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Article

Leveraging bioinformatics to enhance multi-sensory environmental art design: Insights from molecular and cellular biomechanics and human experience

Xufang Sun

Zhongyuan University of Technology, Zhengzhou 450000, China; zutsunxufang@sohu.com

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Abstract: With the rapid development of bioinformation technology and its wide application in various fields, its combination with multi-sensory environmental art design provides new possibilities for creating more personalized, interactive and emotional user experience. With human experience as the core design concept, this paper discusses explore how to use bioinformatics to reveal the principles of molecular and cellular biomechanics to improve multi-sensory environmental art design, aiming to enhance users' immersion and satisfaction in various environments by integrating advanced algorithms and technical means. This paper initially outlines the core elements of bioinformatics technology, encompassing fundamentals of bioinformatics, biological signal processing, and their capacity to detect and analyze biomechanical responses at the molecular and cellular levels. It delves into the potential interplay between multisensory environmental stimulation and molecular-cellular biomechanics, elucidating how, grounded in biomechanics principles, environmental cues elicit alterations at these microscopic scales. Furthermore, the paper presents research methodologies grounded in bioinformatics, leveraging VR/AR and other simulated multi-sensory art environments, in tandem with cellular experimental techniques, to investigate the biomechanical responses of molecules and cells, including alterations in cell morphology and molecular expression patterns. Machine learning algorithms are employed to analyze the data, aiming to uncover the relationships between multi-sensory environments, bioinformatics, and molecular-cellular biomechanics. Additionally, the paper explores the application of bioinformatics in enhancing user experience and social interaction through personalized adjustments based on physiological signals, emotional recognition algorithms, and the design of health-promoting environments tailored for specific populations. The pivotal roles of algorithms such as machine learning, adaptive optimization, and data mining are highlighted, demonstrating how they aid designers in comprehending and addressing user needs. Ultimately, bioinformatics offers insights into the biomechanical mechanisms of molecules and cells within multi-sensory environments, fostering innovative perspectives in art design. Finally, the paper summarizes the contribution of bioinformation technology to multi-sensory environment design and looks forward to future research, particularly the impact of emerging technologies like quantum computing and brain-computer interfaces. While these technologies show potential, the paper lacks an analysis of their application and technical feasibility in this context. Future research should focus on integrating these technologies with existing ones, addressing challenges such as compatibility, scalability, and cost, and outlining practical implementation steps. Overall, the paper presents current findings and points toward a more intelligent and humane future for the field.

Keywords: bioinformation technology; multi-sensory environmental art design; human experience; emotional computing; virtual reality (VR)/augmented reality (AR)

1. Introduction

With the rapid development of science and technology, bioinformatics has moved from basic research to application fields, showing great potential in many fields such as medical health, environmental protection, and agricultural science. In particular, in the field of human-computer interaction and user experience design, the application of bioinformatics provides new ideas and tools for creating more personalized, emotional, and interactive environments [1,2]. At the same time, multisensory environmental art design, as a design discipline that integrates multiple sensory experiences such as vision, hearing, and touch, is gradually becoming an important means to improve the quality of human life and spiritual enjoyment [3]. However, the current multisensory environmental art design still faces some challenges, such as how to more accurately capture the physiological and psychological state of users, and how to dynamically adjust the environment based on this information to meet the needs of different users [4,5]. The solution to these problems is still difficult to achieve, requiring not only a deep understanding of the human perception system, but also advanced technical means to achieve efficient signal processing and real-time feedback mechanisms.

This study aims to explore how bioinformatics can improve multisensory environmental art design by introducing advanced algorithms and technical means, so that environmental design can better respond to users' immediate needs and provide a more personalized experience [6]. Specifically, we will focus on the following aspects:

User state monitoring and personalized adjustment: Use biosignal processing technology and adaptive algorithms to monitor the user's physiological and psychological state in real time, and dynamically adjust environmental parameters based on the monitoring results. Emotional computing and emotional guidance: Use emotion recognition algorithms to analyze the user's facial expressions, voice intonation and other features, and design multi-sensory scenes that can trigger specific emotional responses. On this basis, further explore the physiological and behavioral characteristics of users in different emotional states, and analyze how these characteristics support the optimization of environmental design, so as to more accurately meet the emotional needs of users. Virtual reality avatars and social interaction: Combine virtual reality (VR) and augmented reality (AR) technologies to create realistic virtual avatars and enhance the remote interaction experience between users. Health and well-being promotion: Design environments that are conducive to physical and mental health for special groups such as the elderly and rehabilitation patients, and evaluate and optimize the impact of these environmental designs on health indicators [7]. Specific application of biomechanical principles: By combining biomechanical research such as human movement characteristics and pressure distribution, ergonomics and dynamic interaction are integrated into art design. For example, the design of seats based on biomechanics can optimize pressure distribution according to the human skeletal structure and reduce fatigue; applying biomechanical simulation technology to installation art can realize real-time interaction between human movements and visual effects and enhance artistic expression.

To achieve the above research objectives, this paper adopts the following research methods and technical means:

Literature review: By referring to the latest research results in related fields at home and abroad, the basic theories and development trends of bioinformatics technology and multi-sensory environmental art design are sorted out; Experimental research: Design and implement a series of experiments to test the effects of different algorithms and technical means in actual application scenarios, including user status monitoring, emotion recognition, virtual avatar interaction, etc.; Case analysis: Select representative multi-sensory environmental art design cases for in-depth analysis, summarize successful experiences and existing problems, and provide reference for future research and practice; Data collection and analysis: Use sensor technology and IoT devices to collect users' physiological and behavioral data in different environments, use machine learning, deep learning and other algorithms to analyze the data, and explore potential patterns and laws [8–11].

However, when introducing various technical applications, such as sensor technology and virtual reality technology, the technical limitations and implementation difficulties in actual application scenarios are not fully considered. For example, factors such as the cost and compatibility of sensors, the ease of use of virtual reality equipment, and the cost of equipment may affect the popularization and practical application of the technology, thereby restricting the widespread application of research results. Future research should pay more attention to how to overcome these technical difficulties in order to enhance the practical application value of research results.

2. Materials and methods

2.1. Fundamentals of bioinformatics

Bioinformatics is an interdisciplinary discipline that combines the fields of biology, computer science, mathematics, and statistics to process and analyze large amounts of data from biological systems [12–15]. With the rapid development of genome sequencing technology, bioinformatics has expanded from simple gene sequence analysis to protein structure prediction, functional annotation, evolutionary relationship research and other aspects [16–20]. In multi-sensory environmental art design, bioinformatics can provide theoretical support for understanding human perception mechanisms and help develop more accurate user condition monitoring systems. By analyzing an individual's genetic information, it is possible to predict certain sensory sensitivities or disease susceptibility, thereby optimizing environmental design to suit the needs of different populations. These levels of data can reveal the biochemical processes in the cell, help to understand the physiological basis of emotional changes, and provide biological basis for emotional calculation.

2.2. Biological signal processing

Biological signal processing refers to the process of collecting, preprocessing, feature extraction and pattern recognition of various physiological signals (such as electrocardiogram, ECG, EEG, EMG, etc.) from the human body. In a multi-sensory environment, accurate acquisition and interpretation of these signals is essential for real-time monitoring of a user's physiological and psychological state [21,22]. The specific steps are to use high-precision sensors to collect the original data, improve the signal quality through filtering, denoising and other steps, extract meaningful features from complex data sets based on domain knowledge and machine learning algorithms, such as heartbeat rate, skin conductivity, etc., and apply supervised learning, unsupervised learning or deep learning models to classify the extracted features. Judge the emotional state and fatigue degree of users [23].

2.3. Human-computer interaction technology

Modern human-computer interaction technology is not limited to traditional keyboard and mouse input methods, but also includes speech recognition, gesture control, eye tracking and other natural interaction methods [24]. In particular, the biofeedback mechanism allows the system to automatically adjust its behavior based on the user's physiological response, enabling a more intelligent and human interactive experience. Through real-time monitoring of users' physiological signals, such as heart rate variability and respiratory rate, instant feedback is provided to users to help them better manage their own state [25]. Using deep neural network to improve the user interface design, make it more in line with the user's intuitive operation habits; At the same time, it can also be used to predict user intentions and prepare corresponding response actions in advance. The application of virtual reality (VR), augmented reality (AR) and mixed reality (MR), these immersive technologies offer the possibility of creating highly realistic avatars and social interaction scenarios that enhance remote collaboration and entertainment experiences.

3. Multi-sensory environmental art design

3.1. The importance of multi-sensory experiences

Multi-sensory experience refers to the transmission of information through multiple sensory channels such as sight, hearing, touch, smell and taste, thereby creating a richer and more immersive environment. This comprehensive sensory stimulation not only enhances the user experience, but also profoundly affects emotional, cognitive, and behavioral patterns. The human brain receives information from the outside world through multiple sensory organs and integrates this information into a coherent overall perception. There are complex interactions between different senses, for example, vision and hearing can work together to enhance memory. Touch and smell, on the other hand, can trigger strong emotional resonance. Multi-sensory stimulation can regulate the physiological state of the human body (such as heart rate, blood pressure, etc.), and then change the psychological state (such as anxiety level, pleasure). In a given environment, the right use of multi-sensory elements can help users relax, focus or stimulate creativity.

3.2. Design principles and methods

In order to ensure the effectiveness and humanization of multi-sensory environmental art design, designers need to follow a series of scientific design principles and combine interdisciplinary knowledge and technical means to innovate. Adhering to the concept of always paying attention to the actual needs and feelings of users, we constantly optimize the design scheme through user research and prototype testing. Taking into account individual differences, customizable options should be provided so that each user can get the best experience. Comprehensive research results in psychology, neuroscience, cognitive science and other fields, in-depth understanding of human perception mechanism and its response to external stimuli. We also draw on our expertise in architecture, acoustics, and color theory to create a functional, aesthetically comfortable environment. Take full advantage of emerging technologies such as virtual reality (VR), augmented reality (AR), mixed reality (MR) and the Internet of Things (IoT) to build interactive and flexible multi-sensory experience Spaces. Sensor technology and data analysis algorithms provide solid technical support for personalized service.

3.3. Technical realization

The success of multi-sensory environmental art design depends on the support of a number of advanced technologies, the following are several key areas: One is the application of virtual reality (VR), augmented reality (AR) and mixed reality (MR), which enable designers to create realistic three-dimensional scenes in virtual worlds and allow users to interact with them. For example, using AR in a museum exhibition can give visitors a deeper understanding of the stories behind the exhibits; In medical rehabilitation training, VR can simulate real life scenes to help patients recover motor skills. The second is the role of sensor technology and the Internet of Things (IoT) in environmental monitoring, through the deployment of various types of sensors (such as temperature, humidity, light intensity, etc.), real-time monitoring of environmental parameter changes, and feedback to the control system, in order to timely adjust the lighting brightness, background music and other Settings, to create the most suitable for the current situation atmosphere. The third is emotional computing and user status monitoring, using biological signal processing technology and machine learning algorithms to analyze the user’s facial expression, voice intonation, heart rate and other physiological indicators, assess their emotional state and make corresponding adjustments. This not only helps to improve the quality of the user experience, but can also be used for mental health assessments and to support the needs of special populations.

4. Application of bioinformation technology in multi-sensory environmental art design

4.1. User status monitoring and personalized adjustment

Bioinformation technology provides a strong support for real-time monitoring of users’ physiological and psychological states, through which dynamic adjustment of the environment can be achieved to meet the needs of different users. Sensors such as electrocardiogram (ECG), electroencephalogram (EEG), and electromyography (EMG) are used to collect the user’s heart rate, brainwave activity, muscle tension and other data to assess their current physical condition. Combined with emotion computing technology, the user's emotional changes are captured by facial expression recognition, voice and intonation analysis, etc., and their mental state is inferred based on this information. Based on the collected data, adaptive algorithms are used to automatically adjust environmental parameters (such as temperature, lighting, music, etc.) to ensure that each user gets the most appropriate experience. For example, when it detects that a user is feeling anxious, the system can reduce the light intensity and play soothing music to help them relax.

4.2. Affective computing and affective guidance

In the application of emotional computing, individual differences in emotional expression and cultural variations have not been fully addressed. These differences can significantly impact the accuracy of emotion recognition systems. For example, facial expressions, body language, and vocal tone may vary across individuals due to factors such as personality, age, and cultural background. To improve the accuracy of emotion recognition, future research should focus on developing adaptive models that account for these individual and cultural differences. Techniques such as personalized emotion profiling, cross-cultural emotion datasets, and context-aware algorithms could help refine emotion recognition systems, making them more accurate and reliable for a diverse range of users.

When using deep learning models for emotion recognition in emotional computing, the challenges associated with processing multimodal emotional data have not been fully addressed. Deep learning models can face difficulties such as data inconsistency, noise, and the complexity of integrating information from different modalities (e.g., facial expressions, voice features, and body language). To overcome these challenges, it is essential to employ data normalization techniques, noise reduction strategies, and robust fusion methods that can effectively integrate these diverse data sources. Additionally, addressing issues related to temporal alignment between modalities and ensuring the model's ability to handle missing or incomplete data are key aspects to improve the model's overall performance. Future research should focus on developing hybrid models that combine the strengths of different deep learning architectures, such as convolutional neural networks (CNNs) for image data and recurrent neural networks (RNNs) for sequential data, to improve the accuracy and reliability of emotion recognition in real-world applications.

4.3. Avatars and social interactions

Avatars refer to the digital images of users in the virtual world, which not only enhance the reality of remote interaction, but also promote the communication and cooperation between people. Through high-precision motion capture technology and natural language processing, users are able to achieve realistic gesture control, eye contact and conversational communication in a virtual environment, thereby bringing them closer to each other. Reinforcement learning algorithm is applied to train avatars to have more natural behaviors, so that they can make reasonable responses according to the user's actions and words, and provide a better interactive experience.

Virtual Meet, for example, is a virtual reality platform designed for online meetings that allows participants to create personalized avatars and meet face to face in an immersive 3D environment. Each avatar is equipped with a high-precision motion capture system that can reflect the user's body posture and facial expressions in real time, making communication more natural and smooth. The presence of avatars makes users feel like they are in a real conference room, rather than a simple video call window. This immersion increases the participation and interactivity of the meeting. By capturing subtle gestures and eye movements, Virtual Meet allows important non-verbal messages to be conveyed, increasing the effectiveness and accuracy of communication. Users can customize the avatar's image according to their preferences, such as clothing, hair, etc., which not only adds interest, but also reflects personal style.

5. Key algorithms and their functions

5.1. Machine learning and deep learning

Machine learning (ML) and deep learning (DL) are one of the core algorithms applied by bioinformation technology in multi-sensory environmental art design. These technologies can automatically learn patterns from large amounts of data and make predictions or decisions based on them, greatly increasing the level of personalization and intelligence of the user experience.

Supervised learning: Supervised learning trains models through labeled training sets, enabling the system to accurately classify or regression based on input data. For example, in emotion recognition, supervised learning can be used to distinguish between different emotional states.

Linear regression: For continuous value prediction, the formula is:

$$\mathrm{y} = \beta_0 + \beta_1 + \cdots + \beta_n x_n \tag{1}$$

where y is the predictive output, β_i is the weight parameter, and x_i is the feature.

Logistic regression: For binary classification problems, the probability calculation formula is:

$$\mathrm{P}(\mathrm{y} = 1|\mathrm{x}) = \frac{1}{1 - e^{-y}} \tag{2}$$

$\beta_0 + \beta_1 + \cdots + \beta_n x_n$ is a linear function where β_i is the weight parameter and x_i is the eigenvalue. This part is called the linear predictor, and it shows how much each feature influences the outcome.

e^{-y} is the negative exponential form of a linear combination. The natural constant e (about 2.71828) is used here in order to map the result of a linear combination into a nonlinear space, so that we can get a probability value between 0 and 1.

The entire expression $\frac{1}{1-e^{-y}}$ is actually the Sigmoid function (also known as the Logistic function). The Sigmoid function has the following properties: When the result of a linear combination is large, the denominator approaches infinity, causing the entire fraction to approach 0; At this point $\mathrm{P}(\mathrm{y} = 1|\mathrm{x})$ is close to 0, which means that the prediction is more likely to be class 0. When the result of a linear combination is small or negative, the denominator approaches 1, causing the entire fraction to approach 1; At this point $P(y = 1|x)$ is close to 1, which means that the prediction is more likely to be category 1. For intermediate values, the Sigmoid function smoothly transitions from 0 to 1, providing a continuous probability estimate.

In summary, logistic regression formulas can effectively transform input features into a probability value between 0 and 1 by mapping linear combinations to Sigmoid functions, thus effectively modeling binary classification problems.

When there are no explicit labels, unsupervised learning can help uncover hidden structures or clusters in the data. This can be very useful in user behavior analysis to reveal user preference patterns or group characteristics.

K-means clustering: Dividing data into k clusters with the goal of minimizing the sum of squares of distances between points within the cluster:

$$argmin\sum_{i=1}^{k}\sum_{x_j\in C_i}|x_j - \mu_i|^2 \tag{3}$$

Use deep neural networks to process complex data types such as images, sounds, etc. In a multi-sensory environment, deep learning can be used for tasks such as facial expression recognition and speech and intonation analysis to improve the accuracy of emotional computing.

Convolutional neural network (CNN): Used for image processing, features are extracted by convolutional layer, dimensionality is reduced by pooling layer, and classification is performed by fully connected layer.

$$\mathrm{f}(\mathrm{x}, \mathrm{W}, \mathrm{b}) = \mathrm{softmax}(W \cdot h(x) + b) \tag{4}$$

Where f is the final classification function, $h(x)$ is the eigenvector after multiple convolution and pooling operations, W and b are the weight matrix and the bias term respectively.

Recurrent neural networks (RNN) and their variants LSTM/GRU: For sequential data such as voice intonation analysis, are capable of capturing dependencies in time series.

5.2. Adaptive and optimization algorithms

Adaptive algorithms and optimization algorithms allow multi-sensory environments to be dynamically adjusted based on real-time monitoring of the user's state, providing a more personalized experience. Such algorithms include but are not limited to genetic algorithms, particle swarm optimization, reinforcement learning, etc.

Adaptive algorithm: Automatically adjust parameters for optimal performance based on user feedback and environmental changes. For example, in virtual reality scenes, visual effects, sound effects, etc. can be adjusted in real time according to the user's physiological signals to ensure the most comfortable experience.

Adaptive filter: Such as the minimum mean square error (LMS) algorithm, the update rule is:

$$w(n+1) = w(n) + \mu e(n)x(n) \tag{5}$$

where *w* is the filter coefficient, μ is the step factor, *e* is the error signal, and *x* is the input signal.

Optimization algorithm: It is used to find the optimal solution to minimize the cost function or maximize the objective function. In terms of health and well-being promotion, rehabilitation programs or health management strategies that are most suitable for individuals can be found through optimization algorithms.

Gradient descent: Used to minimize the loss function J(w), the update rule is:

$$w = -\alpha \nabla_w J(w) \tag{6}$$

where α is the learning rate and ∇wJ(w) is the gradient of the loss function with respect to the weight *w*.

Particle swarm optimization (PSO): Simulates the foraging behavior of birds, each particle represents a potential solution, and the global optimal solution is found through speed and position updates.

Reinforcement learning: The reward mechanism allows the agent to learn how to take actions to maximize the cumulative reward. It is suitable for the behavior training of virtual avat.

Q-learning: Update rules are:

$$Q(s_t, a_t) \leftarrow Q(s_t, a_t) + \alpha \left[r_{t+1} + \gamma \max_a Q\,(s_{t+1}, a) - Q(s_t, a_t) \right] \tag{7}$$

where Q is the action value function, α is the learning rate, *r* is the immediate reward, and γ is the discount factor.

5.3. Data mining and recommendation system

Data mining is the process of extracting valuable information from massive data, while recommendation system provides personalized suggestions to users according to their historical behaviors and personal preferences. Both play an important role in multi-sensory environmental art design.

Association rule mining: Look for potential connections between data to help designers understand changing trends in user needs. For example, in a museum exhibition, it is possible to understand the level of interest of visitors in different types of exhibits by analyzing their stay time and click records.

Apriori algorithm: Used to generate frequent item sets and association rules for support and confidence:

$$\text{support}(X \rightarrow Y) = P(X \cup Y) \tag{8}$$

$$\text{confidence}(X \rightarrow Y) = P(\,Y \mid X\,) \tag{9}$$

6. Related experimental studies

In order to verify the effectiveness of bioinformatics in multi-sensory environmental art design, we designed and implemented a series of experiments. The following are the specific experimental results and analysis:

6.1. User status monitoring and personalized adjustment

With the support of bioinformatics, the user's physiological and psychological state can be monitored in real time, thereby achieving dynamic adjustment of the environment. To ensure the accuracy and reliability of the data, high-precision sensors and standardized data collection methods are used. In the experimental demonstration, the physiological indicators of 50 participants in different emotional states (such as heart rate variability, skin electrodermal activity, and brain waves) were recorded, and multiple calibrations and data verifications were performed to ensure the accuracy and consistency of the data. In addition, all data collection processes are subject to strict quality control to ensure the reliability and repeatability of the results. The research results are shown in **Table 1**. By dynamically adjusting environmental parameters, such as reducing light intensity and playing soothing music, the anxiety level of the participants can be effectively reduced, with an average decrease of 20%, and the comfort score increased by 30%. These data verify the feasibility of combining biosignal processing with environmental regulation in improving user experience.

Table 1. User status monitoring and personalized adjustment experimental results.

Experimental conditions	Anxiety level reduction (%)	Comfort score improvement (%)
Dynamic adjustment of environmental parameters	20	30
Fixed environmental parameters (control group)	5	10

6.2. Emotional computing and emotional guidance

Emotional computing technology can achieve accurate recognition of user emotions by analyzing the user's facial expressions, voice intonation and physiological signals. In a virtual reality experiment, we designed two scenarios: one to induce pleasant emotions and the other to enhance alert emotions. The experimental results are shown in **Table 2**. 80% of the participants in the pleasant scene showed positive facial expressions, while 75% of the participants in the alert scene experienced increased heart rate and pupil dilation. The results show that by properly designing multi-sensory scenes, emotional computing technology can significantly enhance users' emotional experience.

Table 2. Emotional computing and emotion guidance experimental results.

Scenario type	Positive expression ratio (%)	Heart rate increase ratio (%)	Pupil dilation ratio (%)
Pleasant scene	80	10	5
Alert scene	20	75	75

6.3. Avatars and social interaction

As an innovative way to improve the quality of remote interaction, the effect of virtual avatars has been verified in experiments. As shown in **Table 3**, in the experiment comparing traditional video conferencing with avatar meetings, the immersion score of the avatar environment was 40% higher than that of traditional meetings, and significantly enhanced the frequency of natural gestures and eye contact between users. This shows that avatar technology has great potential to enhance remote collaboration and entertainment experiences.

Table 3. Results of the virtual avatar and social interaction experiment.

Meeting type	Immersion score improvement (%)	Natural gesture frequency improvement (%)	Eye contact frequency improvement (%)
Avatar meeting	40	30	25
Traditional video conference	0	0	0

6.4. Health and well-being promotion

The multi-sensory healing space experiment designed for the elderly showed that during the 20-min healing process, the participants' blood pressure dropped by an average of 8%, heart rate dropped by 12%, and subjective relaxation scores increased by 25%. This shows that a healing environment that combines bioinformatics technology and multi-sensory design can effectively improve the physical and mental health of the elderly.

7. Conclusion and prospect

Through in-depth discussion on the application of biological information technology in multi-sensory environmental art design, this study draws the following main conclusions: By introducing advanced technologies such as biological signal processing and emotional computing, the system can monitor users' physiological and psychological states in real time, and dynamically adjust environmental parameters according to these information, which significantly improves the quality of personalized experience; The application of virtual reality (VR), augmented reality (AR) and mixed reality (MR) technology enables users to carry out realistic gesture control, eye contact and dialogue communication in the virtual environment, enhancing the sense of realism and immersion of remote interaction; Multi-sensory environments designed for special populations, such as the elderly and recovering patients, not only help to improve their physical function, but also provide mental health support, such as stress reduction and sleep aid; With the help of machine learning, deep learning, adaptive algorithms and recommendation systems, designers can better understand user needs, optimize design solutions, and create more intelligent and humane multi-sensory experience Spaces.

Although this paper has achieved some research results, there are still many directions worth further exploration in this field. With the development of quantum computers, their powerful parallel processing capabilities may bring new breakthroughs for complex biological signal analysis and pattern recognition; Advances in BCI technology will allow us to read brain activity more directly, enabling more accurate emotion recognition and user intent prediction; Deepen the understanding of human perception mechanism and its response to external stimuli, and provide a solid theoretical basis for multi-sensory environmental art design; Study changes in patterns of interaction between people, especially behavioral characteristics on virtual social platforms, to improve avatar technology and remote collaboration experiences; As more and more personal data is collected for analysis and optimization of services, how to ensure user privacy becomes an important issue; The design should take into account people of different cultures and backgrounds and avoid any form of discrimination or inequality. In addition, energy efficiency and material innovation are also the direction of future development.

To sum up, the application of bioinformation technology in multi-sensory environmental art design has made remarkable progress, but it also faces many challenges. Future research needs to continue to focus on technological innovation, interdisciplinary collaboration, and ethical considerations to promote the healthy development of this field. It is hoped that through the research results and the prospect proposed in this paper, more scholars and practitioners can be inspired to participate in this emerging field full of potential.

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