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RESEARCH ARTICLE

3D Simulation Modeling Technology in Architectural Heritage Conservation Based on Internet of Things Data

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The rapid development of modern science and technology has brought new directions to the development of most industries, and the further development of these different industries has also provided more convenience for people's daily life. The protection of architectural heritage has also undergone great changes due to the integration of various modern information technologies. Architectural heritage mainly refers to some ancient buildings with certain cultural value after years of development. These ancient buildings are not only the crystallization of people's wisdom and ideas in the past era, but also a tangible carrier of social excellent spiritual culture. In addition, the protection of architectural heritage can not only meet the needs of contemporary residents in spirit, but also promote the high-quality development of the local economy. Through the restoration and protection of the architectural heritage and the promotion of the excellent spiritual culture of the ancients contained in the architectural heritage to a certain extent in this process, more people can be attracted to travel, thus promoting the economic development of the region. The high-quality development of technology and economy in contemporary society has led to the rapid improvement of people's quality of life. Therefore, this form of cultural tourism can also better meet the entertainment needs of the contemporary people. At this time, the emergence of the Internet of Things (IoT) technology and 3D modeling technology has brought new ideas to the protection of architectural heritage, and optimized many procedures such as the analysis and repair of ancient buildings in the existing architectural heritage protection mode, thus greatly improving the operational efficiency and capacity of architectural heritage protection. First of all, this paper investigated the current research and development progress and application of IoT and 3D modeling technology, identified some of the technologies that can be applied in the existing architectural heritage protection mode, and accordingly proposed a protection mode of 3D modeling of architectural heritage based on IoT data. Finally, it evaluated the performance of the 3D modeling architectural heritage protection model and the existing architectural heritage protection model in many aspects, and determined that the performance of the new architectural heritage protection model in many aspects has increased by about 37% on average.

1. Introduction

Historic buildings often have extremely important cultural and historical research values, but this invisible asset has not been given due attention in a long period of time. At the same time, with the continuous change of time, although part of the architectural heritage has become a

protection unit and has been handed down, more architectural heritage has not been given due attention and has been demolished in the historical change. This paper studies the existing architectural heritage protection model through a variety of modern information technologies, and proposes a new model.

Relevant researchers have studied the development and current situation of architectural heritage, hoping to determine the current development trend of architectural heritage through these studies. Vandesande Aziliz explored the role of planned preventive protection as a new management method of architectural heritage, explored the role of this model in the field of architectural heritage, determined its main operation process, and verified the feasibility and reliability of the application of this model in the field of architectural heritage (Vandesande, 2018). Zhao Chen explored the latest research progress of the repair materials and repair instruments of the architectural heritage, and determined that the latest repair materials and repair instruments of the architectural heritage can play a better role in the protection of the architectural heritage through the role of the repair materials and instruments of the architectural heritage in the protection plan of the existing architectural heritage (Zhao, 2019). Mishra Partha Sarathi explored the classification method of architectural heritage. Through in-depth research on the characteristics of architectural heritage in many aspects, and with the help of multi-class data analysis methods, a classification model of architectural heritage was proposed, and the role of this model in the classification of architectural heritage was verified (Mishra, Soumi, 2022).

Mansuri Lukman E explored the application of architectural information model and digital technology in the protection of architectural heritage. Through in-depth analysis of these two technologies, it was determined that these two technologies can be better applied in the protection of architectural heritage (Mansuri, 2022). Son Le Minh explored the balance between the protection of architectural heritage and urban development in a certain region in a specific period. Through the analysis of a large number of relevant architectural heritage data, it was determined that the current protection mode of architectural heritage can promote urban development to a certain extent (Son, Linh, 2019). Al-Sakkaf Abobakr explored a sustainable method for evaluating the value of architectural heritage and verified the reliability of this method through experiments (Al-Sakkaf et al., 2020). Olga Pastukh explored the universality of the repair methods of architectural heritage with different styles in different regions. Through the study of the historical development and cultural spirit inherited from two specific regions, it was determined that the repair methods of architectural heritage in different regions have strong universality (Olga et al., 2020). Most of these studies have carried out comprehensive analysis on the development of various types of architectural heritage, and have not combined the development background of the region where the architectural heritage is located to study the architectural heritage.

In addition, some researchers have studied the role of architectural heritage in the current society and the protection plan, hoping to get a better protection plan for architectural heritage. Borri Antonio explored the protection scheme and safety issues of architectural heritage. Through the exploration of various natural disasters, he determined that there were many deficiencies in the current architectural heritage protection scheme, and put forward some parts that need to be improved (Borri, Marco, 2019). Banfi Fabrizio explored the application of augmented reality and information model technology in the current field of architectural heritage, determined the role of augmented reality and information model technology in the field of architectural heritage through the analysis of the basic work in the current field of architectural heritage, and proposed a working model of architectural heritage based on augmented reality and information model (Banfi et al., 2019).

Bertolini Cesari Clara explored the protection scheme of a wooden structure roof of a regional architectural heritage. Through the study of the repair mode of wooden structure in the architectural heritage protection mode, a protection mode that can play a better role in the repair of wooden structure architectural heritage was determined (Bertolini, Tanja, 2018). Della Torre

Stefano explored the preventive protection technology of architectural heritage in a certain region, and confirmed the feasibility of the preventive protection mode of architectural heritage through the investigation of the views of many local residents on the preventive protection mode of architectural heritage (Della, 2021). Mazzetto Silvia explored the role of the existing heritage restoration model in the building repair in a specific area, and determined the reliability of the repair method of the existing architectural heritage through the study of the environment and other relevant influencing factors in the area (Mazzetto, 2018). However, these researchers' research on the role and protection mode of architectural heritage is too fragmented, and still cannot support the establishment of a more complete protection mode.

With the continuous progress of time and technology, the capabilities of the existing architectural heritage protection model can no longer meet the needs of the development of the times. Especially in the process of scanning, analyzing and repairing the architectural heritage, the efficiency of the existing model is too low. This article is to update and iterate several functions in the existing architectural heritage protection mode through IoT and 3D modeling technology. This upgrade is mainly to use the multiple intelligent sensors in IoT to carry out 3D modeling of architectural heritage, so as to better complete the repair work of architectural heritage.

2. Evaluation of Architectural Heritage Protection Mode

2.1 Evaluation of Architectural Heritage

In recent years, with the rapid improvement of residents' material living standards, people began to pay more attention to cultural and architecture-related heritage and other things with more cultural value, which also shows that people began to pursue spiritual satisfaction. The architectural heritage is fundamentally different from other cultural relics or old buildings. Generally speaking, historical buildings with certain comprehensive cultural value are required to be recognized as architectural heritage. Secondly, these architectural heritages located in different urban or rural areas have also witnessed the historical development of the region for a long time, and also agglomerated some people's search for the past years. They are generally used as the carrier of historical development information. In addition, although the architectural heritage is owned by individuals according to the policies and regulations of different regions, in terms of the cultural value contained in the architectural heritage alone, this architectural heritage is also related to people's overall social interests. At the same time, architectural heritage can be divided into several categories according to the different values it contains. First of all, there are some buildings that can show the scientific and technological level of the construction era of architectural heritage or have academic research value. These buildings are mainly architectural heritages with high architectural requirements in different regions and too long construction time. These architectural heritages represent a level of architectural technology in the era of building heritage. Then there are architectural heritages with certain political or economic and historical significance. Such architectural heritages are generally of great significance at the time of their completion. Finally, there are architectural heritages with high artistic value, which can generally play a higher role in the study of some artistic expressions in the history of the current era. The general analysis process of architectural heritage is shown in Figure 1.
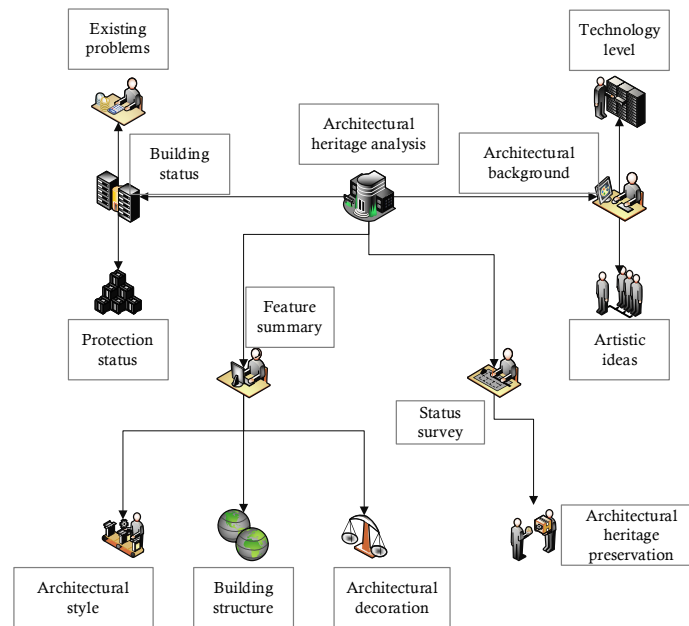
Figure 1. Schematic diagram of the analysis process of architectural heritage
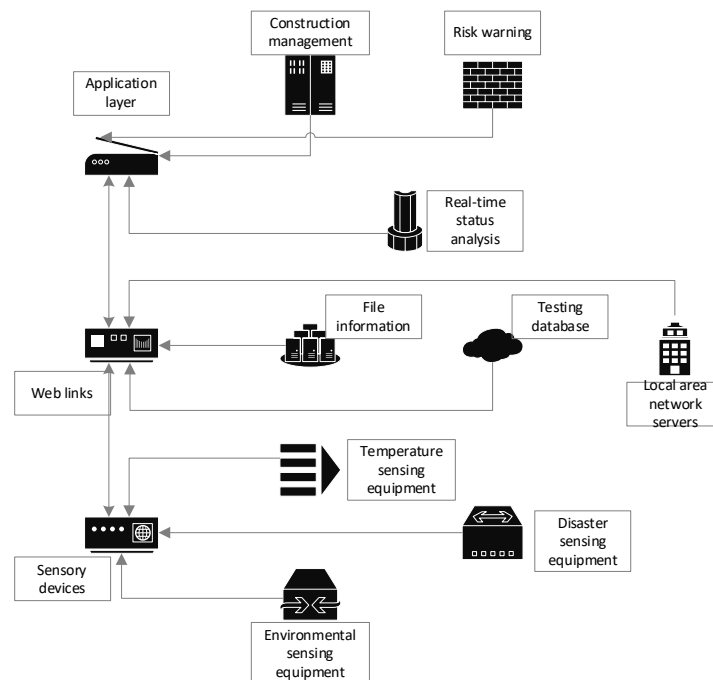
2.2 Evaluation of Architectural Heritage Protection

In recent years, people's increasing attention to architectural heritage has also promoted the further development of the protection model of architectural heritage to a certain extent. If people want to get a modern architectural heritage protection model, people need to carry out in-depth research on architectural heritage first. The first step is to study and analyze the status of architectural heritage and its environment, generally including on-site exploration, environmental mapping, relevant document retrieval and historical and cultural research. Then, it is necessary to study the relationship between the construction scheme of architectural heritage and the characteristics of architectural heritage during the period from the initial construction of architectural heritage to the current era. The next step is to explore the protection mode of architectural heritage. The protection of modern architectural heritage can generally be divided into two types: protection in a broad sense and protection in a narrow sense. First, the protection of architectural heritage in a broad sense generally refers to the maintenance of architectural heritage on the basis of ensuring the authenticity of architectural heritage. On the other hand, the protection of architectural heritage in a narrow sense refers to the minimum degree of protection, that is, the protection only to maintain the architectural heritage from more damage. This paper is mainly to provide more ideas and development directions for the existing architectural heritage protection mode through IoT and 3D modeling technology. This new architectural heritage protection mode incorporates the protection scheme in the broad and narrow sense, and provides a better role for the development of architectural heritage.

3. IoT and 3D Modeling Technology Evaluation

3.1 IoT Technical Evaluation

In the context of the rapid development of many technologies, the emergence of IoT technology can be said to bring new hope for the further development of many information technologies (Ray, 2018). IoT can generally design and manufacture a variety of intelligent information sensing devices, use wireless networks, radio frequency and related technologies and equipment to complete the monitoring of data information in different scenarios, and link various physical objects to collect their different characteristics (Villamil et al., 2020). This behavior of linking different physical objects and collecting their characteristic data can provide new ideas for the management model of entities in the current society. The first is to complete the analysis of the

damage situation and risk factors of the architectural heritage through IoT technology. The architectural heritage is generally faced with risks in terms of the material and structure of the body and the environment. The first step is to complete the information collection of the structure, materials, building components and other related building heritage ontology materials of the building heritage with the help of multiple types of intelligent sensor equipment in IoT technology. On the other hand, IoT technology is used to conduct real-time analysis of the risk factors that can cause damage to the architectural heritage ontology in the environment where the architectural heritage is located. This process generally requires the use of the three layers of IoT technology, namely the application layer, the network layer and the information perception layer, to complete the collection and analysis of data in the environment. Therefore, it can be said that the construction heritage protection mode under IoT mainly realizes a dynamic data analysis and risk assessment mode, which can give early warning to the construction heritage before it may be damaged. The structure of IoT technology applied in architectural heritage is shown in Figure 2.
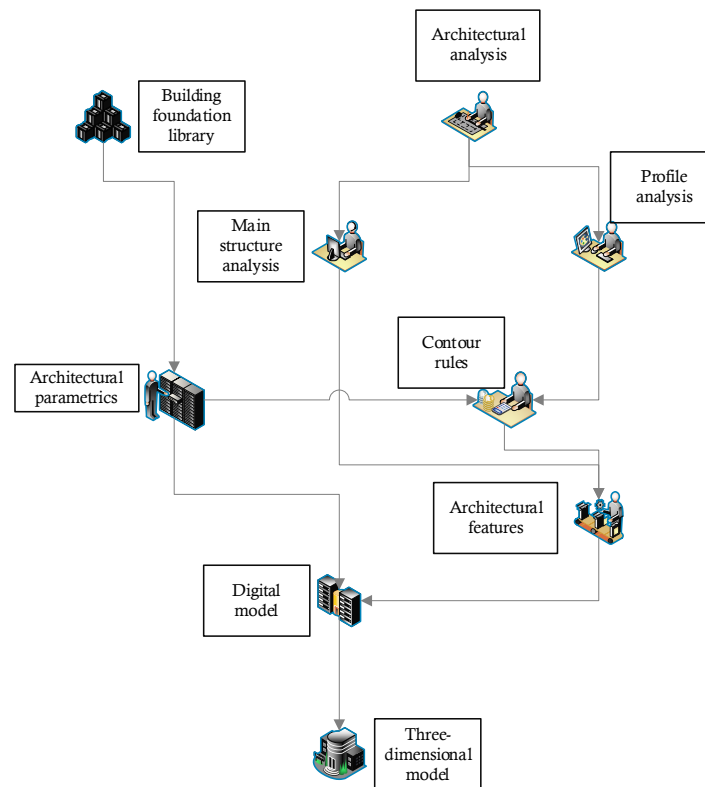

Figure 2. Schematic diagram of the application structure of IoT technology in architectural heritage conservation model

3.2 Evaluation of 3D Modeling Technology

3D modeling technology is a technology that has just emerged recently. This technology can complete the recording and analysis of multiple data of the target object through relevant software, complete the digital modeling of the target object based on the analysis results of these data, and simulate the target entity in a certain proportion in the virtual world (Remondino, 2011). Generally speaking, the establishment of a 3D model cannot be separated from many links, such as environmental mapping, model component technology, resource collection and sharing, model modification, etc. These links can also be combined with relevant technologies to make the final virtual model have higher accuracy. This paper mainly uses IoT technology and 3D modeling to upgrade the existing protection mode of architectural heritage. The first is to use IoT technology to complete the dynamic analysis of the environment where the architectural heritage is located. Then the data of the environmental mapping is analyzed by the relevant operation model in IoT technology to complete the digital transformation of the architectural heritage. 3D modeling technology is used to complete the imitation of architectural heritage in the virtual world based on relevant architectural heritage data. In the process of imitation, the structural parameters of the architectural heritage should be taken into account, and some architectural culture in the initial construction period should be referred to to ensure the authenticity of the

architectural heritage. The last step is to rely on the 3D model of the architectural heritage to complete the repair of the architectural heritage. The application of 3D modeling technology in the protection mode of architectural heritage is shown in Figure 3.

Figure 3. Schematic diagram of the application of three-dimensional modeling technology in architectural heritage conservation model

4. IoT Algorithm Evaluation

In the current era, the development of aesthetics and architectural concepts in architectural technology mostly comes from the in-depth analysis of traditional architecture, and with the continuous development of various technologies, the aesthetic sense of architecture in the current era also presents a variety of forms. Through the analysis of the traditional architecture structure and art form, people can extract the essence from it and combine it with the contemporary architecture model. At the same time, people can also greatly improve the artistic atmosphere of the architectural theory of the current era, and improve the overall beauty of modern architecture. Therefore, the protection of architectural heritage is not only the respect for historical culture, but also the continuous power for the development of modern architectural engineering. However, the current protection mode of architectural heritage can not meet the needs of the society because of the development of information technology. Therefore, this paper mainly analyzes the protection mode of architectural heritage, and studies some work processes that can be optimized. At the same time, IoT, 3D modeling technology and some related algorithm models are combined to simplify or replace multiple processes in the architectural heritage protection mode. For example, the preventive protection mode of architectural heritage is constructed through logical regression algorithm. In the process of optimization, this paper mainly uses k-means algorithm and logical regression algorithm, and then introduces the operation flow of these two algorithms.

The first is to use the logical regression algorithm to establish the preventive protection model of the architectural heritage. This model can determine the factors that would cause damage to the

architectural heritage through the analysis of multiple types of data. The main calculation formula of the algorithm is shown in Formula (1).

$$f(x) = \frac{1}{1+e^{-a_w x}} \quad (1)$$

Among them, a_w mainly represents the weight vector, and x represents the input vector. After that, the main prediction function is constructed, and its formula is shown in Formula (2).

$$f(x) = \frac{x}{1+e^{a_w}} \quad (2)$$

Then, the loss in the whole calculation process is calculated. The calculation formula is mainly derived based on the maximum similarity estimation. The formula is shown in Formula (3).

$$f(\theta) = \frac{1}{m}\sum_{i=1}^{n}(1-y_i)\log(1-f(x_i)) \quad (3)$$

Among them, m mainly represents the number of sample data; n represents the number of sample features; y_i mainly represents the probability of occurrence. Then, the likelihood function is used for operation, and its formula is shown in Formula (4).

$$L(\theta) = \sum_{i=1}^{n}(1-f(x_i))^{1-y_i} \quad (4)$$

Then, the gradient descent operation mode is used to solve the minimum value in the operation process, and the optimal solution of parameter θ is calculated. The formula is shown in Formula (5).

$$J(\theta) = \frac{1}{m}(f(x_i)-y_i) \quad (5)$$

On the other hand, k-means algorithm is used to optimize the process of repairing or establishing the optimal solution of the model. The first is to introduce its calculation formula, as shown in Formula (6).

$$K = \frac{1}{2}\sum_{i=1}^{n}\sum_{j=1}^{m}(x_i-u_j)^2 \quad (6)$$

Among them, u_j represents the category of data, and n and m represent the number of samples or sample types respectively. Finally, the partial derivative of the function of the operation mode is solved. The formula is shown in Formula (7).

$$u_j = \frac{1}{n}\sum_{i=1}^{m}x_i \quad (7)$$

This paper updates the existing conservation mode of architectural heritage through the two IoT-related algorithm models of k-means algorithm and logical regression algorithm, providing a more systematic scheme for the preventive conservation mode. In this mode, the surrounding environment data of the architectural heritage is collected through a variety of intelligent IoT sensor devices. On the other hand, the model is trained by using relevant algorithms to finally get a model that can automatically run analysis and calculation. This model can make the protection of architectural heritage have better performance and effectively improve the working efficiency of the protection model of architectural heritage.

5. Experimental Evaluation on the Protection Mode of Three-dimensional Modeling of New Architectural Heritage

With the further improvement of the material living standards of residents in all regions, residents in all regions began to pay attention to spiritual satisfaction and pursuit, which can often be initially satisfied by exploring and studying history. Therefore, the current era has given full attention to the protection of architectural heritage and various cultural heritage, and this attention has also made the existing architectural heritage protection mode gradually unable to meet the spiritual pursuit of contemporary residents. Therefore, in the protection of architectural heritage, there is an urgent need for a new model of protection and repair to achieve better

protection and repair. On the other hand, in the field of protection of architectural heritage in the current era, various protection theories generally believe that in the process of historical development, each state is a witness of history, and this guarantee of the authenticity of this state can leave a perfect historical and cultural memory in the process of development. The complete retention of this historical and cultural memory also facilitates future generations to fully understand the complete and true historical information to a certain extent. In the current era, relevant researchers have determined that the value and attributes of architectural heritage in the current era are multi-dimensional through in-depth analysis and research on architectural heritage. In addition, research and update on the protection of architectural heritage can also make the society obtain better development. This paper investigates the degree of concern about the architectural heritage in a certain area, and the development of IoT and 3D modeling technology, and determines the development direction and potential of the protection mode of the architectural heritage in the future.

The first step is to analyze the degree of concern for architectural heritage and the protection of architectural heritage in a certain area for a period of time, as shown in Figure 4.

a. Diagram of the level of concern for architectural heritage

b. Diagram of the development of architectural heritage conservation

Figure 4. Schematic diagram of the development of architectural heritage concern and conservation in a region over a period of time

With the rapid change of time, architectural heritage and all kinds of historical and cultural heritage have received more and more attention. This change is not only because the architectural heritage bears the national identity and cultural confidence of a region, but also because the architectural heritage is the concentration of the scientific level and artistic concept of each historical stage. On the other hand, the rapid increase in the degree of attention has also promoted the importance of the protection of the architectural heritage of the relevant units to increase gradually. However, due to its relatively low work efficiency and cumbersome work flow, the current protection mode of the architectural heritage urgently needs a new protection mode to make the architectural heritage better protected.

Through the analysis of the changes in the degree of concern of the residents of the region over the past four years in Figure 4a, it can be determined that the residents of the region have paid more attention to the relevant architectural heritage in the past four years. One of the reasons is the need for social development, and the other is the gradual improvement of residents' material

living standards, which makes residents not satisfied with material satisfaction and start to pursue spiritual satisfaction.

On the other hand, it analyzes the protection of the architectural heritage in this area in Figure 4b, and determines that the degree of protection of the architectural heritage is getting higher and higher with the development of time. However, after analyzing the development situation, it can be seen that the growth rate of the protection of architectural heritage in the past four years is relatively slow, which further indicates that the current protection mode of architectural heritage needs further optimization.

The second step is to analyze the development and application of IoT technology and 3D modeling technology in the same period in the region, as shown in Figure 5.
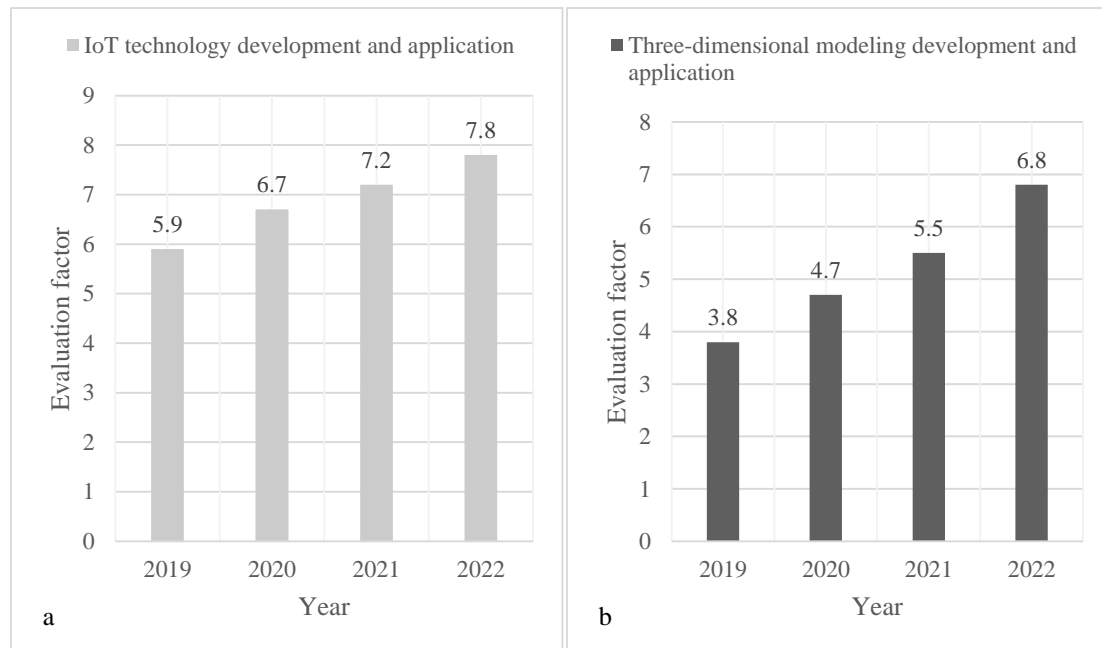
a. Diagram of IoT technology development and application

b. Diagram of three-dimensional modeling technology development and application

Figure 5. Schematic diagram of the development and application of IoT and three-dimensional modeling technologies in the region over a period of time

In the context of the rapid development of various information technologies, the emergence of IoT technology has had a great impact on the development and working mode of various traditional industries. At the same time, this technology has also promoted the emergence of a variety of new technologies and played a positive role in the high-quality development of social economy. At the same time, as people pay more attention to architectural heritage, relevant researchers began to try to integrate IoT technology into the protection model of architectural heritage. On the other hand, the emergence of 3D modeling has also brought new hope to the researchers of the protection mode of architectural heritage. The scanning of architectural heritage is completed through the multi-type intelligent sensors in IoT technology. At the same time, 3D modeling is used to model the architectural heritage, which can further improve the performance of the protection mode of architectural heritage.

Through the analysis of the development and application of IoT technology in the region in the past four years in Figure 5a, it can be determined that IoT technology has been fully developed in the past four years, and this rapid development has brought a positive impact on all walks of life. However, the development and application of IoT technology has been relatively slow in the past four years, which also indicates that IoT technology needs to explore more application fields. In addition, through the analysis of the development and application of 3D modeling in Figure 5b, it can be determined that the 3D modeling technology started relatively late, but its development

and application grew rapidly. The growth rate of research, development and application of 3D modeling technology reached the highest from 2021 to 2022, which also shows that 3D modeling technology would have good development potential for a long time in the future.

Finally, the performance of the new architectural heritage protection model and the existing architectural heritage protection model based on IoT and 3D modeling technology in multiple evaluation indicators is analyzed, as shown in Figure 6.
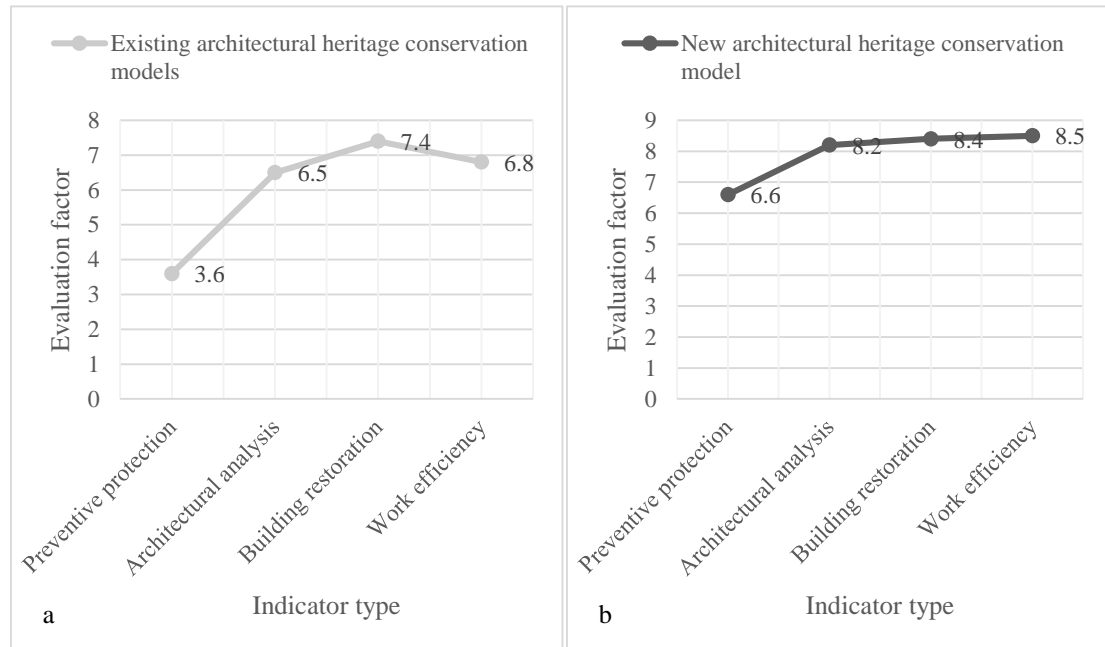
a. Schematic representation of the performance of existing architectural heritage conservation models

b. Schematic diagram of the performance of the new architectural heritage conservation model

Figure 6. Schematic diagram of the performance of the existing architectural heritage conservation model and the new architectural heritage conservation model

At present, people pay more attention to the architectural heritage, which also greatly improved the performance requirements for the protection mode of architectural heritage. At present, the main purpose of architectural heritage protection is to protect the historical information and related culture contained in the architectural heritage, so this also requires that the authenticity and integrity of the architectural heritage should not be damaged in the protection mode of architectural heritage. This requirement has brought IoT technology and 3D modeling technology into the vision of relevant researchers. These two emerging technologies can better complete the analysis and processing of historical data, and establish 3D models of architectural heritage to better complete the protection of architectural heritage.

The first is to analyze the performance of the existing protection model of architectural heritage in Figure 6a in four aspects: preventive protection, analysis of architectural historical data, repair effect of architectural heritage and the overall work efficiency of the model, and determine that the existing protection model of architectural heritage is relatively weak in preventive protection. On the other hand, it analyzes the performance of the new architectural heritage protection model proposed in Figure 6b in combination with IoT and 3D modeling technology on four same evaluation indicators, and determines that the performance of the new architectural heritage protection model in four aspects has improved to a certain extent. This also shows the reliability of the application of IoT, 3D modeling technology and logical regression in the protection mode of architectural heritage, and provides more development ideas for the protection mode of architectural heritage. Finally, after analyzing the performance data of the two models in Figure 6, it can be seen that the performance of the new architectural heritage protection model in many

aspects has increased by about 37% on average compared with the existing architectural heritage protection model.

6. Conclusions

Architectural heritage is not only the physical expression of history and culture, but also the continuation of a national culture. At the same time, architectural heritage also reflects the technological and artistic level of an era, so it can be said that the protection of architectural heritage is also the protection of history. In the current society, architectural heritage is an emerging field that integrates humanities, sociology and engineering science, and its comprehensiveness and discipline span are very wide. From an academic point of view, the current academic field has a very close relationship between the research of architectural heritage and the research of architectural history, but each has a different focus. The study of architectural history mainly focuses on the evolution of architecture in a time cycle, and also analyzes its role in history. Architectural heritage is more about the value of the space where the building is located and the way of its continuation. This research also includes the practice of the protection of architectural heritage. Therefore, although there are great differences in their development directions, they can complement each other and develop together. On the other hand, with the gradual deepening of the research on architectural heritage, the relevant staff have also accumulated a lot of experience in the protection and repair of architectural heritage. However, this protection and repair model cannot be upgraded based on the cognitive theory, protection methods and some existing technical means with high adaptability of architectural heritage in the current era. Therefore, it still needs to spend more time and other resources to update and iterate the existing architectural heritage protection model, so as to better protect the architectural heritage. This paper optimized the existing architectural heritage protection mode through IoT and 3D modeling technology, and verified the performance of this optimized new architectural heritage protection mode in all aspects.

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