Journal of Electronic Research and Application, 2025, Volume 9, Issue 4
http://ojs.bbwpublisher.com/index.php/JERA
ISSN Online: 2208-3510
ISSN Print: 2208-3502

Research on the Application of Virtual Digital Technology in Landscape Engineering Design

Yifei Han, Hongxia Zhao, Zhefeng Li*

Inner Mongolia Agricultural University, Hohhot 010018, Inner Mongolia Autonomous Region, China

**Author to whom correspondence should be addressed.*

Abstract: To investigate the application of virtual digital technology in landscape engineering design, the study adopted the enumeration survey method and observation method. It conducted a comprehensive analysis of the current status and existing challenges of virtual digital technology in landscape engineering design. Additionally, the study provided a detailed description and explanation of the integration between virtual digital technology and landscape engineering design, while exploring its characteristics and application prospects. The findings revealed: (1) In the early design stage, technological integration enhanced design efficiency. The collaborative use of BIM, GIS, and parametric tools enabled a fully digital workflow from conceptual design to construction drawings, reducing design errors and shortening project timelines. (2) After implementation, interactive experiences revolutionized public engagement. AR/VR technologies introduced dynamic interactivity to landscapes, while metaverse platforms expanded the presentation dimensions of virtual landscapes. (3) Smart maintenance promoted sustainability. IoT sensors and AI analytics facilitated real-time plant health monitoring and precise resource management, demonstrating significant advantages. The study identified existing limitations and proposed future directions, aiming to provide new theoretical and practical insights for the research and application of digital technology in landscape engineering design.

Keywords: Virtual digital technology; Landscape engineering; Landscape design; Intelligence

Online publication: August 8, 2025

1. Introduction

As the demand for landscape design work to become smarter and more efficient continues to rise, designers' pursuit of more effective approaches to produce high-quality landscape visualizations has propelled the ongoing updates to virtual simulation technologies [1]. Digital technologies have evolved from mere tools to becoming integral social infrastructure. Technologies such as artificial intelligence (AI) and the metaverse are anticipated to continually drive transformations across various domains, including the economy, healthcare, and education. Landscape engineering design, serving as the core of landscape construction, is not only a fusion of aesthetics and functionality but also a comprehensive reflection of ecological, social, and economic values. High-quality landscape engineering design enhances urban quality, improves living environments, and promotes sustainable development, playing a pivotal role in long-term usage [2–5]. Furthermore, exceptional landscape engineering design can elevate urban imagery, mitigate environmental issues, foster social harmony, and generate long-term economic benefits. The application of virtual simulation technologies in landscape engineering design holds significant potential and advantages. It is expected to efficiently assist in enhancing presentation outcomes and driving innovative development in landscape engineering design. With the diversification of digital media art design models and the growing limitations in spatial dimensions, traditional digital media art is becoming increasingly incapable of fulfilling current design concepts and requirements [6]. Consequently, the investigation into the application of virtual digital technologies within landscape engineering design has emerged as an urgent necessity.

2. Applications of virtual digital technologies in landscape engineering design scenarios

2.1. Virtual reality (VR)

For an immersive preview of landscape schemes, designers and clients can don VR headsets to "step into" the virtual landscape, as shown in **Figure 1**. This allows for an intuitive sense of spatial scale, material texture, and light/shadow variations, moving beyond traditional 2D drawings and static renderings. VR enables collaborative design and remote collaboration. Designers, engineers, clients, and other stakeholders can gather in the same virtual space to mark up and adjust the scheme in real time, cutting communication costs. It also allows for interactive design modifications and real-time rendering. Parameters can be dynamically adjusted, such as terrain elevation, water body shape, or building layout, with the system offering immediate rendering feedback (e.g., the impact of vegetation density on shading). VR can be used to train construction teams to identify differences between design drawings and 3D models, reducing errors. Managers can conduct regular VR-based inspections of landscape facilities (e.g., fountains and lighting systems) and mark areas needing repair [7].

Figure 1. Immersive VR enters the landscape

2.2. Augmented reality (AR)

Used for on-site design and plan adjustment, it can instantly superimpose design models. Designers, via AR devices, directly overlay 3D design schemes on real-world sites as shown in **Figure 2**, checking the match of scale, proportion, and surroundings. Parameters can be dynamically adjusted. Designers can modify vegetation density and material colors in AR models via hand gestures or voice commands, observing real-time effects, like different tree species' impact on shade ranges. Used for AR-based construction layout, it projects contour lines and facility locations from design drawings onto construction sites through AR, guiding machinery operation such as earthwork excavation or planting points, and cutting measurement errors. Additionally, it visualizes hidden projects. Underground pipelines and irrigation systems can be superimposed onto the ground, preventing construction damage.

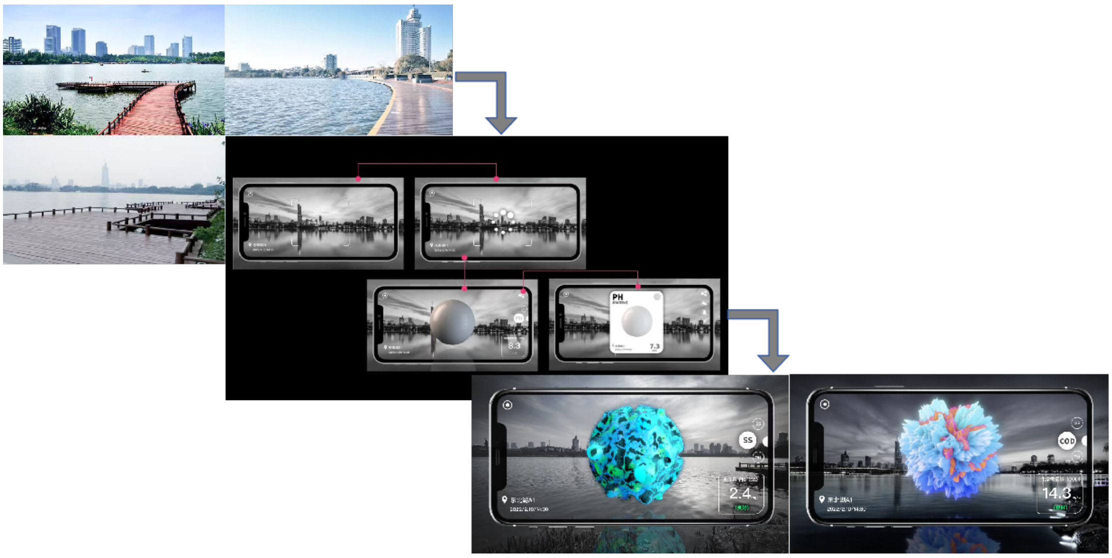

Figure 2. AR landscape overlay desig

2.3. Mixed reality (MR)

Used for landscape engineering design visualization and immersive experience, real-time 3D model overlay through MR headsets (e.g., HoloLens, Magic Leap) can superimpose virtual landscape models onto real sites. As shown in **Figure 3**, engineers can offer on-site construction guidance via MR annotations to ensure proper implementation of complex nodes like landforms and water features. Landscape BIM models (e.g., Revit, Vectorworks) can be imported into the MR environment, with hidden info such as underground pipelines and soil data superimposed to aid integrated design. Combined with GIS data, MR can dynamically display ecological analysis results like wind environment and stormwater runoff to optimize sustainable design [8].

Figure 3. The MR technology superimposes the completed building renderings onto the actual construction site (*Web-sourced images)

2.4. Digital twin

For multi-dimensional modeling, it integrates BIM, GIS, and point-cloud scan data to create a high-precision 3D landscape model as shown in **Figure 4**, covering terrain, vegetation, water bodies, buildings, etc., and supports real-time scheme adjustment and conflict detection [9]. It can simulate the environment, such as wind environment, sunlight/shadow, and stormwater runoff (e.g., via CFD or Envi-met), to optimize plant arrangement and microclimate design. It also enables crowd simulation. By combining Agent-Based Modeling (ABM), it can predict visitor behavior and optimize path planning and node layout (e.g., park entrances, plazas). For construction-process twinning, it uses IoT sensors (e.g., drones, construction-site - site cameras) to collect real-time data, compares it with the digital model, and monitors progress deviations in earthwork, vegetation planting, etc.

Figure 4. Digital twin application scenarios

2.5. Extended reality (XR)

Cloud-based rendering lowers hardware demands for high-quality mobile VR/AR experiences [6]. AI generates landscape schemes via models like Diffusion, with XR enabling real-time visualization. Virtual assistants, such as AI landscape designers, offer smart advice in XR settings. Digital twins, combined with IoT sensor data, allow XR to dynamically show landscape operation status, including plant health and foot traffic.

2.6. 3D modeling and rendering

Used for quick conceptual modeling, tools like SketchUp and Rhino + Grasshopper rapidly construct basic models of terrain, water bodies, and vegetation, supporting scheme development. Algorithms generate complex landscape forms (e.g., curved paving, ecological corridors) to boost design innovation. For high-fidelity scene rendering, real-time rendering (Lumion, Enscape, Twinmotion) enables instant light/shadow and material adjustments, improving efficiency [10]. Offline rendering (V-Ray, Corona) creates high-quality images, animations, and VR panoramas. 3D models are directly converted into construction drawings to cut 2D drawing errors. For example, Singapore's "Gardens by the Bay" (**Figure 5**) used parametric modeling to optimize the supertree grove structure and Enscape for real-time light/shadow adjustments.

Figure 5. Singapore's "Marina Bay Gardens"

3. Integration of virtual digital technologies and landscape engineering design

3.1. 3D modeling and scene simulation

Reality modeling generates centimeter-precise digital twin models via UAV-based oblique photogrammetry and BIM (e.g., the digital base of Baiyun Lake Park in Guangzhou). Dynamic simulation uses Enscape real-time rendering to show sun/shadow and seasonal changes, and predicts plant growth over 20 years. Disaster rehearsals employ the HEC-RAS flood simulation system to verify the rationality of sponge facility layouts.

3.2. Interactive scheme design

AI-assisted generation: MidJourney produces intentional images from keywords like "modern translation of Jiangnan gardens." Parametric optimization: Grasshopper automatically adjusts path density based on crowd heat maps. Collaborative design: Autodesk Forma supports multi-discipline cloud-based synchronous model editing.

3.3. Virtual construction and construction control

4D construction simulation uses Navisworks for visualized schedule management (applied in Beijing Sub-center's Green Heart Park). AR layout positioning: Microsoft HoloLens 2 projects paving patterns on-site at a 1:1 scale. Robotic construction: Boston Dynamics' Spot robot inspects earthwork precision.

3.4. Immersive experience design

VR scene testing: Unreal Engine creates a walkable metaverse garden. Holographic projection: TeamLab uses interactive light/shadow to reconstruct the traditional dry-landscape garden atmosphere. Multi-sensory feedback: Haptic gloves simulate the foot feel of different paving materials.

3.5. Smart operation and maintenance management

Digital dashboard: CIM platforms integrate real-time data like soil moisture and visitor density. AI inspection: DJI Airport automatically identifies seedling pests and diseases. Blockchain tracing: Ginkgo tree growth records are blockchain-certified.

3.6. Paradigm innovation at the practical value level

(1) Breakthrough in design dimensions. Upgraded spatial cognition: MIT Media Lab trials BCI to collect users' subconscious preferences. Non-linear design: Generative AI offers millions of scheme variants (e.g., Spacemaker optimizes landscape plot ratios).

(2) Quantification of ecological benefits. Carbon calculation plugin: Tally real-time tallies of landscape project embodied carbon. Biodiversity prediction: i-Tree assesses tree species' carbon sequestration and oxygen release. Virtual A/B testing compares the urban heat island effects of different paving materials.

(3) Cultural heritage innovation. Digital restoration: Dunhuang Academy uses AI to restore ancient garden colors. Semantic modeling: GIS tags design rules in "The Craft of Gardens." Metaverse exhibitions: Digital-twin Humble Administrator's Garden hosts virtual gatherings.

4. Conclusion

This paper explores the applications of virtual digital technologies in landscape engineering design and draws the following conclusions:

(1) In the early design phase, integrating technologies like BIM, GIS, and parametric tools (e.g., Rhino + Grasshopper) enables full-process digitization from concept to construction drawings, reducing design errors and shortening the project timeline.

(2) After the landscape is put into use, interactive experiences are revolutionized and public participation is enriched. AR/VR technologies bring dynamic interactivity to landscapes, while metaverse platforms (e.g., Decentraland) expand the display dimensions of virtual landscapes.

(3) Smart maintenance promotes sustainability. IoT sensors and AI analysis enable real-time monitoring of plant health and precise resource supervision, offering significant advantages.

Funding

Basic scientific research business expenses of universities directly under Inner Mongolia Autonomous Region, Key project of Philosophy and Social Science Foundation of Inner Mongolia Agricultural University (BR220603). Special project for improving scientific research ability of young teachers of Inner Mongolia Agricultural University (BR230218).

Disclosure statement

The authors declare no conflict of interest.

References

[1] Wen J, Zeng Y, 2022, Application of Virtual Simulation Technology Based on Lumion in Landscape Design. Beauty and Times (Early Monthly), (3): 83–86.

[2] Zhao K, 2017, Design and Implementation of Virtual Landscape Platform Based on GIS. Science of Surveying and Mapping, (3): 165–168.

[3] Xian JH, Ji Z, 2024, Application of Virtual Simulation Technology in Landscape Design. Integrated Circuit Applications, 41(01): 190–191.

[4] Chen T, Zhang P, Chen J, 2014, Application of Lumion Virtual Reality Software in the Field of Architecture. Building Science, (16): 243.

[5] Deng XX, Zheng MY, Chen D, 2016, Design and Implementation of 3D Campus Roaming System Based on VR Technology. Journal of Hunan University of Science and Technology, (5): 100–102.

[6] Xu Y, 2023, Research on Digital Media Art Design under the Development of Virtual Reality Technology. Leather Craft Art, (19): 48–50.

[7] Feng Y, 2024, Application of Virtual Reality (VR) in News Reporting: Possibilities and Challenges in Enhancing Audience Immersion. Journalism and Writing, (3): 6–8.

[8] Wang L, Fan B, 2023, Research on Remote Safety-Assisted Maintenance Based on AR and 5G Network. Manufacturing Automation, (5): 40–44.

[9] Li SX, 2021, On Landscape Vegetation Design and Management Technology in Garden. Green Building Materials, (8): 193–194.

[10] Zeng H, Zhang JD, Ren G, et al., 2014, Design and Implementation of the 3D Visual Simulation System for Ship Engine Room. Journal of System Simulation, (2): 363–368.

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