Nano World Journal

https://doi.org/10.17756/nwj.2023-s5-024

Research Article

Open Access

Nanotechnology Based Building Fire Safety Using Artificial Intelligent Facilities System

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Received: October 11, 2023
Accepted: December 19, 2023
Published: December 22, 2023

Citation: Leong WY, Chan SC, Subash TD. 2023. Nanotechnology Based Building Fire Safety Using Artificial Intelligent Facilities System. *NanoWorld J* 9(S5): S119-S124.

Published by United Scientific Group

Abstract

Artificial intelligence (AI) can be used in building fire safety systems to improve their efficiency and effectiveness. An AI-powered facility management system can detect potential fire hazards and take preventive measures to minimize the risk of fires. In this paper, research on how AI can help in maintaining building fire safety will be presented. On fire detection, AI-based sensors would detect fires early, even before they are visible to the naked eye. These sensors can detect heat, smoke, and other gases that indicate a fire, and alert the building occupants and fire department. To help with fire prevention, AI helps prevent fires from occurring in the first place. It analyzes data from building systems such as HVAC, electrical, and lighting to identify potential hazards and take corrective measures before they become a fire risk. To facilitate predictive maintenance, AI helps with the predictive maintenance of building systems, which helps prevent equipment failure that could lead to a fire. It analyzes building layouts and identifies the best evacuation routes, as well as alerts occupants and emergency responders to the location of the fire and the safest exit routes. A case study will be presented in this paper, of which after a fire, AI helps with post-fire analysis to determine the cause of the fire and identify any areas of the building that need to be repaired or upgraded to prevent future fires. Overall, an AI-powered facility management system can greatly improve building fire safety by detecting and preventing fires, helping with evacuation planning, and providing post-fire analysis to improve building safety in the future.

Keywords

Artificial intelligence, Facility management system, Fire detection, Sensors, Equipment

Introduction

Building firefighting facilities are a collective term for the tools and infrastructure used in buildings to prevent and put out building fires, such as fire hydrant systems, automatic fire alarm systems, and automatic sprinkler systems. Modern structures must include this capability since it ensures the safety of personnel evacuating the building in case of fire.

Over the past 20 years, a large number of comprehensive structures, high-rise buildings, super high-rise buildings, and other modern buildings have cropped up one after another due to the increased rate of urban construction and the quick advancement of design and construction technology. They help improve living conditions and modernization in cities, which are the primary locations of significant fire accidents, especially those involving mass casualties [1]. One factor is that the fire performance that was expected to be attained is prevented by the absence, malfunction, illegal closure of firefighting facilities, and other factors.

But, the complex interior design of the building, its many uses, and its occupied fire passageways do not promote firefighting and rescue, and even cause casualties of firefighters [2].

They mostly rely on the firefighting equipment inside the buildings to save themselves in the case of a fire because of the characteristics of huge, comprehensive buildings. As a result, it is critical to make sure that these structures maintain the firefighting equipment so that it can continue to function effectively every day [3]. Only if the relevant maintenance, supervision, and usage departments are knowledgeable about the design structure, functional layout, personnel distribution, and other specialized information of the building can they play a more effective role in fire prevention and extinguishment. The construction of comprehensive and efficient firefighting facilities is dependent upon this [4].

The management of building firefighting facilities, ensuring the integrity of firefighting facilities, improving the integration and intelligence of firefighting facilities management in various buildings, and effectively enhancing the capacity to prevent and control fires are some of the new topics in fire safety supervision and management.

By integrating various academic subjects, a brand-new, all-encompassing interdisciplinary subject called AI was established. It has steadily developed into the focal point and a hub for research for many different businesses and plays a crucial role in the healthy and sustainable development of society.

Construction engineering has made substantial use of AI at all stages of engineering projects, boosting the field's level of sophistication, digitalization, intelligence, and information technology while also promoting its quick expansion.

This study suggests that using AI in firefighting facilities can restructure fire management, increase the standard for fire safety management, and satisfy those needs. For the purpose of preventing and putting out fires, large-scale, comprehensive structures must be deployed.

The use of AI in the field of construction engineering primarily focuses on three areas: construction, operation, and decision-making [5-7]. Planning and design phases can be broadly separated into various categories in the decision-making process.

Planning

A novel method of learning is to use machine learning in AI to improve the construction industry. Machine learning, which uses past data and experience as a foundation and employs appropriate ways and means to develop or optimize the algorithm, is the main component of AI. A new planning and design mode is established by combining the real scene technology of virtual reality with AI to thoroughly study the external environment, geological conditions, transportation, and other objective factors around the construction project and the big data of nearby human needs [8]. We may successfully avoid dangers that cannot be taken into account in the traditional mode, create a more healthy and green building environment, and realize intelligent planning through this new planning and design model, and realize the intelligent planning degree of construction projects in an all-round way [2].

Design

The Building Information Modelling (BIM) is crucial throughout the design phase of construction engineering projects. Engineering projects can be precisely designed, built quickly, and managed visually with the help of BIM technology. In the 1970s, Professor Eastman of the Georgia Institute of Technology originally put out this concept. The efficiency of engineering construction can be increased by using this technique [5]. China's tallest structure, the Shanghai Center, Wuhan Center, and the tallest structure in the capital, China Zun, all used BIM technology during the building process. In particular, drawing design flaws, project rework, construction period, and other elements decreased by 85%, 70%, and 15% accordingly when Shanghai Center implemented BIM technology in the construction process, and the result was truly amazing [9]. It is possible to effectively avoid design issues like errors, omissions, collisions, and conflicts in various disciplines through the use of visual 3D modelling, cloud computing, virtual reality, and other technologies. These techniques can also help reduce and optimize design costs, significantly reduce engineering changes and conflicts during the construction stage, shorten the construction period, lower construction costs, and significantly enhance the 3D visualization level of engineering project design outcomes.

Construction

AI applications, such as 3D printing technology, intelligent robotics, etc., may be observed everywhere during the development of construction projects. Rapid prototyping technology based on self-designed digital model software, such as 3D printing, can be referred to as a new industrial revolution. According to Wang et al. [10], the study summarized and categorized research findings connected to 3D printing technology in the field of building engineering, including findings linked to domestic and international architecture. This technology may greatly speed up construction, save labor expenses, conserve building supplies, minimize project time, and achieve green, healthy, and intelligent construction through its implementation in construction projects. As 5G technology develops quickly and has the qualities of safety and dependability, intelligent robots with different functional types are designed. These robots gradually replace manual operations in the construction process, such as bricklaying robots and unmanned excavators, which significantly improves the quality of the construction and saves money.

Moreover, AI is present everywhere and at all times when supervising the construction site. Researchers like Gao and Chen [11] have fully utilized augmented reality technology in the management process, allowing field managers to access the design plan, ongoing progress, preliminary budget, and other pertinent information of the project at any time and from any location. At the same time, Sowah et al. [12] introduced the ISS system, which can rapidly and effectively help the project's primary management team understand the ideal project schedule based on the goals and limitations of a particular stage. Sowah et al. [12] used a deep learning-related target detection technique in the project's computer vision. The on-site video captured by the site camera may automatically, quickly, and effectively determine when a safety helmet is not being worn by construction workers as required and can sound an alarm. Through the combined use of intelligent sensors and the Beidou satellite navigation system, which has been substantially accelerated in China, we can obtain dynamic information of the construction site in real time, grasp all aspects of the construction site in a timely and accurate manner, ensure the most efficient connection of all construction processes, and quickly identify and resolve any unforeseen problems of on-site coordination.

Operation

Portable unmanned aerial vehicles (UAVs) with high-definition omni-directional rotating cameras have been utilized extensively in numerous high-rise structures, dams, bridges, and other relevant construction industries during the past ten years, exhibiting an exponential growth trend. The construction project products can be dynamically predicted and maintained during the operation stage using intelligent methods including UAV technology, visual algorithms, and deep learning algorithms.

By adopting laser surveying and mapping technology, a portable UAV equipped with laser radar, for instance, can swiftly and effectively acquire the 3D point cloud of the surveying and mapping site in order to gather low-precision 3D and all-around data about the site. During the bridge monitoring method, 3D digital imaging technology and UAV can be used extensively for real-time health monitoring. During the Wuhan epidemic's outbreak, the construction of Huoshen and Leishen mountain hospitals was crucial. However, in order to prevent too many individuals from contracting Xinguan, the 5G network and UAV technology were used for the first time in China to construct "cloud surveillance" via webcast. The successful adoption of shared project oversight too many people from contracting Xinguan. The effective implementation of joint supervision of the project's design, construction, and construction units, along with the adoption of the off-site construction module and on-site assembly method, resulted in a new construction pace in China. Using a camera's or computer's particular features is called computer vision. Computer vision is the use of a camera's or computer's specific functions to replace some of the tasks performed by the human eye, recognize, track, measure, and fix the predefined target, and optimize the useful information it contains [13].

To develop and mimic the neural network of the human brain for analysis and study, and to analyze data by mimicking the workings of the human brain, is the goal of the deep-learning research area, according to [14-17]. A method for judging the anomalous structural monitoring data that Leong and others [14-17] proposed is mostly composed of three steps: the initial step is to segment the continuously monitored real-time data; The second phase is imaging the segmented data (time-domain and frequency-domain responses) in two channels and labelling them in real-time. The third step entails developing and optimizing the deep learning algorithm in order to deep learn and spot anomalies in the monitoring data. Through the analysis of acceleration data from a super long-span cable-stayed bridge, the monitoring and judgement results are compared and verified, and the balance and probability of the data set as well as other influencing factors are fully taken into account in order to confirm the viability and accuracy of the algorithm. The verification outcomes are excellent. It has been demonstrated that this technology algorithm can rapidly and accurately identify the abnormal circumstances of various types of data.

Su et al. [18] summarized the pertinent machine learning research conducted at the Los Alamos National Laboratory. The relevant machine deep learning methods in the field of construction engineering were categorized and summarized by Li et al. [19], who came to the conclusion that machine deep learning has a lot of potential applications in this industry. In order to iteratively calculate the prediction outcomes of various models, Park et al. [20] used the real-world data collected for the building project with genetic algorithms, convolution depth learning, BP neural networks, and other techniques. They discovered that the prediction model based on the depth learning method has the minimum error when compared to other models, meaning that its predictive ability is the best.

AI algorithms come in a wide variety with clear benefits and drawbacks. To further enhance the algorithm, we must choose the best one for a certain project. In the field of construction engineering, predicting the future data development trend based on the current data development trend can not only significantly save labor costs but also open up new possibilities for project prediction and early warning systems.

Experimentation

Intelligent firefighting facilities management

In order to achieve the computerization and standardization of the management of fire safety work and raise the bar and effectiveness of fire safety management, Su et al. [18] developed a set of suitable applications of fire facilities management system using the web, Ajax, and other information technology in combination with the actual situation of the building.

Data mining is carried out by Zhang and Jiang [21] using the business intelligence module of Microsoft SQL Server. The fire accident cases and data analysis are implemented using four popular algorithms: cluster analysis, association rules, time series, and decision tree. This is based on a synthesis of accident analysis theory, data mining, and data analysis. Although data mining has a number of drawbacks, it also aims to serve as a reference for application techniques in incident analysis, and it has some academic value and practical relevance for data processing and information analysis in fire accidents.

By using big data to manage firefighting facilities, we can achieve dynamic firefighting management, intelligent firefighting information, autonomous learning forms, and maximized return on investment. We have also expanded the useful methods of firefighting social governance and promoted the standardization of firefighting facilities management.

According to Shokouhi et al. [22], the general term for facilities used for fire alarm, fire, personnel dispersion, fire separation, firefighting, and rescue operations is "building fire protection facilities," which refers to the man-machine system in a fixed engineering form composed of various fire protection products in a building. The degree to which building firefighting facilities are capable of completing a particular set of firefighting activities under given circumstances and within a specific amount of time is referred to as their reliability. The criteria for availability, trustworthiness, and efficacy are part of this reliability. In determining the risk of a building fire, the dependability of the facilities for combating fires is crucial. This project will later conduct comparative study using this evaluation criterion.

By utilizing a revolutionary module design of a visual firefighting decision-making system based on AI, Qingzhi [23] investigated how to circumvent the delay of traditional fire control decision-making systems. The module's layout blends AI and the most recent communication technologies to improve the effectiveness of information exchange between the firing field and the outside world. The findings demonstrate that the module design may facilitate the coordination and growth of the four modules, which will enhance the fire decision-making system's accuracy and offer considerable convenience for firefighters.

AI firefighting facility

In order to compare the new facility management approach to the established facility management model and ascertain if the inclusion of AI can increase the effectiveness of fire facility management, this study combines qualitative and quantitative research approaches. A facilities manager in charge of the library and a management of the technology business were involved to conduct analyses regarding the status of the equipment, and 50 employees were chosen to participate in a questionnaire survey on the firefighting system. The project is utilizing the fire suppression system of the public library and the firefighting resources of the nearby technological company Li'an Technology Company.

In order to improve the caliber of the outcomes of the comparative research, this project conducted an investigation focuses on the direction of AI, discussed some fundamental technical issues, and confirmed whether the intervention of AI can increase the efficiency of fire management.

Results and Discussion

In this section, we will discuss the results of the analysis conducted with the managers of two exemplary study examples (Figure 1), one a university library and the other a Shenzhen public library. Through the analysis, we were able to gain a complete grasp of the management situation of the interior firefighting facilities of the two typical public buildings. Since component of the data is subjective, it can only serve as a general direction for additional research.

The Bao'an County library was replaced by the Shenzhen library, which was finished and inaugurated in 1986. It is one of Shenzhen's "eight cultural facilities". The brand-new museum in the heart of the city was finished and inaugurated in 2006. It occupies a space of 29600 square meters in Shenzhen's administrative and cultural hub in front of the lovely Lotus Mountain, has a total building area of 49500 square meters, and houses a collection of more than 10 million volumes. It is a significant public structure in the city with busy crowds and intricate operations. Safety around fires is crucial.

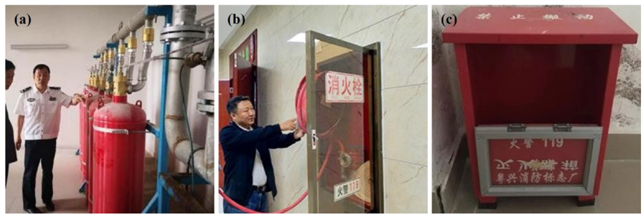

Figure 1: Analysis on the management situation of the interior firefighting facilities of the two typical public buildings.

This section chooses the Shenzhen library as the research subject to examine the administration of current firefighting infrastructure. The primary research methodologies are field surveys, interviews, and analysis, with literature reviews and web data searches as supplements. A community library manager was chosen for this study's in-depth analysis. We chose a facilities management manager for an interview based on the manager's duties, and we created table 1 using the information from the analysis and a field survey.

Conclusions and Recommendations

The goal of this study is to demonstrate how effectively AI can be used to manage fire facilities. The management of firefighting facilities includes the training and teaching of firefighting facility supervision, firefighting facility operation and maintenance, and firefighting facility management in order to ascertain whether management efficiency can be increased through the use of AI technology.

The inability of existing technology to meet the needs of the material world's development is a common foundation for the innovation of new technology. According to a study, there are various management issues with conventional firefighting facilities that can be effectively fixed with new technology tools. The manager interview materials and the staff questionnaire survey findings are gathered through the study of the management of traditional firefighting facilities in Shenzhen library. According to the survey's findings, complex firefighting needs for large-scale public buildings cannot be met by standard facility management, and new technical approaches are required.

AI has corresponding tools to address issues in all facets of managing fire facilities. First, intelligent cameras will be able to record various details and can monitor in multiple time and space when compared to the usual regular patrol of staff in terms of supervision. Following accurate risk identification by intelligent cameras, the automatic alarm system can issue alarm instructions rapidly. Second, AI big data technology can automatically collect data on ongoing operations and maintenance, report equipment problems right away, and repair it right away. AI has not, however, been utilized in the teaching and operation link. Employee satisfaction is higher when education and practical operation go hand in hand, compared to traditional facility management, in the practical operation link. Technology based on artificial intelligence can enhance the management efficiency of firefighting facilities in most links.

By research in the literature and on the ground, we can infer that AI is a trend in the development of facility management in China and that its use in fire facility management is efficient. We discovered that China is not doing

Tabel 1: The issue of the automatic fire alarm systems.

Safety items	Performance issues
Fire detector	• The installation is not secure, and the model choice is not appropriate for the location. • The spacing, installation position, and inclination angle do not follow the specifications. • The confirmation light of the detector is not pointed in a way that makes it easy for staff to see the main entrance. • The controller display and the detector code do not match, making it impossible to determine the detector's precise location. • An anomalous alarm function is present.
Manual fire alarm button	• The alarm function is anomalous, and the alarm address code does not match the controller's display, making it impossible to see where the alarm actually is. • The installation is not secure and does not adhere to the guidelines and standards of the design.
Fire display panel	• The fire alarm controller's power supply and grounding form are not in compliance with the regulations, nor is the installation, nor does the wiring inside the cabinet. • The power capacity and power performance tests on the fire display screen are invalid, and none of the eight fundamental functions fully conforms with the standards.
Controller for fire alarms	• No products are chosen that lack national quality certification. The installation and wiring do not meet the criteria, the standby power capacity and power performance test are insufficient, and the fire alarm controller's power supply, grounding form, and isolator do not meet the standards. Setting do not meet the requirements.
Grounding protection	• The system's functionality and protective grounding are inadequate.
Fire connection control apparatus	• The installation on the wire, the 13 basic control functions' compliance with the criteria, and the electrical performance and power capacity tests' compliance with the criteria are all insufficient.
System wiring	• The wiring does not meet the requirements.

nearly enough to promote AI technology, despite the fact that many academics have studied this aspect of the theory. Zhang provided numerous real-world instances of how AI is being used in construction engineering in 2022, which are in line with the findings of North China University's study. Foreign research in this field is much ahead of schedule compared to domestic research, and AI has developed into an unstoppable trend, therefore future fire facility management development must follow this trend.

This project examines the shortcomings of public buildings in developing Chinese cities in the management of firefighting facilities. It finds that due to the increasing complexity of buildings, the traditional manual management cannot comprehensively and efficiently deal with a large number of complex facilities. It uses the Shenzhen public library as an example of the traditional facility management system. The obstruction of firefighting pathways and other issues have created serious hidden risks to structure fire safety.

By examining typical examples of AI firefighting facility management systems, it has been determined that the addition of AI technologies like intelligent supervision systems, intelligent fire alarm systems, and intelligent operation and maintenance platforms makes the management of building firefighting facilities reduce labor costs, increase facility management efficiency, and satisfy the needs of labor.

In China's expanding cities, firefighting facility administration is still in its traditional stage at this time. The management don't have a broad enough understanding of intelligent operation and maintenance. Traditional firefighting facility management techniques are less effective than those utilizing AI. It should be mentioned, nonetheless, that although employee satisfaction of the AI platform is higher than that of the conventional management measures, there are still certain unsatisfactory situations, according to the survey results. The current AI fire management platform still needs to be enhanced because of the time constraint, which prevented this study from conducting additional in-depth interviews with the unsatisfied participants. In a word, this study will support the transformation of the conventional facility management system into one that is intelligent, efficient, and based on information technology. Second, because the current intelligent platform still has some flaws, it may encourage new businesses to research and experiment more.

Acknowledgements

None.

Conflict of Interest

None.

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