapid development stage, development stage, and fully attenuation phase (Figure 1) were analyzed, and the underground space of the fire decision-making process provide effective suggestions and measures.

(1) In the early stage of fire development, the main task is to give accurate warning, judge the exact location of fire warning signals, and confirm that the emergency disposal plan will be started in the first time after the disaster. Through consulting the existing fire data of underground space, the early stage of a fire can quickly locate the fire source, assess the severity of the fire, and take reasonable and scientific fire extinguishing measures to reduce the loss caused by the disaster, which has a great correlation with the timeliness of fire warning and the accuracy of fire source information determination

(2) In the rapid development stage of fire, it is mainly through controlling the development rate of fire, so as to gain more time for personnel's self-rescue and escape. When the fire spreads rapidly, the fire personnel cannot reach the scene in time, and the main purpose is to save themselves. At this time, the ventilation of underground space adopts emergency ventilation, which is linked with the fire extinguishing equipment to provide conditions for the escape of personnel. At the same time, the radio, signs, and escape channel instructions are used to guide the personnel to escape

(3) In the fully developed stage of fire, mainly by putting out the fire as soon as possible, to provide support for the search and rescue of firefighters and evacuation of personnel. In this stage, emergencies occur in underground space at any time, resulting in the failure of sensors, monitoring systems and fire extinguishing systems. Therefore, it is necessary to grasp the key information of the fire situation as soon as possible to provide decision support for making fire extinguishing plan and evacuation

(4) In the stage of fire attenuation, it mainly focuses on post-disaster assessment, safety assessment of the fire area and emergency treatment to prevent secondary losses. At this stage, the injured should be treated in a timely manner and the onsite personnel should be properly handled to avoid casualties caused by secondary disasters

3. Underground Space Intelligent Disaster Prevention System Based on Multisource Data Deep Learning

In this paper, the intelligent integrated disaster prevention system of urban underground space is established from predisaster prevention, rescue, and postdisaster reconstruction.

Table 2: Urban underground space disaster index system and weight allocation.

The target layer	Disasters	Index weight (%)
Decision model of underground space disaster	Fire	27
	The explosion	22
	The earthquake	16
	The flood	23
	Toxic, flammable gas	12

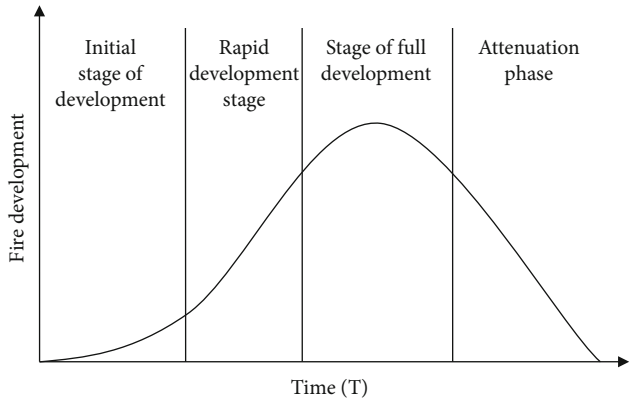

Figure 1: Development of urban underground space fire.

According to the whole process of dynamic development of underground space disaster, based on multisource data of deep learning wisdom underground space disaster prevention system, the system includes disaster prevention module, sensor data acquisition module, multisource data fusion deep learning module, disaster relief, and postdisaster recovery linkage module (Figure 2) and disaster prevention to provide security for the underground space wise.

3.1. Disaster Prevention Module. The disaster prevention module mainly investigates and summarizes the experience of different urban underground space disaster prevention management systems and constructs disaster prevention expert database and disaster case database based on the operation status and disaster prevention standard of urban underground space. Disaster prevention experts should have professional knowledge in the disaster field and be able to predict the evolution of disasters by monitoring data and analyzing key indicators and make accurate prevention and control measures for disasters. By sorting out underground space disaster cases since 1980, including disaster types, locations, and functions of underground space, a disaster case database is established, as shown in Table 3. The database covers the name of underground space, basic information, fire occurrence time, fire causes and overview, fire duration and casualties, structural and equipment damage, related photos and videos, news reports, and other information. We establish a database to facilitate digital management and query historical fire cases, summarize the causes of accidents through the analysis of real accident cases, and formulate operation management plans and emergency evacuation rescue plans.

3.2. Sensor Data Acquisition Module. The sensor data acquisition module is made up of the underground space of the traffic monitoring system, environment monitoring system, automatic fire alarm system, and so on various types of sensors for real-time dynamic data for the disaster prevention of the underground space, and the filter and multiscale analysis method is used to solve objective observation error of sensors (observation and the error due to environment) and provide input data for deep learning module.

The sensor data acquisition module can be thought of as wisdom "eyes" of disaster prevention system, and underground space can be real-time access to the underground space of the temperature, humidity, wind speed, air quality, and video images, such as multisource information; at the same time, each subsystem are relatively independent to each other and get the data format is very difficult to consistent, not directly read in deep learning module. Through the interaction of multisource information data, the deep learning module is input by normalized processing according to the characteristics of data. Multiscale analysis and data assimilation are used to solve the objective error of sensor observation data, improve the accuracy of data, and solve the problem of data uniformity and the "obstacle" of data flow between different subsystems, laying a foundation for multisource data deep learning. The specific process is as follows: after the data monitored by multiple sensors is passed, the dynamic temperature data is recorded by the multiscale analysis method, and key indicators of temperature data at different scales are calculated. In the normal operation of underground space, large-scale and mesoscale analysis results provide decision-making data support for underground space operation, ventilation, and energy saving, etc., and small-scale analysis results provide data support for fire warning, development and other disasters according to temperature changes, as shown in Figure 3.

3.3. Multisource Data Deep Learning Fusion Module. Multisource data deep learning fusion module analyzes historical data and experience through supervised, unsupervised, and reinforcement learning methods under the support of disaster prevention module and sensor monitoring data during underground space operation and uses deep learning algorithm to provide data support for disaster prevention decision-making in underground space. The gradient descent method is used to change the weight and bias of the model, and then, the fire warning is accurate, and the probability of open fire and smoldering fire is given, which provides decision support for the output graded alarm. Considering the characteristics of underground space, the fire

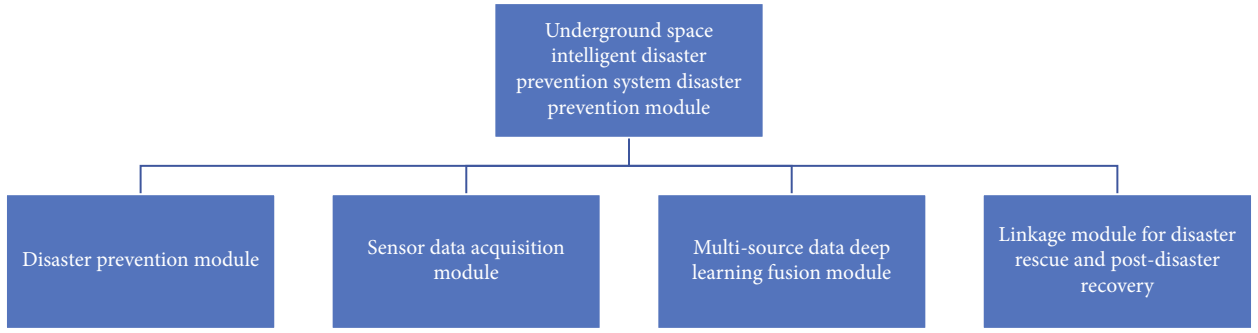

Figure 2: Intelligent disaster prevention system in underground space.

Table 3: Urban underground space disaster case database.

Name of underground space	Disaster type	Function	Time of occurrence	Reason	Disaster situation
Shenzhen bund tunnel	Fire	The road	In 2005	The car burst into flames after hitting the protective wall of the tunnel	The vehicle was damaged and no one was injured

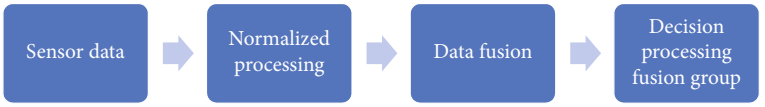

Figure 3: Sensor data fusion process.

warning model trained according to the real fire data of underground space significantly improves the reliability and accuracy compared with the traditional fire warning model.

Deep neural network (DNN) technology has been widely used in disaster warning, showing great advantages in solving some nonstructural problems. In this paper, the fire warning test as an example, infrared wavelength, carbon monoxide concentration, smoke concentration, temperature information set as the input, fire probability and ignition probability as the output parameters. By summarizing the existing fire warning models, the fire experimental data of underground complex were normalized and processed as data samples, and the training data set was selected to train the model. After the training, the model was tested with the verification data set, and four kinds of decisions were given: severe alarm, alarm, alert, and no fire. Through the output results of the model, when the probability of open fire continues to increase and the type of fire can be identified, the output probability of open fire is judged to be above 85%, and the decision of "severe alarm" is finally output, and rescue and fire fighting work is carried out immediately. Compared with the traditional temperature threshold alarm method, the alarm is 16 s earlier, which reflects higher adaptability.

3.4. Linkage Module for Disaster Rescue and Postdisaster Recovery. The core of disaster rescue is to ensure personal safety. According to the emergency response plan of the urban underground space management department according to the existing sudden disasters, accidents, and emergencies, combined with the multisource data deep learning fusion module, disaster situation, and rescue decisions are made, realizing the whole-life dynamic integrated auxiliary decision, including energy-saving risk control system, fire ventilation and smoke extraction, disaster development situation prediction, personnel escape guidance, intelligent rescue response, and multidepartment linkage. Based on all the records of the disaster process, data support will be provided for disaster accident assessment, postdisaster structural risk mitigation, postdisaster investigation, and disaster information release during the linkage of postdisaster recovery.

3.5. Realization of Underground Space Intelligent Disaster Prevention System. This paper will realize the intelligent disaster prevention system of urban underground space from three aspects of predisaster prevention, rescue, and postdisaster reconstruction.

Predisaster prevention stage divided into stages of disaster reduction and the run-up to the relief phase, through the Internet of things technologies such as real-time dynamic acquisition underground space disaster information of time and space, infrastructure, information flow, personnel, information, and climate information, and then the basic information storage, analysis, and processing, through the public information platform to realize data sharing. It is helpful for disaster risk prevention and control of normal underground space disaster prevention, transforming passive disaster prevention into active disaster prevention. Unable to eliminate all disaster risk due to disaster reduction

stage, we need to use wisdom of disaster prevention system for intelligent disaster dynamic monitoring and prepare for emergency, mainly through the establishment of efficient emergency organization system, training professional emergency team, improve citizen consciousness of disaster prevention, and can reduce the threat of potential hazards, easy to grasp the emergency supplies real-time status, provide resources to respond to emergencies.

In the emergency stage of disaster, the information platform of disaster prevention system should be started quickly to ensure the high degree of sharing of information resources and break the boundaries of departments. In the stage of disaster development, the information platform is like the brain, which can not only realize the functions of information collection, storage, processing, and dissemination but also assist in decision-making and command and command and communication. Through data analysis of the information platform, all relevant departments can quickly make shelter arrangements, transportation evacuation, medical assistance, energy distribution, material allocation, and other rescue operations. By accessing the public information platform, citizens can timely feedback their location and the disaster situation around them to the information platform to realize efficient rescue, self-rescue, and mutual rescue. This paper takes fire as an example. In the development stage of fire, there will be traffic jam in underground space. The intelligent disaster prevention system can continuously broadcast escape broadcast and guide personnel to save and escape according to escape signs and driving signs. Meanwhile, the PyTorch framework based on multisource data deep learning uses the training set of image recognition technology to obtain the video data of fire evacuation and improve the accuracy of recognition according to the difference of underground space. Therefore, the intelligent disaster prevention system realizes the dynamic display of escape and the number of firefighters and their predicted escape path in the underground space model, providing reliable data support for personnel's self-rescue, escape guidance, and dynamic evacuation decision.

In the postdisaster recovery stage, there are mainly postdisaster urban reconstruction and postdisaster urban order restoration. By establishing the information platform of urban reconstruction, collecting casualties after a disaster information, facilities damage, damage to property information, such as information, to the urban disaster loss assessment, planning, and postdisaster reconstruction and restore order to the city, and summarize the experience of the disaster, the further optimization and improvement of the underground space disaster prevention system of wisdom, improve the ability of disaster prevention, form the "cyclic progressive" development mode of urban comprehensive disaster prevention system.

4. Conclusion

With the development of big data and artificial intelligence technology, multisource data deep learning method has been applied in intelligent design, intelligent construction, intelligent maintenance, and intelligent disaster prevention of underground space. Based on the concept of emergency toughness of disaster prevention to underground space of disaster prevention decision wisdom as the goal, combining with the field of underground space of disaster prevention knowledge, and the characteristics of the deep learning model, put forward to underground space disaster, disaster prevention expert database, such as multisource data fusion, and disaster rescue and recovery by using deep learning, linkage, and established the wisdom of multisource data depth study of disaster prevention system, realize the full coverage of intelligent disaster prevention in the whole life cycle of underground space, and provide data support for integrated decision-making of disaster prevention and reduction. Main research achievements of this paper are as follows:

(1) Urban underground space disasters mainly include fire, explosion, earthquake, flood, toxic, and combustible gas. The relatively closed environment of urban underground space leads to great losses and rescue difficulties. Based on the in-depth analysis of the present situation of urban underground space disasters, combining with the overlapping of risks caused by different disasters and the inability to define the boundaries, the evaluation index system of urban underground space disasters is constructed, and the theory of emergency resilience and disaster prevention is used to provide effective suggestions and measures for the decision-making and treatment of underground space fires

(2) According to the whole process of dynamic development of underground space disaster, from the predisaster prevention, disaster relief, and postdisaster reconstruction in three aspects: to establish the wisdom of the urban underground space integrated disaster prevention system, the system including the disaster prevention module, sensor data acquisition module, deep learning multisource data fusion module, disaster relief, and recovery linkage module

(3) In the predisaster prevention stage, through the public information platform to achieve data sharing, the passive disaster prevention into active disaster prevention, reduce the threat of potential disasters, facilitate the real-time status of emergency supplies, to provide resources to deal with emergencies. In the emergency stage of disaster, quickly start the information platform of disaster prevention system, to achieve efficient help, self-rescue, and mutual rescue. In the postdisaster recovery stage, through the establishment of urban postdisaster reconstruction information platform, urban disaster loss assessment, postdisaster reconstruction planning, restoration of urban order, further optimization and improvement of underground space intelligent disaster prevention system, improve disaster prevention ability, and the formation of a "cyclic progressive" development model of urban comprehensive disaster prevention system

Data Availability

The figures and tables used to support the findings of this study are included in the article.

Conflicts of Interest

The authors declare that they have no conflicts of interest.

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