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Study on Bridge Structural Health Monitoring System Based on BIM And GIS

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Abstract. In the context of rapid urbanization, the importance of bridge construction has become increasingly prominent, but problems such as bridge aging and environmental impact have also brought security risks. To deal with these problems, it is very important to establish an efficient and accurate bridge monitoring system. Firstly, this paper analyzes the research status of bridge health monitoring system and points out that there are some problems in the current system, such as weak analysis system, imperfect data storage and analysis. Then, the basic principle of Building Information Modeling (BIM)and Geographic Information System (GIS) technology and its application advantages in bridge monitoring are introduced in detail. BIM technology provides detailed building information through 3 Dimensions(3D) models to improve the accuracy of monitoring; GIS integrates geospatial data to realize data visualization and spatial analysis. After that, the paper discusses the specific application of BIM and GIS integration, including 3D model display, perception and monitoring, assessment and early warning, intelligent inspection and other functions. Through the deep integration of BIM-GIS technology, the system can monitor the bridge in real time, find and warn potential problems, and improve management efficiency and safety. Finally, the paper summarizes the research results, points out the significant advantages of the integration of BIM and GIS technology in bridge health monitoring, and looks forward to the future development trend.

Keywords: BIM; GIS; Structural health monitoring.

1. Introduction

In the context of rapid urbanization, bridge projects have received unprecedented attention and development, such as the Hong Kong-Zhuhai-Macao Bridge, which was officially opened to traffic in 2018, and the Lingdingyang Bridge, a Shenzhen-China channel, which will be completed in 2024. With the increase of service life, environmental impact, material aging and other problems will follow, and more serious will cause major traffic accidents. For example, on November 1, 2020, a major railway traffic accident occurred in Tianjin, resulting in 8 deaths, 1 serious injury and 5 minor injuries [1]. On May 1, 2024, a highway pavement collapse occurred from Guangdong Meida Expressway to Fujian Province, resulting in 48 deaths and 30 injuries [2]. In order to avoid serious accidents, it is very important to establish an accurate and efficient bridge monitoring system. Bridge structural health monitoring system is a system that uses sensor technology for data acquisition, data transmission, analysis and evaluation, real-time monitoring of bridge operating status, timely detection of structural damage and anomalies, so as to ensure the healthy operation of the bridge. At present, the bridge structural health monitoring system has been gradually developed, and the rapid development of big data and artificial intelligence technology has improved the efficiency and accuracy of data collection. However, there are still challenges in practical application. For small and medium-sized Bridges, the traditional health monitoring method is still used, which relies more on manual inspection and simple data collection, and can not respond to and deal with emergencies in time. Compared with traditional health detection methods, the health monitoring system based on Geographic Information System (GIS) and Building Information modeling (BIM) is more excellent. GIS includes geographic spatial database, which can realize information visualization by collecting, processing, simulating and displaying related information. BIM is a new information processing technology, the database changes dynamically, always present the latest data, improve the timeliness of health monitoring system.

2. Research Status and Related Technologies

2.1. Research Status of Bridge Health Monitoring System

Structural Health Monitoring (SHM) has just begun to be used in the aerospace field, using wireless sensing technology to collect and process data to correctly determine the damage and aging of structures. Nowadays,SHM has been widely used in various fields. SHM is used to measure, collect, process, analyze and evaluate Bridges, and provide reference for bridge maintenance and treatment. SHM began to be applied in the last century. In 1987, the United Kingdom installed sensors on the Foyle Bridge to monitor bridge vibration, deflection and other data, and the system realized data monitoring, analysis and sharing [3]. China's bridge health monitoring system was first used in Hong Kong. The Hong Kong Government has used the "Wind and Structural Health Monitoring System" on the Tsing Ma Bridge, Kap Shui Mun Bridge and Ting Kau Bridge, including sensor system, information collection system and information processing, to monitor the indicators of the bridge in the daily operation process and provide a reliable basis for bridge evaluation and bridge maintenance [4].

At present, the bridge health monitoring system has been gradually improved. However, from the operation effect of the existing bridge health monitoring system, there are still problems such as weak analysis system, imperfect monitoring data storage and analysis, and untimely information transmission, which need to be further studied and improved.

2.2. BIM

BIM is a digital technology-based information management framework that integrates digital representations of projects through visualization techniques. The core of BIM technology is to use dynamic visual information models to help decision-making and realize effective monitoring of the whole life cycle of buildings [5]. From the perspective of application status, BlM technology has significant advantages in improving project quality, optimizing design process and reducing errors [4]. At present,BlM technology has been widely used in the field of engineering construction, with the help of three-dimensional models, intuitive display of geometric and spatial relations and other detailed information. This technology improves the accuracy and coordination efficiency of monitoring. The use of BIM technology can achieve more refined bridge management, making the data more intuitive and reliable.

2.3. GIS

GIS is a system used to analyze and process geospatial information. Supported by computer hardware and software systems, it integrates computer graphics and databases on the basis of mapping. Effectively integrate geographic data from multiple sources, and use charts and other forms to visually present spatial changes. In terms of information analysis and expression,GlS can complete operations such as spatial analysis, statistics and query, providing an important basis for subsequent decision-making [6]. GIS can realize the visual expression of data and make people understand the spatial information better. In the bridge structure health monitoring system, GlS technology can be used to collect and analyze the spatial information such as the surrounding environment and geographical location of the bridge, so as to provide technical support for the bridge monitoring and management. There is a large amount of monitoring data in the bridge. To realize real-time online monitoring and evaluating the reliability of data, the database of the system is very demanding. GIS technology has the ability to store and analyze massive information, and can invoke remote data, providing strong technical support for the timeliness of data transmission [7].

3. Bridge Structural Health Monitoring System Based on BIM and GIS

3.1. BIM and GIS Integration

In the field of engineering construction, the integration of information technology is becoming a major development trend, especially the combination of BIM and GIS. BIM focuses on creating detailed 3 Dimensions (3D) building models and capturing detailed information about components and their associations, while GIS provides a broader perspective and focuses on the integration and analysis of geospatial data. By combining the detailed 3D model data of BIM and the extensive spatial data of GIS, information can be exchanged and shared at multiple levels. The BIM model enables accurate tracking of the bridge's maintenance records and component details. At the same time, the integration of GIS can provide the precise geographical location of the bridge and the spatial information of the surrounding environment [6]. In the field of intelligent bridge management, the combination of BIM and GIS shows great application prospects. The combination of BIM and GIS technology can realize the integration of information from macro to micro. The spatial analysis and data query functions of GIS at the macro level make up for the gaps of BIM in environmental background information, provide BIM with a broader vision of decision support, and help BIM move from a single refined model design to a more comprehensive multidimensional spatial data analysis [8]. GIS makes it possible to locate bridge projects and display environmental features on a large scale. In addition, the accurate model of BIM provides rich data support for GIS analysis at the detail level. The increasing improvement of BIM and GIS technology has reduced the cost of staff operation and maintenance management and better promoted the construction of bridge projects.

3.2. BIM-GIS Technology 3D Model Display

The integration technology of BIM and GIS plays a key role in 3D bridge modeling. GIS, through its spatial analysis capabilities, accurately presents the geographic location of the bridge and integrates the geographic coordinates into the BIM model. This integration allows the model to show the full picture of the bridge from a macro perspective. At the same time, BIM technology enables users to easily retrieve detailed information on each component by integrating structural and non-structural information of the bridge in a 3D model.

(1) Multi-angle observation of bridge model

Software is used to integrate the bridge model with the GIS model built by aerial survey data, and the BIM model is integrated into the environment to show the landforms around the bridge through GIS technology. As shown in Fig. 1, a visual model is used to show the appearance of the bridge in different directions.

Figure 1. Side view of the bridge [3]

(2) Simulation of weather

As shown in Fig. 2, the network is used to query the local weather conditions, and the simulation of different weather is realized in the three-dimensional scene, which makes the monitoring more intuitive and efficient.

Figure 2. Simulation of rain scenario[3]

3.3. Functions of Monitoring System

3.3.1. Perception and monitoring.

The bridge detection system built by BIM-GIS technology is mainly processed and evaluated according to the monitoring data, and the sensing and monitoring functions play a very important role in use. Engineers usually place sensors at key parts of the bridge, so that the detection system can obtain real-time information related to the bridge, and monitor the overall and local health of the bridge through the efficient transmission of data, to ensure the safety of the bridge. Through the deep integration of GIS-BIM technology, perception and detection play an important role in health monitoring system.

3.3.2. Assessment and early warning.

BIM-GIS integration technology plays an important role in assessment and early warning. In terms of bridge assessment, BIM-GIS technology can realize electronic inspection and quick visual query of Bridges, and managers can clearly see the safety status of Bridges, so as to accurately customize care plans. For the early warning system, BIM-GIS technology, through the use of big data, enables the detection platform to preset the trigger threshold and early warning level of bridge disasters, and in-depth analysis of key monitoring data such as structural response, environmental information and load. With the support of data, the online safety assessment of Bridges can be completed quickly and early warning information can be sent timely [6]. In the BIM-GIS platform, the spatial position relationship between the construction progress and the surrounding environment buildings, pipelines and other risk sources can be calculated according to the GIS coordinate system and BIM spatial information. According to the preset risk discrimination, the risk source is automatically identified, and the risk source is displayed on the platform through color differentiation and highlighting, which effectively avoids risks [9].

3.3.3. Intelligent inspection.

Risk inspection is to dynamically control the problems found in the daily inspection during the construction process, and the system can automatically create inspection tasks according to the predetermined schedule. In the process of inspection, image recognition technology is used to complete the inspection work, and the inspection report is automatically generated, and the report is archived and stored. In this way, operation and maintenance personnel can easily access these reports

at any time, and the system can realize continuous monitoring and inspection 24 hours a day, thus simplifying operation and maintenance work and reducing the work burden of operation and maintenance personnel [10].

4. Conclusion

This paper mainly studies the bridge structural health monitoring system based on BIM and GIS technology. Through in-depth analysis of the application and combined advantages of these two technologies in bridge monitoring, the following conclusions are reached:

(1) The integration of BIM and GIS shows great potential in bridge health monitoring systems. BIM technology provides detailed information on bridge components through its detailed 3D building models, while GIS complements extensive geospatial data, and the two combine to achieve comprehensive information integration. In terms of three-dimensional model display, BIM-GIS technology can view bridge models from multiple angles and simulate different weather conditions, improving the intuitiveness and efficiency of monitoring. Through efficient data collection and transmission, the system can monitor the health status of the bridge in real time, and use big data and artificial intelligence technology to conduct in-depth analysis, timely detection of potential risks, and effectively prevent major accidents.

(2) Although the combination of BIM and GIS has made remarkable progress in bridge health monitoring, the existing system still has problems such as weak analysis system, imperfect monitoring data storage and analysis, and untimely information transmission. Traditional health monitoring methods are still dominant and lack of efficient and intelligent monitoring means.

(3) With the further development of big data, artificial intelligence and Internet technology, the bridge structural health monitoring system will develop in a more intelligent and automated direction. Future systems are expected to enable more efficient data collection, more accurate damage identification and assessment, and more timely early warning and emergency response. At the same time, with the continuous maturity of technology and cost reduction, this intelligent monitoring system will gradually spread to small and medium-sized Bridges, and improve the overall intelligent level of bridge management. Cross-field technology integration and innovation will also bring more possibilities to the field of bridge health monitoring and promote the continuous progress and development of the industry.

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