Next-Gen Landscape Design: Agentic AI + Digital Twins

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Abstract: The complexity of issues confronting landscape architects and other environmental designers, in the face of the global polycrisisvare immense and growing. Artificial Intelligence (AI) tools, may represent a panacea, but they are still very little beyond infancy; results across many domains are so far quite mixed; and limitations and concerns are abundant. In this context, several different but related emergent technological advances do seem likely to be key drivers of the next generation of AI-enabled computer-aided-design tools intended to help design thinking and manage real-world complexity: 'Agentic AI' (AAI) platforms connected to 'Digital Twins', esp. 'Digital Twin Earths' (DTEs), with 'Model Context Protocol' (MCP) and 'Retrieval-Augmented Generation' (RAG) used to control and constrain the AI agents. Following a brief description of these technologies and their foundations, I explore some application possibilities by re-visiting a decade-old 'System for Geodesign' with AAI, MCP, RAG, and DTE integrated, and outline an updated prescription for a technologically enhanced and enabled next-gen 'AAI+DTE' design system (not just for geodesign). A highly simplified prototype agentic system implementation is described.

Keywords: Next-Gen Computer-Aided Landscape Design, Agentic AI, Digital Twin Earth, Retrieval-Augmented Generation, Model Control Protocol

1 Introduction

As the big-data, scale-hopping, information-processing, multitudinous detail-managing, and time-consuming collaboration-choreographing demands on digital landscape architects continue to grow, especially in the face of global environmental issues, the promise of computer-aided design to alleviate some time-consuming and repetitive tasks so as to give designers time and space to design is evermore seductive. From Sutherland's seminal SketchPad, through 2D and 3D CAD, GIS, Remote-Sensing and Image-Processing, GPS and then BIM, and now AI-in-CAD, some productivity gains have been achieved. Over the same time span, the complexity of issues confronting environmental designers, and the complexities of marshaling design and construction projects in the real world, have been even further increased. The current explosion of AI, with its similar promises, is still in its infancy; results are so far mixed; concerns are real; and speculation is rampant.

For the past few years, it has been apparent that the long-awaited potential of Artificial Intelligence (AI) as foreseen by (TURING 1948), (MINSKY 1986), and (SIMON 1996) may have begun to be delivered (albeit with some already apparent downsides!). The explosion of Machine Learning (ML), Large Language Models (LLMs), Generative Pre-Trained Transformers (GPTs), Generative Adversarial Networks (GANs), Diffusion Model Generative Pre-trained Autoregressive Diffusion Transformers (GPDiTs), Model Context Protocol (MCP), and Retrieval-Augmented Generation (RAG), along with other techniques and platforms including ChatGPT, Gemini, Claude, DALL-E, Stable Diffusion, and now a whole host of other technologies and acronyms, in just a few years' time, has absolutely rocked worlds – of de-

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sign (CANTRELL et al. 2021), construction (ABIOYE et al. 2021), education (BOWEN & WATSON 2024), communication, entertainment, and everything else in between.

In recent years, a number of papers published in JoDLA and elsewhere have chronicled the emergence of AI in Landscape Architecture (BRAIDEN et al. 2025), (XING et al. 2025). This emergence is proceeding so rapidly that already these early reviews and experiments seem almost quaint.

What most AI at this moment in time (2025) is already very good at doing includes organizing, summarizing, modifying, and even synthesizing textual data and responding to natural language prompts, based on a huge library of background knowledge in ways which are usually coherent, well-structured, plausible, and believable, even if not always factually true. And, to a somewhat lesser extent, doing the same for images, music, computer code, and other media. Its facility with interaction and apparent understanding of the meaning of the text prompt (s) it is responding to are deceptively good, notwithstanding that we know, in fact, there is no real understanding or reasoning, only statistical similarity and likelihood, at work; and despite the many flaws and potential problems with the current technologies, which depend on a large body ('corpus') of training samples, possibly biased or incomplete, for all of their power.

As to whether and how the GenAI programs may be designing, there is much discussion; on this topic, ChatGPT-4.1 itself says: "[Generative AI]'s processes lack intentionality, contextual awareness, and critical reflection that are central to design as traditionally understood."

This observation is behind the oft-repeated suggestion that "there needs to be a human in the loop" (WIKIPEDIA 2025), and the assertion that "co-design between humans and machines is the logical evolution of computer-aided design". There is good evidence that already, AI tools *can* aid design and designers in various ways, and so belong in the modern Computer-Aided Design toolbox. How these tools will become sharper, more accurate, and effective, more widely and creatively used, etc., will doubtless continue to consume the Digital Landscape Architecture community, along with much of the rest of the world. The goal of the tools in the CAD toolbox is no longer just to "free designers from burdensome and repetitive tasks", and their promise is not to *reduce* complexity, but rather more critically: to help *manage* complexity.

Two important recent developments in related technologies will likely be central in this evolution: *Agentic AI* (AAI) platforms (WANG, L. et al. 2024) and Digital Twins, especially *Digital Twin Earths* (DTEs) (GRIEVES & VICKERS 2017).

These two emergent technologies promise to be mutually supporting and truly transformational for digital landscape architecture in the rest of the 21st century.

1.1 Agentic AI (AAI)

The 'chat'-style Generative AI many people are most familiar with now is a highly episodic interaction, initiated by a specific prompt, which elicits a response, and then often a refined or follow-on prompt spurred by some deficiency in the response, or some new avenue of inquiry, and so on. The human is not just in the loop but is leading the interaction at each step; the AI is mostly responding (or sometimes leading with canned "Do you want me to provide or explain anything in more detail?" questions). And there is effectively just one AI in the loop – typically, a LLM 'foundation model' trained on some very broad corpus of

training samples. By contrast, a*gentic systems,* given high-level goals and other directives in initial prompts, can become proactive, goal-driven, and collaborative, using generative AI and other special-purpose software tools and APIs as components in a larger, self-directed, multi-step process. These agents may also be aware of change, and so can monitor changing contextual information, whether from sensors, or websites, or other sources. AAI systems aggregate several individual AI agents (AIAs) together, in a communicating network, often along with an 'orchestrator' or dispatcher agent (ANTHROPIC 2025).

Two additional developments promise to further control AI generative capabilities, and reduce hallucination, by adding an element of algorithmic/procedural workflow control via Model Context Protocol (MCP) (ANTHROPIC 2024); and factual lookup from one or more specialized / tailored databases via Retrieval-Augmented Generation (RAG), (LEWIS et al. 2020) which can provide the independent agents each with a suitable database of domain-specific information for their intended specialization. RAG-based agents can be much simpler than the full-bodied LLM behind generative AI; and their performance can be guided by rules, algorithms, and workflows managed by MCP, which can function like conventional computer code, running procedures, writing to databases, sending emails, and querying live APIs, rather than just probabilistic pattern matching.

1.2 Digital Twins (DTs)

Digital Twins are virtual replicas of real-world systems, capable of reflecting and predicting system behavior, such that ordinary and unusual conditions can be simulated computationally, monitored, and analyzed, and used to predict system behavior over time, under stress, etc. (WANG et al. 2024, HAZELEGER et al. 2024). First named and formalized in the context of modern aircraft design, construction, and operation, the idea has been spread to other domains and scales – from the human body, or individual organs therein, to the building-, region-, watershed-, and even planetary-scale – including the specially named Digital Twin Earths (DTEs). Perhaps the most advanced such efforts are Europe's Destination Earth (DestinE) (THE DIGITAL EUROPE PROGRAMME) and NASA's Earth System Digital Twins (ESDT) (ESA) initiatives; there are others, such as Google Earth Engine (GOOGLE 2024), from various sources (NASA), (NVIDIA) with various aims. DTEs can generate literally mountains of data, and so the interfaces for querying, analyzing, and storing their outputs is a rapidly evolving branch of technology. In more familiar traditional computer information terminology, AIAs contain *algorithms* or *procedures*, and the digital twins are databases – but in both cases, they are each hybrid, containing a combined mass of factual and procedural knowledge.

Specialized AIAs are especially well-suited to interface with special-purpose big data, such as with DTEs, giving rise to the following 'AAI+DTE' System proposal:

2 AAI+DTE Applied to Ervin's 'System for Geodesign'

A 'System for Geodesign', (ERVIN 2011) was originally presented at the DLA Conference as a proposal for a system of 15 distinct 'modules', which in combination would provide, in the author's view, the technological support – integrating CAD, GIS, database, version management, simulation, programming, and other functions – required for full-fledged geodesign as