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Computer-Aided Design AND APPLICATIONS

Application of Graph Neural Network in Matching Intangible Cultural Heritage Models with Virtual Reality Scenes

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Abstract. This study aims to address the matching challenge between the computer-aided design (CAD) model (ICH) and the virtual reality (VR) scene, ultimately enhancing the digital preservation and presentation of ICH. We introduce an innovative matching approach leveraging the graph neural network (GNN) to accomplish this. Initially, by constructing a GNN model, we capture the spatial structure and relationships within the CAD model, extracting crucial features. Subsequently, these extracted features facilitate matching with corresponding elements in the VR environment. Our findings reveal that GNN exhibits significant advantages in aligning the CAD model of ICH with the VR scene, thereby effectively boosting the digital conservation and showcase of ICH. Experimental outcomes confirm the superiority of the GNN-based matching technique in this context. This study offers a novel technological approach for digital safeguarding and exhibition of ICH, which has substantial practical and application value.

Keywords: Intangible Cultural Heritage; CAD Model; Virtual Reality; Graph Neural Network; Feature Matching
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1 INTRODUCTION

Amidst the swift progression of science and technology, VR technology finds increasingly broader applications in cultural preservation, exhibition, and safeguarding. Timely feedback and practical guidance are equally crucial in the inheritance and innovation process (ICH). Alique and Linares [1] applied this concept to the graphic expression course. They analyzed the benefits of introducing meaningful and timely feedback when using AutoCAD for laboratory practice in intangible cultural heritage graphic expression courses. In the course, CAD technology not only helps students better understand and analyze traditional patterns, structures, and design elements but also promotes their ability to apply these elements in innovative design. Through this timely feedback mechanism, students can not only gain a deeper understanding of the creative essence of traditional art but also quickly grasp the protection and innovation. Intangible cultural heritage (ICH) plays an important role in China's traditional culture. ICH is the core of national culture and the essence of national culture. At present, most shot boundary detection methods often rely on artificially designed complex features and similarity measurement methods, and algorithms often have high time and space complexity, occupying a lot of computing resources. Therefore, as a medium, it holds an irreplaceable position in inheritance, dissemination, and protection. As a medium of communication, video has its unique advantages, covering both visual and auditory aspects, and being easy to produce and store. Banfi [2] designed a shot boundary detection model for intangible cultural heritage videos based on three-dimensional convolutional neural networks. However, 2D networks can only capture spatial features when processing videos, and cannot effectively capture temporal information. By calculating the inter-frame difference, it is possible to effectively discard non-shot boundary frames that have not undergone significant changes. In video processing, inter-frame difference is a commonly used feature used to detect changes between video frames. Traditional video analysis methods are often based on 2D convolutional neural networks. 3D convolutional neural networks greatly reduce the computational complexity of subsequent processing by adding convolutional kernels in the time dimension. Being able to capture both spatial and temporal features simultaneously is particularly crucial for identifying subtle changes in camera boundaries. This technology can help researchers, protectors, and the public to deeply understand the rich connotations and diverse values in a single cohesive interface. Considering the urgent necessity for effective preservation and promotion of ICH, an essential aspect of human civilization, through cutting-edge technology, this study focuses on GNN. GNN, as a robust deep learning instrument, excels in profoundly comprehending the spatial frameworks and connections inherent in intricate datasets, making them invaluable in aligning the CAD models of ICH with VR environments. The aim of this endeavor is to investigate the efficient utilization of GNN in this domain, thereby facilitating the precise and efficient continuation of ICH [3].

Its solution not only fully considers the needs and expectations of users but also combines the unique charm and cultural connotation of Yi's intangible cultural heritage so that the product not only meets technical requirements but also has high cultural value and market competitiveness. TRIZ theory provides a complete set of tools and methods for problem-solving, including contradiction matrix tables. By querying the contradiction matrix table, we have found reasonable solutions and innovative ideas to resolve these conflicts. By comparing the feasibility, innovation, and practicality of different schemes, the most suitable creative product design scheme for Yi's intangible cultural heritage was ultimately determined [4].

This virtual display model is based on advanced computer graphics technology and controls the basic form of the model through up to eight key feature points [5]. In the process of constructing a virtual model, it first calculates the feature point coordinates of seamless weft knitted knee pads in a planar state, which represent the basic shape and structure of the knee pads. After obtaining all the necessary data, it utilized pipeline geometry drawing technology to construct a virtual display model of seamless knee pads, a traditional handicraft, but also to enable more people to appreciate this precious intangible cultural heritage. Cultural heritage is not only a witness to the past but also a bridge connecting history and the future, inheriting wisdom and art. The preservation status of the paintings inside the church, especially those in the advanced stage of degradation, is worrying. Demenchuk et al. [6] uncovered the internal mysteries of these paintings, namely the true composition of the colours and materials used. We have unprecedented opportunities to enhance the protection of cultural relics by obtaining detailed data. In the city of Oradea, Romania, an ancient wooden church is known for its rich artistic value and historical significance. Therefore, ensuring that these priceless treasures are preserved in a suitable environment is a crucial task for future generations. These data not only reveal the chemical elements of pigments and materials used in painting but also provide important clues about how they change over time.

Digital reconstruction technology not only provides researchers with a rich asset database to study new associations and discoveries but also provides the public with a brand-new interactive experience. This visualization approach allows for diverse interpretations and exploration of methods, promoting broader understanding and dissemination. Even participate in the practice, such as simulating traditional handicraft production processes or participating in interactive performance arts. Digital reconstruction provides an asset database for researchers and multiple members of the public, which can be used to study new associations 7 and experiment with innovative public outreach methods [7]. The field of three-dimensional digital sculpture art is facing unprecedented development opportunities. In the digital sculpture art of material cultural heritage, a key technology is three-dimensional measurement technology. In practical applications, through the verification of specific cases, we can find that computer sculpture modelling methods not only have high accuracy and repeatability. Especially based on the non-contact depth of field 3D measurement methods, it can restore 3D shapes (defocus depth) from focused images, providing the possibility for precise modelling of digital sculptures. In the production process of cultural heritage digital sculpture art, the selection of modelling steps and evaluation methods is particularly important. The advantage of this method is that it does not require additional hardware costs and can be achieved solely through software processing. Through reasonable wiring design and modelling steps, the form, structure, and details of the sculpture can be accurately presented [8]. Currently, research on GNN is escalating, and its implementation in areas like image recognition and natural language processing has yielded impressive outcomes. Nonetheless, its utilization in aligning ICH CAD models with VR scenes remains unprecedented.

Despite some research touching on VR technology's application in ICH perpetuation, the majority remain rooted in conventional image processing and computer vision techniques. However, with the steady progression of GNN technology, its proficiency in handling intricate spatial configurations and relationships is increasingly evident, paving the way for new avenues in the digital preservation and perpetuation of ICH.

Our study extends beyond mere technical advancements, striving to apply these findings across diverse fields like cultural heritage preservation and VR gaming, thereby widening the technological reach.

The article is structured as follows: The introductory section outlines the research context, relevance, current state, and aims. Next, we delve into the fundamentals of GNN and ICH CAD models. Following this, we explore VR environments and feature alignment techniques. The fourth segment details our GNN-based matching approach. Subsequently, we showcase experimental outcomes and insights. We conclude with a summary and future outlook.

2 RELATED WORK

As a treasure of traditional Chinese culture, the script Beijing Opera contains rich connotations and numerous unique elements related to Beijing Opera art. In order to make up for this deficiency in Beijing Opera scripts, Hou and Zhang [9] designed and implemented a Beijing Opera script visualization system based on HTML5 and related technologies. This module graphically shows the overall structure and main plot of the script. Users can quickly locate the scripts they are interested in by browsing the list and then gaining a deeper understanding of their background, content, and characteristics. This module generates unique "script fingerprints" by extracting key elements and features from the script. Through the overview diagram, users can intuitively see the ups and downs, climaxes, and complex relationships between various characters in the script, providing powerful visual assistance for understanding the content of the script. Indrie et al. [10] successfully applied 3D technology to the design and production of clothing for intangible cultural heritage. It explores how to apply 3D technology to the design and production of clothing. Through official and internal standards, they have determined the material properties that must be accurately measured through 3D simulation for these fabrics. The application of these automation technologies enables designers and craftsmen to have a more intuitive understanding of the final effect of clothing, thereby improving design efficiency. Consumers can intuitively feel the charm and value of traditional clothing by viewing 3D models, making it easier to make purchasing decisions. 3D simulation models can not only help designers and craftsmen preview effects but also serve as a tool for communicating with consumers. With the assistance of computer technology, designers can innovate and develop traditional handicrafts to better meet the aesthetic needs of modern consumers. They can quickly try different design solutions on the computer and immediately see the results, thus finding the best solution faster. This intuitive communication method helps to improve consumer satisfaction and loyalty. This fusion of traditional and modern design concepts not only helps to inherit and develop traditional handicrafts but also opens up new market opportunities for them.

The research of Liu et al. [11] provided us with profound insights into the unique style and complex structure of Qin Opera costumes. Secondly, 3D virtual visualization technology also provides infinite possibilities for the innovative design of Qin Opera costumes. The application of this technology not only realizes the comprehensive and in-depth digital protection of Qin Opera costumes but also opens a new way for the innovative design of Qin Opera costumes. He carefully analyzed the colour matching and pattern design of Qin Opera costumes. These elements are not only an important part of Qin Opera art, but also a treasure of Chinese traditional culture. Through 3D virtual visualization technology, we can accurately capture and record all details of Qin Opera costumes. So as to create a Qin Opera costume that conforms to modern aesthetics and retains traditional charm. Through the virtual restoration of many sets of traditional Qin Opera costumes, they successfully presented these ancient costumes to the world in a digital form. These elements not only carry the essence of Qin Opera art but also are an important part of Chinese traditional culture. Sweater pattern design not only plays a crucial role in actual production, affecting product quality and customer satisfaction, but it is also an important embodiment of handicraft art in intangible cultural heritage. Lu et al. [12] proposed two new sweater pattern design algorithms: synchronous filling algorithm and asynchronous filling algorithm, to address the issues of complex technical calculations and long design cycles in traditional sweater pattern design processes. They conducted in-depth research on the technological characteristics and traditional pattern design principles of sweaters, and based on these characteristics, we established a data structure for sweater specifications and styles. In the process of algorithm implementation, fully considers the fusion of traditional cultural elements and the diversity of patterns to ensure that the designed sweater patterns not only conform to modern aesthetics but also carry the essence of traditional culture.

In order to better explore the network structure evolution of team collaboration in the protection and inheritance process [13]. Based on the unique projects and the actual needs of team collaboration, tasks are classified and refined into areas closely related to cultural heritage protection, inheritance, and development. In this model, multiple dimensions such as collaboration frequency, collaboration intensity, and collaboration content among team members are considered to comprehensively reflect the complexity and dynamics of team collaboration. In order to more intuitively display the characteristics and evolutionary patterns of team collaboration relationships, we have designed a specialized visual view. Through the visualization and in-depth analysis of case data, they revealed the important role of team collaboration. Under the wave of new technologies, digital material architecture and digital display undoubtedly bring enormous potential to the development of cultural tourism. Through digital means, Radosavljevi and Ljubisavljevi [14] present the stories to the public in a more vivid and interesting way. In recent years, more and more museums and cultural institutions have begun to engage in the digitalization process of material and intangible heritage, aiming to provide innovative ways for more people to access, understand, and appreciate this precious cultural heritage. By incorporating elements into game design, players can understand and learn the stories and knowledge behind this cultural heritage during the game. Especially young people, often lack a deep understanding of history and culture, but this does not mean they are not interested in cultural heritage. As a digital advocate, I firmly believe that the appropriate combination and integration of new digital tools and technologies into cultural marketing strategies is key to enhancing public interest in cultural heritage. With the assistance of augmented reality, tourists can interact with digital cultural heritage in the real world and gain a more immersive experience.

The digitization of traditional Chinese opera clothing patterns and the generation of new styles are of great significance. However, the existing digital technology forms are monotonous, and manual design is difficult and inefficient. Saleh et al. [15] used convolutional neural networks to integrate traditional culture with digital technology and innovate the styles of traditional clothing. It proposes to obtain images with varying degrees of stylization by adjusting the content loss function and style loss function. And optimize the selection of convolutional network framework and corresponding feature layer selection. Most existing style transfer algorithms are based on Western oil painting style transfer. The excessive abstraction of texture is not suitable for the expression of Chinese cultural elements such as opera. The transferable style features are single, and the jitter generated by frame-by-frame video artistic output affects the output effect. Solved the problem of single-style transmission, achieved the artistic transfer of multiple styles, and designed a new loss function to obtain a new style feature to enrich the expression of traditional culture. Expand the perspective to the protection and dissemination (ICH), and summarize and reflect on the challenges faced in carrying out collective memory projects representing the rise and fall of empires. Schuster and Grainger [16] emphasized how digital cultural heritage initiatives can stimulate public interest in digitizing and archiving RUSI collections, including intangible cultural heritage elements. After reviewing RUSI and its museum collections, they further discussed the value of establishing partnerships between the academic community and institutions for the protection. This kind of partnership not only helps to protect and inherit this valuable cultural heritage but also promotes interdisciplinary research and innovation. These projects aim to encourage students to participate in the recording, protection, and dissemination.

In order to promote the production efficiency of traditional intangible cultural heritage (ICH), while integrating modern aesthetic concepts, and creating ICH cultural creative products that not only carry traditional charm but also conform to modern aesthetics, Tiancheng and Tieyi [17] combine traditional ICH manufacturing technology with modern advanced processing technology, particularly focusing on the design innovation of Wuhu iron painting, a traditional craft. Wuhu Iron Painting is not only a unique form of arts and crafts in the Anhui region but also a treasure of traditional Chinese culture. Taking the design of official document creation products as an example, it demonstrates how to apply modern processing technology to innovative products. This innovation not only improves the production efficiency of the product but also makes it more modern and aesthetically pleasing, thus attracting the attention of more young consumers. By improving and innovating the cutting and processing technology of iron painting, they successfully integrated the design theme into their iron painting works, achieving a perfect combination of craftsmanship and art. In image processing, grayscale processing is a common operation that converts colour images into grayscale images to simplify the processing process. Due to the loss of colour information in the image during grayscale processing, video detection becomes inaccurate in recognizing colour features. The lens is the smallest semantic unit in a video, which includes the continuity and completeness of the video content. Especially in scenes where colour information is crucial for detection, such as traffic monitoring, medical image analysis, etc., the application of grayscale processing can greatly reduce the accuracy of detection. Therefore, the accuracy of shot boundary detection directly determines the performance of video retrieval. If the camera boundary detection is not accurate, the results of video retrieval will deviate and cannot meet the needs of users. Given the importance of shot boundary detection, we can develop more accurate shot boundary detection algorithms to improve the performance of video retrieval. Although grayscale processing can simplify the processing process, in some scenes that require colour information, we can consider using colour image processing techniques to improve detection accuracy. This includes methods such as utilizing multiple features for fusion and introducing contextual information [18].

3 METHODOLOGY

Aiming at the task of matching the ICH CAD model with the VR scene, this article designs a GNN model. This model can deeply deal with the complicated spatial structure and relationship in CAD models, so as to accurately extract key features. In the implementation, in order to ensure the efficient construction and training of the model, we choose the deep learning framework Geometry. The framework provides strong support for the implementation of GNN, which enables us to make full use of its rich functions and optimized performance to build and train an efficient GNN model. Figure 1 clearly shows the network structure of 3D modelling of VR scenes. Through this advanced GNN model, it is expected that the matching between the CAD model of ICH and the VR scene can be realized more accurately, and then the digital protection and display effect of ICH can be improved.

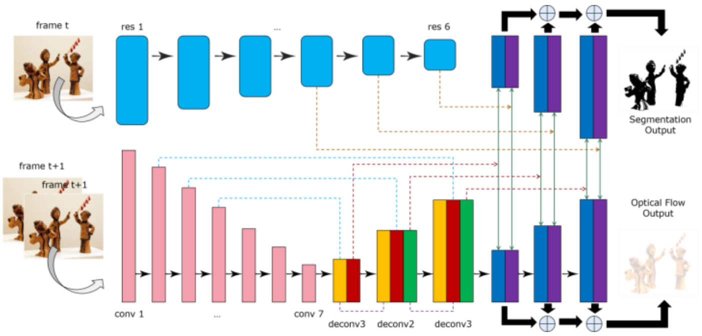

Figure 1: GNN structure.

The network receives input and the required output, where the input is represented as interconnected nodes in the hidden layer. Each connection carries a randomly weighted value. The formula below calculates the output for all layers:

$$a_j^l = f\left(\sum_k w_{jk}^l a_k^{l-1} + b_j^l\right) \tag{1}$$

In this formula, the graph attention mechanism is a neural network structure that runs on the graph based on the graph structure. In graph attention networks, the feature representation of nodes is similar to that of ordinary graph neural networks, both of which use pooling to vectorize the feature representation of nodes. There are generally two solutions to the problem of information loss that convolutional networks may encounter when extracting image features. When using graph convolutional networks for small sample image classification, the classification model consists of two parts: a feature extraction module and a message passing module. Using a formula, it means h=h, h, h H, h RF, n is the number of nodes, and F is the feature vector dimension. The feature extraction module generally uses convolutional neural networks, but convolutional neural networks are prone to some limitations and shortcomings in the process of image feature extraction. For the graph attention mechanism, its initial input is also the combination of features of each node. The feature extraction module of graph convolutional networks is limited in extracting features from sample image data, especially when the image data undergoes rotation or tilting, the extraction effect is affected. Two methods have proposed solutions to the problems in feature extraction networks, such as insensitivity to local feature changes, inability to learn positional relationships between features, and the need to improve the generalization ability for images of different categories. For example, insensitivity to feature information such as positional relationships, and the problem of local information loss during pooling operations. The feature extraction module is used to extract the feature information of the sample image, and the message passing module is used to pass messages among nodes to obtain the label information of unknown sample images.

$$E = \sum_{i=1}^{M} \left\| f\ \ x_i, y_i\ \ - z_i \right\|^2 \tag{2}$$

$$\varepsilon = \sqrt{\frac{\sum_{i=1}^{n} \left(x_i - \hat{x}_i\right)^2 + \left(y_i - \hat{y}_i\right)^2 + \ z_i - \hat{z}_i\ ^2}{n}} \tag{3}$$

The given formula x_i, y_i, z_i stands for the real coordinates of the scanned points, $N_{new}\left(\hat{x}_i, \hat{y}_i, \hat{z}_i\right)$ refers to the recorded coordinates of these points, and n represents the total scanned points count. The formula aids in evaluating the scanned data's accuracy.

The core mechanism of GNN is to capture the global and local structural information of the graph by iteratively updating the representation vector of each node. In each iteration, the representation of nodes will be updated according to the information about their neighbours and their relationships. This iterative process enables each node to finally encode the rich information of its surrounding environment, thus reflecting the overall structure of the CAD model. Figure 2 shows the semantic segmentation principle of GNN.

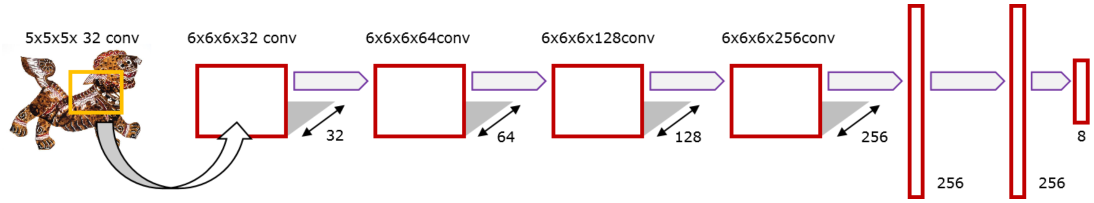

Figure 2: Semantic segmentation based on GNN.

In the VR scene, it is also necessary to extract and process features for matching. This is achieved by similar image processing techniques and computer vision algorithms. Figure 3 shows the layered rendering process of ICH 3D images, which is not only related to the fidelity of visual effects but also directly affects the matching accuracy with VR scenes. Through refined layered rendering, the unique details of ICH can be presented more clearly, thus providing richer and more accurate feature information for GNN and further improving the performance of the matching algorithm.

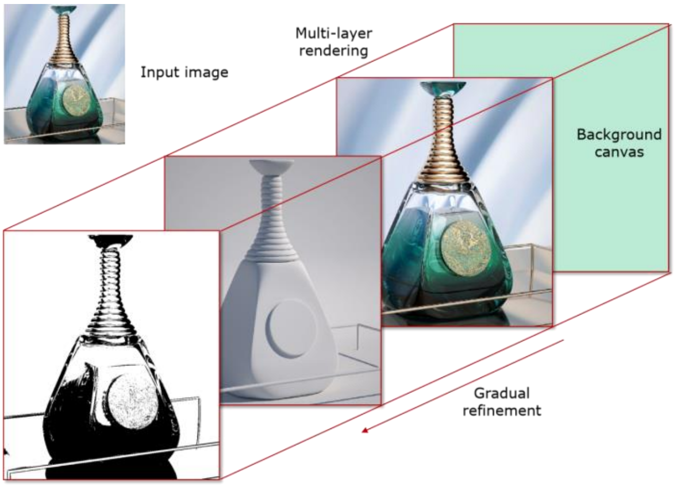

Figure 3: Layered rendering process.

To define the average plane of a vertex, we first determine the normal vector n_k of each triangle within the relevant triangle group linked to the vertex v_i. We then designate the centre x_k and the area a_k. Using the normal vector and the defined centre, we construct a plane, which we refer to as the average plane of the vertex.

$$N = \frac{\sum n_k a_k}{\sum a_k} \tag{4}$$

$$n = \frac{N}{|N|} \tag{5}$$

$$x = \frac{\sum x_k a_k}{\sum a_k} \tag{6}$$

The displacement between point P in 3D space and mesh model TM is described as:

$$d(P, TM) = \min d(P, X) \tag{7}$$

Here, $d(P, X)$ denotes the Euclidean distance from point P to point X. The error metric introduced in this study primarily serves to regulate the simplification process. The error function is defined as follows:

$$\cos t(u,v) = \|u - v\| \times \max_{f \in T_u} \left\{ \min_{n \in T_{uv}} \left(\left(1 - f \cdot normal \cdot n \cdot normal\right) \div 2 \right) \right\} \tag{8}$$

In this setting, $\|u - v\|$ indicates the distance between two points labelled u, v. T_u designates all triangles neighbouring u, whereas T_{uv} identifies all triangles sharing uv as their boundary. $f \cdot normal \cdot n \cdot normal$ signifies the dot product between the normal vectors of two triangular faces, meaning the smaller the angle between these two vectors, the greater the value of this dot product.

Let the plane P traverse through the centroid P' of the closest points K, with its normal vector n fulfilling condition $|n| = 1$. As a result, the characteristic vector linked to the minimum eigenvalue of M may be deemed as the normal vector of point :

$$M = \sum_{i=1}^{K} \left(P_i - P'\right)\left(P_i - P'\right)^T / K \tag{9}$$

In the training stage of the GNN model, this article uses a specific aggregation function and activation function to extract key features in the CAD model. The aggregation function is responsible for summarizing the information of neighbouring nodes to the current node, while the activation function introduces nonlinearity, which enables the model to learn more complex feature mapping. By the combined efforts of these functions, we can not only acquire fundamental details like the shape and texture of the CAD model but also delve deeper into sophisticated information such as its spatial configuration and semantic connections.

4 RESULT ANALYSIS AND DISCUSSION

4.1 Experimental Design

This article conducted an in-memory server experiment on CAD models using the diversity of cultural heritage scene data stored at high speed. The biggest difference between digital storytelling and traditional storytelling lies in its interactivity with digital storytelling. At the story level of human narrative mode, through digital media technology, digital narrative endows readers with the ability to participate in the progression of the story plot, achieving interactive non-linear narrative methods and further expanding the possibilities of the story. By independently exploring the different possibilities of the story plot, Si Shi can also participate in the construction of the story by adding his own creative elements. In terms of external interactivity: Users are outside the virtual world, directly control characters in the virtual world through a God's perspective, or imagine their own ideas to be freely changed in the database. This interactive narrative not only enriches the presentation of the story but also increases the reader's sense of participation and creativity. Secondly, based on the relationship between users and the fictional world, from the perspectives of location and influence, the interactivity of digital Chinese events can be divided into two categories: internal and external, as well as exploration and ontology. In this environment, users can achieve fast and cross-regional dynamic interaction with video creators. So as to better understand and experience the narrative content, and provide feedback and sharing on the narrative, bringing better results to marketing. In terms of intrinsic interactivity: Users create media that transform themselves into participants in the virtual world, often participating in the construction and interaction of virtual worlds from a first-person or third-person perspective. Users do not have any impact on characters with a shared future in the virtual world. Users can freely explore the database of the virtual world, but this activity does not affect the use of historical phrases or fictional history. This means that a user's decision can affect the historical direction and data storage of the virtual world. The interactivity of digital storytelling is that the audience spontaneously participates in the process of the story itself through digital media technology, thereby indirectly influencing the development of the story.

4.2 Experimental Results

Firstly, the performance of GNN and traditional convolutional neural networks (CNN) in VR scene matching is compared. The results show that GNN has excellent matching accuracy and stability. By comparing Figure 4 and Figure 5, it becomes evident that GNN excels in accurately capturing and reproducing the spatial structure and intricate details of the model during the matching of the VR scene for the ICH model. In contrast, the traditional CNN is unable to deal with complex spatial relations, which leads to some distortion and deviation in the matching results.

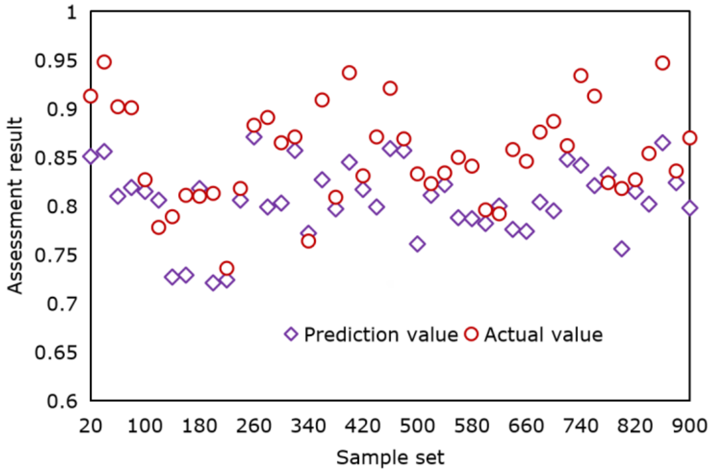

Figure 4: VR scene matching results of CNN.

Figure 4 shows the VR scene matching results of CNN. Although CNN can roughly match the outline of the ICH model, there are obvious shortcomings in detail processing and spatial relationship restoration. Especially in the complex parts of the model, such as sculpture, ornamentation, etc., the matching results of CNN are vague and distorted.

Figure 5 shows the VR scene matching results of GNN. GNN has shown remarkable advantages in dealing with complex spatial structures and relationships. It can not only accurately match the overall shape of the ICH model, but also accurately restore the various parts and details of the model. This makes the audience feel the charm and historical value of ICH more truly in the VR scene.

In order to show the differences between GNN and CNN in scene matching more intuitively, the image processing errors of different algorithms are shown in Figure 6. The matching error of GNN is obviously lower than that of CNN, which further verifies the technical advantages of GNN in VR scene matching of the ICH model.

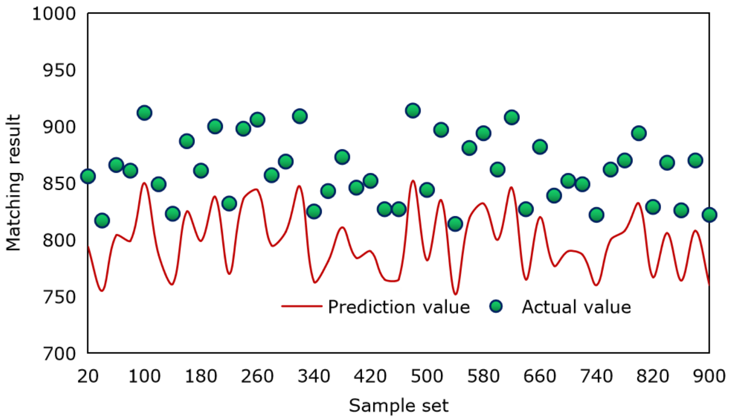

Figure 5: The VR scene matching result of GNN.

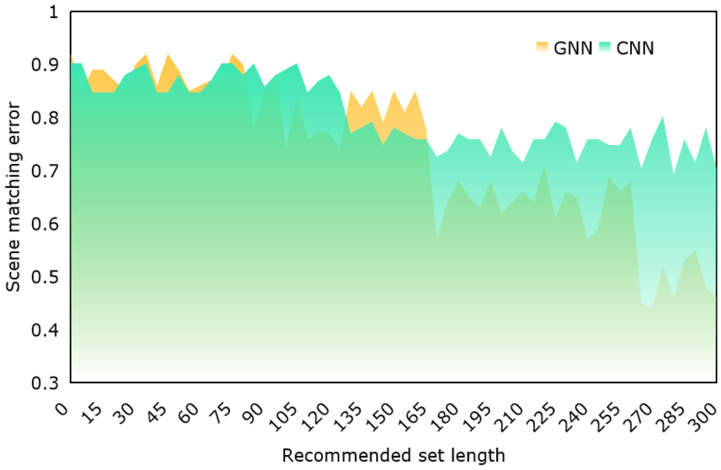

Figure 6: Image processing errors of different algorithms.

Apart from evaluating technical performance, the study also gauges the interactive experience of digital ICH from the user's perspective. Numerous observers were invited to engage in the experience and rate it on three fronts: interactive experience, content presentation, and knowledge acquisition (refer to Figure 7).

In terms of interactive experience, the audience generally said that the interactive forms of digital ICH are diverse and rich in depth. They can freely explore every corner of the ICH model through VR equipment and have zero-distance contact with cultural heritage. In terms of content presentation experience, the audience spoke highly of the quality and accuracy of digital ICH content presentation. They believe that the VR scene matched by GNN technology can truly restore the original appearance of the ICH model, with rich details and lifelike. Finally, in terms of the knowledge-learning experience, the audience said that through the interactive experience of digital ICH, they not only gained rich visual enjoyment but also learned a lot about ICH.

By comparing the experimental results of GNN with traditional CNN and the audience's assessment of the interactive experience of digital ICH, it can be concluded that GNN has obvious advantages in matching the CAD model of ICH with the VR scene, which can effectively improve the digital protection and display effect of ICH. Furthermore, the high-quality interactive experience of digital ICH has also been widely recognized and loved by the audience.

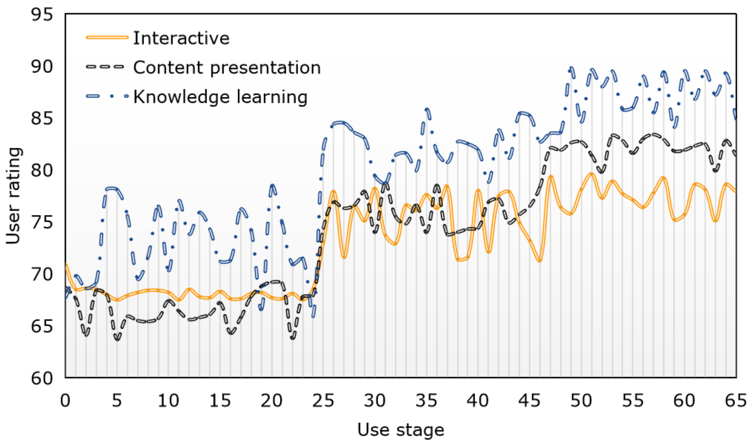

Figure 7: Evaluation of ICH interactive experience.

4.3 Discussion

GNN has demonstrated its unique advantages in handling ICH CAD models and VR scene-matching tasks. In the ICH CAD model, key information not only exists in the local features of the model but also in the spatial relationships and structural features between the various components of the model. GNN can comprehensively consider the relationships between nodes by constructing graph structures, thereby more accurately capturing key information in ICH CAD models. This is mainly due to GNN's ability to naturally process graph-structured data with complex spatial structures and relationships. Traditional matching methods often find it difficult to fully consider these complex factors, resulting in inaccurate matching results. When processing image data, CNN mainly focuses on local features and extracts texture, edge, and other information from the image through convolution operations. Viewers can gain a deeper understanding of the historical, cultural, and artistic value, and feel its unique charm and charm.

ICH CAD models typically contain rich spatial details and complex feature relationships, which need to be accurately captured and presented in VR scenes. By capturing the spatial relationships between nodes, GNN can more accurately locate key features and achieve more accurate matching. Compared with traditional Convolutional Neural Networks (CNNs), GNNs exhibit more significant advantages in processing ICH CAD models. The experimental results show that compared with CNN, GNN performs well in preserving model details and maintaining spatial integrity, achieving more accurate matching. Through precise matching of GNN, ICH models in VR scenes can more realistically restore real-world details and features. In addition, the precise matching of GNN also makes the audience's interaction in VR scenes more natural and smooth, improving their participation and learning enthusiasm. Through high-precision matching techniques, the authentic appearance and underlying meaning of ICH can be captured and presented with greater fidelity and completeness. Furthermore, the incorporation of digital technology has paved the way for a more expansive platform to disseminate ICH.

Nonetheless, this study has its limitations. For instance, there is a need to increase the quantity and diversity of experimental samples to further substantiate the versatility and stability of GNN in matching various ICH models. Moreover, as technology progresses, there is scope to explore more sophisticated algorithms and models in the future, aiming to refine the matching efficacy and elevate the audience's experience.

5 CONCLUSIONS

Aiming at the matching problem between the CAD model of ICH and the VR scene, this article proposes a matching method based on GNN. By constructing a GNN model, we can learn the spatial structure and relationship of the CAD model, extract key features and match them with features in VR scenes. Following an extensive series of experiments, the superiority of our proposed method has been established. Looking ahead, we anticipate this method finding further applications in cultural heritage preservation, VR gaming, and education, thereby advancing the perpetuation and evolution of ICH. The significant contributions of our study encompass the introduction of a groundbreaking matching algorithm that notably elevates matching precision and efficiency. Furthermore, our research offers a fresh technical approach to the digital safeguarding and exhibition of ICH, serving as a valuable reference for scholars in affiliated domains.

By adopting cutting-edge technical solutions, our study has adeptly tackled the primary challenges associated with the digital exhibition of ICH, bolstering the preservation and continuation of ICH with renewed vigor. Nevertheless, for certain intricate ICH artifacts, prevailing feature extraction techniques might lack the requisite precision, necessitating further investigation and refinement. Moving forward, we are committed to exploring more potent feature extraction and matching algorithms to enhance the model's versatility and resilience.

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