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DANIEL KOEHLER, *COMPOSITIONAL INTELLIGENCE: ARCHITECTURAL TYPOLOGY THROUGH GENERATIVE AI*, ROUTLEDGE, ABINGDON / NEW YORK, 2026.

The study of automata has long occupied a central position in discussions of automation and technical systems. From early mechanical automata to modern computational models, these systems explore how complex behaviour can emerge from structured rule-based processes. A particularly influential contribution to this field comes from Stephen Wolfram, whose work on cellular automata demonstrated that simple computational rules can generate highly complex and unpredictable patterns. Wolfram argues that even systems governed by deterministic rules may produce behaviours that appear irreducibly complex and difficult to predict.<sup>1</sup>

This insight fundamentally reshaped the understanding of automated systems. Rather than viewing automata as rigid machines executing predictable instructions, Wolfram's research revealed that deterministic systems themselves can give rise to emergent phenomena. The implications of this discovery extend beyond computer science into fields such as biology, physics, and architecture, where rule-based systems have been used to model growth, adaptation, and spatial organisation.

Architectural interest in automata emerged particularly in computational design research, where cellular automata and generative algorithms were explored as mechanisms capable of producing complex spatial structures from simple local interactions.<sup>2</sup> These approaches suggested that architecture could be understood not only as a designed object but also

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<sup>1</sup> S. Wolfram, *Cellular Automata and Complexity*, Addison-Wesley, Reading, Mass., 1994.

<sup>2</sup> W. J. Mitchell, *The Logic of Architecture: Design, Computation, and Cognition*, MIT Press, Cambridge, Mass., 1990; J. Frazer, *An Evolutionary Architecture*, Architectural Association, London, 1995.

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as the emergent result of dynamic systems. However, the emergence of generative artificial intelligence introduces a new form of automated systems that differs significantly from the deterministic automata explored by Wolfram. Machine learning models do not operate through explicit rules defined in advance; instead, they derive patterns from large datasets through statistical learning processes. In this sense, contemporary generative systems represent a shift from deterministic automata toward probabilistic autonomous systems.

Daniel Koehler's *Compositional Intelligence: Architectural Typology Through Generative AI* enters precisely at this moment of transition. While the book does not explicitly position itself within automata theory, it can be read as an investigation into how architecture operates within a new generation of automated systems shaped by machine learning and generative AI. The central question therefore becomes: does generative AI represent a continuation of the automata tradition in architecture, or does it mark the emergence of a fundamentally different form of automated intelligence?

#### AUTOMATA AND THE ORIGINS OF COMPUTATIONAL INTELLIGENCE

The intellectual foundations of automata theory are closely linked to early developments in computer science. In the 1930s, Alan Turing introduced the concept of the universal machine, demonstrating that a single computational system could simulate any other machine through symbolic manipulation.<sup>3</sup> Turing's work established the theoretical basis for programmable computation and provided the first formal description of automated reasoning.

Shortly afterward, John von Neumann extended these ideas by developing the concept of self-reproducing automata. Von Neumann explored how machines could replicate themselves through formal rule systems, introducing models in which complex structures emerge from interactions between simple components.<sup>4</sup> His work laid the groundwork for cellular automata, systems in which discrete elements evolve through local rules applied iteratively across a grid.

<sup>3</sup> A. Turing, "On Computable Numbers, with an Application to the Entscheidungsproblem," *Proceedings of the London Mathematical Society*, 42, 1936, pp. 230–265.

<sup>4</sup> J. von Neumann, *Theory of Self-Reproducing Automata*, University of Illinois Press, Urbana, 1966.

Automata theory therefore emerged as a framework for understanding how complex behaviours could arise from simple rule-based mechanisms. In these systems, global patterns result from local interactions governed by deterministic procedures. A significant expansion of this idea occurred in the late twentieth century through the work of Stephen Wolfram. Wolfram demonstrated that even extremely simple cellular automata rules could produce behaviours of remarkable complexity and unpredictability. Some cellular automata generate repetitive patterns, while others evolve into chaotic or seemingly random structures. Importantly, these behaviours arise despite the underlying rules remaining entirely deterministic.<sup>5</sup>

Wolfram's research revealed a paradox central to automata theory: deterministic systems can produce outcomes that appear unpredictable. Emergence, in this sense, does not require randomness but can arise from simple recursive interactions. For architecture, these ideas opened new possibilities. Designers began exploring rule-based computational systems as tools for generating spatial structures, allowing form to emerge from dynamic processes rather than predetermined geometries.

#### ARCHITECTURAL GENERATIVE SYSTEMS AS AN AUTOMATED ENVIRONMENT

The influence of automata theory on architecture has been visible in various strands of computational design. Cellular automata, shape grammars, and parametric systems have all been used to generate architectural configurations through algorithmic procedures.<sup>6</sup> These approaches share a common principle: architectural form emerges from explicit rule sets. Designers specify the rules governing interactions between elements, and the system iteratively produces spatial structures according to those rules. Within this framework, architectural automation remains fundamentally deterministic. Even when the resulting patterns appear complex or unpredictable, the generative process can be traced back to the underlying rule structure.

Generative artificial intelligence, however, introduces a different model of computation. Instead of operating through predefined rules, machine learning systems derive patterns from data through statistical training processes. In this direction, diffusion models generate images by

<sup>5</sup> S. Wolfram, *A New Kind of Science*, Wolfram Media, Champaign, 2002.

<sup>6</sup> K. Terzidis, *Algorithmic Architecture*, Routledge, New York, 2006.

progressively refining noise according to probability distributions learned from large datasets. Large language models generate text by predicting likely sequences of tokens based on prior training. This shift marks a transition from deterministic rule-based automation to probabilistic generative systems.

Koehler begins his book by situating architecture within what he describes as the digital city. Contemporary urban environments are increasingly shaped by algorithmic infrastructures such as financial analytics, environmental monitoring systems, and logistical optimisation platforms. These computational systems operate continuously, influencing how buildings are designed, evaluated, and constructed. Rather than functioning as discrete machines, these automated processes form distributed networks embedded within urban space. Real estate algorithms determine property values, energy optimisation systems regulate building performance, and data-driven planning models influence urban development patterns.

Within this context, architecture appears as a component within a larger automated environment, where the traditional role of the architect as a singular author of form becomes less clear when design decisions are shaped by algorithmic evaluations and computational constraints. Koehler's analysis therefore frames the contemporary city as a kind of distributed automaton, in which spatial outcomes emerge from interconnected technical systems rather than centralised design control.

#### GENERATIVE SYNTHETIC AND THE DISCRETISATION OF ARCHITECTURE

The emergence of generative AI introduces a new layer to this automated environment. According to Koehler, machine learning models possess the ability to synthesise architectural imagery and spatial patterns from large datasets. These models encode what he describes as synthetic knowledge, derived from the aggregation of collective visual and spatial information. When prompted to generate architectural scenes, diffusion models produce images that resemble plausible urban environments despite not reproducing specific precedents. The resulting compositions often incorporate landscape elements such as vegetation or environmental context even when these features are not explicitly requested.

Koehler interprets this phenomenon as evidence that generative systems internalise latent cultural patterns present in their training data,

being in that sense the architectural knowledge is not programmed into the system through explicit rules but emerges from statistical relationships within datasets. This process differs fundamentally from the rule-based logic of classical automata, instead of executing predefined instructions, generative AI navigates a high-dimensional space of learned correlations.

A central methodological concept in the book is tokenisation (borrowed from natural language processing), a key to understanding how buildings can be represented as data and how this enables new forms of computational analysis and design. Language models represent text as sequences of tokens, discrete units that serve as the basic elements of computation, in that sense Koehler proposes that architecture can be interpreted in a similar way, in where buildings and urban environments can be decomposed into informational components that function as tokens within generative systems (these components may include spatial relationships, architectural elements, or environmental features).

Tokenisation introduces a form of architectural discretisation reminiscent of cellular automata for urban simulation models<sup>7</sup> explaining how cities can be modelled as complex adaptive systems, where urban patterns emerge from local interactions between spatial units such as parcels, roads, or agents. In both cases (Batty and Koehler), complex structures emerge from interactions between smaller units. However, the mechanisms governing these interactions differ significantly. In cellular automata, the state of each cell evolves according to explicit transition rules applied locally. In generative AI systems, tokens interact through statistical correlations learned during training. The relationships between elements are therefore implicit rather than explicitly defined.

#### SUPERPOSITION, UNPREDICTABILITY AND CREATIVE PROBABILISTIC SYSTEMS

Another important concept introduced by Koehler is superposition, derived from observations about neural networks. In these systems, multiple functions can coexist within overlapping parameter spaces. A single neural network may encode numerous patterns simultaneously without separating them into discrete modules. Koehler suggests that architecture

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<sup>7</sup> M. Batty, *Cities and Complexity: Understanding Cities with Cellular Automata, Agent-Based Models, and Fractals*, MIT Press, Cambridge, Mass., 2005.

could adopt a similar logic. Instead of organising buildings through clear hierarchical divisions between structural, environmental, and programmatic systems, architectural elements could participate in multiple functions simultaneously. Superposition challenges the modular logic that has historically structured architectural design. Rather than dividing systems into separate layers, generative approaches encourage overlapping relationships between different spatial and functional components. From the perspective of automata theory, this shift reflects a movement from sequential rule execution toward parallel distributed computation.

A key theme explored by Koehler concerns the role of unpredictability in generative systems. Classical automata are deterministic: given the same initial conditions, they produce identical outcomes. Although complex patterns may emerge, the process remains fully reproducible. Generative AI systems behave differently. Because they rely on probabilistic sampling within latent spaces, their outputs can vary even when prompted with identical inputs. Each generation represents a new exploration of the underlying probability distribution. This unpredictability introduces a new relationship between human designers and automated systems. Rather than specifying every aspect of the design process, architects interact with generative models through prompts and iterative refinement. The machine produces variations that the designer evaluates and curates. In this sense, generative AI does not eliminate human agency but transforms it. The architect becomes less a controller of deterministic processes and more a collaborator navigating a space of possibilities generated by autonomous systems.

#### AUTOMATA RECONSIDERED/REVISITED/REINVENTED IN THE AGE OF AI

Viewed through the lens of automata theory, Koehler's concept of compositional intelligence represents both a continuation and a departure from earlier computational paradigms. The work of Turing, von Neumann, Conway, Langton, and Wolfram established a tradition of rule-based computational systems in which complex behaviour emerges from simple deterministic interactions. These models emphasised transparency: the mechanisms governing system behaviour could be fully described through formal rules. Generative AI introduces a different form of automation characterised by statistical inference and large-scale pattern synthesis. The resulting systems operate as probabilistic environments

rather than deterministic machines. Koehler's framework therefore suggests the emergence of a new class of automated systems, in which generative behaviour arises from learned correlations rather than explicit rules.

Daniel Koehler's *Compositional Intelligence* provides a thoughtful exploration of how generative AI reshapes architectural design and theory. While the book does not explicitly situate itself within automata theory, its arguments intersect strongly with longstanding debates about automation, emergence, and human agency. By tracing a trajectory from deterministic rule-based systems toward probabilistic generative models, Koehler highlights a fundamental transformation in architectural computation. Contemporary generative AI systems operate less like classical automata executing predefined instructions and more like complex probabilistic environments that produce emergent spatial possibilities.

This shift raises important questions about authorship, control, and the role of unpredictability in design. The architect is no longer the sole generator of form but becomes a participant within a broader ecosystem of computational processes. In this sense, *Compositional Intelligence* can be understood as an exploration of architecture within a new generation of automated systems. Rather than replacing the tradition of automata, generative AI extends it into a domain where emergence arises not only from rules but also from data. The future of architectural automation may ultimately lie in the interaction between these two paradigms: the deterministic structures explored by classical automata theory and the probabilistic generative systems emerging from contemporary artificial intelligence.