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Research Article

The Application of BIM Technology in Construction of Intelligent Medical Laboratory: A Review and Prospect Analysis

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Abstract

With the rapid development of the medical laboratory construction industry and the expansion of the market scale, the demand for intelligence and multidisciplinary cooperation in medical laboratories is increasingly growing. Building Information Modeling (BIM) technology, as an information management tool, can effectively enhance the efficiency and precision of the medical laboratory construction process and promote coordination among various professional trades. BIM technology meets the demand for multidisciplinary comprehensive automation and cooperation in the process of medical laboratory intelligence transformation, driving the refinement and specialization of management in medical laboratory construction. Currently, BIM technology has realized the comprehensive automation and cooperation functions in construction projects. And it exhibits an application trend towards multidisciplinary parameter comprehensive three-depersonalization, providing a foundation for comprehensive collaborative control throughout the intelligent medical laboratory construction process. The application prospects of BIM technology in this field will be broader in the future.

Keywords: Intelligent Medical Laboratory; Building Information Modeling (BIM) Technology; Cooperation

Introduction

Recently, there has been a growing emphasis on constructing medical laboratories, leading to an increase in construction projects. Additionally, there is a noticeable trend towards incorporating intelligence into these projects, making it a rapidly expanding sector within the construction industry with promising prospects for future development.

Intelligent Medical Laboratory Requires Information Management with Multi-Professional Cooperation.

Traditional medical laboratories, with their low level of intelligence, necessitate a substantial number of resources for management. In addition, it is challenging to comprehend the connectedness and interaction between the operational area and the staff, which could result in personal safety concerns, inaccuracies in experimental results, or potential biosafety hazards. Ultimately, there is a squandering of resources and a lack of effectiveness [1]. The swift advancement of emerging information technologies, such as artificial intelligence and big data, has led to a gradual transformation in the conventional design and operational methods of medical laboratories. Intelligent medical laboratories are established by integrating several equipment and components with intelligent controllers, resulting in efficient resource management, reduced operating expenses, and improved precision in management. Intelligent medical laboratories have the ability to efficiently handle time and quality, streamline information transfer procedures, and fully integrate the intelligent information cycle and digital closed loop [2]. In an intelligent medical laboratory, the main building components, decoration components, and intelligent control equipment can utilize intelligent information loops to establish a cooperative mode of interconnection and interaction. This enables systematic connectivity and synergistic operation, allowing these components to perceive and adjust to their surroundings. Therefore, the completed equipment uses, and operation space is also more humanized, easy for laboratory personnel to operate, can realize the control and monitoring of environmental effects and experimental effects, improve the accuracy of experiments, reduce safety risks, and more efficient resource allocation.

The medical laboratory construction procedure must be focused on the complicated structures and many trades involved in developing component assembly patterns. The use of virtual rehearsal enables the establishment of a construction management program for each specific period, leading to a more synchronized construction process. An intelligent laboratory system with enhanced process synergy and overall effectiveness can only be constructed by engaging in collaborative planning and predetermination throughout project implementation. Therefore, the cooperation and management of multiple engineering disciplines are crucial in the creation of an intelligent medical laboratory. In the BIM system, engineers can predict potential issues during the construction phase of a project by generating and utilizing a three-dimensional model of the medical laboratory and its analysis function in conjunction with the multi-professional model. These problems can then be analyzed to develop a precise and scientific response plan.

As medical laboratory intelligence progresses, the need for information management technology that can facilitate cooperation between different work types and handle complex information loops becomes increasingly important. This technology is essential for the design and construction of medical laboratories, as well as for the collaborative management of multiple specialties and job types.

The Current BIM Technology Facilitates Automated Cooperation for Multiple Tasks.

The concept of BIM originated from Professor Chuck Eastman's architectural vision in 1975, and later encompassed the idea of "Building modeling," eventually developing into the concept of "Building Information modeling" [3]. Autodesk introduced Revit software in 2002 and actively promoted its worldwide use, signifying the official integration of BIM technology into the engineering industry [4]. Following an extensive period of research [5], BIM technology worldwide has now achieved its current level of technological effectiveness and has given rise to the following two trends:

BIM technology is being advanced to streamline and facilitate cooperation across the whole project process.

Recently, numerous academics have focused on conducting thorough investigations into BIM technology, including the exploration of capacity extension, automation, data analysis, model sharing, and other related areas. The relevant research is mainly about the overall parametric design cooperation application combined with the actual engineering, as a way to solve the problem of interaction and sharing of BIM data between different platforms. For instance, Akinci B, Sawhney, et al. [6] employed modular MC standards, BIM technology, and visual programming tools to create rule-based architectural components. This greatly streamlines the entire design process for creating parametric modular component models and promotes the adoption of BIM technology in the prefabrication industry. Staub-French [7] suggested creating an IFC standard using an internet-based tool that can produce a cost-effectiveness model for a construction project depending on its cost. This would help to establish a clearer relationship between project cost and construction. Lipman R [8] examined the conversion mechanism of the CIS/2 data model, which is based on the structural steel data model under the IFC standard. This mechanism enables the structural steel data model to interact with various standards, identify flaws in the steel framework, and produce IFC test files for the creation of steel entities. Po-Han Chen, Lu Cui, et al. [9] created a collaborative information server architecture that enables multidisciplinary interaction and distant visualization operations. This architecture is based on the IFC information server idea and incorporates web server coordination and sharing.

BIM technology has been extensively utilized across various areas of the digital information life cycle over time. Romberg R, A Niggl, et al. [10] presented a model that collects geometric model characteristics from a BIM 3D model and converts them into a computational model suitable for P-type simulations. M. Nour [11] incorporated data from every stage of the building lifecycle into the IFC model to enable the simultaneous transfer of real-time information about the building and its associated data. Costin AM, J Teizer, et al. [12] employed the integration of RFID and BIM technology to produce real-time data for the purpose of creating leading indicators for protocol control, visualizing information data protocols, and conducting real-time analysis, tracking, and detection of data to prevent risks. Amirebrahimi [13] utilized BIM technology and integrated GIS data models to conduct a comprehensive evaluation of structures and simulate flood damage using 3D visualization. Furthermore, the application scope of BIM technology has significantly broadened. In a study conducted by Manu Akula and Robert R. Lipman, et al. [14], point cloud data, 3D imaging technology, and BIM technology were integrated to investigate the precise location of rebar within concrete structures. This approach allows for non-destructive determination of embedded positions, thereby enabling effective quality control during construction. Hong Y, et al. [15] utilized a Neural Network system to forecast the profit and principle of the BIM model. This prediction serves as a reference for decision-makers and aids in finding the most optimal management approach. Cheng H-M, et al. [16] also employed BIM technology in the restoration of historical buildings. They utilized 3D laser scanning and photogrammetry to automate the creation of a digital model through HBIM. Dang NS [17] employed 3D scanning to reverse engineer a surface model based on the digital twin model of BIM. This allows for adjusting the information in the model for preventive maintenance of existing aging PSC bridges. It enables the determination of the bridge's location, extent of damage, and severity.

The development of BIM information technology has enabled the creation of scenario models, automatic model generation, data interchange between different types of work, automatic coordination and cooperation, multi-user data interaction, and the application of reverse engineering models throughout the entire process of engineering construction. Significant advancements have been made in the fields of model data sources, data translation and integration, data and user interaction, and the collaborative use of construction engineering data across the entire process. These features will also be significant areas of use for BIM technology in engineering.

The development of BIM technology presents the trend of comprehensive three-dimensional of multi-species parameters.

Due to its extensive application in several professional domains of construction engineering, BIM technology has progressively established the technological inclination towards three-dimensional representation of multi-trade models and the exchange of three-dimensional data across multiple platforms. Bao-ku Qi and Chang-fu Li [18] suggested that the implementation of BIM technology in the assembly construction industry can address the challenge of collecting and sharing information in assembly construction projects. Yue-jun Shen [19] employed a custom-made aluminum template set program panel during the aluminum template design and building process to achieve three key functions: aluminum template design, calculation, and statistics. Qiang-qiang Li [20] utilized BIM technology to create a waveform steel web model, which was then loaded into ANSYS software for further analysis. The purpose of this analysis was to examine the model's stress levels. Jian-yang Ding and Hou-guo Fu [21] created a toolbox for quickly modeling rail transit components. They achieved this by using APIs to access information such as models, families, instances, and other relevant data, enabling the rapid development of rails and support hangers. Hao Ma [22] conducts Revit-based secondary development to implement BIM management and application for pipeline corridor project components and prefabricated components in assembly buildings. This involves creating a management modeling platform, a model family library for building components, a component coding system, an information entry system, and a parametric family library. Enhance the level of integration and complexity of building component design, achieve full implementation of BIM application, and ultimately integrate the BIM model with finite element software to enable operational management and disaster preventive simulation [23-26].

Revit, being the central 3D modeling software in BIM technology, possesses strong adaptability and can be customized to build modeling software that fulfills specific technical requirements through secondary development. Yan Huang [27] suggested utilizing the C# programming language for secondary development in order to enhance the efficiency of modeling the assembly family library in BIM technology. Fei-yu Long [28] achieved efficient automated modeling of subway station enclosure structures by developing a diaphragm wall family library. This library enables the automatic generation of reinforcement and calculation of the required quantity of reinforcement. Lu-yu Ding [29] developed a modeling technique that can automatically design spatial walls, boundaries, and ground tiles. Additionally, they created a library of relevant case studies. Ru Lin [30] included BIM secondary development in the decorating project to address the technical challenges associated with complex construction in decoration. Shen Zhang and Hao Yang [31] utilized the C# programming language to conduct secondary development of Revit. They embedded a software page that serves as an external plug-in, enabling the automatic arrangement of fire sprinkler heads. This feature facilitates the automatic generation of fire sprinkler head arrangement. Additionally, Nai-wei Cheng and Xin Yan [32] swiftly position fire protection facilities within the model, providing valuable assistance to design and management personnel.

In terms of software interaction, Xuan-xuan Wang and Yu-lin Huang [33] developed a software interface called Revit-Abaqus model conversion interface and Revit-ANSYS interface. These interfaces were designed to address the challenge of modeling intricate structures in structural computation software. Lu-lin Cao, Xi-sheng Li, et al. [34] conducted a secondary development of the Revit software using BIM-CSKB (Construction Knowledge and Safety Base). They established an Access database as a design tool and created a construction safety verification plug-in. This development is of practical significance in enabling worker localization, real-time data uploading, and other related tasks. Bao-juan Qiao, Zheng-xian Deng, et al. [35] conducted an analysis on the development of PKPM and Revit bi-directional data interface software. They successfully achieved the integration of Revit's modeling capabilities with PKPM's analysis capabilities, allowing for the seamless exchange of data between the two software programs.

At the same time, the positive design of Revit has a greater reference significance for the development of the industry. Li-jun Niu [36] uses Revit API and MVC programming architecture to create parametric 3D models, and compiles the secondary development of Revit software, which can be used to carry out forward design of water conservancy project drop channel examples, and realize the automatic generation of drawings, budgets. Ming Chen and Yang Li [37] proposed BIM forward design simulation modeling, supplementing the relevant mesh frame structure family library, and secondary development to achieve automatic modeling of the mesh frame structure. In order to address the issue of low efficiency and accuracy in urban rail modeling, Jiao-jiao Bai [38] successfully implemented the automatic generation of models and other methods through secondary development control parameterization, resulting in the invention of forward three-dimensional quick assembly methods.

For the shaped space structure and special structure of the node design and node construction modeling difficult problem, Shi-lin Xu [23] used C # language Revit software for shaped space secondary development, realizing the curved curtain wall high precision modeling analysis method and parameterization program development. Nian-fu Gu and Mei Lin [39] suggested that the glass sash window family module can be utilized to create the ceiling instance family, specifically for the construction of the light steel keel ceiling model. Zhong-hua Xue [40] focused on developing software for space grid structure modeling, with the goal of enhancing efficiency and practicality. This involves creating several models for loads, supports, and other components of the structure. Xiao-yu Ding [41] utilized the JGJ7-2010 space mesh technical specifications to perform secondary development in Revit, resulting in the design of a secondary curved mesh shell model. Jianhua Cui [42] took the engineering example as the background and used the parametric modeling technology of the platform software CATIA as well as the secondary development of BIM to create solid models of the steel structure nodes and realized the functions of roaming and collision checking.

The classification and three-dimensional construction of multi-professional models of building engineering have been established, improved and expanded, especially the family model database required for building maintenance separation components, structural components, decoration components, equipment and other types of work. The original complicated and rough three-dimensional modeling of construction projects has become more convenient and accurate. At the same time, the connection relationship, collision relationship and use relationship of different types of models in the BIM platform can be more easily coordinated, or easier to test and analyze. The application of BIM model in mechanical analysis has formed a more convenient connection between engineering information modeling and the analysis of usage attributes, which is very conducive to the coordination of related professional jobs. Therefore, the two major application trends of BIM's construction engineering 3D model in the field of construction engineering are as follow: the increasingly rich system and content, as well as the interaction and coordination of three-dimensional data for multiple types of work.

BIM Technology Provides Possibilities for Collaborative Control of The Whole Process of Intelligent Medical Laboratory Construction.

Medical laboratory advancements typically exhibit a high degree of intelligence. Since the 1950s and 1960s, significant advancements in medical technology in certain nations have facilitated the establishment and technological enhancement of medical laboratories [43]. Globally, the planning and building of medical laboratories has progressively evolved into a distinct and highly specialized discipline. Due to the ongoing advancements in computer and Internet technologies, as well as other emerging information technologies, medical laboratories are increasingly adopting intelligent approaches. In certain countries, scientific and technological experts have been at the forefront of advancing the use of information technology in the domain of medical architecture. They have conducted extensive research on intelligent medical laboratories [44]. In other countries, scientific and technological experts have gradually begun exploring this field. The current intelligent medical laboratory is a comprehensive and synergistic laboratory that combines medical research, artificial intelligence, and big data technology. It integrates multiple equipment systems and various experimental operations to provide more efficient and accurate scientific research and technical services for the medical industry, driven by technological exploration. The construction of smart medical laboratories requires the integrated coordination of multiple working modes of the main structure, including buildings, accessory structures, facilities and equipment. This coordination needs to be based on a multi-professional model and includes automated coordination between different types of work. This will enable efficient and accurate information management of the construction project. The construction process of intelligent medical laboratories relies heavily on modern BIM building information technology due to its complex and extensive information management requirements. These requirements include the generation and coordination of multi-professional information models, as well as the virtual analysis, preview, and on-site application of multi-disciplinary models.

The construction of a medical laboratory building encompasses various aspects such as body construction, decoration, and equipment. These aspects are all part of the design, construction, maintenance, and operation process, which requires the implementation of comprehensive and synergistic multi-professional information management technology. The modern medical laboratory is designed to meet the functional requirements of medical treatment, scientific research, teaching, and other aspects. Its construction requires the comprehensive implementation and operation of multi-disciplinary and multi-professional technology to ensure safety, durability, cleanliness, and other necessary factors. The construction process necessitates the use of multi-disciplinary and multi-professional technology. The building process necessitates the involvement of multiple specialized fields and various forms of work to effectively establish a coordinated program involving persons, equipment, materials, and other factors. This ensures the convenient, smooth, and safe completion of the project. The current BIM technology possesses the necessary features to fulfil the requirements of the medical laboratory construction process and its intelligent information management needs. This technology facilitates the refinement and specialization of management in medical laboratory construction, leading to increasing integration of these two applications [45].

Along with the intelligent development of medical laboratories, the construction industry has developed many new materials, new technologies, new equipment, and new technologies, continuously enriching and optimizing the building effect of medical laboratories. These new materials, equipment, and technologies are constantly changing the fundamental information of medical laboratories, and the volume of data is becoming larger and more diverse.

The management of procurement information and project use necessitates the integration of a big data, systematic information management platform in order to accurately and orderly arrange materials, equipment, and processes, as well as timely monitoring and updating of information and data, and accurate three-dimensional visualization of the data, provided for professional analysis and use. Due to the advancement of materials, equipment, and processes, the construction of medical laboratories must rely on the big data information integration and management system of BIM in order to be completed efficiently and precisely. As a result, the medical laboratory building project model type, model combination, model type of subsidiary information, and information analysis function, among others, must be updated and deepened using a BIM information management system.

The current growth of BIM technology in construction project information management has resulted in the integration and use of data from numerous jobs, as well as automation and synergy. These technologies use a three-dimensional model to incorporate data from multiple project-related activities. This produces a comprehensive three-dimensional information model, which is exhibited to the personnel. The model can also be linked to the construction site, enabling remote monitoring and direction of the project's progress [46]. This can change the original operational mode of categorizing task types in the construction of medical laboratories, improving the design and management of construction projects by making them more intuitive, precise, and efficient. BIM technology uses program automatic modeling to simplify repetitive and labor-intensive modeling operations, handle challenges associated to modeling large and diverse structures, and allow model integration with data from other platforms or software. This allows for the effective deployment of BIM technology in the development of intelligent medical laboratories. BIM technology not only increases engineers' knowledge and communication of complicated engineering structures in intelligent medical laboratories, but it also improves project management precision and accuracy, resulting in fewer risks and lower costs.

BIM technology is a three-dimensional digital information technology that combines project design, construction, operation, and maintenance. It has useful features such as visualization and coordination, making it an indispensable tool for the design and operation of intelligent medical laboratories. Currently, BIM technology is used for more than just building component design, including modeling, layout, collision checking, batch drawing, and the design of building enclosure separation components, machinery, and pipelines. It can also be used to track the use of these components, help with their operation and maintenance, and support the complete project management process, such as problem prediction, program development, implementation monitoring, and so on.

In general, the intelligence of medical laboratory construction has the characteristics of complex multi-professional work integrated synergy, and there is a demand for multi-professional automation synergy, and this development needs to be based on modern BIM technology in order to ensure that the project construction is carried out efficiently and accurately, and that there is a smooth and efficient synergy between the various professional work types. Additionally, the current BIM technology can offer a platform for information sharing and exchange for all parties involved in the project's construction, lowering barriers to information sharing and speeding up the flow of information [47]. This has a wide range of potential applications at the level of medical management organizations, hospitals, medical research institutions, and related businesses.4. In conclusion.

Conclusion

At present, the information management of construction projects combined with BIM technology tends to be comprehensive, visual, refined, automated and collaborative, which can be well used in the construction of intelligent medical laboratories with high linkage demand for multiple types of work. BIM technology can solve the problem of complex information management and collaborative interaction, including the whole process of project establishment, design, construction, maintenance and operation of such buildings, and provide a visual three-dimensional support model with high degree of simulation, automation and virtual analysis function deepening. At the same time, it provides an irreplaceable technical foundation as a basis for problem prediction and countermeasure formulation of coordination work and management operation. With the intelligent development of modern medical laboratory construction, this field will become an important application field of new BIM technology.

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Conflict of Interest

No conflict of interest.

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