

# Digital Technology and Artificial Intelligence: New Paradigms and Trends in Environmental Design

Jiachuan Zhang, Zhipeng Jia

College of Arts and Media, Shenyang Urban Construction University, Shenyang 110167, Liaoning, China

## ABSTRACT

With the rapid evolution of information technology, digital process and artificial intelligence (AI) are becoming decisive forces in the innovation of environmental design discipline. This paper examines how these advances have transformed the core mechanisms of environmental design practice, from the early days of computer-aided design (CAD) and building information modeling (BIM) to the latest machine learning strategies and the use of intelligent design platforms, revealing their significant contribution to improving design execution efficiency and optimization quality. As well as catalyzing environmentally friendly sustainability and user experience innovation. At the same time, this paper also evaluates the current technology implementation obstacles, including security concerns, regulatory constraints and other aspects of the shackles, and carries out strategic foresight on the potential development prospects.

## KEYWORDS

Digital Technology; Artificial Intelligence; Environmental Design; Ecological Sustainability; Intelligent Design Tools.

## 1. INTRODUCTION

In recent years, the pace of global scientific and technological progress has been accelerating, especially the outstanding breakthroughs achieved within the boundaries of digital technology and artificial intelligence, and various industrial fields have encountered unprecedented transformation. Environmental design as a comprehensive consideration of natural conditions, social needs and aesthetic value of the professional field, under this background is no exception has been deeply affected. The introduction of digital technologies such as CAD and BIM has significantly increased the productivity of designers. Artificial intelligence technologies, including machine learning algorithms, deep learning architectures and various intelligent design assistance platforms, have created new possibilities for building more livable and green environmental Spaces[1]. Through a detailed investigation of a series of examples, we can gain insight into how these advanced technologies revolutionize the theoretical basis of traditional design strategies in environmental design practice and reveal their subversive impact on the paradigm of environmental design. At the same time, this paper analyzes the core problems in this field and the foreboding future evolution trend. After an overview of the basic concepts of digital technology and its function in environmental design, this article will focus on how artificial intelligence technology can change the way we think about design solutions, and how it can help designers accurately predict user behavior and further optimize design outcomes. In addition, we will explore the synergies that arise when these two forces are combined - both in terms of improving work efficiency and promoting green building design.

Finally, this paper will make suggestions to improve the limitations of existing technologies, and make predictions about the new trends that may emerge in the next few years.

## **2. APPLICATION OF DIGITAL TECHNOLOGY IN ENVIRONMENTAL DESIGN**

Computer aided design has been used in the field of architectural design since the 1960s. It uses software tools to help designers create accurate design drawings and three-dimensional models. For environmental design, CAD not only simplifies the conversion process from conceptual sketches to detailed construction drawings, but also provides powerful editing capabilities that allow designers to easily modify design schemes to adapt to changing needs [2]. In addition, modern CAD systems often integrate rendering capabilities that allow designers to preview the actual effects of their work in advance, which improves communication efficiency and reduces error rates. Specifically, CAD can not only carry out landscape planning such as terrain analysis and vegetation layout, but also quickly generate plane layout and elevation view, support material mapping simulation interior design and optimize people flow path planning, and ensure safe evacuation of public space design.

Building Information Modeling (BIM) is a methodology based on three-dimensional digital technology, which goes beyond the traditional two-dimensional drawing method and provides an integrated data platform for the entire building life cycle [3]. The core of BIM is its ability to go beyond visual presentation and, more importantly, to manage all relevant information about a project, including geometry, material properties, cost estimates, and more. This allows for more efficient collaboration between different professional teams, reducing errors and delays caused by information asymmetry. One of its advantages is that multi-disciplinary collaboration, architects, structural engineers, mechanical and electrical engineers can cooperate seamlessly. The second is cost control and time management, by pre-simulating the construction process to identify potential problems and reduce the number of reworks. Third, sustainability assessment. Built-in energy analysis tools can help evaluate the energy performance of buildings and promote green building practices [4]. BIM can be applied to large complex projects, such as shopping malls or office buildings, where future operational and maintenance needs are taken into account at the design stage; Historical building protection: Use BIM technology to record and analyze existing conditions to provide accurate data support for restoration projects; Smart city planning: Combining geographic information system (GIS) data to realize the optimal allocation of city-level resources [5].

Whether it is CAD or BIM, these advanced digital technologies are constantly changing the face of the environmental design industry. They not only enhance work efficiency and facilitate effective communication across disciplines, but also promote the development of more sustainable and humane design concepts.

## **3. APPLICATION OF ARTIFICIAL INTELLIGENCE IN ENVIRONMENTAL DESIGN**

### **3.1. Artificial Intelligence (AI)**

AI technology's rapid advancement is revealing great potential in environmental design applications. Artificial intelligence technologies - including machine learning and deep learning, intelligent design tools, and data analysis and user behavior prediction - and how they change the methodology and practice of environmental design. Intelligent design tools combine AI technology to increase the automation and creativity of the design process. These tools can generate multiple design options for designers to choose from by defining a set of parameters and rules. Provide real-time feedback and even complete part of the design work yourself to support the designer's work, extract key elements from concept sketches, and quickly generate detailed design drawings. Figma is a cloud-based design

software with built-in AI-assisted features such as automatic layout adjustment, rapid prototyping, and more. Designers can complete complex interface designs with simple drag and drop operations, and Figma also supports real-time collaboration among multiple people, which is especially useful in team projects. In addition, big data analysis and user behavior prediction is another important application area of AI technology in environmental design, Ikea uses big data analytics to understand the lifestyles and buying habits of consumers around the world. By collecting data from its retail stores, website and social media, Ikea is able to accurately predict the needs of customers in different regions. In the Chinese market, for example, IKEA has seen a growing interest among the younger generation in multi-functional furniture. Based on this insight, IKEA has introduced product lines that are more suitable for small living Spaces, such as foldable tables and chairs and embedded storage solutions. This not only increased product sales by 20%, but also significantly increased customer satisfaction scores to over 90%[6]. Through the analysis of a large number of user data, designers can better understand user needs and behavior patterns, so as to create more in line with user expectations of the design scheme. This analysis can also predict future trends and guide design decisions.

### **3.2. Machine Learning and Deep Learning**

Machine learning is a technique that lets computers learn from data and improve performance on specific tasks. In environmental design, by automatically identifying patterns and analyzing spatial layout data of a large number of existing buildings, the optimal spatial configuration scheme can be recommended[7,8]. Improve the efficiency of decision-making. In energy efficiency assessment, machine learning technology is used to predict building energy consumption, allowing designers to achieve more energy-efficient designs. Deep learning, a branch of machine learning that utilizes deep neural networks and processes complex data structures such as images and speech, offers new ways for environmental designers to understand and model complex natural environments and social behaviors.

## **4. THE IMPACT OF COMBINING DIGITAL TECHNOLOGY WITH ARTIFICIAL INTELLIGENCE**

### **4.1. Improve Design Efficiency and Quality**

The convergence of digital technology and artificial intelligence has greatly improved the efficiency in the environmental design process and the quality of the final product. With automated tools like parametric design software, such as Grasshopper, and intelligent algorithms, designers can generate complex designs faster while reducing the possibility of errors and rework. For instance, using generative design tools, architects can explore numerous design alternatives that meet specific criteria, enabling them to select the most efficient and innovative solutions for their projects. Moreover, with the help of 3D printing, the production of fast physical models can accelerate the design verification process significantly. This technology allows designers to create tangible prototypes of their concepts, such as intricate façade elements or structural components, which can be tested for functionality and aesthetics before full-scale production begins. AI-based real-time analysis tools, like Autodesk Insight, enable real-time evaluation of the technical feasibility and aesthetic value of design proposals. For example, by integrating energy simulation capabilities, designers can assess the energy performance of various design iterations instantly, optimizing for both functionality and sustainability.

Multidisciplinary team members can collaborate seamlessly on platforms like BIM 360, where they can share data and resources in real time[9]. The integration of Building Information Modeling (BIM) with AI tools helps automatically detect potential conflicts in designs, such as clashes between structural and mechanical systems, and suggest solutions to resolve these issues proactively. The application of digital technologies and artificial intelligence not only improves design efficiency but also promotes more environmentally friendly and sustainable design practices. Through data analysis

and simulation, designers can better understand environmental impacts and develop greener solutions. For example, the use of machine learning models to predict building energy consumption enables teams to optimize energy use effectively. A notable case is the design of the Edge in Amsterdam, where predictive analytics were employed to minimize energy consumption and enhance occupant comfort. Simulation software, such as EnergyPlus and Rhino's Ladybug, allows designers to simulate lighting and ventilation conditions across different design schemes, enabling them to select the optimal scheme that maximizes natural light while minimizing energy use. These tools evaluate various factors, including daylight availability, thermal comfort, and airflow patterns, to create a holistic view of the building's performance. Finally, assessing environmental impact throughout the entire lifecycle—from construction to demolition—facilitates sustainable design decisions. For instance, Life Cycle Assessment (LCA) tools can quantify the carbon footprint of materials used, their energy consumption during operation, and waste generated at the end of life, guiding designers in selecting more environmentally friendly building materials. By employing these advanced technologies and methodologies, the design process becomes not only more efficient but also significantly more sustainable.

## **4.2. Enhance User Experience and Interaction**

The application of digital technology and AI significantly enhances design efficiency, quality, user engagement, and overall experience. Existing products like Oculus Rift and HTC Vive utilize virtual reality (VR) to immerse users in indoor and outdoor designs, allowing them to intuitively grasp the designer's intent and provide valuable early feedback[10-12]. For instance, in the design of the The Edge office building in Amsterdam, VR was employed to allow stakeholders to explore the space before construction, leading to informed decisions and refinements based on user input. Augmented reality (AR) tools, such as Microsoft HoloLens, enable users to overlay virtual elements onto real environments. This capability allows stakeholders to visualize new designs on existing buildings or vacant lots, enhancing their understanding of the future space. An example of this application can be seen in the City of San Francisco's AR project, where planners used AR to visualize proposed developments within the urban landscape, facilitating real-time adjustments and improving design feasibility. Combining VR/AR technology with platforms like SketchUp Viewer, designers can create an online feedback system where users can navigate the design model in a virtual environment and submit their opinions through simple interactions. This instant feedback mechanism empowers designers to respond quickly to user needs, leading to more personalized customization. In large public projects, such as urban planning initiatives or park design, VR/AR technology has been instrumental in fostering public engagement. For example, the Dallas Park and Recreation Department utilized VR to gather community input on park designs, ensuring diverse opinions were considered and enhancing community identity. Big data analytics tools, like Google Analytics and Tableau, collect and analyze user behavior and preferences, while machine learning models predict future user behaviors. These insights help designers better understand user needs and habits, enabling them to create spaces that align closely with user expectations. In office space design, for example, companies like WeWork have optimized space layouts based on the working habits and activity patterns of employees, resulting in more functional and enjoyable work environments. An intelligent recommendation system, such as Houzz, offers tailored design solutions based on users' historical data and preferences, providing personalized interior design schemes. Integrated smart home systems, like Nest and Philips Hue, automatically adjust lighting and temperature to user preferences upon entering a room. Voice assistants, such as Amazon Alexa and Google Assistant, enhance convenience by enabling easy control of home devices like lights, curtains, and audio systems. This natural language interaction simplifies user operations and significantly improves the living experience. Smart home systems can create various automation scenarios, such as "Home Mode" or "Away Mode," allowing users to initiate multiple device linkages with a single command, thereby streamlining the user experience. In commercial spaces or exhibition halls, interactive touch screen interfaces, like those used in Samsung's Smart Signage, allow users to explore information through

simple touch operations and even participate in the design process. Additionally, gesture recognition technology, as seen in products like Leap Motion, enables users to interact with virtual environments through simple gestures, enhancing engagement and enjoyment in the experience. These innovations collectively transform the design process, making it more inclusive and user-centric.

## 5. CHALLENGES AND FUTURE TRENDS

While digital technologies and artificial intelligence present unprecedented opportunities for environmental design, their application also faces a host of challenges. This chapter explores these challenges and looks at the way forward. With the continuous advancement of technology, digital technology and AI are being applied more and more widely in environmental design. However, technology maturity and security remain key issues that need to be addressed. Some current AI algorithms still have limitations when dealing with complex environmental data, especially in the face of changing natural conditions and social behavior. High-quality data is fundamental to training effective models, but obtaining comprehensive and accurate data remains challenging in some cases. When collecting and analyzing user behavior data, how to protect personal privacy becomes an important issue. Intelligent design tools and platforms can be at risk from cyber attacks, and ensuring the security of your systems is critical. The promotion of new technology not only depends on the technology itself, but also needs to consider the acceptance of users and relevant laws and regulations. Designers and related practitioners need to be trained in new skills to make the most of these technologies. The level of trust users have in new technologies directly affects their acceptance, so confidence needs to be enhanced through successful cases and transparent operational processes. Develop unified technical standards and industry norms to ensure the consistency and reliability of technical applications. Clarify the ownership of intellectual property rights of design achievements and protect the rights and interests of innovators.

Facing current challenges, future R&D will focus on: technological innovation, developing intelligent algorithms, handling complex tasks, interdisciplinary integration with IoT, big data, etc., enhancing design quality. AI will offer personalized space solutions. Intuitive design tools will lower thresholds and boost user engagement. Higher green building standards and eco-friendly, renewable materials will promote sustainability.

## 6. CONCLUSION

This paper explores how digital technologies and AI are transforming environmental design, enhancing efficiency, quality, and sustainability. CAD and BIM significantly improve design accuracy and collaboration. Machine learning, deep learning, and intelligent tools offer powerful analysis and innovation. It has practical significance, demonstrating technology's role in improving productivity and design quality, and highlighting implementation factors. Findings can guide policymakers. With technology advancements, innovative methods and tools will emerge. Continuous R&D investment, technical training, and legal frameworks are needed to overcome challenges and ensure technology maturity, security, and standardization.

## REFERENCES

- [1] Lu Y. Artificial intelligence: a survey on evolution, models, applications and future trends[J]. *Journal of Management Analytics*, 2019, 6(1): 1-29.
- [2] Obaid A J, Sharma S. Recent trends and development of heuristic artificial intelligence approach in mechanical system and engineering product design[J]. *Saudi Journal of Engineering and Technology*, 2020, 5(2): 86-93.
- [3] Cozac E B. The Process of Designing Artificial Intelligence: Development Trends and Prospects[J]. *НАУКОВИЙ ВІСНИК*, 2021, 8(3): 83.

- [4] Mühlroth C, Grottko M. Artificial intelligence in innovation: how to spot emerging trends and technologies[J]. IEEE Transactions on Engineering Management, 2020, 69(2): 493-510.
- [5] Devagiri J S, Paheding S, Niyaz Q, et al. Augmented Reality and Artificial Intelligence in industry: Trends, tools, and future challenges[J]. Expert Systems with Applications, 2022, 207: 118002.
- [6] Huda N U, Ahmed I, Adnan M, et al. Experts and intelligent systems for smart homes' Transformation to Sustainable Smart Cities: A comprehensive review[J]. Expert Systems with Applications, 2024, 238: 122380.
- [7] Gao J, Tang Y, Martella D, et al. Stimuli-responsive photonic actuators for integrated biomimetic and intelligent systems[J]. Responsive Materials, 2023, 1(1): e20230008.
- [8] Vyas B. Java-Powered AI: Implementing Intelligent Systems with Code[J]. Journal of Science & Technology, 2023, 4(6): 1-12.
- [9] Virmani D, Ghori M A S, Tyagi N, et al. Machine Learning: The Driving Force Behind Intelligent Systems and Predictive Analytics[C]//2024 International Conference on Trends in Quantum Computing and Emerging Business Technologies. IEEE, 2024: 1-6.
- [10] Hu H, Xu J, Liu M, et al. Vaccine supply chain management: An intelligent system utilizing blockchain, IoT and machine learning[J]. Journal of business research, 2023, 156: 113480.
- [11] Chowdhury R H. Intelligent systems for healthcare diagnostics and treatment[J]. World Journal of Advanced Research and Reviews, 2024, 23(1): 007-015.
- [12] Taherdoost H, Madanchian M. Analytic Network Process (ANP) method: A comprehensive review of applications, advantages, and limitations[J]. Taherdoost, H., & Madanchian, M.(2023). Analytic Network Process (ANP) Method: A Comprehensive Review of Applications, Advantages, and Limitations. Journal of Data Science and Intelligent Systems, 2023.