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Computer-Aided Design AND APPLICATIONS

Digital Protection and Reproduction Algorithm of Intangible Cultural Heritage Using Virtual Reality Technology

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Abstract. Cultural heritage faces many challenges. This article aims to explore the combination of computer-aided design and virtual reality technology to achieve digital protection and reproduction. By reviewing relevant research progress at home and abroad, it is found that the current mainly focuses on the application of technologies such as data acquisition, 3D modelling, virtual reality, and augmented reality. This article elaborates on the specific methods of combining CAD and VR technology, including using high-precision 3D scanning equipment to obtain intangible cultural heritage data, using CAD software for 3D modelling and optimization, and combining VR technology to achieve an immersive experience and interactive presentation. In addition, this article also designs a series of data processing and rendering algorithms to enhance the authenticity and expressiveness of digital results. Through experimental verification of multiple intangible cultural heritage samples, it is proved that the method proposed in this article has significant advantages in digital protection and reproduction. Finally, this research provides a new and feasible technical approach for inheritance and innovation and lays a foundation for future research in this field.

Keywords: Traditional Intangible Cultural Heritage; Protection and Inheritance; Computer-Aided Design; Virtual Reality
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1 INTRODUCTION

The current protection of folk culture requires multiple forms of collaboration, including traditional artistic language, music, and dance. They are an important part of human cultural diversity and have irreplaceable value. However, due to the acceleration of modernization and globalization, many ICH projects are facing the crisis of gradual disappearance. Therefore, the protection and inheritance of ICH is crucial. Globalization and social transformation have brought unprecedented challenges to intangible cultural heritage (ICH), which serves as the foundation of national identity and cultural

knowledge, and its protection and inheritance are particularly important. Through digital means, Adewumi [1] presents intangible, thus realizing another expression of the right to cultural life. Taking traditional craftsmanship in Nigeria as an example, this paper delves into the issue of digital protection [2]. It used stratified data collection to conduct a survey and collection of art tourism data on tourists interested in different material cultures. Through observing the cultural experiences of the interviewees who were immersed in the technology, over 70% of the respondents showed great interest in the artistic tourism landscape of the technology. It also enhances their understanding and association with related brands. After enjoying the intangible cultural heritage experience brought by mixed reality technology, tourists are more likely to form a positive attitude and loyalty towards the brand. Digital narrative is an emerging way of information expression and dissemination. Big data analysis technology can deeply explore and analyze the public's interest and demand for intangible cultural heritage, providing a scientific basis for the formulation of inheritance strategies. In the integration of digital storytelling and intangible cultural heritage inheritance, knowledge and technology from various fields continue to merge, opening up new opportunities for the inheritance of resources and culture. Digital media presents stories to the public in vivid and intuitive forms, providing new possibilities for the inheritance and protection of intangible cultural heritage. Digital narrative, through storytelling, can deeply explore and showcase the cultural connotations and historical value behind intangible cultural heritage. This allows the public to appreciate the story while gaining a deeper understanding and appreciation of the charm of traditional culture [3].

Its discovery has unprecedented development momentum and opportunities in the inheritance driven by cultural digitization strategies and emerging technologies. Media elements are a crucial element in digital storytelling. With the development of technology, digital media has become an important carrier for the inheritance of intangible cultural heritage. Digital storytelling should not only attract public attention but also evoke resonance and reflection among the public. At the same time, digital media also has the characteristic of strong interactivity, which can stimulate the public's enthusiasm for participation and improve the effectiveness of inheritance. Through creative and infectious digital narrative works, it is possible to deepen the public's understanding and recognition of traditional culture and improve the effectiveness of inheritance. Finally, the effectiveness factor is an important indicator for measuring the success of digital narrative inheritance of intangible cultural heritage. This immersive visiting experience allows users to have a more intuitive understanding of the charm and value, promoting inheritance and development. In the data processing stage, these models not only record the current status of the site but also provide an important reference for subsequent restoration work. Bernardi et al.'s [4] research reveals the degree of digitization that should be integrated into museum communication strategies and points out the logic that hinders the digital transformation of cultural heritage strategic management. Although the majority of respondents are aware of the strategic role of digitization in museum development, the level of digital readiness is still relatively low. Some museums may have inertia thinking towards traditional working methods and operating models, and insufficient understanding of the necessity of digital transformation. Some museums may lack professional digital talents and teams, making it difficult to independently undertake the task of digital transformation. There are multiple reasons for this. Firstly, some museums may find it difficult to bear the high cost of digital transformation due to limitations in funding, technology, or talent. In addition, the integration of digital processes in cultural heritage management also faces many challenges, such as data security and privacy protection, cross-departmental collaboration and communication. Museums need to reshape the way they convey information about their collections and attract tourists, in order to better adapt to the needs of the digital age.

How to balance the enthusiasm of public participation with the accuracy of professional knowledge is a question that needs to be further explored. In the field of digital protection of cultural heritage, Challenor and Ma [5] suggest that cultural institutions adopt a diversified approach, especially by deepening public understanding of cultural heritage through storytelling. As an important venue for cultural display, museums should actively innovate exhibition forms, such as launching invisible virtual reality experiences. The environment reconstructed through interactive digital technology and 3D virtual technology allows tourists to personally participate in the narration

of historical stories, thereby enhancing the attractiveness and effectiveness of history teaching. This experience can not only attract more young people to pay attention to intangible cultural heritage but also help them understand and appreciate the unique charm more intuitively. By combining storytelling with 3D virtual technology, a digital experience that is both entertaining and educational can be created. Therefore, while promoting digital protection, it is necessary to continuously explore and improve relevant technology and policy systems to ensure sustainable inheritance. With the increasing importance of digital protection (ICH), many cultural and tourism organizations are actively exploring the use of augmented reality (AR) technology, especially augmented reality smart glasses (ARSG), to deepen tourists' experience of ICH culture. Han et al. [6] aim to contribute to the field of technology adoption literature and digital protection by investigating the attributes of tourists using ARSG in intangible cultural heritage tourism. Through in-depth interviews, we explored the views and feelings of tourists towards using ARSG to enhance their intangible cultural heritage experience, as well as their behavioural choices. It proposes a framework for ARSG to be adopted in intangible cultural heritage tourism. Although the adoption of mobile AR applications in cultural tourism has been widely studied, research on the use of ARSG in digital protection is still relatively limited.

In the field of digital protection (ICH), it is crucial to effectively extract and represent the 3D global features of ICH projects for their inheritance, display, and protection. Han et al. [7] took the cultural heritage of urban villages as the research object and selected Liede Village, which has been comprehensively renovated in Guangzhou. The introduction of narrative space methodology explores the applicability of cultural heritage in villages. And construct a theoretical research framework that connects the three aspects of "renewal mode - narrative space - urban village cultural heritage". Secondly, use the point pattern spatial analysis method to analyze the changes in the narrative space of cultural heritage before and after renovation. The micro renovation of ancient villages has integrated cultural protection with the tourism industry, resulting in a weakening of community identity. The comprehensive renovation not only eliminates the traditional street texture and architectural spatial pattern but also expands the social impact scale. Exploring the protection and revitalization paths of cultural heritage in urban villages under different renewal modes from two dimensions: material cultural heritage and intangible cultural heritage.

This article aims to explore the application and effectiveness of the combination of computer-aided design and virtual reality technology. Intangible cultural heritage is an important carrier of human cultural diversity, and traditional protection methods face challenges such as incomplete recording and preservation, and difficulty in comprehensive presentation and promotion. By combining CAD and VR technology, this article proposes a novel and efficient strategy for digital protection and reproduction. This combination enables precise data collection, 3D modelling, and immersive presentation, providing a multi-dimensional display and inheritance space for intangible cultural heritage. Through detailed research and experiments, this article analyzes the impact of the combination of CAD and VR on intangible cultural heritage and explores how to enhance visualization and interactivity with the support of digital technology. In the research process, we focus on the digital characteristics of different intangible cultural heritage projects and verify the effectiveness and advantages of the proposed method through experiments.

2 RELATED WORK

Documentaries have many irreplaceable advantages in the digital protection of cultural heritage, firstly in terms of intuitiveness and vividness. Audio recording can to some extent avoid such errors. But pure sound recording still has a certain distance from the restoration site. Before the popularization of visual methods, written records, audio recordings, and other methods were the most commonly used recording methods in cultural field research. In the subsequent decoding process by readers, there may be greater deviations, ultimately leading to a deviation from the original understanding. However, as an indirect symbol of meaning, text inevitably incorporates the recorder's own intuitive feelings and personal understanding during the encoding process. If there are operational errors in the acquisition and subsequent processing of simultaneous sound and

ambient sound, it will cause immeasurable huge losses. Due to differences in personal writing style and language preferences, there are still some differences in the records made at the same site. The digital protection concept can be well inherited in the reconstruction of 3D models. This innovative approach not only provides a new way for the inheritance and promotion of traditional opera but also allows audiences to experience the charm of traditional opera in an immersive way, further enhancing the dissemination effect. In addition, some researchers have used artificial intelligence and big data technology to study intangible cultural heritage Heritage projects Data analysis and processing. The application of these technologies has greatly improved the efficiency and accuracy of digital protection. Through data mining and analysis, researchers can delve into Understanding non. The history, development and inheritance of cultural heritage provide important guidance for future conservation work. At the same time, these technologies can also help researchers to analyze a large amount of Legacy data information extracted from the Heritage projects. The digitalization of protection and reconstruction provides a more scientific and precise solution.

China is known for its rich world heritage, which not only reflects its profound cultural heritage but is also an important reflection of the country's cultural soft power and economic development. Not only to preserve and inherit this precious cultural heritage but also to strengthen the cultural cohesion and national identity of the country. By incorporating the cultures of ethnic minorities into the national cultural heritage list, China has not only strengthened its own cultural diversity. Lee [8] has made this precious cultural heritage more widely spread and recognized through the Internet and other modern means of communication. This protection method comprehensively records and preserves the original form. Digital protection can also provide new ways and means for the cultural inheritance of ethnic minorities so that the inheritance of traditional culture is no longer limited by geography and time. Further consolidating national borders and reducing external influence from cross-border ethnic or cultural relatives on ethnic minorities. Through digital platforms, cultural exchange and interaction between different ethnic groups can be more convenient and efficient. This is conducive to promoting cultural exchange and understanding between different ethnic groups. The presentation has shifted from traditional single and static forms to more diverse, experiential, and interactive modes. This transformation not only greatly enriches the public's understanding, but also promotes deep communication between intangible cultural heritage and the public. In order to gain a deeper understanding of the public's needs and expectations for the digital experience, as well as to evaluate the effectiveness of digital technology in protection and display, Liu [9] adopted a mixed method of questionnaire surveys and semi-structured interviews. The research results show that intangible cultural heritage digital display technology has been highly welcomed and accepted by tourists. More importantly, digital technology has created a new and immersive experience for tourists to perceive, participate in, and communicate history, allowing them to more intuitively experience the charm.

Cultural tourists are becoming increasingly interested in intangible cultural heritage and areas surrounding ethnic minorities. In the digital age, the protection and inheritance methods are undergoing changes. Lonardi and Unterpertinger [10] pay special attention to the intangible cultural heritage of ethnic minority communities and take the Latin community in South Tyrol, Italy as an example to deeply explore the role of ethnic minority languages in it. Based on this trend, this study not only adopted traditional qualitative methods but also conducted 16 semi-structured interviews with German and Italian-speaking tourists in Valpustria. We also use digital means, such as creating videos, to showcase the real situation of the Latin community. This multimedia presentation method enables tourists to more intuitively experience and understand the charm. Masciotta et al. [11] explored the dominant role of digitalization in the protection of tangible cultural heritage, while further expanding the analysis of digital protection. It has developed a comprehensive method based on numbers. This method is not only applicable to the protection of tangible cultural heritage buildings, but also to the recording, inheritance, and protection. The discussion has been further expanded to adapt to the characteristics. Encourage the owners, inheritors, and relevant communities of cultural heritage to directly participate in the protection process of their heritage.

In the field of heritage research, intangible cultural heritage has gradually become a priority due to its unique human sensory enjoyment value and inheritance significance. Traditional definitions are

often limited to forms of expression such as dance, music, and oral traditions, but the diversified development of modern society has continuously expanded the scope. Based on the trend of digital protection, Mohamed et al. [12] will conduct an in-depth analysis of Malaysia's legal provisions for protecting intangible cultural heritage under the responsibility of member states. Digital protection provides new possibilities and opportunities for protection and inheritance. They discussed how to improve and expand the protection scope through digital protection methods. Through digital technology, we can digitize the recording and dissemination, making it no longer limited by geography and time. Specifically, it establishes a digital protection platform for intangible cultural heritage. Digitally record and showcase Malaysia's intangible cultural heritage, providing convenient access and learning opportunities for the public. The study by Nishanbaev et al. [13] reveals the most advanced geospatial semantic web concepts related to the field of cultural heritage. Although the Geospatial Semantic Web has enormous potential for application in the field of cultural heritage, there is currently a lack of in-depth research on the concept of Geospatial Semantic Web targeting cultural heritage audiences. The Geospatial Semantic Web combines geospatial data and semantic web technology, endowing geospatial information with semantic meanings, making data easier to understand, query, and utilize. Among them, the data integration and interoperability issues between national and regional digital cultural heritage repositories are particularly prominent. By introducing geospatial semantic web technology, cultural heritage data can be endowed with rich semantic information, improving the comprehensibility and query ability of the data. Due to the different data standards, storage formats, and access interfaces used between different repositories, sharing and exchanging data becomes extremely difficult. To address these issues, their research has provided us with some useful insights. The use of semantic web technology can achieve data integration and interoperability between different repositories, break down data silos, and achieve data sharing and exchange.

A key observation in big data research is that creating value from data often relies on the coordination of interests among different stakeholders. In order to delve deeper into this issue, Pesce et al. [14] conducted detailed case studies on two platforms that have a significant influence on online dissemination. This ability does not depend on the specific industry knowledge level possessed by the platform coordinator. When these platforms are able to activate multiple drivers of value creation, they can effectively readjust the interests of previously conflicting or unrelated stakeholders. In the context of digital protection, it has been observed that Google Arts&Culture plays the role of a system integrator in the cultural ecosystem. By integrating big data and advanced digital technology, Google Arts&Culture provides new possibilities for protection, inheritance, and promotion. Documentaries, as an important branch of dynamic imaging, have a long history of assisting in the protection and inheritance of traditional culture through their artistic expressions that combine authenticity and narrative, as well as diverse communication media. Trunfio et al. [15] conducted a study on digital protection using literature research, case analysis, and field research methods. There are various types and their existence is complex. Documentaries have excellent cases in presenting various types. Taking the production technique of cloisonn é as a case study, this paper analyzes the characteristics and advantages of documentaries in protecting and disseminating relevant intangible cultural heritage and attempts to propose optimization strategies and directions for reference. Define the connotation and extension of digital protection and documentary films on intangible cultural heritage. In digital protection, if the advantages of documentaries can be reasonably utilized, it will significantly enhance the dissemination and social influence in contemporary times, promote public awareness protection, and strengthen cultural confidence. Among them, traditional handicrafts' intangible cultural heritage has characteristics such as tradition, humanity, aesthetics, and artistry. Promoting its inheritance and dissemination in the form of documentaries has a relatively broad audience base. With the deepening of practice in the protection, documentaries continue to play a role in the protection. Taking representative image works in China's digital protection methods as an example, traditional handicraft intangible cultural heritage documentaries are selected. This technology allows tourists and researchers to gain a deeper understanding of the unique aspects of traditional Japanese culture and to learn and experience in a more innovative and intuitive way. This combination not only expands the audience for traditional crafts but also enhances tourists'

understanding and appreciation of traditional culture. In addition, research teams in some European countries are exploring the use of augmented reality technology to integrate intangible cultural heritage into modern education and tourism, further promoting inheritance and dissemination. Through augmented reality, tourists can see intangible cultural heritage in the real environment chemical related to the digitalization content, such as historical background introduction, craft production process, stories of inheritors, etc., provides a new display channel for intangible cultural heritage and allows people to obtain richer knowledge and experience during their visits and travels. These international studies and applications provide diversified and innovative solutions for digital protection and reappearance and also promote inheritance and dissemination worldwide.

3 HERITAGE PROTECTION DESIGN WITH REPRODUCTION SYSTEM

3.1 Virtual Reality Technology

Virtual reality technology is a three-dimensional environment generated by computer simulation, allowing users to enter and interact with it through specialized devices such as head-mounted displays and haptic controllers. In this simulated environment, users can feel an immersive experience as if they were in a completely different world. VR technology aims to provide users with an immersive and interactive virtual experience. Augmented reality technology is a technology that combines digital information with the real environment. Unlike virtual reality, augmented reality superimposes virtual images, text, and other data in the real world, providing users with rich information and interactive experiences. Users can see the augmented reality environment through devices such as smartphones, tablet computers, or dedicated AR glasses.

The history of VR technology dates back to the 1960s when prototype devices provided a basic immersive experience. With the continuous development of computer and display technology, VR technology has gradually matured, especially in the early 21st century, where the performance and experience of VR devices have been significantly improved. Today, VR technology is widely used in games, education, medical treatment, military training, and others. The concept of AR technology was first proposed in the 1990s, but its real application and development began in 2010. With the popularization of smartphones and the advancement of computer vision technology, AR technology has developed rapidly and has been widely applied, such as mobile AR applications and AR glasses. AR technology has demonstrated great potential in education, shopping, tourism, and gaming. Overall, virtual reality and augmented reality are developing rapidly and are gradually penetrating various industries. Each has its unique advantages and application areas, and future development will continue to promote innovation, providing users with richer, more immersive, and interactive experiences.

3.2 Selection of Experimental Hardware

When we delve deeper into the current mainstream VR (virtual reality) hardware devices, we will find that there are multiple products with unique features on the market. Meanwhile, as a technology giant, Meta also has a rich content ecosystem behind it, where users can find diverse content from gaming to education and from entertainment to socializing. In addition, its memory and storage space are relatively limited, which may limit the installation of some large games or applications. This device does not require additional external sensors, greatly reducing the user's setting threshold, and the lightweight design provides a comfortable experience for long-term use. However, this also makes its price relatively high, which may be a significant challenge for users with limited budgets. Next, let's take a look at HTCVive Pro 2. This device is known for its high resolution and precise tracking performance, providing users with an immersive experience. Among them, Meta's Quest 3 undoubtedly attracted a lot of attention with its integrated design and excellent portability. However, the display effect of Quest 3 is not top-notch in the industry and may be slightly insufficient for some users who pursue the ultimate visual experience. In addition, the HTCVive Pro 2 requires the installation of external sensors, which may be a bit complicated for some users who are not familiar

with technical settings. Figure 1 shows the display and processing of data by the VR device MetaQuest 3GNN header.

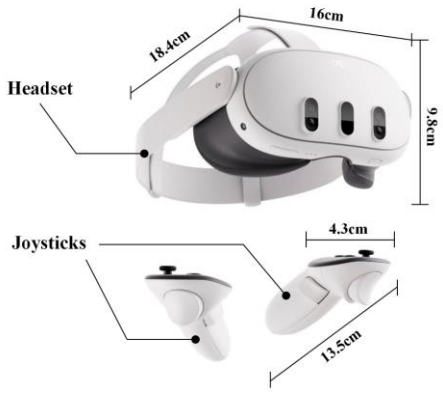

Figure 1: VR device Meta Quest 3GNNHead displays and handles data.

Finally, the experiment chooses Meta Quest 3 as a VR device; the Quest 3 is highly portable, requires no external sensors, and is relatively affordable, making it ideal for mobile deployment of experiments. Its rich content ecosystem offers a wide range of options and possibilities for experiments. The setup and operation of the Quest 3 are simple and easy to use, making it suitable for all types of users. Considering these factors, the Quest 3 not only meets research needs but also provides an excellent user experience, making it an ideal choice for experiments.

3.3 Heritage Protection Selection of Algorithm

Many problems encountered in the process of protection and reconstruction can be abstracted as multi-objective evolutionary problems. Considering the technology used in this study, the system can be considered a general mathematical form of conversion for multi-objective evolutionary problems.

$$\min f(x) = (f_1(x), f_2(x), \cdots, f_m(x))^T, x \in \Omega \subseteq R^n \tag{1}$$

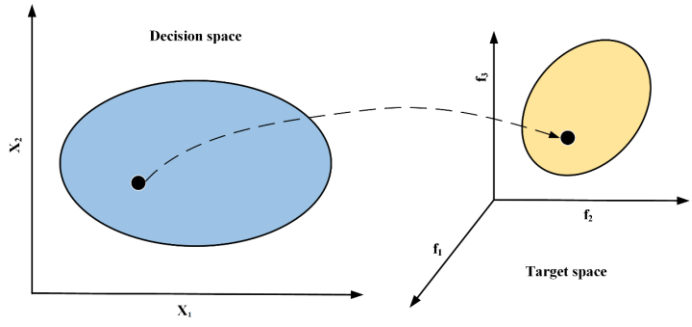

Figure 2: Mapping from decision space to target space in multi-objective evolutionary algorithm.

Figure 2 illustrates the mapping from decision space to objective space in multi-objective evolutionary algorithms. Dynamic decision vector refers to the vector of decision variables that change over time or a certain parameter in multi-objective optimization problems. The Pareto optimal solution (also known as Pareto efficiency or non-dominated solution) is a concept defined in multi-objective optimization problems. In a dynamic environment, decision-makers need to

constantly adjust these variables to adapt to changes in the environment in order to achieve or approach the optimal state. Dynamic decision vectors are commonly used to describe complex systems that require continuous monitoring and adjustment, such as economic systems, ecosystems, or engineering systems. These vectors may contain multiple elements, each representing a decision variable that may be influenced by time or other external factors.

$$PS = \ x \in \Omega \Big| x \subset ParetoBest \tag{2}$$

$$PF = \ f(x) \in R^m \Big| x \subset PS \tag{3}$$

If it is selected as an ideal point, its value range is:

$$z^* = (z_1{}^*, z_2{}^*, \ldots, z_m{}^*)^T, i \in \ 1,2,\ldots,m \tag{4}$$

The point corresponding to the ideal point is the worst point, and its value range is:

$$z^{na} = (z_1{}^{na}, z_2{}^{na}, \ldots, z_m{}^{na})^T, i \in \ 1,2,\ldots,m \tag{5}$$

In the process of digitalizing intangible cultural heritage, there are two major sub-problems: the path sub-problem and the sorting sub-problem. The former refers to the allocation of several operations to appropriate virtual reality technologies, while the latter refers to the priority of several operations allocated to each project. The three most important objectives of digitalization are as follows:

$$C_{\max} = \max \ C_i \Big| i = 1,2,\ldots,n \tag{6}$$

$$W_T = \sum_{k=1}^{m} W_k \tag{7}$$

$$W_{\max} = \max \ W_k \Big| k = 1,2,\ldots,m \tag{8}$$

The target genetic algorithm is an optimization algorithm that simulates natural selection and genetic mechanisms, which is particularly suitable for handling multi-objective optimization problems. Unlike traditional genetic algorithms, MOGA not only considers individual fitness but also considers the trade-off relationship between different objectives, thus being able to find a balanced solution set among multiple objectives. In this study, we chose the objective genetic algorithm as the basis for improving and optimizing multi-objective evolutionary algorithms. On the basis of MOGA, we will focus on researching and designing dynamic mutation operators further to improve the searchability and adaptability of the algorithm. In MOGA, by simulating the selection, crossover, and mutation operations in biological evolution, the algorithm can generate new individuals in the solution space and evaluate their strengths and weaknesses through fitness functions. The dynamic mutation operator can adaptively adjust the mutation intensity and direction based on the evolutionary state and search requirements of the algorithm, thereby achieving an organic balance between extensive search and centralized search.

Figure 3 illustrates the moderation allocation used in the multi-objective evolutionary algorithm improved by the target. Assuming that the fitness of all non-dominated can be used to quickly select individuals with the same fitness. In the NSGA-2, non-dominated dynamic individuals can be ignored initially, and set to 2. Then, iterative processes are continuously carried out to ensure that all individuals have a fitness value. The crowding distance is then used to differentiate between them.

Confirm the multi-objective problem generator. First, optimize the generation of a single-objective problem, divide it, and then subdivide it. Represented as the following equation system:

$$\begin{cases} \min f_1(x_1) \\ \min f_1(x_1) \\ \quad \cdots \\ \min f_{m-1}(x_{m-1}) \end{cases} \tag{9}$$

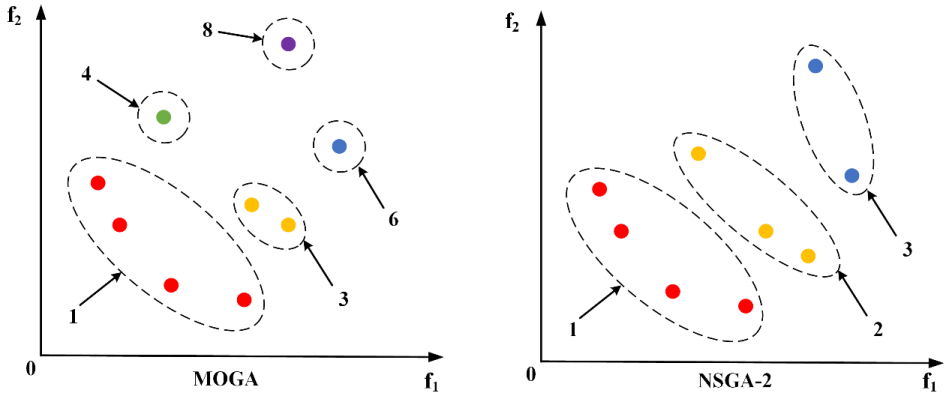

Figure 3: Schematic diagram of the distribution of individual fitness in the population in MOGA and NSGA-2.

$$\begin{cases} \min f_{m-1}(x_{m-1}) \\ \min f_m(x) = g(x_m)h(f_1(x_1), f_2(x_2), \ldots, f_{m-1}(x_{m-1}), g(x_m)) \end{cases} \tag{10}$$

Based on the dimensional distribution of individuals on the Pareto boundary, we can classify the problem. Normalization problems typically refer to problems where the solution set exhibits significant advantages on a specific objective, which may be due to the specific properties or high weights of the objective in the decision space. As shown in Figure 4, the selected reference point is crucial for calculating the super volume as it defines the boundaries of the decision space. The non-normalization problem means that the trade-offs between different objectives are more complex, and no objective dominates in the solution set. A reference point is usually a point set by the decision-maker that is not dominated by any solution to all objectives. On the contrary, if the Pareto boundary is uniformly distributed across multiple dimensions (such as the horizontal axis of dimension 0.5), then this problem may be considered a non-normalization problem. Super volume refers to the decision space volume enclosed by reference points and Pareto boundaries. By calculating the super volume, we can quantify the diversity and quality of the solution set found by the algorithm in the target space. Specifically, if the Pareto boundary mainly extends on a specific dimension of the decision space (such as the horizontal axis of dimension 1), then this problem can be classified as a normalization problem. A larger super volume means that the algorithm can find more diverse and higher-quality solution sets. This usually means that the algorithm achieves a better balance between multiple objectives without ignoring any important ones.

The application of multi-objective evolutionary algorithms in the protection and reproduction has improved the adaptability of the algorithm through the improvement and optimization of the selection-based genetic algorithm. This algorithm achieves the convergence and diversity balance in the target space by selecting excellent individuals in the population. Finally, by evaluating the hypervolume space, the algorithm's performance is assessed, effectively addressing the issues of path and sorting in the process of digital protection.

4 DIGITIZATION AND REPRODUCTION

4.1 Hue Analysis of the Mural

Dunhuang murals are the artistic treasures of China's thousand-year history, boasting high cultural and artistic value. In the new era, the digitization of Dunhuang murals is not only a necessity for protection but also an important way to realize reproduction and dissemination. Therefore, this study

takes Dunhuang murals as the experimental object and combines CAD and VR technology to establish an innovative algorithm model for practice.

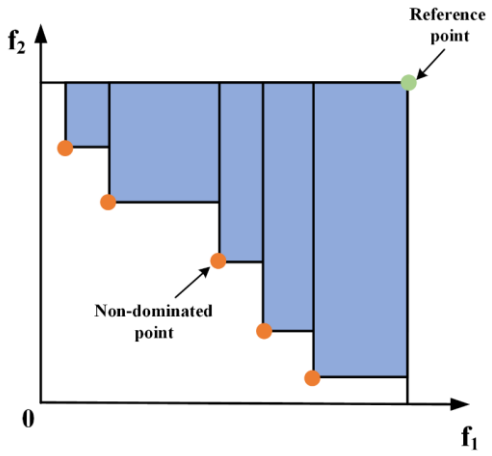

Figure 4: Schematic diagram of target space hypervolume index.

Through these advanced technologies, it is possible to achieve precise digital protection of Dunhuang murals and reproduce their rich details and artistic styles in a virtual environment, providing an immersive experience for the audience. Firstly, this experiment selects two murals for hue analysis and then uses CAD technology to carry out digital processing smoothly. The analysis results are shown in Figure 5.

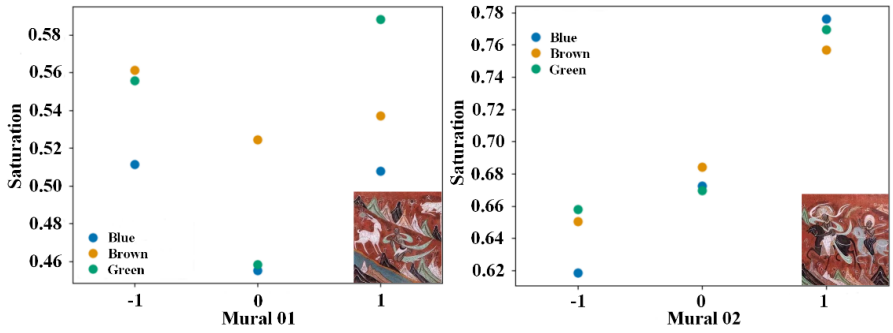

Figure 5: Color hue analysis results of the algorithm model on the mural.

Figure 5 shows the hue analysis results. The red background can be clearly seen to be dominated by blue, green, and brown hues with low saturation. Hue analysis provides an important reference for the digitalization process, making the digitalization work more precise. Additionally, the results of hue analysis also facilitate subsequent virtual reality reconstruction, ensuring that the original hues and visual effects of the mural are maintained during the reconstruction process

4.2 Space Structure of Murals

When recreating a three-dimensional mural, accurately grasping spatial positioning is an important step to ensure the reproduction effect is consistent with the original. First, the spatial data of the

mural, including its shape, size, and position, is obtained through high-precision three-dimensional scanning technology. Then, the acquired data is processed and analyzed using computer-aided design tools to create a three-dimensional model of the mural. During this process, special attention should be paid to details such as depth, concavity, and curvature of the mural to accurately restore the spatial structure of the original. Figure 6 precisely positions the spatial layout of the mural, which will help accurately present the mural in a virtual reality environment and ensure that the audience's visual experience aligns with the original in a virtual experience.

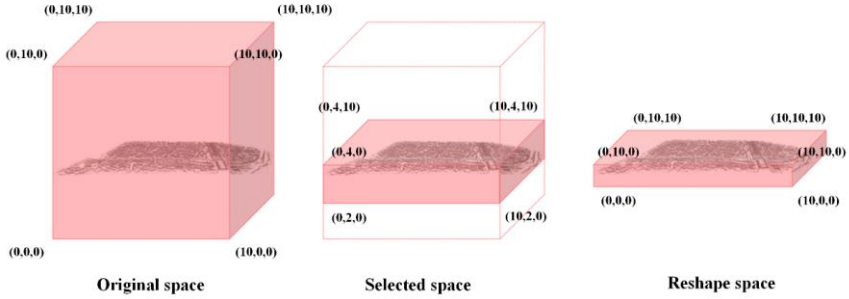

Figure 6: The algorithm model reshaping the mural space.

Once the 3D modelling is completed, the model can be combined with hue analysis results for further digital processing. This precise spatial positioning not only ensures the authenticity and artistry of the reproduction of the mural but also provides a solid foundation for the application of virtual reality technology. In the virtual environment, viewers can experience the magnificence of the three-dimensional mural in an immersive experience, while avoiding any damage to the original. This method of digital protection and reproduction provides a new way for inheritance and innovation.

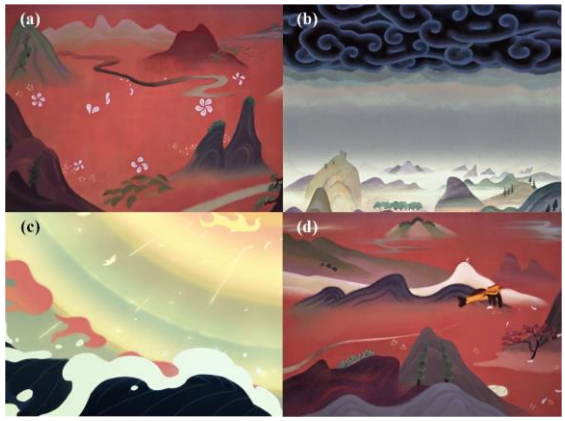

Figure 7: Picture presented by virtual reality after digitalization.

Through the use of algorithm models and the aforementioned steps, this study successfully rendered the mural, as shown in Figure 7. While maintaining the original artistic style, it underwent modernization. This rendering method not only preserves the unique beauty of the original work but also, through colour adjustment and detail optimization, makes the work more in line with the aesthetic needs of modern audiences, thereby enhancing acceptance. Additionally, such a digital rendering approach facilitates the widespread dissemination of the mural, creating better conditions for the promotion and inheritance of traditional art.

5 CONCLUSIONS

The innovative way of digital display is of great significance to the dissemination of traditional art, not only broadening the audience for intangible cultural heritage but also enabling more people to experience the charm of traditional culture through the power of technology, thereby further promoting inheritance and protection.

However, the research also has some shortcomings. Firstly, although digital processing has achieved certain successes, there may be some deviations in the restoration of the tone and spatial structure of the murals, especially in the realism and detail of three-dimensional murals. Secondly, technical limitations may prevent the audience from experiencing exactly the same feeling as the real murals during VR experiences. Additionally, the research scope is limited, with only two murals selected for analysis and reconstruction. In the future, it is necessary to expand the research objects to verify the effectiveness of the method more comprehensively. The research directions include optimizing existing algorithms and technologies to improve the accuracy and realism of digital murals. Meanwhile, it is also possible to explore methods combined with AR technology to expand the reconstruction of murals into the actual visiting environment. In addition, further research should be conducted on how to apply these methods in more types of protection and reconstruction to enrich digital presentation and promotion. Through continuous improvement and innovation, research can better achieve protection, inheritance, and dissemination.

In conclusion, the study combined CAD and VR technologies to digitally preserve and recreate the three-dimensional murals, successfully showcasing the precise details and original artistic style of Dunhuang frescoes. Integrating modern processing and hue analysis, enhanced the audience's acceptance and participation. This innovative digital presentation not only promotes the promotion and inheritance of traditional art but also provides a new way to protect and spread intangible cultural heritage. By using technology to allow more people to experience and understand traditional culture, it injects new vitality into inheritance and protection.

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