Innovative Application and Development Trend of BIM in Construction Engineering

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Abstract. Building Information Modeling (BIM) has fundamentally altered management, construction, and design of buildings. Two sections of this work address technological uses and future development of BIM. The first section examines how different computer technologies—Artificial Intelligence (AI), Machine Learning (ML), Big Data, Cloud Computing, and so on—can solve the shortcomings of conventional BIM in real-time construction progress reflection and data management, so enhancing construction efficiency and production. The second section addresses the new technological challenges and social demands confronting BIM, including the requirements of smart city construction and sustainable development concepts for environmental monitoring, energy management and multi-disciplinary collaboration, as well as the digital transformation of the construction industry for data interoperability, user experience and security. By means of thorough investigation of the application and future evolution of BIM technology, this article seeks to offer reference for the building sector and hence support BIM in a more general spectrum of application situations.

Keywords: Building Information Modeling (BIM), deep learning, digital transformation, design optimization, technical challenges.

1. Introduction

Constructing detailed digital models [1], realizing cooperative work among many disciplines, and so improving the general efficiency and accuracy of projects, Building Information Modeling (BIM), as an innovative technology, has been extensively used in the worldwide construction industry, integrating various types of information in the building design, construction, and operation phases. Bim still has several difficulties in actual implementation, nevertheless, given the size and complexity of building projects: real-time construction progress reflection, dynamic resource allocation, and massive data management. BIM technology has been constantly coupled with cutting-edge technologies including artificial intelligence, machine learning, big data and cloud computing to help cope with these issues and further improve its purposes and advantages. Concurrent with this, the building of smart cities and the support of the idea of sustainable development have presented fresh needs for BIM, which must be constantly upgraded and improved in terms of environmental monitoring, energy management, and multi-disciplinary collaboration to satisfy the rising social needs. The digital revolution of the building sector also depends on BIM to create fresh discoveries in security, user experience, and data interoperability. This paper will address BIM in depth from the aspects of technical application and future development, analyze the application of various computer technologies in BIM and their supplementation and enhancement of BIM insufficiencies, explore the new technical value of BIM faced with reference, and promote the Bim technology to play a role in a wider range of application scenarios showing in Figure 1. Aiming to provide the building sector a complete framework for integrating advanced technologies in BIM, improving efficiency, and meeting the changing expectations of society, the new requirements brought by the technical difficulties and social demands suggest the corresponding solutions.

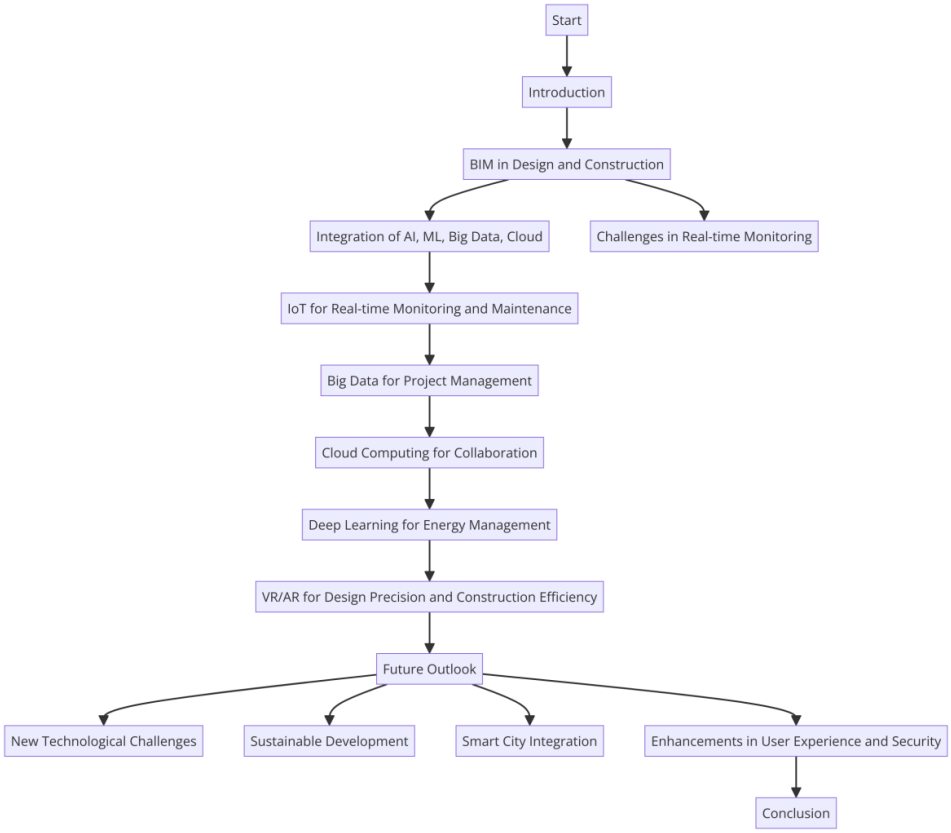


Figure 1. Text Structure

2. BIM and computer technology integration and efficiency improvement

2.1. IoT technology to help BIM development: from real-time monitoring to accurate maintenance of the overall upgrade

Building Information Modeling (BIM) confronts several difficulties as we enter the 2010s, including restrictions in real-time monitoring and maintenance that directly affect the management efficiency and cost control of building projects. Although conventional BIM models can offer comprehensive building design and construction data, real-time monitoring and accurate predictive maintenance of structural and environmental factors throughout building operation is challenging. structure management teams find it difficult to quickly obtain important data to properly prevent possible equipment failures or structural damage, therefore affecting repair and replacement costs as well as the general dependability and service life of the structure.

By use of several kinds of sensors - such as temperature, humidity, vibration, and energy consumption sensors - that enable real-time monitoring and analysis of structural and environmental characteristics of buildings - Internet of Things (IoT) technology helps [2]. These sensors taken in concert with the BIM model enable the building management team to promptly identify possible issues and effectively comprehend the operational state of the structure. Real-time energy consumption data monitoring of a building, for instance, allows one to precisely estimate the service life and maintenance needs of the equipment, so enabling prompt maintenance actions to extend the life of the equipment and save maintenance costs. It raises the general operating efficiency and building sustainability as well as the management's intelligence and efficiency [3]. By means of IoT technology, BIM not only addresses the shortcomings of conventional models in terms of monitoring and maintenance capacity during operation, but also offers a more refined and predictive management approach to the building sector, so supporting the building sector to progress in the direction of digitalizing and intelligence.

2.2. Big Data and Cloud Computing Technologies Drive BIM Innovation: Improving Project Management Efficiency and Collaboration

Big data and cloud computing technologies have helped to offset some of the restrictions of building information modeling (BIM) in project management in the framework of technical developments [4]. Large and complicated building data and implementing real-time cooperation present difficulties for conventional BIM models. Data management and inadequate information sharing in the past often presented challenges for building projects, therefore restricting the accuracy and efficiency of cooperation among project participants during design, construction, and management. Big data technology has helped BIM to handle and examine vast building data, thereby optimizing design solutions and building techniques. Big data analytics enhances project productivity as well as enables construction teams to better grasp and handle challenging project-related problems including material selection, structural optimization, and predictive maintenance needs. By means of this accurate data analysis and optimization procedure, design quality and construction efficiency of building projects are much enhanced, thereby lowering cost increases and delays resulting from design revisions and mistakes.

2.3. Cloud Computing and Big Data Technologies to Enhance BIM: Optimizing Project Management and Energy Safety Assessment

The development of a cloud computing platform improves BIM's efficiency even in project management. Cloud computing offers a real-time collaborative work environment and effective data storage that let every project participant view and change the BIM model at any moment, wherever [5]. This improved information exchange and teamwork help team members to communicate far more effectively and coordinate their efforts. By means of the cloud computing platform, the team managing the construction project is able to more dynamically modify the project schedule and resource allocation, thereby enabling prompt response to changes and challenges and hence enhancement of the general management level and success rate of the project. Along with addressing the drawbacks of conventional BIM models in data processing and cooperation management, the combined application of big data and cloud computing technologies offers the construction sector a more efficient, exact, and cooperative approach of working. The progress and implementation of such technology have driven building projects towards digitalization and intelligence, so supporting the industry's sustainable development and innovation.

Conventional approaches in the engineering application of building information modeling (BIM) face some limits in structural safety assessment and energy management optimization. Although conventional BIM models can offer comprehensive building design and construction data, designers and engineers sometimes find great difficulty with high data complexity and low predictive accuracy for energy consumption analysis and building structural safety assessment. These constraints result in possible omissions of structural safety concerns and a lack of accuracy in energy management initiatives, therefore raising the running costs and safety hazards of projects.

2.4. Deep Learning Technology Leads BIM Innovation: Improving Energy Management and Structural Safety Assessment

Deep learning technology in artificial intelligence is becoming increasingly important in society, hence its implementation by BIM has resulted in notable gains and advances at this period. Deep learning technology can efficiently examine vast building data and extract important information using its strong data processing and pattern recognition capabilities, thereby enhancing energy management systems. By means of data analysis and usage patterns, deep learning algorithms can effectively predict and optimize energy consumption, so lowering building running costs and increasing energy efficiency. This form of intelligent energy management not only increases the economic efficiency of construction projects, but also helps to lower the negative influence on the environment, thereby guiding the building sector toward sustainable development.

Conversely, deep learning technology also exhibits special benefits in terms of structural safety evaluation. Deep learning algorithms can create reliable structural safety prediction models and spot possible structural flaws and risk areas by examining a lot of historical data and real-time monitoring information of building constructions. By allowing designers and engineers to implement efficient preventative actions before real problems develop in the building construction, this predictive maintenance strategy helps to enhance the general safety and dependability of the construction. Deep learning technologies provide additional intelligence and predictability to building design and construction, therefore offsetting the constraints of conventional BIM models in energy management optimization and structural safety evaluation. These technologies not only increase the safety and cost efficiency of projects but also help the building sector to shift toward smart and sustainable development.

Concerning design accuracy and construction quality control in the engineering use of building information modeling (BIM), conventional approaches have several restrictions. Although conventional 2D and 3D models can offer comprehensive building design information, during design verification and field construction designers and builders sometimes find it challenging to grasp and convey. This restriction causes design flaws and needless delays in the building process, therefore raising project risks and costs.

2.5. VR and AR Technologies Revolutionize BIM: Improving Design Accuracy and Construction Efficiency

Virtual Reality (VR) and Augmented Reality (AR) technologies have presented fresh opportunities and challenges to the evolution of BIM, which has been greatly expanded and improved upon. VR technology lets designers and engineering teams view and interact with BIM models in real time with fresh angles and interactions. Designers can more precisely evaluate the feasibility and viability of architectural options by simulating the spatial layout and vision of a building in a virtual reality headgear. Apart from enhancing the correctness of design judgments, this visualizing experience lowers late changes and extra expenses resulting from design mistakes. Conversely, augmented reality (AR) technology overlays virtual information on the real world so that designers and construction workers may see and grasp the consequences of architectural design as it is implemented in field building. By means of smart devices and real-time access to pertinent build instructions and data, AR technology allows constructors to examine BIM models in the field [8], thereby helping to lower errors and increase construction efficiency. AR technology allows construction workers, for instance, to precisely pinpoint pipelines and equipment installation sites, therefore preventing mistakes and building delays brought on by conventional paper blueprints.

By means of virtual reality and augmented reality technology, the limits of conventional BIM models in design verification and field construction are offset, so providing a fresh visualization experience and operation for building design and construction. These technologies not only increase the accuracy of design and quality of construction but also lower the project's cost and risk, so advancing the construction sector in line with digitalization and intelligence.

3. Prospects for new technologies in BIM applications

Though Building Information Modeling (BIM) technology is making amazing strides in building design, construction, and management, some society demands and issues still go unmet. How to improve the environmental friendliness and sustainability of building projects even more is one of the main problems. The building sector has always been growing more and more worried about environmental effects and energy consumption; so, BIM technology offers smarter and more sustainable solutions to help to solve this issue. In this regard, the integration of artificial intelligence (AI) technology and Big Data analytics presents fresh approaches to handle construction sustainability. Big data technology enables designers and developers maximize building design and operational strategies by processing massive building data and provide in-depth analysis of energy

use patterns and environmental implications. Real-time energy efficiency prediction made possible by artificial intelligence algorithms helps buildings to react more intelligibly to environmental changes and human needs, hence optimizing energy efficiency and lowering carbon footprints.

Using artificial intelligence and big data analytics to dynamically change the operation modes of air conditioning and heating by real-time monitoring of temperature, humidity, and people's activities inside a building, an MIT research team has developed an intelligent temperature control system [9]. This type of technology not only increases the comfort of the indoor surroundings but also helps to maximize the energy use. By means of big data analysis and artificial intelligence, Philips has developed an intelligent lighting system that automatically modulates lighting brightness and modes depending on outdoor light intensity, time period, and building personnel activities. In addition to lowering power usage, this enhances the lifetime of lighting equipment. Big data technologies and artificial intelligence are applied at the building design stage to create environmental simulations evaluating environmental elements including sunshine, ventilation, and noise in constructions [10]. Based on simulation findings, designers can maximize the use of natural resources and lower energy consumption by optimizing the structural design and building layout. Using sensors both inside and outside the building, a smart water management system in Seattle tracks water use and quality in real time. Big data analytics and artificial intelligence technologies enable the optimization of water use methods, thereby lowering of water waste and enhancement of water use efficiency.

In essence, BIM technology's future aim is to improve construction projects' environmental adaptability and sustainability by means of big data and artificial intelligence technologies. It is assured to be sufficient to satisfy the present social needs for environmental protection and energy economy as well as to provide the building sector new commercial possibilities and competitive advantages.

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