Data Mining-based Enhancement of Environmental Art Design

Shilai Zhang[1] and Changchang Xu[2]

[1]School of Art, Anhui Jianzhu University, Hefei, Anhui 230601, China,
13965007580@163.com
[2]School of Marxism, Anhui Jianzhu University, Hefei, Anhui 230601, China,
Zhx100824@ahjzu.edu.cn

Corresponding author: Changchang Xu, Zhx100824@ahjzu.edu.cn

Abstract. The core goal of environmental art design is to create a harmonious, beautiful, and functional spatial environment. Computer-aided design (CAD) technology provides a powerful creative platform for environmental art designers, enabling them to more conveniently and quickly transform their creativity into concrete 3D models. In this study, the DM algorithm is utilized to process and analyze extensive datasets within the CAD environment, enabling the extraction of valuable insights. Additionally, we introduce the Fuzzy Neural Network (FNN) to address the challenge of optimizing design parameters in environmental art design within the CAD context. Our method offers enhanced detail representation, improved modeling efficiency, and increased flexibility compared to traditional CAD modeling approaches. The results of our study demonstrate that the proposed method can generate more realistic and refined CAD models, significantly reducing the need for manual intervention and enhancing modeling efficiency. These advancements open up new avenues for innovation in the field of environmental art and design, contributing to improved design quality, shortened project timelines, and cost reduction.

Keywords: Data Mining; Environmental Art Design; CAD; Fuzzy Neural Network
DOI: https://doi.org/10.14733/cadaps.2024.S19.132-147

1 INTRODUCTION

Environmental art design, being a multidisciplinary domain, encompasses various fields such as architecture, interior design, and landscape design, with the primary objective of creating a harmonious, aesthetically pleasing, and functional spatial environment. In sculpture art, space is an important component of a work. CAID technology can help sculptors better understand and express spatial relationships. Through the three-dimensional modeling and rendering technology of computers, sculptors can simulate the final presentation effect of works in a virtual environment and more accurately grasp the spatial and three-dimensional sense of the works. CAID technology allows sculptors to design shapes more freely. Guo and Wang [1] used parametric design tools to create complex surfaces and curves, achieving smoother and more dynamic shapes. Meanwhile, by simulating and analyzing physical properties such as gravity and wind, sculptors can better understand the relationship between form and environment, thus creating more realistic works. In sculpture art, the expression of texture is crucial for the visual effect of a work. CAID technology can help sculptors simulate and adjust the texture of materials such as stone, wood, metal, etc. By adjusting the properties of materials, such as reflection, refraction, texture, etc., sculptors can create more realistic works. As society progresses and people's aesthetic sensibilities evolve, the demand for environmental art design continues to escalate. Conventional methods in environmental art design typically rely heavily on the designer's individual expertise and intuition, resulting in a time-consuming and often unpredictable design process. In traditional design processes, aesthetic evaluation often relies on the designer's experience and subjective judgment. Fuzzy neural networks can form an objective and quantitative aesthetic evaluation system by learning a large amount of aesthetic data. In this way, designers can more scientifically evaluate the aesthetic value of design schemes and make more reasonable decisions. Fuzzy neural networks combine the advantages of fuzzy logic and neural networks, possessing both the reasoning ability of fuzzy logic and the self-learning ability of neural networks. It can effectively handle uncertainty and nonlinear problems by simulating the thinking patterns of the human brain. A fuzzy neural network consists of a fuzzification layer, a rule layer, and a deblurring layer, which can infer based on input information and generate corresponding outputs. Interactive design can be achieved by combining fuzzy neural networks with virtual reality (VR) technology. He and Sun [2] observe real-time changes in design solutions in a virtual environment and interact with models to improve and optimize the design. CAD technology provides a powerful creative platform for environmental art designers, which enables designers to transform their ideas into concrete three-dimensional models more conveniently and quickly. Intelligent adaptive systems, as an emerging technology, can automatically adjust their behavior according to environmental changes to meet various complex design requirements. Hoang et al. [3] explored how to use intelligent adaptive systems to form construction trajectories for computer-aided design environments in order to provide new ideas for practical applications in related fields. The intelligent adaptive system combines the advantages of artificial intelligence and adaptive control and can automatically adjust its internal parameters and behavioral strategies according to environmental changes and target requirements to achieve optimal performance. In computer-aided design environments, intelligent adaptive systems can perceive the needs and feedback of designers in real-time, automatically optimize design solutions, and improve design efficiency and quality. Through real-time feedback and iterative optimization, intelligent adaptive systems can continuously improve design solutions until the designer's expected goals are achieved. This dynamic and adaptive design process helps to improve the flexibility and adaptability of computer-aided design environment design. However, in the process of environmental art design in a CAD environment, designers still face many challenges, such as how to effectively manage and optimize a large number of design parameters to improve the design level and innovation.

DM is the process of extracting meaningful insights from vast amounts of data, aiding designers in gaining a deeper understanding and making more effective use of data within the CAD environment. In recent years, DM has garnered significant achievements in diverse fields, such as image processing, speech recognition, and natural language processing. Environmental art planning is a comprehensive design work involving multiple disciplines, including landscape design, architectural design, urban planning, and other aspects. In this process, parameterized models, as an important design tool, can help designers better understand and grasp the inherent laws and characteristics of design objects. Jia [4] explored computer-aided design methods for parameterized models of environmental art planning. A parameterized model is a model designed based on parameters and variables, and its core is to control the changes in the model through parameter adjustment. In environmental art planning, parameterized models can help designers better grasp the inherent laws and characteristics of design objects, thereby achieving more accurate and efficient design. By utilizing software such as AutoCAD and Revit, designers can establish parametric models through a graphical interface. This method is relatively simple and easy to learn but may not be able to implement some complex parameterized logic. Its ability to extract valuable information and knowledge from extensive datasets provides designers with more intelligent and efficient design methodologies. The FNN, as an advanced intelligent algorithm, combines the strengths of both fuzzy logic and neural networks. In the CAD environment, landscape design involves a large amount of elements and data, and designers need to extract useful information from the massive data. Data mining algorithms can deeply analyze these data, uncover patterns and patterns hidden behind the design, and provide decision support for designers. In landscape design teaching, the application of data mining algorithms can help students better understand the design process, improve design efficiency, and cultivate innovative thinking. Association rule mining can help designers discover the correlations between different design elements. In landscape design, this correlation may be reflected in plant configuration, terrain treatment, spatial layout, and other aspects. By mining association rules, students can better understand the relationships between different design elements and improve the quality and efficiency of design. Cluster analysis can classify similar landscape designs, helping students understand the characteristics and differences of different design styles. In landscape design teaching, teachers can use the results of cluster analysis to provide targeted guidance to students and help them form their own design style [5]. It excels in handling uncertainty and fuzziness, boasting robust self-learning, self-adaptation, and fault-tolerance capabilities. Environmental art and design, as a comprehensive discipline, aims to create a harmonious, beautiful, and fully functional human living environment. In this process, aesthetics, as an important design principle, plays a decisive role in the success or failure of environmental art design. With the advancement of technology, computer-aided design (CAD) software has been widely used in environmental art design. Jin and Yang [6] discussed the application of computer-aided CAD design software in environmental art design aesthetics, with the aim of providing inspiration for related design and educational work. CAD design software provides precise modeling and rendering tools, enabling designers to better express and shape the beauty of form by adjusting elements such as proportions, lines, and colors, allowing harmonious and beautiful environmental art designs to be created. CAD design software can help designers simulate and optimize spatial layouts in virtual environments to achieve the creation of spatial aesthetics. Through the perspective and shadow rendering functions in the software, spatial depth and hierarchy can be presented, enhancing spatial aesthetics. Environmental art design often involves the integration of cultural elements. CAD design software supports the import and use of various textures, symbols, and graphics, enabling designers to better express and inherit cultural aesthetics. These attributes make FNN particularly well-suited for tackling complex and variable design parameters within the CAD environment, enabling designers to optimize these parameters with greater precision.

This article is devoted to improving the innovation of environmental art design in the CAD environment and optimizing the design parameters by applying the FNN algorithm. Firstly, collect and preprocess relevant data and extract key design features. Subsequently, the FNN model is formulated and undergoes training to grasp the correlation between design parameters and innovation. Once trained, the present design parameters are fed into the model, and adjustments to these parameters are made based on the model's output, aiming to elevate the design's innovation. The primary contributions of this article encompass the following areas:

(1) In this study, a large quantity of data in a CAD environment is processed and analyzed by a DM algorithm, and valuable information is extracted to guide designers in carrying out more innovative and efficient designs.

(2) FNN is introduced into environmental art design in a CAD environment to solve the problem of design parameter optimization.

(3) This article not only shows the advantages of FNN in CAD environmental art design but also discusses the challenges it may face in practical application, which helps readers understand the practical application value of this method more objectively.

The article is structured as follows:

First of all, this article will analyze the basic principles and advantages of FNN from the theoretical level, as well as its application potential in environmental art design. Then, this article will discuss how to construct and apply the FNN model in a CAD environment, including data preprocessing, network structure design, training, and optimization. Through experimental verification, this article will show the excellent performance of FNN in CAD environmental art design.

2 RELATED WORK

Urban environmental art landscape design is an important link in urban planning and construction, involving knowledge and skills from multiple fields. With the development of technology, parameter simulation technology has been widely applied in landscape design, enabling designers to understand and control design objects more scientifically. However, traditional parameter simulation methods are often based on linear theory and cannot fully meet the complex and ever-changing needs of urban environmental art design. Therefore, Liu et al. [7] proposed a multidimensional urban environmental art landscape design parameter simulation method based on nonlinear theory. Nonlinear theory is relative to linear theory, as it describes the relationships between variables that are not simply proportional but rather exhibit complex and irregular changes. In urban environmental art landscape design, the application of nonlinear theory can help us better understand and simulate complex natural and social phenomena. Thus creating designs that are more realistic and full of vitality. In today's era of the integration of technology and art, computer-aided design (CAD) is increasingly prominent in artistic creation. How to effectively utilize computer technology to promote artistic innovation is an important issue in contemporary art education. Liu and Yang [8] aim to explore the contemporary art computer-aided design teaching model with innovation as its core in order to provide new ideas and methods for art education. Computer-aided design provides artists with unprecedented creative tools, such as 3D modeling, virtual reality, augmented reality, and other technologies, providing infinite possibilities for artistic creation. Computer technology can help students and teachers break free from the limitations of traditional art forms, explore new ways of expression and visual effects, and stimulate innovative thinking. Through practical operation, students can have a deeper understanding of the combination of art and technology and improve their ability to solve practical problems.

The Environmental Art major is a comprehensive field that involves multiple disciplines. Its core lies in creating a space that harmoniously coexists with the environment through artistic and design means. In this process, computer-aided design (CAD) has become an indispensable tool, providing designers with more efficient and accurate design methods. However, traditional CAD technology still has certain limitations in terms of image expression. To address this issue, Niu [9] proposed applying data mining algorithms to promote the expression of communicative images in computer-aided design for environmental art majors. By analyzing the data of design works, representative image features such as lines, colors, textures, etc., are extracted from the works. These features can be used to describe the overall style and characteristics of a work, providing reference and inspiration for designers. Analyze user feedback information through data mining algorithms to understand their needs and preferences for environmental artworks. These data can help designers better understand user needs and consider their feelings and experiences during the design process. The development of neural networks has brought revolutionary changes to computer-aided design. Neural network-based computer-aided design not only improves the efficiency and accuracy of design but, more importantly, provides designers with new creative methods and infinite creative space. Saleh et al. [10] delved into the importance of high-quality environmental art product design based on neural network computer-aided design. Neural networks perform well in image recognition and processing, helping designers quickly and accurately recognize and process images, improving the accuracy and efficiency of design. Neural network-based computer-aided design can automatically optimize design schemes based on input data and conditions, reduce the workload of designers, and improve design efficiency. Neural networks can learn a large number of artworks and imitate their styles for creation. This style transfer technology provides designers with new creative ideas and inspiration. High-quality environmental art product design should fully consider environmental factors and achieve harmonious coexistence between humans and nature. High-quality environmental art products can enhance a company's brand image and market competitiveness. As a carrier of culture, the design of environmental art products should reflect regional characteristics and cultural connotations. High-quality environmental art product design can promote cultural exchange and enhance cultural identity.

Coastal landscape environmental art design is a complex and diverse field that involves multiple aspects, such as ecology, culture, geography, and art. With the advancement of technology, especially the development of virtual reality (VR) technology and intelligent algorithms, new possibilities have been brought to this field. Wang [11] explored how to apply these technologies to coastal landscape environmental art design. Taking the landscape design of a coastal city as an example, the designer first used virtual reality technology to construct a realistic virtual environment and simulated the initial effect of the design. Then, intelligent algorithms were used to analyze local climate, soil, ecology, and other data, providing data support for the design. At the same time, the designer also utilized intelligent algorithms to optimize the design scheme adaptively, improving the feasibility and practicality of the design. In the end, the design scheme received high praise from all parties in the virtual environment and achieved good results in practical implementation. In the CAD environment, urban planning and management involve a large amount of data, including geographic information, building information, population distribution, etc. Data mining algorithms can conduct in-depth analysis of these data, discover patterns and patterns hidden behind the data, and provide decision support for urban planning and management. Especially in the design of art spaces, data mining algorithms can help us better understand the relationship between art spaces, urban functions, and resident needs, providing a scientific basis for the planning and management of art spaces. Association rule mining can help us discover the correlations between different urban elements. In urban planning, this correlation may be reflected in aspects such as architectural style and historical culture, road traffic, and commercial layout. Through association rule mining, Wu et al. [12] better analyzed the relationships between different urban elements, providing decision support for urban planning. Cluster analysis can classify similar urban spaces, helping us understand the characteristics and differences of different urban spaces. In urban management, this clustering analysis can help us better grasp the distribution and development trends of urban space and provide a scientific basis for urban management.

The existing BIM technology still has certain limitations in the processing of artistic spatial structures, mainly manifested in the low degree of automation and insufficient accuracy of model generation. To address this issue, Yang et al. [13] proposed a semiautomatic BIM method for generating artistic spatial structural models based on CAD construction drawings. It collected the required CAD construction drawings, structural design drawings, and other data and preprocessed them, such as format conversion and coordinate system I. Convert the two-dimensional geometric information in CAD construction drawings into three-dimensional geometric information and generate a preliminary structural model. This step mainly relies on the support of CAD software and reverse engineering technology. Parameterize the structural model and establish the corresponding relationship between parameters and the model. This step can be achieved by writing scripts or using the functionality of relevant software. According to the characteristics and requirements of the art space, the model is artistically processed, such as adding textures, adjusting colors, etc. Computer-aided design (CAD) software is playing an increasingly important role in landscape art planning and design. Among them, the integrated application of software such as CAD, SketchUp, and Photoshop provides more efficient, accurate, and aesthetically pleasing design solutions for landscape design. Yang and Yang [14] discussed the application prospects of CAD SketchUp PS integrated software technology in landscape art planning and design. By integrating CAD, SketchUp, and PS software, it can complete the entire process from preliminary design to post rendering on one platform. This integration method avoids the tedious operation of switching back and forth between different software and improves design efficiency. CAD software provides precise 2D and 3D geometric modeling capabilities, ensuring the accuracy of design data. The ease of use and intuitiveness of SketchUp enables designers to create and modify models quickly. PS is used for post-rendering and rendering, enhancing the visual expression of the design.

In the traditional art design process, designers need to spend a lot of time and effort on manual drawing and adjustment. Computer graphics and image-assisted design greatly simplify this process, improving the efficiency and quality of design. The three-dimensional modeling technology in computer graphics provides powerful creative tools for art designers. Zhang and Rui [15] create various complex scenes and objects through 3D software and use rendering techniques to present realistic visual effects. Computer graphics supports dynamic design and simulation, allowing designers to observe the dynamic changes in design in real time during the creative process. This is very beneficial for evaluating the feasibility and visual effects of the design. In the entertainment industry, such as movies and games, computer graphics is widely used to create special effects. Through advanced graphic algorithms and techniques, stunning visual effects can be created, enhancing the attractiveness of artistic works. Computer graphics and image-assisted design provide art designers with more possibilities for creative expression. Designers can use these tools to explore a wider range of creative fields and achieve more unique and imaginative works. Under the trend of globalization and modernization, the cultural characteristics and historical heritage of cities are gradually being valued by people. Especially in coastal cities, due to their unique geographical location and historical background, traditional cultural elements have irreplaceable value in urban environmental art design. In recent years, data mining algorithms have been widely applied in various fields, providing new perspectives and methods for mining traditional cultural elements in coastal urban environmental art design. Coastal cities often have rich historical and cultural heritage and unique natural environments, which constitute important materials for urban environmental art design. Integrating traditional cultural elements into urban planning, architectural design, landscape design, and other aspects can enhance not only the cultural quality of the city but also the cultural identity and sense of belonging of citizens. Zhang [16] utilizes association rule mining algorithms to analyze the relationships between traditional cultural elements, identify their inherent connections and patterns, and provide design inspiration for designers. Predictive model algorithms can predict the development trend of environmental art design in coastal cities, helping designers grasp the design direction and market demand.

3D CAD technology can not only help designers carry out design work more efficiently but also provide more accurate and three-dimensional visual representation for design schemes. Zhao [17] discussed the application of 3D CAD in art landscape design and how to optimize hierarchical details. In the conceptual design phase, 3D CAD can help designers quickly create and modify preliminary models, laying the foundation for subsequent design work. Through 3D modeling, designers can better understand spatial relationships and morphological features, thus enabling better creative conception. During the scheme design phase, 3D CAD can be used for detailed design and layout. Designers can use 3D models to measure and adjust dimensions, angles, proportions, and other aspects accurately, ensuring the scientificity and feasibility of the design scheme. At the same time, 3D models can also be used for communication and exchange with clients, enabling them to have a more intuitive understanding of design solutions. The richness and rationality of landscape spatial hierarchy is one of the important criteria for evaluating the quality of a landscape design. Using 3D CAD technology, designers can optimize the hierarchy and spatial sense of landscape space by simulating and analyzing elements such as spatial form, height changes, and perspective relationships. As a comprehensive and practical field, the demand for CAD technology is particularly evident in environmental art and design. Traditional CAD design mainly focuses on the accuracy and efficiency of design but often overlooks designers' emotional expression and collaboration with others. Zhou et al. [18] explored the environmental and emotional design in collaborative design and traditional CAD design and analyzed their advantages and disadvantages. Collaborative design allows designers to share emotional states in real-time, which helps them better understand the emotional changes of team members and enhances team cohesion. Through brainstorming, collaborative design can integrate multiple opinions and suggestions, making the design more emotional and creative. Collaborative design helps to break down professional barriers, allowing designers from different fields to participate in environmental and emotional design and provide more comprehensive solutions. Through artificial intelligence technology, collaborative design systems can automatically recognize and analyze the emotional state of designers, providing them with more personalized support. Environmental and emotional design requires the integration of knowledge and skills from multiple disciplines. In the future, collaborative design will pay more attention to the intersection and integration with disciplines such as psychology and sociology.

3 ART DESIGN OF CAD ENVIRONMENT BASED ON FNN

3.1 Introduction to FNN Principle

DM is the art of unearthing concealed yet potentially valuable information and knowledge from vast amounts of data that may be incomplete, noisy, fuzzy, or random. This multifaceted discipline converges the expertise and tools of statistics, machine learning, database technology, pattern recognition, visualization techniques, and more.

The cornerstone tasks of DM encompass classification, clustering, association rule mining, sequential pattern mining, and prediction. Classification involves deciphering a model from data that can describe and distinguish various classes or concepts, enabling the categorization of unknown objects. Clustering, on the other hand, is the organization of physical or abstract entities into groups based on their similarities. Association rule mining reveals intriguing connections between data elements. Sequential pattern mining identifies patterns in the sequence of data. Lastly, prediction leverages historical data analysis to discern underlying patterns and forecast future trends.

CAD has become an indispensable tool in the field of modern design. It enables designers to transform ideas into concrete three-dimensional models more conveniently and quickly, which greatly improves design performance. In the process of CAD modeling, designers need to set a large quantity of design parameters. The selection of these parameters directly affects the final design level. Through the analysis of historical design data by the DM algorithm, we can find out the key parameters that affect the design quality and their internal relations.

DM algorithm can extract implicit knowledge and rules from a large quantity of historical design data. This knowledge and laws can provide inspiration and reference for designers and support them to make innovations and breakthroughs in design. Real-time analysis and processing of data in the stage of CAD modeling through the DM algorithm can realize the intelligence of the design process. The DM algorithm can help enterprises establish a design knowledge base and realize effective management and sharing of design knowledge. Through the mining and analysis of historical design data, valuable design knowledge and experience can be extracted and stored in the knowledge base in a form that is easy to understand and use. FNN is a sophisticated algorithm that integrates the principles of fuzzy logic with the capabilities of a neural network. It amalgamates the reasoning prowess of fuzzy logic with the self-learning trait of neural networks, making it adept at handling uncertainties while also optimizing its performance through data-driven learning. Unlike conventional binary logic, which confines the states of objects to either true (1) or false (0), fuzzy logic allows for a more nuanced representation where states can fall anywhere between 0 and 1, signifying varying degrees of membership.

Typically, an FNN architecture comprises an input layer, a fuzzification layer, a rule layer, a normalization layer, and an output layer. The input layer serves as the interface for external data entry. The fuzzification layer then translates this input into fuzzy quantities by determining the degree of membership for each input datum across different fuzzy sets. The rule layer makes inferences based on predefined fuzzy rules, while the normalization layer standardizes the outputs from the rule layer. Finally, the output layer presents the conclusive results.

In terms of operation, FNN initially undergoes training to learn fuzzy rules and membership functions. During this phase, the neural network adjusts its connection weights and membership function parameters iteratively to minimize discrepancies between the network's output and actual outcomes. Once trained, the FNN can swiftly compute outputs corresponding to fuzzy inputs through a forward propagation algorithm.

3.2 Application of FNN in CAD Environmental Art Design

In CAD environmental art design, designers often face various uncertain problems, such as the uncertainty of user demand and design parameters. These problems are difficult to deal with by traditional deterministic methods. FNN can learn and optimize membership functions and fuzzy rules according to historical data and empirical knowledge, thus giving a more reasonable design scheme.

Environmental art design involves many different design styles, such as modern, classical, and industrial styles. Feature detection needs to be able to analyze and identify the design style adopted by the space. This can be achieved by extracting visual features such as shapes, lines, colors, and materials in space and comparing and classifying them with known design style databases. Feature detection needs to be able to perceive and evaluate the atmosphere of the space, such as warmth, vitality, and quietness. This can be achieved by analyzing the light, color, layout, furniture, and other elements in the space and evaluating them in combination with human psychological perception and emotional response. Feature detection needs to consider the cultural and historical background of the space in order to identify and understand its artistic features more accurately. By accurately identifying and analyzing the artistic characteristics of environmental space, we can provide a more comprehensive and in-depth understanding and support for environmental art design. The architecture of environmental art feature detection is shown in Figure 1.

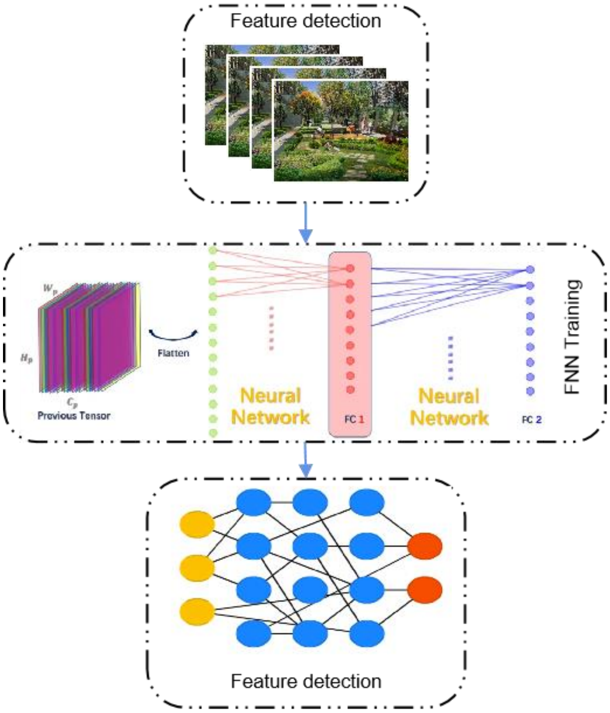


Figure 1: Environment art feature detection architecture.

The global attention module of environmental art image feature fusion is shown in Figure 2. The global attention module of environmental art image feature fusion is an important part of deep learning, especially when dealing with complex image and visual tasks. The main purpose of this module is to fuse feature maps with different scales so as to enrich feature information and to guide the generation of shallow feature maps through deep features so as to ensure the consistency and stability of information flow in the whole stage. In image processing, different levels of feature maps contain different information. The function of the global attention module is to effectively integrate these different levels of features so that the model can make use of both spatial details and semantic information. The attention mechanism simulates the working principle of the human visual system, that is, focusing on some parts of the image and ignoring other parts. In the global attention module, the network will learn which features are important for the current task and give them higher weight.

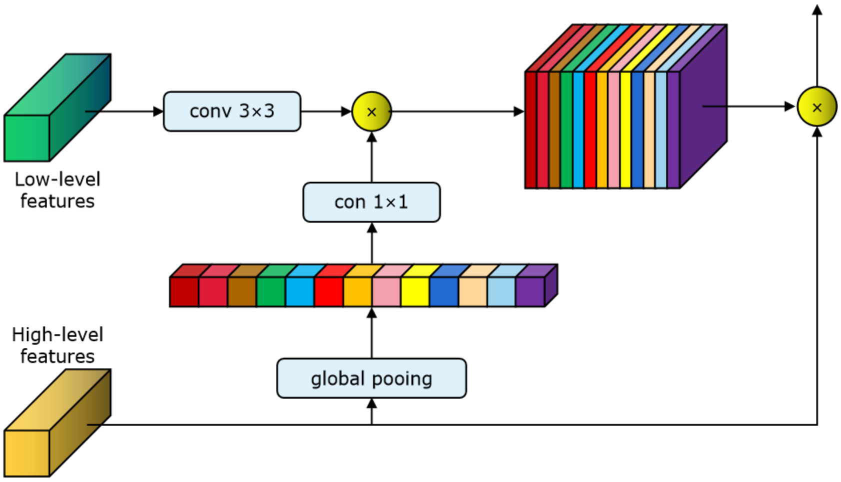


Figure 2: Global attention module.

Through the global attention module, the features obtained from the deep network can be used to guide the generation of shallow feature maps. The advantage of this is that the shallow feature map can obtain some semantic information while retaining the spatial details. This cross-layer guidance ensures the coherence and consistency of information and helps to improve the performance of the model. In the deep neural network, with the deepening of layers, the information flow may become unstable, leading to problems such as gradient disappearance or gradient explosion. The global attention module helps to stabilize the information flow by keeping the information flow consistent throughout the stage.

SVM tries to find an optimal hyperplane so that the projections of different kinds of samples on this hyperplane are as far away as possible and as close to the boundary of correct classification as possible. This hyperplane can be obtained by maximizing the interval between different classes of samples, so it is also called the maximum interval classifier. We can deal with the multi-classification problem by constructing multiple binary classifiers or using other strategies. The aim of SVM in classifying environmental art images is to acquire the decision function:

$$f\ x\ =\sum_{i=1}^{n} w_i k\ x, x_i\ + b \tag{1}$$

Where is $k\ x_i, x_j\ = x_i, x_y$, and the objective function of the kernel function is:

$$\min_{w,\varepsilon,b}\left\{\frac{1}{2}\left\|w\right\|^2 + c\sum_{i=1}^{n}\varepsilon_i\right\} \tag{2}$$

The parameters FNN needs to learn are mainly the connection weight ω_{dk} of the last layer, and the central value $\omega_{b_{ij}}$ and width value $\omega_{c_{ij}}$ of the membership degree. The error function is defined as:

$$\arccos\ N_{new} \cdot N_{ini}\ \le \varepsilon \tag{3}$$

Where i is the quantity of learning samples, Y_{di} what is the expected output of the system, and Y_i what is the actual output of the controlled object?

The input data must be fuzzified since the fuzzy controller relies on fuzzy sets for processing. Essentially, fuzzification involves determining the membership function of fuzzy sets within their respective numerical domains:

$$\mu(u)=\begin{cases}\frac{1}{a-b}(u-b), b\le u\le a\\ \frac{1}{a-c}(u-c), a\le u\le c\\ 0, \text{other}\end{cases} \tag{4}$$

Let the connection weight between the rule layer and the deblurring layer be λ_{ij}, and here, the weighted average method is adopted to calculate the output value V of FNN as follows:

$$V=\frac{\sum_i\sum_i\lambda_{ij}\mu_{ij}}{\sum_i\sum_i\mu_{ij}} \tag{5}$$

Reinforcement learning of objective function Y. Parameters in FNN are adjusted by reinforcement signal to minimize the mean square error function and reinforcement learning signal r is defined:

$$r=Y^*-Y(k) \tag{6}$$

FNN can learn and analyze historical design data, extract implicit design knowledge and laws, and provide designers with inspiration and support for innovative design. In CAD environmental art design, designers need to set a large quantity of design parameters. The selection of these parameters directly affects the final design level. Through the study and analysis of historical design data, FNN finds out the key parameters that affect the design quality and their internal relations.

3.3 Design of DM Process Based on FNN

In FNN-based DM, firstly, the historical design data in the CAD environment are collected and sorted out. These data may include design drawings, design parameters, user evaluation, and other types of information. Then, the data is preprocessed. After the data preparation is completed, an FNN model suitable for CAD environment art design should be constructed. This model can reflect the relationship between design parameters and design quality and can learn and optimize itself according to historical data. The construction of the model includes the steps of determining the network structure, selecting the membership function, and formulating fuzzy rules. Remember that the probability of a random event is $P(E)$, so the amount of information it contains is:

$$I(E)=\log\frac{1}{P(E)}=-\log P(E) \tag{7}$$

A picture can be seen as a random output source capable of producing a sequence of symbols from a restricted set. This set of source symbols is defined as $\{b_i\}$ all possible symbols B. Each individual element, b_i, is known as a source symbol, and the likelihood of the source generating symbol b_i is denoted as $P(b_i)$.

The self-information of the single symbol b_i generated by the source is:

$$I(b_i)=-\log P(b_i) \tag{8}$$

If the source generates k symbols, the symbol b_i will generate $kP(b_i)$ times on average. If the average information output by each source is recorded as $H(u)$, then:

$$H(u)=\sum_{i=1}^{n}P(b_i)\cdot I\left[P(b_i)\right]=-\sum_{i=1}^{n}P(b_i)\log P(b_i) \tag{9}$$

$H\ u$ is known as the source's entropy, which quantifies the average amount of information gained from observing a single symbol from the source.

After the model training is completed, the new design data can be DM and analyzed by using this model. This process includes inputting new data into the model, calculating the corresponding output results, and then analyzing and interpreting according to the output results. The analysis and explanation of the mining results can provide valuable design suggestions and support for designers and help them make more reasonable and innovative design decisions.

4 RESULT ANALYSIS AND DISCUSSION

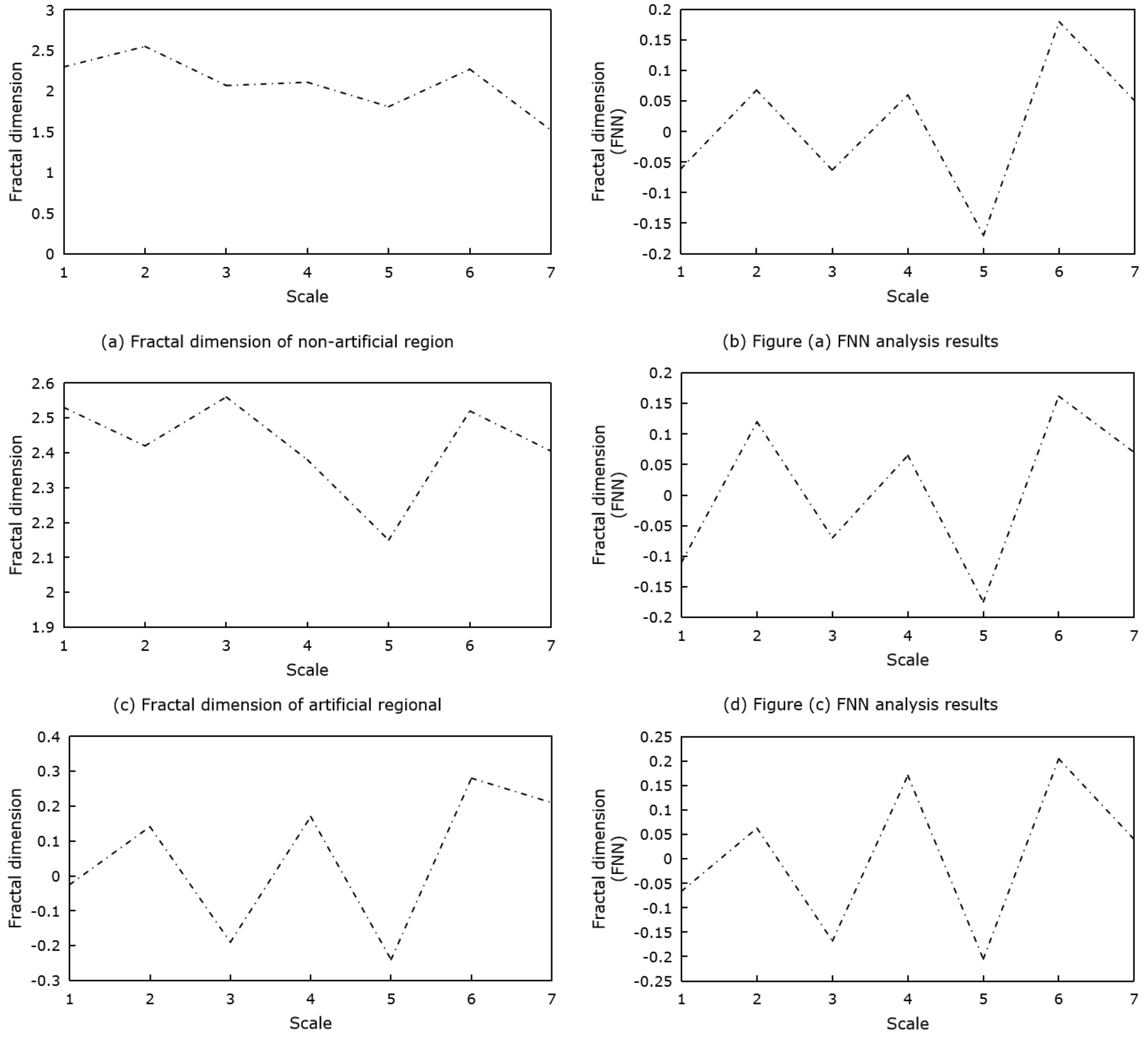
In order to divide and identify different areas in environmental art images more accurately, especially artificial areas and non-artificial areas, a method based on fractal dimension calculation and multi-directional high-frequency information analysis can be adopted. Firstly, the low-frequency part is extracted from the original environmental art image. This can be achieved by image filtering or transformation methods, such as Fourier transform or wavelet transform. Next, the fractal dimension of two different parameters is calculated for the low-frequency part. The fractal dimension is a measure to describe the complexity and irregularity of objects, which is often used in image analysis and pattern recognition. After the preliminary region division is obtained, the mathematical morphology operation is applied to optimize the results further. Mathematical morphology is a mathematical theory based on shape, which is used to analyze and process structural elements in images. High-frequency information usually corresponds to the details and edge information of the image, which can reveal the subtle differences between different regions. Through multi-directional analysis, these differences can be captured more comprehensively. Combined with the fractal dimension calculation results of the low-frequency part and multi-directional high-frequency information analysis, the precise boundaries and attributes of artificial and non-artificial areas can be finally determined. These results can be visualized and explained by the calculation process and data analysis shown in Figure 3.

Figure 4 presents a comparative analysis between the output parameters of the FNN algorithm and the characteristic features of authentic environmental art images. Notably, the algorithm-generated feature parameters closely resemble those of actual environmental art images, indicating that the FNN algorithm proficiently captures essential features from such imagery.

A comparison of the algorithm's output feature parameters with those of real images reveals a high level of consistency across multiple dimensions. This resemblance demonstrates that the FNN algorithm is capable of precisely learning and capturing significant features in environmental art images. These features, which may encompass color, texture, shape, spatial layout, and more, are crucial for comprehending and categorizing such images. The FNN algorithm can automatically learn and extract key features that are useful for classification tasks when processing environmental art images. These key features may be the same or similar features that the human visual system relies on when appreciating and understanding environmental art. Therefore, the similarity between the feature parameters extracted by the algorithm and the real image feature parameters further verifies the effectiveness of FNN in feature extraction.

Figure 5 shows the classification accuracy of the algorithm for three different types of environmental art images (indoor environmental art, urban environmental art, and natural environmental art). The algorithm proposed in this article shows good performance in these three types of image classification.

For indoor environmental art images, the classification accuracy of the algorithm is relatively high. Indoor environmental art images have certain regularity and characteristics in scene layout, object arrangement, light, and color, which makes it easier for the algorithm to learn and identify these characteristics. Urban environmental art images usually contain complex elements such as buildings, sculptures, and installations and are rich in visual information. The algorithm can accurately identify these elements and classify them, which shows that the algorithm has a strong ability to deal with complex scenes and diverse visual information. Natural environment art images usually have complex backgrounds, changeable light and color, and rich natural elements, which increase the difficulty of classification. The algorithm can still accurately identify the features of these images and classify them to some extent, which shows that the algorithm is also robust in dealing with complex natural scenes.



(a) Fractal dimension of non-artificial region
(b) Figure (a) FNN analysis results
(c) Fractal dimension of artificial regional
(d) Figure (c) FNN analysis results
(e) Results of fractal dimension (parameter 1) FNN analysis of artificial region
(f) Results of fractal dimension (parameter 2) FNN analysis of artificial region

Figure 3: Data analysis of the test process.

Figure 6 intuitively shows the effect changes of the style transfer algorithm based on neural networks in the iterative process. In the initial stage, the algorithm takes the content picture plus noise as the starting point to generate the picture, so the generated picture is visually very similar to the content picture. However, in style, it is quite different from the target style picture. With the increase of iterations, the style of the generated pictures gradually changes. When iterating for the 100th time, it can be clearly observed that the generated picture has been significantly different from the content picture in style, and it is getting closer and closer to the target style picture.

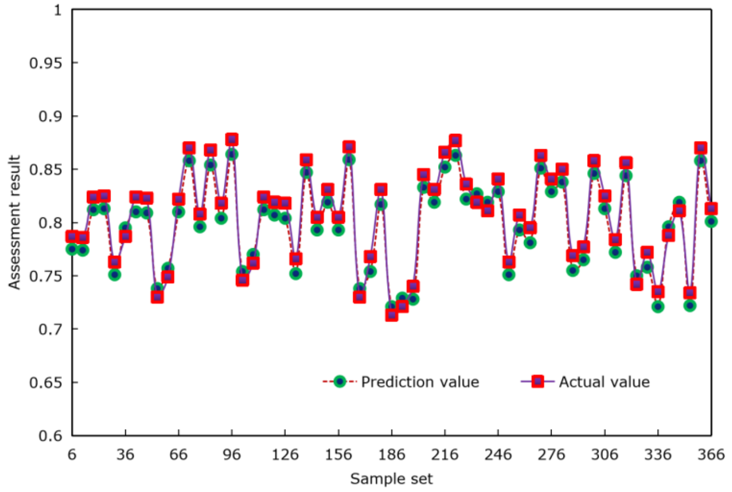


Figure 4: Learning results of FNN algorithm.

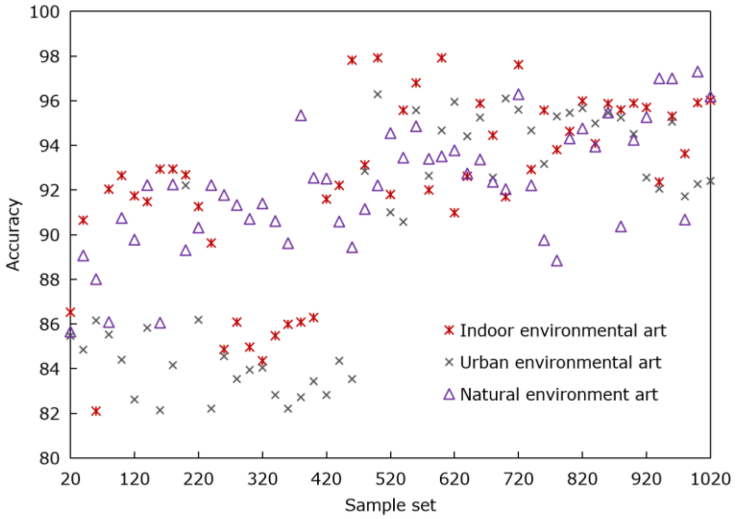


Figure 5: FNN's classification accuracy of environmental art images.

When the iteration reaches the 600th time, the generated picture presents amazing visual effects. It is not only highly consistent with the original picture in the content but also very close to the target picture in style. This kind of generated image that combines content and style shows the powerful ability of the algorithm, which can combine two different image styles to create a novel and harmonious visual effect.

Figure 7 compares the effects of environmental art CAD modeling based on different algorithms. Compared with traditional methods, the algorithm proposed in this article shows a better effect in modeling optimization. Judging from the fineness of modeling, the CAD model generated by this method is better in detail. Traditional methods have limitations in dealing with complex structures or subtle features, resulting in relatively rough modeling results. By introducing advanced optimization techniques, such as deep learning, point cloud processing, or surface reconstruction, the algorithm in this article can capture and reproduce the nuances of environmental art design more accurately, making the modeling results more realistic and precise.

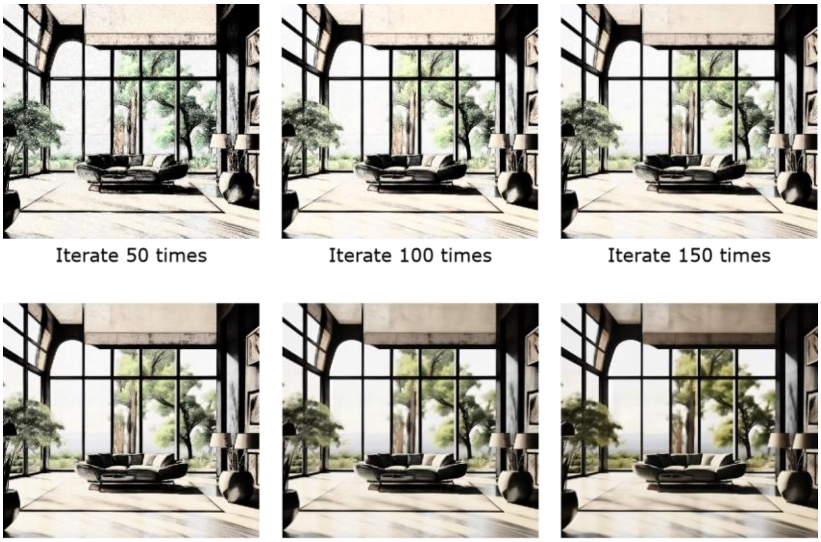


Figure 6: Graphic iterative optimization effect.

Figure 7: CAD modeling effect of environmental art.

In contrast to conventional approaches, the algorithm introduced in this article offers superior precision, efficiency, and adaptability in CAD modeling for environmental art. This opens up new opportunities in the domain of environmental art design, facilitating improvements in design quality, reduction of project timelines, and cost savings.

5 CONCLUSION

DM has the capability to sift through vast amounts of data, unveiling invaluable insights and knowledge that can empower designers with smarter and more streamlined design techniques. The approach outlined in this article, which hinges on fractal dimension calculations and multi-directional high-frequency information analysis, has demonstrated impressive outcomes in the extraction of features and the segmentation of regions within environmental art images. Through a comparative analysis of these feature parameters against actual environmental art images, it has been confirmed that the algorithm-generated parameters closely align with real-world features, highlighting the method's efficacy in pinpointing key characteristics within such imagery. Furthermore, this algorithm excels in accurately classifying different genres of environmental art images, be it indoor settings, urban landscapes, or natural surroundings. This proficiency underscores the algorithm's robustness in handling complex visual scenarios and diverse information.

In the realm of CAD modeling for environmental art, the algorithm introduced in this article stands out for its precision, efficiency, and adaptability. In contrast to traditional methodologies, this advanced approach leverages sophisticated optimization techniques to capture and replicate the intricate details of environmental art designs more precisely, thereby elevating the overall quality of the modeling process.

AI technology continues to evolve, and the potential of techniques like FNN in CAD design for environmental art is bound to increase exponentially. Looking ahead, future research efforts could explore several avenues: firstly, how to further enhance the performance of FNN, be it through refining the network architecture or optimizing training algorithms; secondly, examining the application of alternative DM algorithms in CAD design for environmental art; and thirdly, exploring ways to integrate DM algorithms with the creative process of designers, paving the way for a new era of collaborative human-machine design.

Shilai Zhang, https://orcid.org/0009-0002-5174-4619
Changchang Xu, https://orcid.org/0009-0002-3391-0214

REFERENCES

[1] Guo, S.; Wang, B.: Application of computer aided modeling design in the expression techniques of sculpture art space, Computer-Aided Design and Applications, 19(S3), 2021, 1-12. https://doi.org/10.14733/cadaps.2022.S3.1-12

[2] He, C.; Sun, B.: Application of ai technology in computer aided art teaching, Computer-Aided Design and Applications, 18(4), 2021, 118-129. https://doi.org/10.14733/cadaps.2021.S4.118-129

[3] Hoang, C.; Avksentieva, E.; Fedosov, Y.: Forming an individual trajectory of teaching computer-aided design by means of an intelligent adaptive system, Ergodesign, 2021(1), 2021, 41-48. https://doi.org/10.30987/2658-4026-2021-1-41-48

[4] Jia, J.: Computer-aided design method of parametric model for landscape planning, Computer-Aided Design and Applications, 19(S3), 2022, 55-64. https://doi.org/10.14733/cadaps.2022.S3.55-64

[5] Jiang, W.; Zhang, Y.: Application of 3D visualization in landscape design teaching, International Journal of Emerging Technologies in Learning (Online), 14(6), 2019, 53-62. https://doi.org/10.3991/ijet.v14i06.10156

[6] Jin, H.; Yang, J.: Using computer-aided design software in teaching environmental art design, Computer-Aided Design and Applications, 19(S1), 2021, 173-183. https://doi.org/10.14733/cadaps.2022.S1.173-183

[7] Liu, C.; Lin, M.; Rauf, H.-L.; Shareef, S.-S.: Parameter simulation of multidimensional urban landscape design based on nonlinear theory, Nonlinear Engineering, 10(1), 2022, 583-591. https://doi.org/10.1515/nleng-2021-0049

[8] Liu, F.; Yang, K.: Exploration on the teaching mode of contemporary art computer aided design centered on creativity, Computer-Aided Design and Applications, 19(S1), 2021, 105-116. https://doi.org/10.14733/cadaps.2022.S1.105-116

[9] Niu, F.: Communicative image expression in teaching of computer-aided design for environmental art major, Computer-Aided Design and Applications, 18(S2), 2021, 25-35. https://doi.org/10.14733/cadaps.2021.S2.25-35

[10] Saleh, B.; Rasul, M.-S.; Affandi, H.-M.: The importance of quality product design aspect based on computer aided design (CAD), Environment-Behaviour Proceedings Journal, 5(3), 2020, 129-134. https://doi.org/10.21834/ebpj.v5iSI3.2545

[11] Wang, H.: Landscape design of coastal area based on virtual reality technology and intelligent algorithm, Journal of Intelligent & Fuzzy Systems, 37(5), 2019, 5955-5963. https://doi.org/10.3233/JIFS-179177

[12] Wu, H.; Gui, Z.; Yang, Z.: Geospatial big data for urban planning and urban management, Geo-spatial Information Science, 23(4), 2020, 273-274. https://doi.org/10.1080/10095020.2020.1854981

[13] Yang, B.; Liu, B.; Zhu, D.; Zhang, B.; Wang, Z.; Lei, K.: Semiautomatic structural BIM-model generation methodology using CAD construction drawings, Journal of Computing in Civil Engineering, 34(3), 2020, 04020006. https://doi.org/10.1061/(ASCE)CP.1943-5487.0000885

[14] Yang, S.; Yang, J.: Application prospect of CAD-SketchUp-PS integrated software technology in landscape planning and design, Computer-Aided Design and Applications, 18(S3), 2020, 153-163. https://doi.org/10.14733/cadaps.2021.S3.153-163

[15] Zhang, B.; Rui, Z.: Application analysis of computer graphics and image aided design in art design teaching, Computer-Aided Design and Applications, 18(S4), 2021, 13-24. https://doi.org/10.14733/cadaps.2021.S4.13-24

[16] Zhang, G.: Application analysis of traditional cultural elements in the environmental art design of coastal cities, Journal of Coastal Research, 115(9), 2020, 27-30. https://doi.org/10.2112/JCR-SI115-009.1

[17] Zhao, X.: Application of 3D CAD in landscape architecture design and optimization of hierarchical details, Computer-Aided Design and Applications, 18(S1), 2020, 120-132. https://doi.org/10.14733/cadaps.2021.S1.120-132

[18] Zhou, J.-J.; Phadnis, V.; Olechowski, A.: Analysis of designer emotions in collaborative and traditional computer-aided design, Journal of Mechanical Design, 143(2), 2020, 1-18. https://doi.org/10.1115/1.4047685