www.cad-journal.net
Computer-Aided Design AND APPLICATIONS

Architectural Style Transfer Algorithm in Digital Traditional Residential Village Protection and Collaborative Design

Shuying Zhao[1] and Hengxing Xie[2]

[1]School of Communication, Weinan Normal University, Weinan, Shaanxi 714099, China, shuyingzhao@163.com
[2]College of Environment and Life Science, Weinan Normal University, Weinan, Shaanxi 714099, China, xiehengxing@nwsuaf.edu.cn

Corresponding author: Hengxing Xie, xiehengxing@nwsuaf.edu.cn

Abstract. Traditional dwellings are the core carriers of village development and housing, carrying national culture and inheritance. Their introverted and unique architectural style provides a reliable historical reference value for the world architectural system. There are many architectural styles in traditional residential villages, which are of great significance to human civilization and the evolution of architectural systems. In the modern era and modern society, digital protection of traditional residential villages is a key focus of attention for many architectural designers, allowing them to rejuvenate while showcasing their authenticity and integrity. This article studies the protection mechanism and effectiveness of traditional digital residential villages using architectural style transfer algorithms from the above background and explores the practical application of the integration of style transfer algorithms and CAD collaborative design. Firstly, conduct a specific analysis of the protection issues of traditional residential villages, understand the necessary cultural background in the protection work, and better grasp the development laws of residential villages. Combining theoretical research with empirical analysis, explore architectural styles suitable for the protection of traditional residential villages from classic cases. Secondly, using architectural style transfer algorithms to generate image style transfer models, traditional residential architectural styles are integrated with modern design to preserve architectural design details and structure better. Finally, the CAD collaborative design algorithm is used to train a style transfer model, completing the transformation of multiple styles while protecting natural design and meeting unique digital design requirements. Research has shown that architectural style transfer algorithms and CAD collaborative design can not only preserve natural design details in traditional residential villages but also reflect the concept of modern life, promoting cultural inheritance and development.

Keywords: Architectural Design; Style Transfer Algorithm; Digitization; Traditional Residential Villages; CAD Collaborative Design
DOI: https://doi.org/10.14733/cadaps.2024.S26.30-43

1 INTRODUCTION

Traditional residential villages are a key focus of rural development and protection. How to effectively maintain the preserved residential buildings and how to renovate the damaged residential buildings are all key concerns in our research on the protection of traditional residential villages. In the protection of traditional residential villages, the application of CAD digital technology not only improves the design efficiency but also provides a new way for the protection and inheritance of traditional architectural culture. Caetano and Leitao [1] summarized the evolution process of CAD digital technology in the calculation and design method of traditional residential village protection buildings. As the carrier of history and culture, the architectural style and characteristics of traditional residential villages have rich cultural connotations. However, with the acceleration of modernization, many traditional residential villages are facing the risk of disappearing. Therefore, how to protect and inherit this valuable cultural heritage has become an urgent problem to be solved. The application of CAD digital technology provides a new technical means for the protection and inheritance of traditional residential villages. Through digital modelling, parametric design and other methods, CAD technology can achieve precise protection and sustainable development of traditional residential villages. In addition, in the process of protecting traditional residential villages, in addition to paying attention to the changes in architectural styles, the core values of traditional residential buildings should also be reflected in multiple aspects such as cultural and ethnic connotations. With the continuous development of computer vision and digital modelling technology, indoor camera pose estimation has become an important research field. Chen et al. [2] proposed a method of indoor camera pose estimation based on a digital 3D model of architectural style conversion. By constructing three-dimensional building models with different styles, and using these models for pose estimation, it provides a new solution for indoor environment navigation, virtual reality and other fields. In the process of architectural style transformation, it adopts deep learning technology, especially the generation of confrontation networks (Gans) and other models. By training these models, we can learn the mapping relationship between different styles, and apply these relationships to the construction of 3D models. In this way, you can generate 3D building models with different styles but maintaining structural consistency.

From existing data, it is known that the renovation of traditional residential villages is the main way to promote rural digital construction. The protection work truly reflects the characteristics of simple and natural architecture and seizes the unique characteristics of residential villages. Chen et al. [3] explored how novice computational designers can effectively assist in the exploration and practice of residential village building protection design through empowering algorithms. As an important carrier of historical and cultural heritage, the architectural protection design of residential villages is of great significance for inheriting regional culture and promoting national spirit. However, in the actual process of protective design, designers often face many challenges. Empowerment algorithms can quickly collect and process a large amount of residential village building data, including building dimensions, structural features, material properties, etc., providing designers with comprehensive and accurate information support. Through technologies such as deep learning, empowering algorithms can automatically identify the style features of residential village buildings, classify and summarize them, and help designers better understand and grasp architectural styles. Dinh and Thi [4] discussed the application of CAD collaborative design in the construction of sustainable development-related minority residential space models. Based on the analysis of the characteristics of minority living space and the advantages of CAD collaborative design, this paper proposes a design method for a minority living space model based on sustainable development, in order to provide beneficial ideas for protecting and inheriting minority culture and promoting sustainable development. The residential space of ethnic minorities usually has a unique architectural form and decorative style, which reflects the history, culture and living habits of all ethnic groups. These features are not only reflected in the architectural appearance but also in the spatial layout, functional zoning and other aspects. Therefore, when constructing the minority residential space

model, we need to fully consider these characteristics to ensure the accuracy and representativeness of the model.

Huang et al. [5] explored the optimization strategy of traditional village architectural layout based on spatial syntax and spatial resistance model. It improves the utilization efficiency of village space, improves the quality of life of residents, and protects and inherits the historical and cultural value of the village. Under the rapid development of modern society, the spatial layout of traditional villages often finds it difficult to adapt to new living needs and development requirements. Therefore, optimizing the architectural layout has become an important issue for the protection and development of traditional villages. Spatial syntax is a method of studying spatial organization rules by analyzing spatial structural relationships. In the analysis of traditional village architectural layout, spatial syntax can help us reveal the internal logic and laws of village spatial structure. By constructing a syntactic model of village space and analyzing indicators such as accessibility and integration, we can gain a deeper understanding of the hierarchy, nodes, and streamlining of village space, providing a scientific basis for formulating optimization strategies. Translate surface renovation work into internal renovation achievements that truly improve the quality of life of the people, and improve the quality of building safety, structural stability, and other aspects. Secondly, the protection of traditional residential villages also requires attention to the inheritance of style, culture, and values. Not only should ethnic and cultural symbols be preserved, but also the architectural style should be shifted towards a more digital direction based on the actual situation and the needs of the masses for modern life. According to the survey, traditional residential villages are a representative part of most village buildings and an extremely valuable ecological and cultural heritage. After years of continuous traditional village protection projects, the National Cultural Relics Department, finance department, and urban and rural construction department have saved hundreds of thousands of historical buildings and traditional residential buildings that are on the brink of disappearance. Augmented reality technology provides users with an immersive experience by overlaying virtual information in the real world. In the field of architecture, augmented reality-based 3D building scene construction technology can integrate virtual building models with real environments in real time. Krner et al. [6] created a building model using 3D modelling software, including the geometric structure, material texture, and other information about the building. Then, using image processing techniques, the real-world images are recognized and processed to extract key information such as spatial location, lighting conditions, etc. Finally, through spatial positioning technology, the virtual building model is accurately aligned with the real environment to achieve augmented reality effects.

Lin [7] discussed how to use algorithmic frameworks to develop topology algorithms for the conceptual design of digital residential buildings, in order to achieve innovative, efficient, and personalized architectural design. By introducing the basic principles and application scenarios of topology algorithms, the advantages of algorithm frameworks in the conceptual design of residential buildings are analyzed. A topology algorithm development method based on algorithm frameworks is proposed, and its potential applications and challenges are discussed. In the field of architectural design, topology algorithms can be used to generate building models with specific shapes and structures. By defining a series of topological rules and constraints, the algorithm can automatically generate building forms that meet the requirements, thereby achieving innovative design. The digital technologies involved include style transfer algorithms and CAD computer-aided collaborative design. Style transfer algorithm is a technology that utilizes computer and information processing methods to integrate content such as images, videos, multimedia elements, etc. with other resources. The online architectural style draws on various elements of traditional architectural styles while incorporating features such as modern technology, digital art, and interactive experiences. The online architectural style emphasizes integration with the environment, interaction with people, and innovative expression, bringing a unique visual feast to modern cities. Ma et al. [8] explored how to use AutoCAD for the transformation of network architectural styles and conducted a systematic analysis. By extracting and integrating style elements, balancing functionality and aesthetics, and evaluating technical feasibility, the rationality and feasibility of design style transformation can be ensured. The design of network architecture style should not only focus on aesthetics but also

consider the functionality of the building. Designers need to transform and innovate their styles while meeting their usage needs. At the same time, it is also necessary to consider the relationship between buildings and the environment to ensure their coordination.

Although traditional computer-aided design can meet the requirements of planar creativity, facing the limitations of the multi-dimensional spatial environment in practical applications, computer-aided design CAD technology requires higher collaborative strategies. As an important carrier of historical and cultural heritage, traditional villages have unique regional and ethnic characteristics in their spatial form and architectural features. Meng et al. [9] proposed a data-driven method for constructing traditional village spatial databases, aiming to achieve accurate recording and effective management of traditional village spatial information through data analysis and processing. As a typical representative of traditional villages, Yunnan courtyard houses have unique regional and ethnic characteristics in terms of spatial form and architectural features. Taking Yunnan courtyard residential buildings as an example demonstrates the effectiveness of a data-driven spatial database construction method in practical applications. By collecting, processing, and analyzing spatial data of courtyard houses in Yunnan, a spatial database containing multi-dimensional information such as spatial layout, architectural characteristics, and environmental characteristics was constructed. CAD technology can meet the spatial requirements of architectural style in the final visual presentation. In the protection of digital traditional residential villages, architectural styles inspired solely by the personal experience and intuition of designers can no longer meet people's requirements for modern life[10]. Therefore, utilizing the high computing power, high precision processing, and high fault tolerance of architectural style transfer algorithms and CAD collaborative design, we provide the most direct design assistance for architectural designers and simplify the complexity of traditional residential village protection work.

2 RELATED WORK

CAD collaborative design, as an efficient design method, reduces communication barriers and errors among different specialities through unified design standards and platforms and improves design efficiency and quality. In high-density residential planning, Ng et al. [10] used CAD collaborative design to ensure close collaboration among various specialities, forming an integrated design scheme from spatial optimization, and functional layout to building material selection. Digital gamification, on the other hand, provides interesting and effective tools for participatory design in high-density residential planning due to its educational and recreational nature. The digitalization of traditional ancient villages has gradually become an enhanced democratic feature of current tourism development. Huizhou ancient dwellings, as an important component of China's ancient architectural system, are treasures of traditional Chinese architecture with high academic research value and modern inheritance significance. Based on field research and analysis of surveying and mapping data of ancient dwellings, Shen et al. [11] analyzed the landscape perception and cognitive preferences of ancient Chinese villages. It participated in the digital construction and protection of village landscape planning through network data. Using mathematical statistical analysis based on digital architecture technology and the pressure white ruler method in feng shui theory to solve the modulus of ancient residential buildings. The overall layout and spatial level of the village are the important cognition of tourists to the overall image of the village, and the landscape line of sight is related to the visual experience of tourists during the tour. The CAD collaborative design network data can accurately record the spatial layout and line of sight relationship of the village landscape, which provides strong support for the study of tourists' spatial perception.

Tai and Sung [12] discussed the necessity and implementation of computer-aided methods for digital archiving of the perception experience of architectural space. It provides new ideas and methods for the design, protection, and dissemination of architectural spaces. Ververidis et al. [13] combined the history of measurement and traditional residential construction to digitally calculate the carpentry scale values of six Huizhou ancient villages in the Yixian, Shexian, and Wuyuan districts. And summarize the development trend of woodworking rulers during the Ming and Qing dynasties. On this basis, the knowledge of academic disciplines such as geography, sociology,

economics, and history was applied to analyze the changing trends, regional distribution characteristics, and related influencing factors of woodworking rulers. Finally, the application ideas of the research results are elaborated from three aspects: the analysis of the origin of Huizhou ancient dwellings, the repair and protection of Huizhou ancient dwellings, and the dating. Due to the highly systematic architectural characteristics of traditional ancient dwellings, their modular system, planar spatial structure, and the proportional relationship between various spatial elements are different. The generation rules of its plan are closely related to the design and creation of architecture. In the past, scholars often used research methods and content from the perspectives of ancient dwellings or collective villages, with a focus on qualitative research. There are few studies that use mathematical methods to conduct an in-depth analysis from a quantitative perspective, which is not conducive to a comprehensive and in-depth analysis of the characteristics of Huizhou's ancient dwellings. Wang et al. [14] proposed a hybrid evolutionary algorithm for optimizing the design style strategy of ancient architecture. By freezing the architectural heritage style, a genetic algorithm was used for a natural selection of architectural style. By analyzing the evolutionary strategy algorithm, it has protected the decorative elements of ancient buildings. At present, research on the flat form of traditional cultural heritage houses still mostly focuses on the perception of their form. There is relatively little content that statistically analyzes the proportion of its form composition to obtain substantive and objective laws. The research on the application of architectural digital technology in traditional architecture, including formal grammar, is mostly conducted at the level of abstract form and neglects the meaning of mathematical proportions. There are very few studies in China that combine the two with ancient residential buildings as the research object. Xin and Daping [15] conducted an analysis of an art digital analysis system based on image architecture technology decoration. It has been constructed in a digital style, using the architectural style of ancient villages. By preserving the adaptive digital architectural style structure, the characteristics of ancient architectural art and decorative elements have been inherited.

Zhang and Deng [17] discussed the architectural style atmosphere parameters under landscape colours. It analyzed the architectural style results under different colour combinations by coordinating and controlling the colour matching of buildings. In the colour scheme, the use of computer-aided collaborative design has played a good role in finely controlling the impact of colours. Its research needs to combine two analysis strategies of sufficient hand and foot characteristics, so the number of samples selected varies in different regions. For example, in villages that are also under the jurisdiction of the county, due to the significantly smaller number of residential buildings in the town compared to other villages and towns, a smaller and more representative number of residential buildings are selected as the research sample. Zhang et al. [18] conducted an analysis of building model construction for image cases, using scene recognition with different spatial positions and lighting conditions to overlay model information and provide spatial positioning with great care.

3 RESEARCH ON ARCHITECTURAL STYLE TRANSFER ALGORITHM IN THE PRACTICE OF DIGITAL TRADITIONAL RESIDENTIAL VILLAGE PROTECTION AND CAD COLLABORATIVE DESIGN

3.1 Research on the Application of Architectural Style Migration Algorithm in the Protection of Traditional Residential Villages in Digital Needs

With the rapid integration and development of new technologies in the field of architecture, various innovations in materials, structures, and processes continue to emerge. The concept of energy-saving and emission-reducing buildings, as well as the new ideas of enhancing building technology through photovoltaic technology, have also brought opportunities and challenges to the development of traditional residential protection building design. On the one hand, utilizing new technologies can accelerate the speed of digital residential construction, and on the other hand, it can increase the safety and durability of traditional buildings, ensuring the sustainable development of traditional residential village protection. In the design of protecting ethnic village architecture, it is not only necessary to restore the authenticity of historical culture but also to achieve cultural continuity. Integrating ethnic culture with modern life is truly in line with the development

requirements of social construction for rural revitalization. We first explore the actual forms of multiple ancient villages that meet the protection conditions of traditional residential villages based on the data database. In data analysis, it was found that these traditional residential villages have been designated as key places for rural tourism, not only possessing rich historical and cultural resources but also possessing significant natural ecological value. Secondly, we selected classic residential villages located in the northern region as research cases. The village is located in a relatively flat area with a concentrated distribution of residential buildings, and the interior of the village is crisscrossed. The architectural design is mainly made of grey tiles and stone walls. We conducted a statistical analysis of the use of building materials in traditional residential villages, as shown in Figure 1:

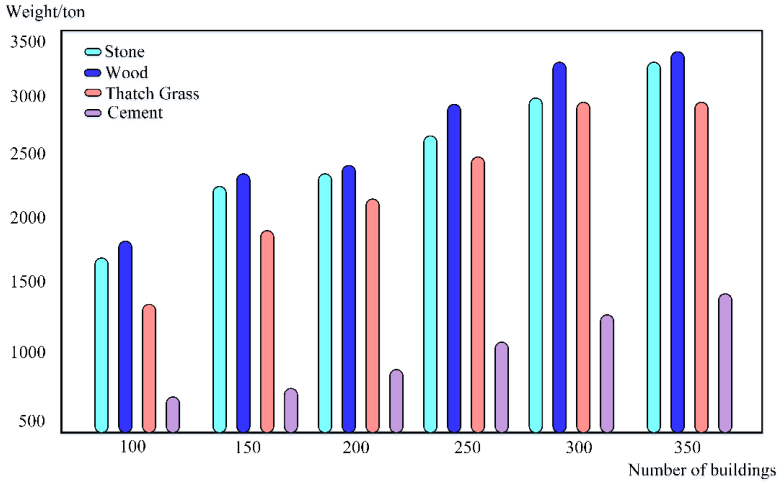

Figure 1: The use of materials in traditional residential village buildings.

From Figure 1, it can be seen that traditional building materials extensively use natural resources such as stones, wood, and thatch, with only a small portion using finely processed materials such as cement. These residential buildings were originally designed to meet basic survival needs, and the adaptability of the ecological environment was fully considered in site selection and construction. The architectural style also continues the traditional courtyard construction model, facing north and south, with the main gate generally located in the eastern part of the south wall, with a clear horizontal axis plan, and a clear hierarchy of building structures. From this, it can be seen that the protection and planning of traditional residential villages need to be different from general village design, with a focus on the overall and unified architectural style, as well as meeting the limitations of building material selection under the integration of the ecological environment. Pay attention to the historical environment and cultural inheritance, and protect the spiritual characteristics of traditional architectural style. This article uses a style transfer algorithm to construct the architectural design system of digital traditional residential villages in the research. Style transfer algorithm is an important technical means in the field of visual design, which can map the style features of one design image to another image while maintaining the overall characteristics of the original design style unchanged. This technology is very in line with the protective requirements of traditional residential design styles, which can not only preserve the characteristics of original ethnic and cultural elements but also meet the needs of modern and digital architectural style transformation. The adversarial network capability contained in the architectural style transfer algorithm can break the limitations of data training and use non-composite training data to complete the transfer of design style. This adversarial structure does not have overly complex loss functions and only requires a generator to achieve dynamic balance in the design.

We collected visual elements from traditional residential village architectural styles and incorporated them into the style transfer model to form a discriminative network pattern to generate architectural style design. Replace the original architectural style images with real image samples with highly similar data in the migration model. By iteratively training the model, sample design works that are increasingly realistic and in line with digital design are generated. In order to minimize the optimal solution of the entire model for similar features in computation, the objective function is defined as:

$$\min V(D,G) = E_{X\sim Pdata(X)}[\log D(X)] \tag{1}$$

$$\max V(D,G) = E_{X\sim Pz(X)}[\log(1-D(G(x)))] \tag{2}$$

Among them, X after defining the distribution range between the input noise in the transfer generator and the real data of the design image, representing the style image data, the loss function of the data during the training cycle can be obtained:

$$loss = loss_{CAN} + loss_{cycle} \tag{3}$$

$$loss_{CAN} = l_{GAN}(G, D_Y, X, Y) + l_{GAN}(F, D_X, X, Y) \tag{4}$$

Adding the style similarity feature data calculated by the formula to the transfer model can generate real design solutions with traditional design styles. Ensure that the output style of the model is different from the original design of residential villages, but the overall style is the same. The network structure diagram of the style transfer model is as follows:

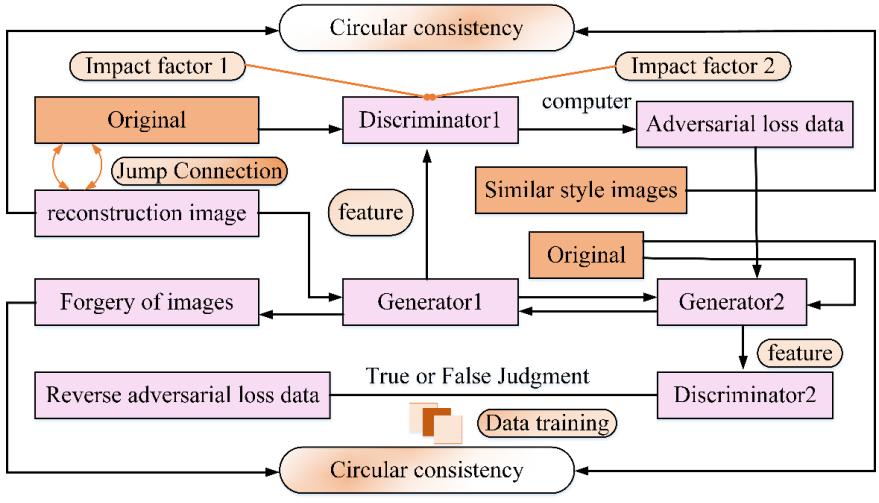

Figure 2: Network structure diagram of style transfer model.

From Figure 2, it can be seen that the initial image is calculated by the discriminator to obtain the feature data under adversarial loss calculation, which is then added as an input source to the generator and transformed into a forged image. Generate a reconstructed architectural design plan based on the style requirements of digital residential buildings. Among them, the main goal of generating models also includes reducing the impact of original architectural design elements on the real design scheme. In order to maintain the consistency of design image style conversion, a cyclic consistency loss mechanism is introduced to restore the traditional residential village architectural style to the maximum extent. The formula for calculating the consistency loss function is as follows:

$$L_{identity}(G_{P2S}, G_{S2P}, P, S, L_P, L_S) = E_{P\sim Pdata}[G_{S2P}(P \mid L_P) - P] \tag{5}$$

Among them, $E_{P\sim Pdata}$ the mathematical expectation value representing similar feature coefficients, if the design image input to the model is the demanding style, according to the principle of consistency loss, the corresponding style label remains unchanged. We define the style discretization calculation function as:

$$L_{ds}(G_{p2s},P,L_s)=E_{S\sim P}[G_{p2s}/G(P\mid L_s)] \tag{6}$$

Among them, G represents the style label type generated by the design. In order to enable the style transfer model to handle more complex image data, we have improved the original formula of its objective function:

$$L(X)=\frac{1}{1+e^{-x}} \tag{7}$$

Add a faster mechanism for exporting design data, expressed as:

$$y(x)=\max(0,x) \tag{8}$$

By extracting content and style features through design, calculate the formula for the information lost in the extraction:

$$L=\alpha\times L_P+\beta\times L_X \tag{9}$$

In the formula, α the data weight represents style loss. In the style transfer algorithm model, we attach great importance to the analysis of global information through the attention mechanism and choose task objectives that are in line with digital residential villages as key information, which can better apply all feature styles of architectural design images. Given content data and a style input, matching the corresponding style cases by adjusting the mean and difference of the input data requires a large number of samples for this feature mapping. The formula for calculating the mean and difference of each feature sample is as follows:

$$u(x)=\frac{1}{NHW}\sum_{n=1}^{N}\sum_{h=1}^{H}\sum_{w=1}^{W}x \tag{10}$$

$$\sigma(x)=\sqrt{\frac{1}{NHW}\sum_{n=1}^{N}\sum_{h=1}^{H}\sum_{w=1}^{W}(x-u(x))^2+\varepsilon} \tag{11}$$

The normalization formula for the data sample style is as follows:

$$BN(X)=a(\frac{x-u(x)}{\sigma(x)})+\beta \tag{12}$$

Unlike the style transfer of a single sample, the mean dimension of a diverse set needs to retain standard information:

$$IN(x)=a(\frac{u+(x)}{\sigma})+\beta^2 \tag{13}$$

$$u(x)=\frac{1}{HW}\sum_{h=1}^{H}\sum_{w=1}^{W}x \tag{14}$$

$$\sigma_{nc}(x)=\sqrt{\frac{1}{HW}\sum_{h=1}^{H}\sum_{w=1}^{W}(x_{nchw}-u_{nc}(x))^2+\varepsilon} \tag{15}$$

In the formula, ε represents a very small constant, and the position of the constant is the final generated style sample. Our style transfer model can also focus on its own design orientation, extracting more key information from traditional design images without using additional data. However, this style transfer work that generates digital architectural design schemes based on existing data information has certain shortcomings in the face of multi-user needs and natural

ecological conditions. In the future, we will use CAD collaborative design strategies to optimize and update its transfer model.

3.2 Research on the Practical Effect of the Integration of CAD Collaborative Design and Architectural Style Transfer Algorithm

The combination of digital information and computer software in architectural design can accelerate the formation of design schemes and assist designers in collecting and analyzing information and files related to architectural style in the early stage of scheme generation. Computer-aided drawing CAD technology is one of the most mature tools in application. It can directly use graphic software to generate multi-dimensional images and parameterize architectural styles through human-computer interaction. We have recorded the number and development of research on CAD collaborative design technology in various fields, as shown in Figure 3:

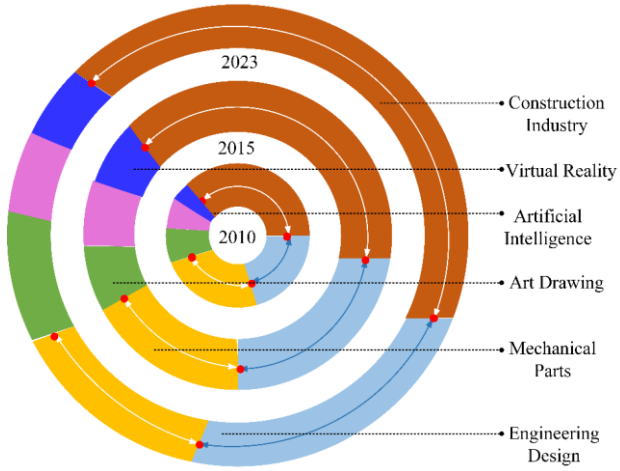

Figure 3: The development and changes in the research quantity of CAD collaborative design technology in various fields.

As shown in Figure 3, CAD computer-aided collaborative design has a relatively large research proportion in the construction industry, followed by engineering design and mechanical component manufacturing. With the gradual maturity of this technology, it has also been well applied in other design industries. Due to the digital updating of traditional residential village architectural design, which needs to meet both modern functional requirements and various conditions such as comfort, safety, and information exchange, these basic requirements are likely to have an impact on the design process of architectural style. At the same time, the architectural style transfer algorithm mainly relies on manual analysis as the data support for the style model when constructing the system model, and creates a simulated image style rendering based on the data information. This style transfer technique relies heavily on specific artistic elements in simulated environments and cannot be extended to more realistic natural style effects. So we incorporated CAD collaborative design technology into our research to optimize the process of image style conversion, making the architectural style transfer effect more visually enhanced and meeting the functional requirements of digital residential buildings. Before conducting CAD collaborative design optimization, it is necessary to unify the drafting standards based on the data provided for architectural style transfer. The platform needs to be embedded with a CAD work environment, using resources such as image libraries, text libraries, templates, etc. that conform to traditional residential architectural styles. The internal working structure of the CAD collaborative design optimization style transfer algorithm design platform is shown in Figure 4.

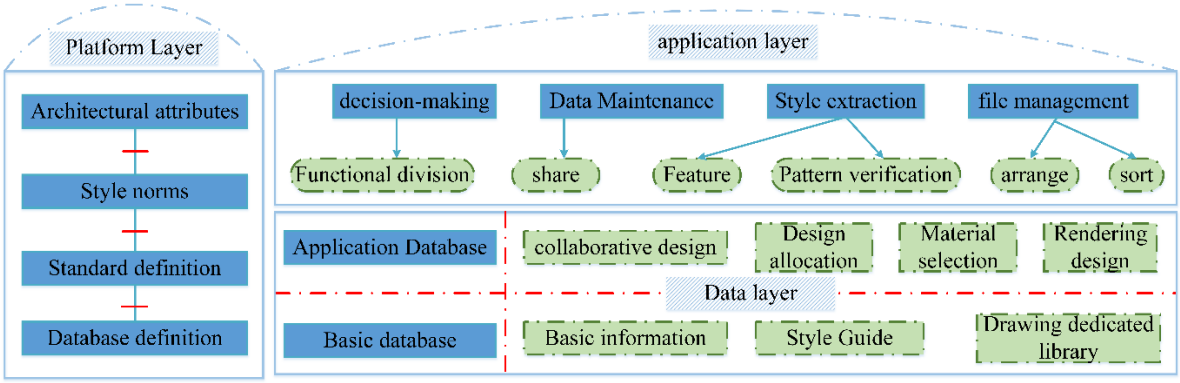

Figure 4: The style transfer algorithm for CAD collaborative design optimization and the internal work structure of the design platform.

As shown in Figure 4, the first step is to define resources such as architectural style specifications, standards, and databases. The collaborative application of the system includes the maintenance of data, extraction of style information, and management of design archives. The data layer also includes a basic database to store basic project information, specialized drawings, and traditional residential-style catalogs. The style transfer model for CAD collaborative design optimization adopts a three-layer architecture. In addition to being able to access style data, it can also establish a certain service foundation and assist in the conversion and connection between servers and databases, making it convenient for designers to use. In addition, CAD collaborative design can also improve the rendering effect of architectural style transfer models. The original design image only contains basic texture information and does not provide systematic explanations for detailed content such as colour, layout, and structure. The optimized architectural style transfer model can deeply extract visual element features and maximize the creation of digital, traditional residential design concepts by architectural designers. In the future, we will explore the changes in architectural effects after the integration of the architectural style transfer algorithm and CAD collaborative design based on the practical application of traditional residential villages in order to further verify the effectiveness of the research algorithm.

4 ANALYSIS OF RESEARCH RESULTS ON ARCHITECTURAL STYLE TRANSFER ALGORITHM IN THE PRACTICE OF DIGITAL, TRADITIONAL RESIDENTIAL VILLAGE PROTECTION AND CAD COLLABORATIVE DESIGN

4.1 Analysis of Research Results on the Application of Architectural Style Transfer Algorithm in the Protection of Traditional Residential Villages in Digital Demand

Traditional residential villages are an important carrier of Chinese ethnic culture and a crystallization of wisdom in cultural inheritance. They not only reflect the essence and soul of ethnic architectural technology but also embody people's desire for social development. The architectural skills of traditional residential villages are gradually falling behind in the transformation of modern society, so we need to pay more attention to the recognition and protection of traditional residential buildings. The use of scientific and information technology to protect the characteristics of traditional residential buildings is necessary to meet the requirements of digital urban and rural construction. We use style transfer algorithms to innovate and generate architectural designs for the protection of traditional residential villages. To verify the effectiveness of the algorithm, we measured the similar changes in

brightness and contrast between traditional architectural design styles and migrated architectural design styles, as shown in Figure 5:

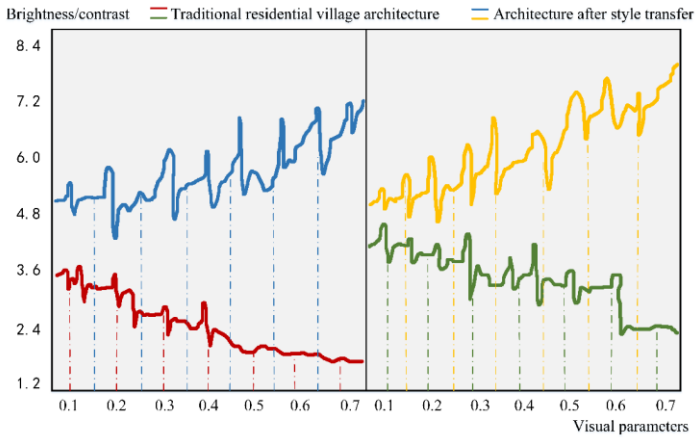

Figure 5: Similar changes in brightness and contrast before and after style transfer.

From Figure 5, it can be seen that the brightness coefficient of the architectural style in traditional residential villages is relatively low, the brightness of the architectural design style generated by the digital migration algorithm is significantly increased, and the contrast is also larger than that of traditional design styles. This indicates that the style transfer algorithm retains the original design elements and only adjusts the target parameters based on visual changes, making traditional residential village design more modern. In addition to judging the effectiveness of the research based on the training results of the style transfer model, we can also study the process of training data features from the system. Extract the adversarial loss value changes of model feature visual data in style transfer transformation and compare it with a regular design system without using transfer algorithms, as shown in Figure 6:

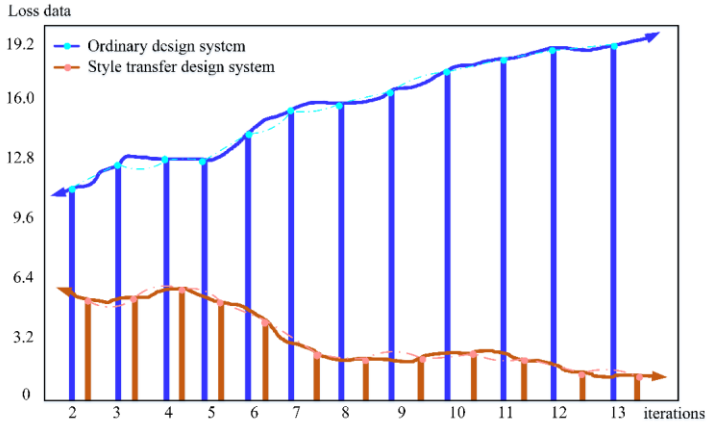

Figure 6: Changes in Loss Data for Two Systems.

From Figure 6, it can be seen that as the number of iterations through sample training increases, the loss value of the method used in this paper during visual data training becomes smaller and smaller.

Systems that do not use transfer algorithms consume more effective data during style transformation. The protection concept of digital traditional residential villages also needs to organize and display the historical and cultural information as well as natural environment information contained in traditional villages and complete the inheritance of cultural values through visual forms that are visual, interactive, and innovative.

4.2 Analysis of Practical Application Research Results on the Integration of CAD Collaborative Design and Architectural Style Transfer Algorithms

The protection of digital traditional residential villages is not only about updating the design concept of traditional residential buildings to better meet the needs of modernization but also interpreting the culture of residential villages from multiple dimensions and perspectives to achieve sustainable development of protecting traditional residential buildings. The concept of digital protection is not only applied in data collection, data analysis, design and creation but also through digital means to present traditional residential villages, which can not only reflect national cultural values but also improve modern resource construction. So, in our research, we use CAD collaborative design and style transfer algorithms to integrate and pay attention to the scene rendering of traditional residential buildings when generating architectural style design models. Add matching colours and architectural structures based on local cultural heritage and natural ecological environment. We applied the architectural design scheme generated by the fusion of CAD collaborative design and style transfer algorithm in the renovation of traditional residential buildings in a certain area, and statistically analyzed the feedback performance of existing residents and foreign tourists, as shown in Figure 7:

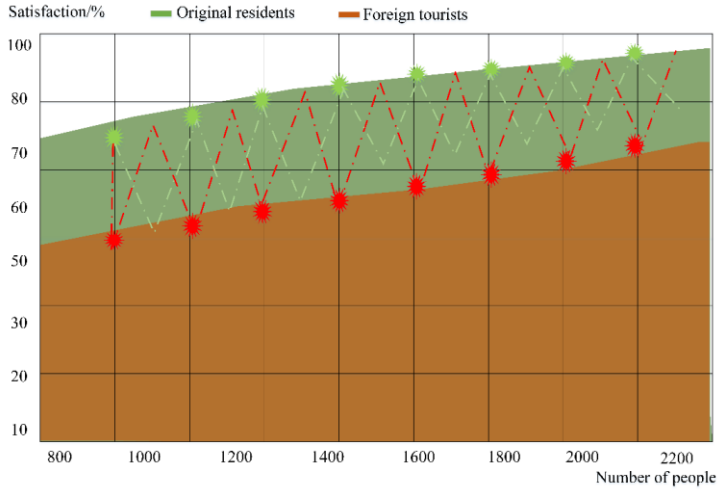

Figure 7: Feedback from existing residents and foreign tourists.

As shown in Figure 7, the traditional residential design scheme generated by the architectural style transfer algorithm and CAD collaborative design model studied in this article has received high satisfaction feedback from the original residents, and foreign tourists are also highly satisfied with the optimized architectural design style of traditional residential buildings. After the optimization of CAD collaborative design, the original architectural style transfer model also showed a significant improvement in data processing speed. In addition, in the protection and construction of traditional residential villages, attention should also be paid to the maintenance of the surrounding natural environment. Residential buildings are not separate building bodies, but a building community that complements nature. Traditional residential buildings can only demonstrate their aesthetic value

against the backdrop of natural ecology. At the same time, in the process of architectural style transfer, it is necessary to incorporate as much feature information related to traditional architecture as possible in the CAD collaborative design system, maintain the same height of the residential building and the original site, and use the same internal structure and materials. For example, traditional residential buildings use integral stone as the building base, so after the design style is transferred, it is also necessary to ensure that the design scheme can be constructed with stone. We have found in our research practice that digital residential buildings presented in 3D models can better represent the historical and cultural style of traditional villages, dynamically display various material cultural heritage, and thus form a unique ecological industry of residential buildings.

5 CONCLUSIONS

The protection of traditional residential villages is an important way to maintain the essence of traditional culture and achieve the integration of inheritance and innovation. Focusing on regional characteristics and the ecological environment of residential buildings, building a digital architectural design style is essential to ensure the sustainable development of traditional residential villages. These digital protection concepts in modern environments can showcase the inherent culture of traditional residential villages in more open spaces. Therefore, the digital transformation of traditional residential village protection is a long-term and complex task. This article uses an architectural style transfer algorithm and CAD collaborative design to study the protection process of digital traditional residential villages and explores the practical effects of the final generated architectural style changes. Firstly, analyze the distribution pattern of traditional residential villages from the database environment, with a focus on exploring external influencing factors such as residential structure and materials used. The adversarial network-generated design model using a style transfer algorithm breaks the limitations of design elements on data training and enhances the modern atmosphere of architectural design style on the basis of the original design. Finally, by combining CAD collaborative design with style transfer algorithms, the architectural design generation model is optimized to achieve a design scheme transformation that combines with the surrounding ecology of traditional residential buildings. And conduct practical analysis on the effectiveness of digital traditional residential village protection, and obtain specific research and application results from feedback from different groups. This study indicates that the architectural style transfer algorithm and CAD collaborative design have reliable applicability value in the protection of digital traditional residential villages. Not only does it protect the ecological environment around residential buildings, but it also inherits the original architectural design style of residential buildings, integrating it with digital styles to meet the modern living needs of residents.

6 ACKNOWLEDGEMENTS

The phased results of the scientific research project funded by the Shaanxi Provincial Department of Education, "Research on the Digital Protection of Traditional Residential Villages in Hancheng Dangjia Village" (No. 20JZ047); The results of the scientific research project of the Key Laboratory of Shaanxi Provincial Department of Education, "Investigation and Risk Assessment of Invasive Plants in the Weihe Wetland" (No. 20JS047).

Shuying Zhao, https://orcid.org/0009-0003-8952-3448
Hengxing Xie, https://orcid.org/0009-0002-3133-0216

REFERENCES

[1] Caetano, I.; Leitao, A.: Architecture meets computation: an overview of the evolution of computational design approaches in architecture, Architectural Science Review, 63(2), 2020, 165-174. https://doi.org/10.1080/00038628.2019.1680524

[2] Chen, J.; Li, S.; Liu, D.; Lu, W.: Indoor camera pose estimation via style-transfer 3D models, Computer-Aided Civil and Infrastructure Engineering, 37(3), 2022, 335-353. https://doi.org/10.1111/mice.12714
[3] Chen, K.-W.; Choo, T.-S.; Norford, L.-K.: Enabling algorithm-assisted architectural design exploration for computational design novices, Computer-Aided Design and Applications, 16(2), 2019, 269-288. https://doi.org/10.14733/cadaps.2019.269-288
[4] Dinh, T.-N.; Thi, H.-L.: Models of residential space for ethnic minorities in thanh hoa province associated with sustainable livelihoods, Heritage and Sustainable Development, 6(1), 2024, 127-144. https://doi.org/10.37868/hsd.v6i1.258
[5] Huang, Y.; Zhang, Z.; Fei, J.; Chen, X.: Optimization strategies of commercial layout of traditional villages based on space syntax and space resistance model: a case study of Anhui Longchuan Village in China, Buildings, 13(4), 2023, 1016. https://doi.org/10.3390/buildings13041016
[6] Krner, A.; Born, L.; Bucklin, O.: Integrative design and fabrication methodology for bio-inspired folding mechanisms for architectural applications, Computer-Aided Design, 133(80), 2020, 102988. https://doi.org/10.1016/j.cad.2020.102988
[7] Lin, C.-J.: Topological vision: applying an algorithmic framework for developing topological algorithm of architectural concept design, Computer-Aided Design and Applications, 16(3), 2019, 583-592. https://doi.org/10.14733/cadaps.2019.583-592
[8] Ma, K.; Mao, Z.; He, D.; Zhang, Y.: Design a network architectural teaching system by auto CAD, Computer-Aided Design and Applications, 17(S2), 2020, 1-10. https://doi.org/10.14733/cadaps.2020.S2.1-10
[9] Meng, Y.; Zhai, H.; Teoh, B.-K.; Tiong, R.-L.-K.; Huang, S.; Cen, D.; Cui, C.: A data-driven method for constructing the spatial database of traditional villages—a case study of courtyard residential typologies in Yunnan, China, Buildings, 13(12), 2023, 2956. https://doi.org/10.3390/buildings13122956
[10] Ng, P.; Li, Y.; Zhu, S.; Xu, B.; Ameijde, J.: Digital common (s): the role of digital gamification in participatory design for the planning of high-density housing estates, Frontiers in Virtual Reality, 3(1), 2023, 1062336. https://doi.org/10.3389/frvir.2022.1062336
[11] Shen, H.; Aziz, N.-F.; Huang, M.; Yu, L.; Liu, Z.: Tourist perceptions of landscape in Chinese traditional villages: Analysis based on online data, Journal of Tourism and Cultural Change, 22(2), 2024, 232-251. https://doi.org/10.1080/14766825.2023.2240297
[12] Tai, N.-C.; Sung, L.-W.: Digital archiving of perceptual experiences of an architectural space with computer-aided methods, Computer-Aided Design and Applications, 17(3), 2019, 585-597. https://doi.org/10.14733/cadaps.2020.585-597
[13] Ververidis, D.; Nikolopoulos, S.; Kompatsiaris, I.: A review of collaborative virtual reality systems for the architecture, engineering, and construction industry, Architecture, 2(3), 2022, 476-496. https://doi.org/10.3390/architecture2030027
[14] Wang, L.; Janssen, P.; Ji, G.: SSIEA: a hybrid evolutionary algorithm for supporting conceptual architectural design, AI EDAM, 34(4), 2020, 458-476. https://doi.org/10.1017/S0890060420000281
[15] Xin, W.; Daping, Q.: Digitalization system of ancient architecture decoration art based on neural network and image features, Journal of Intelligent & Fuzzy Systems, 40(2), 2021, 2589-2600. https://doi.org/10.3233/JIFS-189251
[16] Yu, X.; Zhou, G.: Arbitrary style transfer via content consistency and style consistency, The Visual Computer, 40(3), 2024, 1369-1382. https://doi.org/10.1007/s00371-023-02855-5
[17] Zhang, M.; Deng, X.: Color effect of landscape architecture design under computer-aided collaborative design system, Computer-Aided Design and Applications, 19(S3), 2021, 13-22. https://doi.org/10.14733/cadaps.2022.S3.13-22
[18] Zhang, X.; Yao, J.; Dong, L.; Ye, N.: Research on 3D architectural scenes construction technology based on augmented reality, Journal of Computational Methods in Sciences and Engineering, 21(2), 2021, 311-327. https://doi.org/10.3233/JCM-204390