BIM integrated smart monitoring technique for building fire prevention and disaster relief

Min-Yuan Cheng, Kuan-Chang Chiu*, Yo-Ming Hsieh, I-Tung Yang, Jui-Sheng Chou, Yu-Wei Wu

Department of Civil and Construction Engineering, National Taiwan University of Science and Technology, Taipei 10607, Taiwan, ROC

ARTICLE INFO

Keywords:
Building Information Modeling
Wireless sensor networks
Evacuation/rescue route optimization
Bluetooth-based technology

ABSTRACT

Modern high-rise buildings may be configured into spaces of widely varying specifications. This situation creates a diverse building environment with multiple variables that make fire hazards difficult to predict and monitor accurately. Therefore, developing and implementing an integrated fire disaster prevention system is necessary in order to effectively prevent fire disasters and adequately protect life and property.

In Taiwan, the response to an organization of fire prevention and disaster relief as well as evacuation planning and rescue guidance continue to rely primarily on human-provided intelligence. This method makes disaster-response decision-making inherently prone to error due to the inaccuracy, incompleteness, and poor communication of this intelligence. However, Building Information Modeling (BIM) and wireless sensor networks have been widely discussed in many aspects of building disaster-prevention management as approaches to increasing the accuracy and effectiveness of disaster-response decision-making. The present study uses BIM to construct a BIM-based Intelligent Fire Prevention and Disaster Relief System. This system integrates information on personal localization, on evacuation/rescue route optimization with Bluetooth-based technology, and on a mobile guidance device to create an intelligent and two-way fire disaster prevention system framework that displays the real-time and dynamic fire information in three dimensions (3D). The results of applying the BIM-based system demonstrate that it may effectively provide 3D visualization to support the assessment and planning of fire safety, to provide early detection and alarm responses, to direct efficient evacuation, and to facilitate fire rescue and control efforts in order to increase overall building safety and disaster-response capabilities.

1. Introduction

In Taiwan, rapid economic development, improved construction techniques, and urbanization trends have led to the intensive use of land in urban areas, which has greatly increased the prevalence of high-rise residential and office buildings and distinctive large-scale structures such as Taipei 101, Taipei Main Station, and underground light-rail (MRT) stations. The use of inner spaces in these buildings is more complex than in other types of buildings. Moreover, their high capacity and centralized nature increase the complexity of designing efficacious escape and rescue routes that adequately ensure the safety of life and property during a fire disaster. Traditionally, the users/occupants of building have been required to make use of building escape facilities and fire extinguishers themselves. However, this condition increases the hazards of fire in high-rise and large-scale buildings [1]. Therefore, the fire and disaster prevention integration system and application development for these types of buildings has become an urgent requirement for preventing disasters.

Furthermore, disaster risks are becoming diverse and difficult to predict as building environments change on a regular basis. Fire disaster prevention and management is a critical issue, with key sub-issues including alarm notification [2,3,4], the design of fire evacuation guidance [5,6], and evacuation route simulation [7,8,9]. However, as evacuation route charts are commonly displayed in a two-dimensional format, these charts cannot identify the location of the fire (or other danger) or recommend the ideal evacuation route. In recent years, applications of the Building Information Modeling (BIM) have been used to improve building disaster prevention and management [10,11,12,13]. Using BIM permits the display of a site in three dimensions, which helps building occupants/users to visualize and immediately understand the status of a fire or other emergency. BIM is a new concept that improves the traditional two-dimensional model of disaster prevention and management. Effective fire disaster prevention methods integrate sensing technology, analysis, judgment, decision, and action functions. Therefore, the key aspects of the present study include: [1] “Effective Detection” to provide early detection, effective
alarm notification, and the onsite tools necessary to handle a fire emergency; [2] the “Correct Refuge” perspective, which allows those in danger to get to safety in an orderly and secure manner; [3] the “Fire Relief” perspective, which provides firefighters with critical and accurate information and identifies the most appropriate routings to accomplish fire rescue and control tasks; [4] “Integration System” to integrate and share fire and rescue information using a BIM information integration platform. Achieving all four aspects is critical to resolving the current communication problems that are inhibiting effective information transmission between firefighters and persons in danger.

The present study proposes applying BIM in a 3D massing model for the construction industry that integrates information on fire-prevention facilities, Bluetooth sensors, and evacuation-and-rescue-route-optimization and disaster-prevention functions. Creating a framework for an intelligent fire and disaster prevention system using the BIM model works as follows: When the Bluetooth sensors detect sufficiently high temperature or smoke levels, the system works to determine the authenticity of the detection, sounds the alarm, and then monitors the fire-outbreak locations and the evacuation/rescue routes, which are calculated by back-end operations in the BIM 3D model. Next, the system instantly shows in the 3D model the floor(s) that are affected by the fire and the floor plan of the suspected fire area and then uses an application software program to automatically activate dynamic evacuation guidance in real time on the devices of users in the fire-affected area. The proposed integration system is designed to enhance the timeliness and safety of evacuation/rescue actions.

The remainder of this paper is organized as follows. Section 2 reviews current studies on BIM in the context of fire safety management, wireless sensor networks, and the planning of evacuation/rescue routes. Section 3 introduces the design of the proposed model in detail. Section 4 provides the results of a related case study simulation and compares these results with traditional systems. Section 5 presents the conclusions.

2. Literature review

This section reviews the currently published studies on the application of BIM-based systems in fire safety management, wireless sensor networks, and the planning of evacuation/rescue routes [11,12,13]. Interviews that the research team for the present study conducted with firefighters indicated that high-rise buildings and residential complexes are difficult to escape during emergencies and are associated with a higher risk of emergency-related deaths than other types of buildings. Thus, supplementary fire-safety systems and tools should be developed for both residents and firefighters to enhance fire safety management and the effectiveness of fire rescue efforts.

2.1. Applications of BIM in disaster prevention management

The need to improve the traditional 2D perspectives of fire safety design projects encouraged the development of an automated, rapid-response monitoring system to prevent and minimize the damage of disasters using the 3D BIM framework. However, firefighters require real-time, explicit information from the scene of a fire in order to make rapid, correct decisions regarding response and rescue. For instance, the fire scene information in the BIM model may help firefighters make judgments on the relative relationship of locations among the ignition point, field personnel, rescue routes, and fire facilities, effectively reducing uncertainty and the disaster response time [14,15]. Most currently published studies that address the use of BIM applications in fire disaster prevention management focus on providing 3D visual effect and connecting building elements in order to support real-time evacuation information inquiries and simulations.

Rüppel et al. [14] established a BIM-based real-time information query system that combines an ultra-wide band, wireless local area network and radio frequency identification (RFID) to assist rescuers to find the shortest and safest route to an assigned location and to access information on their immediate surroundings within a building complex.

Wang et al. [11,13] proposed the four modules of evacuation assessment, escape route planning, safety education, and equipment maintenance and applied these to a case study of a high-tech facility in northern Taiwan. The first three modules used the 3D geometric data in BIM to assess fire safety requirements, while the equipment maintenance module combined safety management with property management within a web-based environment. Chang [16] combined BIM and an online building fire monitoring system that used sensors, monitors, and relative spatial information to help owners pinpoint the ignition point so that firefighters could be dispatched effectively to accomplish fire rescues in a large-scale building.

The use of BIM for facility management (BIM FM) represents a relatively new use of BIM. Wetzel and Thabet [17] used a BIM-based framework to develop safe maintenance and repair practices during the facility management stage using safety attribute identification/classification, data processing, rule-based decision making, and a user interface.

2.2. Applications of wireless sensor networks in disaster prevention

Wireless sensor networks have been discussed and applied widely in many areas. Normally, a ZigBee network is used to handle environmental monitoring tasks. Once emergency conditions have been detected, the network modifies its topology adaptively in order to ensure the reliability of transportation, to quickly identify hazardous areas that should be avoided, and to find navigation paths for the safe evacuation of people [18].

Lorincz et al. [19] proposed to apply wireless sensor networks in an infrastructure named CodeBlue to assist rescuers in disaster response simulations. The proposed application integrates handheld devices into disaster response, medical, and emergency care scenarios using a particular communication protocol and a software framework. Furthermore, S.F. Ochoa and R. Santos [20] presented the concept of a “human-centric” wireless sensor network as an infrastructure that supports the capture and delivery of shared information in the field to increase the availability of information and the efficiency and effectiveness of the emergency response process.

S. Bhattacharjee et al. [21] proposed a system that detects fire hazards using wireless sensor networks. The fire prevention system uses these networks to detect the exact location of a fire and its direction of spread, providing critical information necessary to stop the spread of fire and save natural resources and the lives of mining personnel. The proposed system may be used at the early fire-detection stage, with an alarm generated when an emergency situation is detected.

Tan et al. [22] proposed a system called the WSN-based Mine Safety System (WMSS) to monitor underground mine environments in real time. WMSS functions include providing pre-warnings of fire disaster and helping people evacuate as soon as possible.

2.3. Evacuation/rescue route planning and guidance

In the evacuation phase, evacuation routes are mainly divided into indoor and outdoor evacuations based on the location of a disaster. Most fire disasters occur indoors. Some studies [23–25] have worked to identify minimum evacuation times without considering the behavior or mental state of evacuees. The results of these studies are mainly applicable to regional evacuation planning. Ahn and Han [26] developed the RescueMe system as an application that recommends efficient evacuation paths over mobile phone devices to evacuees during emergency situations. This system assists evacuees to avoid crowded bottlenecks within a building by detecting changes of speed in real time. When the moving speed of an evacuee slows significantly, the system recalculates the shortest path and provides a new routing proposal to the evacuee. However, the shortest path may not be the safest.
دریافت فوری
متن کامل مقاله

امکان دانلود نسخه تمام متن مقالات انگلیسی
امکان دانلود نسخه ترجمه شده مقالات
پذیرش سفارش ترجمه تخصصی
امکان جستجو در آرشیو جامعی از صدها موضوع و هزاران مقاله
امکان دانلود رایگان ۲ صفحه اول هر مقاله
امکان پرداخت اینترنتی با کلیه کارت های عضو شتاب
دانلود فوری مقاله پس از پرداخت آنلاین
پشتیبانی کامل خرید با بهره مندی از سیستم هوشمند رهگیری سفارشات