A Study on the Application of Artificial Intelligence in Ecological Design

Hengyue Zhao

School of ArchitectureCarnegie Mellon University， Pittsburgh, PA, USA；

ABSTRACT： This article explores the shift from human dominance over nature to an interconnected relationship facilitated by artificial intelligence (AI), viewing nature as possessing "personhood." It examines AI ’ s role in current ecological transformations, particularly within art and design, distinguishing this new AI-nature paradigm from traditional methods. By analyzing how artists and designers integrate AI into ecological and geophysical practices — through data analysis, image recognition, and ecological restoration — the study highlights innovative artistic expressions enabled by combining AI with non-human life. This approach offers new creative possibilities beyond traditional human-centered design frameworks.

CCS CONCEPTS

• Artificial intelligence • Ecological design • Sustainable architecture

KEYWORDS: Artificial Intelligence; Ecological Transformation; Non-human Life; Ecological Restoration; Sustainable Design; Human AI Interaction

DOI:10.69979/3041-0843.25.01.059

1 INTRODUCTION

1.1 Background of the Study

For centuries, humans have dominated and controlled nature, building a civilization that contrasts with natural systems. This antagonistic relationship has led to ecological destruction, as civilization and nature are often seen as opposing forces. Infrastructure development, driven by imperial expansion, capital accumulation, and warfare, has accelerated industrialization, urbanization, and commercial agriculture, worsening environmental degradation. If this trajectory continues, the planet will be destroyed by human actions, necessitating new pathways for ecological transformation to reshape the human-nature relationship.

Ecological design emerged in the 1960s alongside growing awareness of the environmental crisis and the focus on sustainable development. It has become a dominant design paradigm, emphasizing environmental protection, resource efficiency, and social responsibility. Its core goal is to reduce environmental impacts and achieve harmonious development between the economy, society, and environment.

As humans confront complex natural systems, it is clear that our limited knowledge cannot fully grasp the entirety of nature. This realization calls for recognizing humans as part of the world and rethinking our relationships with other entities. Ecological restoration thus becomes a means of coexistence, based on mutual benefit and compassion. Integrating science, art, social innovation, and design, AI may serve as a new tool in establishing this connection and promoting ecological transformation.

1.2 Research Objectives, Methods, and

Significance

This research explores ecological transformation through AI-integrated plant-based ecological practices. By combining ecological actions, design, art, and AI technology, it investigates new approaches to rebuild human-nature relationships and alleviate ecological crises. Using literature review, case analysis, inductive reasoning, and comparative research, it addresses challenges in ecological protection in China, highlighting AI's necessity in accuracy, efficiency, intelligence, and sustainability. Three AI-driven interventions—intelligent early warning, supervision, and maintenance—are proposed to strengthen ecological protection. Additionally, the study discusses how AI can enhance human-nature connections and introduces new design models for environmental conservation.

1.3 Research Status at Home and Abroad

In recent decades, artists and designers have increasingly engaged with ecological issues through projects such as Buckminster Fuller's Manhattan Dome, Joseph Beuys' Elbe River cleanup, Agnes Dénes' symbolic wheat field, and Mel Chin's "Revival Field," employing cross-disciplinary collaboration. However, these works often lack a systemic approach and rarely explore technological interventions.

Current research on AI in ecological design remains limited, with early efforts seen in interior, architectural, and rural ecological design. John Thackara highlights AI's potential to foster kinship rather than control over nature, advocating concepts like "citizen ecology" and platforms such as TreesAI for urban ecological improvement. Domestic scholars like Liang Jianian, Cao Shengsheng, and Guan Zenglun emphasize AI's value in enhancing interior and rural environments and smart buildings. Liu Zhixiong, Li Yanfei, and others also discuss AI's role in ecological protection through digital economy and smart technologies.

Overall, AI integration into ecological design is still emerging, and existing literature and practices provide key references for this research.

2 EXPLORING THE POTENTIAL OF INTE-

GRATING AI AND ECOLOGICAL DESIGN TO PROMOTE ECOLOGICAL TRANSFOR- MATION

2.1 Artificial Intelligence and Ecological Design

With rapid socio-economic growth in China, ecological challenges such as pollution, deforestation, and biodiversity loss have intensified. Traditional ecological design often relies on subjective experiences, lacks comprehensive data analysis, and insufficiently accounts for future uncertainties, resulting in inadequate solutions. Artificial Intelligence (AI), a computer science discipline introduced in 1956, has increasingly been applied in ecological design, addressing these limitations. AI techniques like machine learning and simulation offer precise data analysis, scenario prediction, and design optimization, significantly enhancing ecological solutions and promoting sustainable environments.

2.2 The Necessity of Integrating AI into Ecological

Design

The history of modern humanity is characterized by a growing separation from nature. Our excessive pursuit of development has often led us to neglect ecological concerns. Human societies typically prioritize economic growth, overlooking the foundational role that ecosystems play in supporting economies. This oversight has significantly harmed the environment that sustains our lives.

As ecological crises and environmental issues grow increasingly complex, human capabilities alone are insufficient to address these challenges. Integrating artificial intelligence (AI), as another complex system, into ecological design offers a viable solution:

1.AI-driven ecological design emphasizes the purpose and outcomes of design, beyond mere aesthetics and form.

2.AI provides intelligent analysis and optimization of environ- mental and resource data, significantly enhancing design efficiency and accuracy.

3.AI-driven design leverages extensive datasets and models through machine learning and data mining techniques to detect and analyze environmental trends, thereby offering designers more comprehensive and accurate data support.

4.AI-driven ecological design considers entire ecosystems, taking into account diverse factors to achieve sustainable design outcomes that protect the environment and human health.

5.AI-driven design facilitate modeling and simulation, enabling scenario-based predictions and rapid identification and correction of design flaws, thus optimizing design processes.

Therefore, developing AI-integrated modern ecological design is an inevitable trend. With AI assistance, harmonizing the relation- ship between humans and nature holds significant potential for addressing environmental challenges such as air and water pollution and climate change.

2.3Pathways for Integrating AI into Ecological

Design

With the increasing prominence and widespread adoption of sustainable development concepts, enhancing ecological environ- ments has gained heightened attention. Particularly with rapid economic growth, harmonizing ecological conservation and high-quality development has emerged as a critical issue today.

In the AI era, adopting advanced technologies such as satellite remote sensing, drone inspections, real-time monitoring, and big data analysis enables "non-contact" and "remote" management approaches. These technologies significantly enhance environmen- tal management efficiency, reduce pollution, prevent environmen- tal crises, and substantially improve ecological outcomes. Integrat- ing AI into ecological design to promote environmental protection can be approached through three primary pathways: intelligent early warning, intelligent supervision, and intelligent maintenance.

Firstly, high-density monitoring stations for fixed pollution sources and key regions utilize AI for deep learning data analysis, enabling rapid response and intelligent early-warning systems, with real-time alerts disseminated through data platforms and mobile applications.

Secondly, intelligent supervision employs sensors for real-time monitoring of target areas. The sensor data are transmitted to data centers for comprehensive analysis, allowing precise and scientifi- cally grounded environmental management solutions that surpass traditional manual supervision methods.

Finally, intelligent maintenance introduces the Internet of Things (IoT) and 5G technologies into environmental education and advocacy, fostering greater public awareness and participation in ecological protection. Additionally, applying AI technologies in daily production and life conserves human resources and reduces water and electricity consumption, effectively maintaining ecologi- cal balance.

Currently, integrating AI into ecological design in China is still at a preliminary exploration stage. The strategic implementation of intelligent early warning, intelligent supervision, and intelligent maintenance can effectively enhance ecological protection efforts.

3 "HEAVY METAL LOCK" ARTISTIC

DESIGN PRACTICE: EMPOWERING

ECOLOGICAL AND CREATIVE FORMS THROUGH NEW TECHNOLOGIES

3.1 Design as Research: Ecological Blind Spots

Created by Electronic Devices

3.1.1 Heavy Metal Pollution Caused by Electronic Waste

The rapid development of digital devices has significantly increased electronic waste, posing severe threats to soil, water, and air quality. Electronic waste contains harmful heavy metals like lead, mercury, and cadmium, as well as persistent organic pollutants (POPs), which cannot degrade naturally and are challenging to remove once released. Global electronic waste reached 65.4 million tons in 2017, with China becoming a major disposal site, especially in towns like Guiyu and Taizhou, where severe heavy metal pollution has been detected. Waterborne heavy metal pollution originates from both natural processes and human activities, particularly industrial wastewater from industries like mining, electroplating, and chemicals.

3.1.2 Analysis of the Causes of Heavy Metal Pollution

The main causes of heavy metal pollution due to electronic waste are threefold. First, the raw materials used in electronic devices contain significant amounts of heavy metals, such as copper, lead, and nickel, which are essential in processes like PCB manufactur- ing. For instance, in the electronic industry's PCB manufacturing process, multiple stages such as pre-treatment, drilling, and exposure require the use of heavy metals.Second, the manufacturing of electronic devices often necessitates the addition of heavy metals. For example, the assembly of various digital devices involves adding different metals, such as lead-free solder and soft soldering materials, which are required to ensure the appropriate melting point, wetting, flexibility, and filling capacity of the solder.

Finally, improper disposal of discarded electronic devices contrib- utes to heavy metal pollution. These devices are either discarded improperly or treated using outdated recycling methods, such as pyrometallurgical and hydrometallurgical processes, which direct- ly release large amounts of heavy metals into the environment. For example, during hydrometallurgical processes, acid washing or acid baths produce waste acid that contains high concentrations of copper ions, which are often indiscriminately dumped into rivers or soil, causing secondary pollution.

3.1.3 Ecological Blind Spots

I introduce "ecological blind spots," which arise from our overreliance on technology and reduced attention to natural ecology. Massive digital infrastructures behind everyday devices, like smartphones and video games, silently contribute significant ecological damage through CO_2 emissions and resource overuse—yet these impacts often remain unnoticed. Our focus on digital information rather than natural ecosystems prevents us from recognizing and addressing these harmful effects. In this context, AI could provide a new approach to mitigating such crises.

3.2 Design as a System: Next-Generation Water- borne Heavy Metal Treatment System

Based on the research above, the project Heavy Metal Lock utilizes innovative technology in ecological design to address waterborne heavy metal pollution. Traditional remediation methods are costly and unsustainable, often causing additional environmental harm. Thus, plant-based remediation emerges as an effective and economical alternative.

Inspired by botany, this new system employs hyperaccumulating plants to naturally absorb, immobilize, and remove heavy metals from water. This approach includes processes like phytoremediation, phytodegradation, phytoextraction, and phytostabilization. Efficiency depends on factors such as water pH, organic matter, and plant tolerance, with higher biomass yield enhancing extraction effectiveness.

The design also emphasizes localized solutions, engaging local communities and plant expert systems to accurately identify pollution sources. Utilizing locally available materials, users can assemble tailored treatment units and contribute data via an accessible interface, facilitating collective action to resolve environmental crises.

Figure 1: An overview of the modular water remediation system, showing the five-step design process integrating plants, sensors, and bio-modular spheres for in-situ heavy metal treatment.

In the design of Heavy Metal Lock, AI plays a pivotal role by enabling intelligent and automated water treatment systems. Here are some key AI attributes in this process:

1.Prediction and Pattern Recognition: AI models predict and identify heavy metal pollution in water bodies in real-time, providing accurate early warnings, making remediation efforts more targeted and timely.

2. Adaptability: AI systems can adjust parameters like the angle, height, and absorption area of the plant absorption

devices in real-time, ensuring optimal remediation results.

3. Data Analysis and Decision Support: AI systems automatical- ly collect and analyze environmental data, providing decision support for optimizing plant-based remediation strategies.

4.Learning and Self-Optimization: The system continuously optimizes its predictive models and decision rules through ongoing data collection, improving the efficiency of remedia- tion over time.

5. Interactivity and Community Participation: The system can automatically generate remediation plans based on user-up- loaded pollution data, assist with seed package purchases, and guide the assembly of devices. It can also help initiate commu- nity engagement by inviting like-minded locals to participate in the restoration efforts.

These attributes not only enhance the efficiency of remediation but also lower costs and foster community involvement, offering strong technological support for realizing the design vision.

4 CONCLUSION

Humanity’s historical pursuit of controlling nature has led to severe ecological degradation. Ecological design now demands a globally informed perspective, prompting this research to examine whether artificial intelligence (AI) can foster harmonious coexistence.

Addressing China's freshwater heavy-metal contamination, we highlight traditional ecological design's limitations, such as fragmented data and subjective judgments. AI's advanced predictive modeling and optimization capabilities can overcome these issues, enabling sustainable solutions. We propose three AI-driven design pathways—intelligent early warning, monitoring, and maintenance—that demonstrably improve environmental protection.

Acknowledging digital consumption’s hidden ecological impacts, we advocate shifting AI’s role from extraction to mediation, promoting care instead of control. We prototype an AI-enabled device for in-situ remediation of water pollution caused by digital waste, aiming to transition design culture from consumerism toward ecological responsibility and crisis mitigation.

REFERENCES

[1]McGovern, Gerry. 2021. Technology Is Destroying Nature. Accessed July 15, 2025. https://gerrymcgovern.com/technology-is-destroying-nature/

[2]McGovern, Gerry. 2023. Hold on to It! Tips for Sustainable Laptops. Accessed July 15, 2025. https://gerrymcgovern.com/turning-off-deleting-tips-for-sus-tainable-laptops-part-2/

[3]Thackara, John. 2022. From Control to Kinship: Ecological Restoration in a More-Than-Human World. Accessed July 15, 2025. https://thackara.com/

[4]Zhang, Yang, and Zhanbo Zheng. 2021. “Tujian jinzhu wuran zhilifa yanjiu jinzhan chutan [An Initial Exploration of Methods for Remediation of Soil Heavy-Metal Pollution].” Ziyuan Jieyue yu Huanbao [Resources Conservation and Environmental Protection] 000(012): 24 - 26.

[5]Zhu, Jianlong, Weijie Xu, Yuankun Guo, et al. 2022. “Shuiti zhongjingshu wuran weihai ji zhilizhong jishu [Hazards and Remediation Technologies of Heavy-Metal Pollution in Water].” Xiandai Nongye Keji [Modern Agricultural Science and Technology] 2022(006): Article 000.

[6]Gao, Shiqing, Guangxiang Ma, Guang Ma, et al. 2021. “Zhiwu xiufu turang zhongjingshu wuran jishu yanjiujinzhan [Research Progress on Phytoremediation Techniques for Soil Heavy-Metal Pollution].” Keji Feng [Science and Technology Review] 2021(11): Article 2.

[7]Li, Yiling, and Xiaolin Yang. 2018. “Changjiang liuyu shuizhiyang wuran zonghe fangkong nengli kongjian chayiji yingxiang yinsu fenxi [Spatial Variation and Influencing Factors of Integrated Water Pollution Prevention in the Yangtze River Basin].” Huanjing Kexue Daokan [Environmental Science Guide] 2018(6).

[8]Barr, A., and E. A. Feigenbaum. 1981. The Handbook of Artificial Intelligence. Los Altos, CA: Morgan Kaufmann.

[9]Cao, Shengsheng. 2022. “Rengong zhineng zai xiangcun shengtai sheji zhong de yingyong jijiazhi quxiang [Application and Value Orientation of AI in RuralEcological Design].” Wenhua Yishu Yanjiu [Culture and Art Research] 2022(4).