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ARCHITECTURAL PARADOXES BEYOND AI: THE UNQUANTIFIABLE QUALITIES OF ARCHITECTURE

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Abstract

The use of Artificial Intelligence (AI) in architecture presents both opportunities and challenges. It offers powerful tools for design generation, optimization, and analysis, on one hand, and raises fundamental questions about the inherent paradoxes and unquantifiable qualities that define the discipline, on the other hand. This research investigates the complexities of implementing algorithmic methodologies into the architectural design process, examining the limitations in capturing the contextual sensitivity, aesthetic qualities, and human experience that are central to creating meaningful and impactful architecture. By analyzing the historical context of computational design methods vis – a – vis algorithmic design methods and reviewing current applications in architecture, we aim to compare the potential of AI with the timeless values and paradoxes that shape the essence of architectural design.

Keywords*:* **AI, architecture, floorplan, paradoxes, complexities, unquantifiable**

1. Introduction

In the recent years, artificial intelligence (AI) is finding a growing role in architectural practice. It's no longer just some futuristic concept, it already assists designers with automating layouts, optimizing multiple aspects of a building systems and, most importantly, constructing schemas or ideas. But there is a fundamental question in all this excitement: can an architecture so deeply rooted in intuition, emotion, memory etc., ever be encoded and guided by algorithms?
In this paper, we do not seek to dismiss AI. On the contrary, do recognize its great potential. But we also argue that architecture is not just about data. It includes contradictions, cultural layers, and experience – which cannot be measured employing data. The depth and visual perception of a shadow bouncing in a stone corridor, the symbolism of a dome in a central hall, or the informal way the courtyard is used over time, are the things that define architecture. These are the kinds of values that are the essence of architecture, and which defy being fully understood by any algorithm.
We start by going back to a time when computational thinking entered architecture, long before there was AI, in the rationalist approaches of the 20th century. Then, we review existing applications of AI in architecture, in particular in space layout planning. From here, we shift focus on what AI cannot grasp: paradoxes and the unquantifiable aspects that remain the soul of architecture. In this paradox, we find not a rejection of AI but a clearer view of its proper place, as a tool.

2. Science in architecture

Long before AI and the digital age, architecture was already experimenting with the idea of logic-driven design. Architects started in the mid-20th century to move from intuition that was pure art, towards planning design more methodically and analytically, even scientifically. It was fundamentally influenced by the increasing importance of scientific thinking and the systems

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theory which, being an efficient apparatus for providing a more accurate method of design, envisioned it more objectively and systemically (Jones, 1970).

During this time Christopher Alexander was one of the major voices. In Notes on the Synthesis of Form (1964) he suggested that design tasks could be broken down into smaller parts and solved logically, much as if they were a puzzle. His idea was to match design forms exactly to the context where they would be used, and this set the foundations for subsequent generations ' approach to algorithmic design. These ideas were further elaborated on by John Christopher Jones, another major figure. In Design Methods (1970) he used tools like decision trees and flow diagrams to help architects make choices more systematically and with less subjectivity. However, he urged that design could benefit from other disciplines such as systems theory and behavioral science. The aim was to get away entirely with what he saw as too personal or artistic decision-making (Jones, 1970). Modernist figures like Le Corbusier echoed similar ideas. His famous line, "A house is a machine for living in," captured the modernist dream of order and efficiency. Through using standard measurements and following rational planning he wanted to make everyday life more orderly. Meanwhile, Theo van Doesburg and the De Stijl movement publicly called for the elimination of all subjectivity in design, advocating formal objectivity and mechanical purity (Van Doesburg, 1924).

But this rationalist movement didn't last unchallenged. By the late '60s, even some of its founders began opposing this idea. Alexander eventually dissociated himself from the very design theories he had championed, declaring that they felt disconnected from the true nature of architecture. Jones, too, expressed regret over the mechanistic mindset he had once advocated.

This growing unease opened the door for new voices, like Horst Rittel, who introduced the concept of "wicked problems." Unlike neat, solvable tasks, wicked problems are messy, full of contradictions, and tied to specific contexts, just like architecture. Rittel argued that such problems couldn't be tackled with flowcharts or algorithms. They required discussion, negotiation, and often, accepting that no perfect solution exists. (Rittel & Webber, 1973)

This turn marked a shift toward a more open, flexible understanding of the design process – one that acknowledged complexity, uncertainty, and the human element. Still, the seeds of computational thinking had already been planted. So, when AI arrived years later, it inherited both the strengths and the blind spots of that earlier rationalist legacy.

3. Artificial Intelligence in Architecture: A Review

Artificial Intelligence has gradually made its way in architecture, not as a creative force, but as a tool for improvements. Over the past two decades, it's been used in areas like layout automation, performance simulations, BIM clash detection, and sustainability modeling. Systems based on machine learning, genetic algorithms, or generative design help architects test options quickly and manage and handle technical complexities (Babakhani, 2023).

Yet despite its growing presence, AI remains confined to the *'measurable'*. It is great with numbers and even patterns (energy use, daylight, structural logic) but falls short when it comes to cultural meaning, emotional depth, or symbolic resonance. A veranda in one part of the world may carry deep social significance that an algorithm trained on generic data simply can't grasp. Even tools like Spacemaker or Delve, which generate urban forms based on large datasets, raise questions. They're fast and data-rich, but can lead to sameness and take creative decision-making out of the architect's hands. As more of the process becomes automated, many worry that architects risk becoming mere curators of algorithmic suggestions.

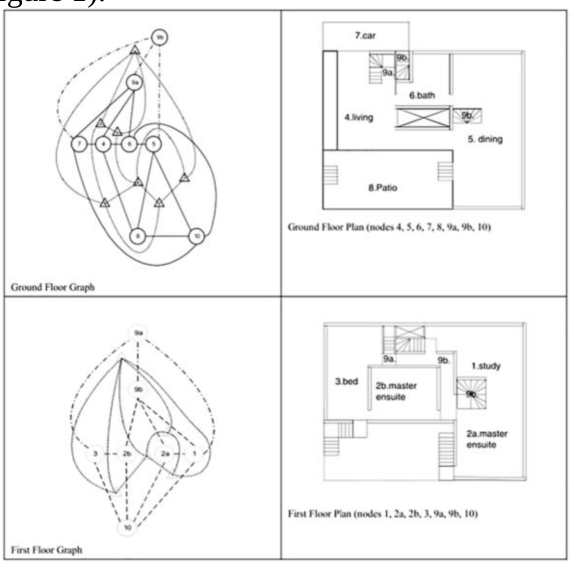
Ultimately, AI can help with a lot of the architectural workflow, particularly the technical aspects. But the soul of design – its cultural, emotional, and conceptual dimensions – still belongs to the human imagination.

3.1 AI and Space Layout Planning: Space layout planning (SLP) is considered as one of the most commonly investigated areas for AI application in architecture. Space layout planning, which involves the arrangement of spatial units (rooms, corridors, voids, structural elements) within a defined boundary, is suitable for algorithmic optimization and even creation. It poses a structured yet creative challenge – balancing spatial efficiency with functional logic and experiential quality.

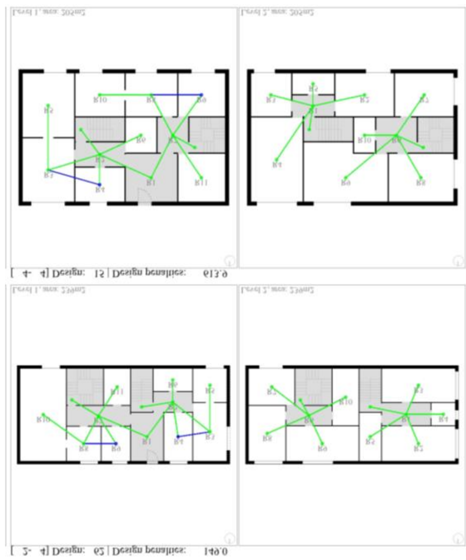
Traditional architectural layout planning relies on a combination of programmatic logic, cultural norms, site-specific constraints, and designer intuition. However, these principles are difficult to encode into strict computational rules. In response, researchers have responded by designing different AI-based systems that try to simulate or enhance the spatial organization decision process.

3.1.1 Evolutionary and Genetic Algorithms One of the earliest methods was the application of evolutionary algorithms – these are algorithms that simulate the process of natural selection to evolve optimal solutions.

Samuel Wong and Keith C.C. Chan (2009) introduced *EvoArch*, a system that generated floor plans by evolving space topologies according to user-defined criteria. This method treated spatial elements as 'genes' that could be combined and mutated to find alternative configurations (Figure 1).



Optimal architectural space topology generated by experiments with corresponding floor plans. Wong, 2009

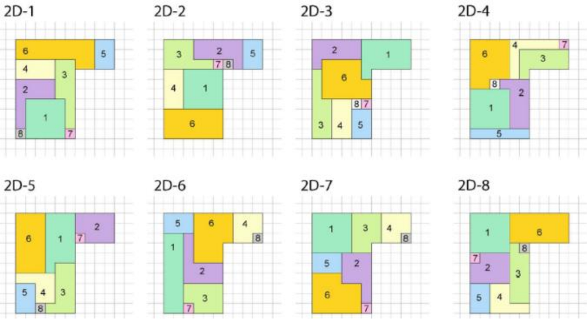


Results for the second case study for two single-family houses. Rodrigues (2014)

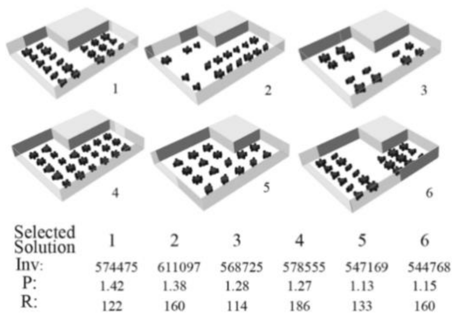
Figure 1. Case studies of Evolutionary Algorithms applied in SLP

Later work by Eugenio Rodrigues (2014) extended this model with a hybrid evolutionary based model that combined simulation with optimization for improved spatial arrangement (Figure 1). These systems could handle multiple objectives simultaneously, such as minimizing circulation distance, maximizing daylight, or maintaining adjacency between functionally related spaces (e.g., kitchen and dining room).

Another notable effort was the work of Gürsel Dino (2016), who experimented with three-dimensional space planning using evolutionary strategies. This advanced the field beyond 2D plan generation, introducing volumetric reasoning into the algorithmic toolkit (Figure 2).



2D Solutions of library layout. Ipek, 2016

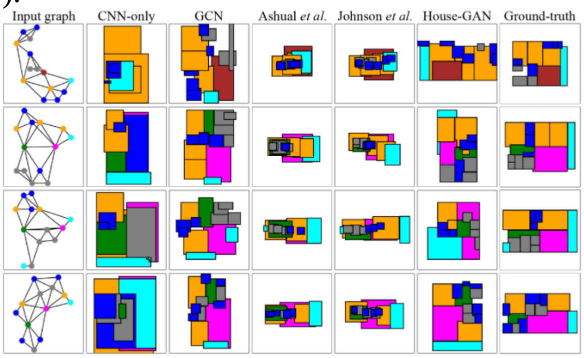


Selected solutions for a restaurant design with NSGA II (Above) and jDEMO (Below), Cubukoglu et al. (2016)

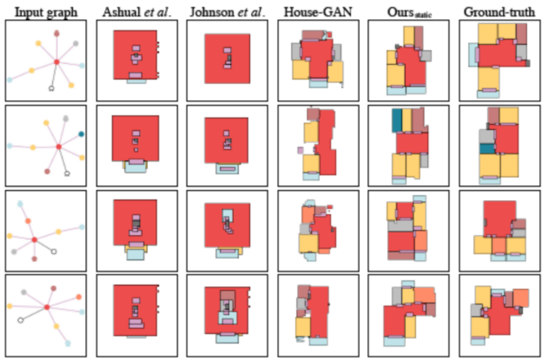
Figure 2. Three dimensional planning using Evolutionary Algorithms

3.1.2 Multi-Objective Optimization and GANs: In 2016, Cubukoglu et al. optimized restaurant seating plans using multi-objective differential evolution, and balanced the trade-offs among the seating ability, circulation, and service efficiency using multi-objective differential evolution to restaurant layouts (Figure 2). Their research showed that even complex, program-specific requirements could be translated into objective functions that AI systems could optimize simultaneously.

Later developments have used machine learning and GANs to consider layout planning as a generative (in addition to an optimization) problem. *House-GAN* (Nauata et al., 2020) used a graph-constrained network to generate floor plans that respected adjacency rules between programmatic zones (Figure 3). Its successor, *House-GAN++* (2021), improved these layouts via an additional set of neural layers that assess circulation quality and spatial balance (Figure 3).



Layout sample generated by each method from each input graph: Nauata et al. (2020)

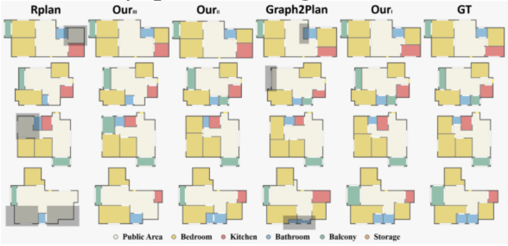


Layout sample generated by each method from each input graph: Nauata et al. (2020)

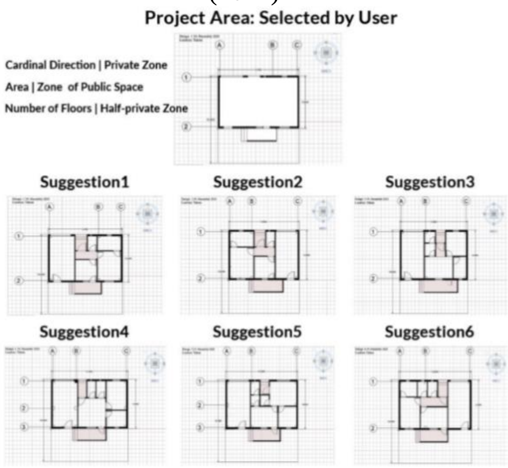
Figure 3. Machine learning and GANs applied to SLP

These methods differed from classical rule-based planning by "learning" of patterns from a database of existing architectural plans. But the results were strongly dependent on the training data being used, and the biases which were inherent in them. If the majority of plans in the data set were Western housing types in suburban settings, the AI would find it difficult to develop layouts for other cultural or urban settings

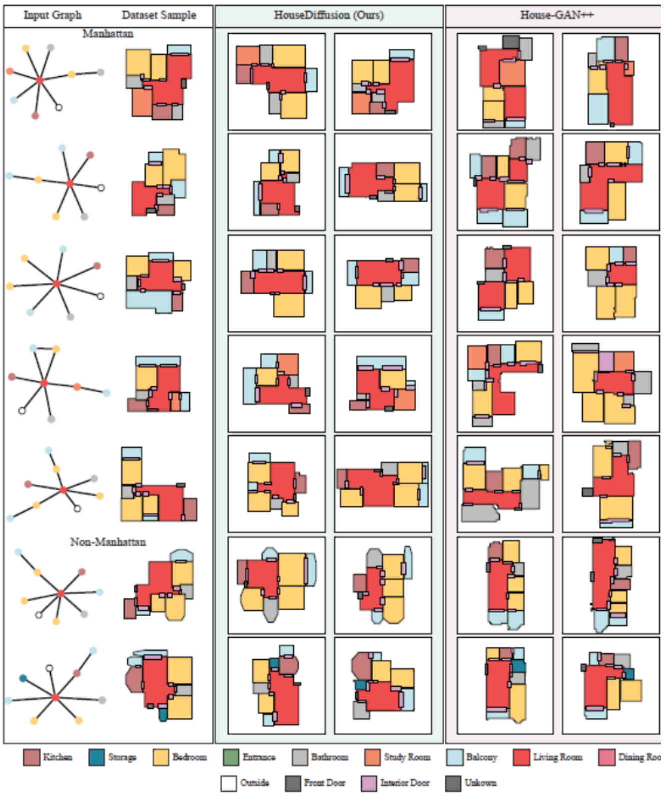
3.1.3 Procedural and Diffusion-Based Approaches: iPLAN *(He et al., 2022) and* HouseDiffusion *(Shabani et al., 2022) introduced more complexity into layout generation in that they combined procedural logic and diffusion models, enabling layouts to develop by gradually going from noise to order (Figure 4). These methods are inspired by image synthesis* *methods, and instead of constructing layout using semantic logic, generate layout by taking it as a kind of spatial "image".*



Generated floorplan from iPLAN: He et al. (2022)



Sample plan compiled by the automated design intelligence: Babakhani (2023)



Generated floorplan samples against House-GAN++: Shabani et al. (2022)

Figure 4. Diffusion models and procedural logics applied to SLP

Procedural AI systems offer interactivity: designers are able to steer or code layouts toward desired results, rather than passively selecting from a set of algorithmic results. These tools enable rapid prototyping and exploration of design variants – benefits that can be significant in fast-moving design environments.

3.1.4 Limitations and Failures: Despite these technical achievements, the layouts automatically generated by the AI system commonly exhibit a number of limitations. Research by Ploennigs & Berger (2023) found that the majority of algorithmically generated plans have awkward adjacencies (e.g. bathrooms next to kitchens), confusing circulation paths, or unpractical room shapes (Figure 1 to 5).

While AI can replicate patterns and optimize known functions, it struggles with the underlying logic of human movement, privacy, social interaction, or emotional experience in space. Moreover, aesthetic unity is rarely considered in these systems. Layouts may be functionally efficient but lack compositional harmony or spatial delight. The poetics of arrival, the drama of vertical movement, or the intimacy of enclosure are difficult – if not impossible – for AI to duplicate or estimate.

Another significant gap lies in cultural adaption. An ideal formation for one area or school of thought can be hostile in another. Vernacular, indigenous, climate-sensitive typologies are affected by space differently than that represented by a traditional western database show, thus strong objections arise in space-reliant AI models based on such databases.

3.1.5 The Illusion of Completeness: Perhaps the greatest challenge is the illusion that these systems offer complete solutions. In reality, they provide suggestions - provisional, partial, and dependent on hidden assumptions. Even the most sophisticated A.I. system lacks the comprehensive awareness of human architects, who balance client demands with social context, symbolic meaning, sensory perception and future flexibility.

AI Image Generator Design Results Instructed By The Parametric Architecture Bureau Team And AI Metaverse

Example failure cases of Midjourney: Ploennigs & Berger (2023)

Figure 5. Midjourney generated facades and SLP

So, while AI in the space layout planning clearly contributes utility, it fails to describe the architectural imagination. It can propose, but it cannot understand. It can simulate, but it can’t feel. And it can generate, but it cannot evaluate the deep qualities that make a plan not just functional but meaningful.

4. Unquantifiable Qualities of Architecture

Architecture, unlike most algorithmic systems, does not live by certainty, but instead on contradictions. It is a field defined by paradoxes – between function and emotion, shape and meaning, permanence and temporality. It is exactly these tensions that create architecture. As AI grows more capable, this paradoxical nature becomes increasingly critical to defend and understand.

4.1 Architecture as a Field of Contradictions: The very nature of architectural thought and process lies in the engagement of opposites. It transfers between the abstract and the concrete, the ideal and the real, the theoretical and the practical. A successful architectural work does not resolve these binaries; rather, it gives form to their coexistence. Take, for example, Louis Kahn’s buildings, which are often simultaneously monumental and intimate, rational and poetic. Their meaning emerges not from singular logic but from layered, even conflicting readings.
Zaha Hadid’s Vitra Fire Station (1993) is a classic example. The project started with series of abstract paintings and exploded perspectives – artistic investigations unchained from function. Yet, these drawings eventually materialized as a building with precise functional requirements. The result is a space where movement, geometry, and form intersect in ways that defy linear thinking (Figure 6). The project cannot be reduced to an optimization problem; it is, instead, the result of an interpretative process rooted in intuition, context, and conceptual thoroughness – now and always paradoxical.


Sketch of Hadid's artistic exploration of spatial relationships on the site


Perspective painting by Hadid, first stage of design process


Perspective view of the resulting forms and theoretical language

Figure 6. Vitra Fire Station by Zaha Hadid (Hadid, 1993)

This situation is diametrically opposed to the algorithmic way of thinking. The AI-based systems work best if they can find the best solution while following certain constraints. Paradox, by definition, is not optimal – it is unstable, unresolved, and often illogical. But paradox is where architecture becomes more expressive and more evocative. It is the reason a quiet cloister can feel more profound than a perfect diagram, or why a one-sided ceiling may evoke tension in ways that resist programming.

4.2 Dualities as Generative Forces

Architecture is filled with dualities: inside/outside, public/private, heavy/light, closed/open, crafted/mechanical. These are not simply formal devices but conceptual apparatuses. When well executed, they enhance experience. Consider the paradox of *"less is more,"* a phrase originated by Ludwig Mies van der Rohe. It captures the tension between reduction and richness. A minimalist space, when masterfully articulated, does not feel empty – it feels essential.

It is difficult to encode these tensions, if not impossible. There is no universal algorithm for determining when a space is "open enough" or when "less" becomes "more." The architect must feel their way through these decisions, guided by cultural knowledge, phenomenological awareness, and historical intuition.

In other cases, paradox occurs between the expected use of a space and its actual experience. A hallway may be conceived as a circulation zone, yet it becomes a place of pause or encounter because of light, scale, or acoustic softness. These emergent qualities resist modeling – they cannot be modeled. They cannot be accurately anticipated by software or assessed through performance metrics.

4.3 Atmosphere and the Emotional Presence of Architecture

One of the most compelling arguments for the unquantifiable dimension of architecture comes from Peter Zumthor, who has written extensively about atmosphere – the emotional and sensory presence of architecture. For Zumthor, atmosphere is not a side effect but the very goal of design. It is how architecture communicates without language (Zumthor, 2006).

Atmosphere is not produced by one variable but by an orchestration of many: material texture, light diffusion, scale, acoustics, and even smell (Zumthor, 2006). It is profoundly subjective and ephemeral. AI can simulate lighting, analyze airflow, and calculate acoustic reverberation, but it cannot feel the quiet majesty of light falling across a rough plaster wall at dusk. It cannot know how a scent embedded in timber triggers memory, or how a breeze through a clerestory window stirs a sense of sanctuary.

Figure 7. Therme Vals by Peter Zumthor

The Therme Vals in Switzerland by Zumthor is not just a bathhouse - it's an atmosphere sculpted from stone, water, silence, and shadow. No algorithm can calculate the calmness aroused by stepping barefoot onto the cool slabs of local quartzite while soft light spreads through a slit in the ceiling gradually diffused through the vertical wall.

Architecture, in this way, surpasses information. It becomes emotional presence (Zumthor, 2006). This is not a domain where AI has any true foothold - at least not without reducing atmosphere to a checklist of proxies and measurable surrogates.

4.4 Memory, Place, and Cultural Resonance: Spaces carry memories – not just personal ones, but collective, historical, and intergenerational (Norberg-Schulz, 1980). The layout of a village, the ornament of a doorway, the orientation of a prayer niche: these are spatial codes that carry the weight of culture. They signal belonging, tradition, and transformation (Pallasmaa, 1996; Norberg-Schulz, 1980).

Daniel Libeskind's Jewish Museum in Berlin is structured by voids and broken lines – its jagged geometry not only defies symmetry but materializes absence and loss. A neural network might mimic it in shape, but cannot process the depth of its memorializing gesture.

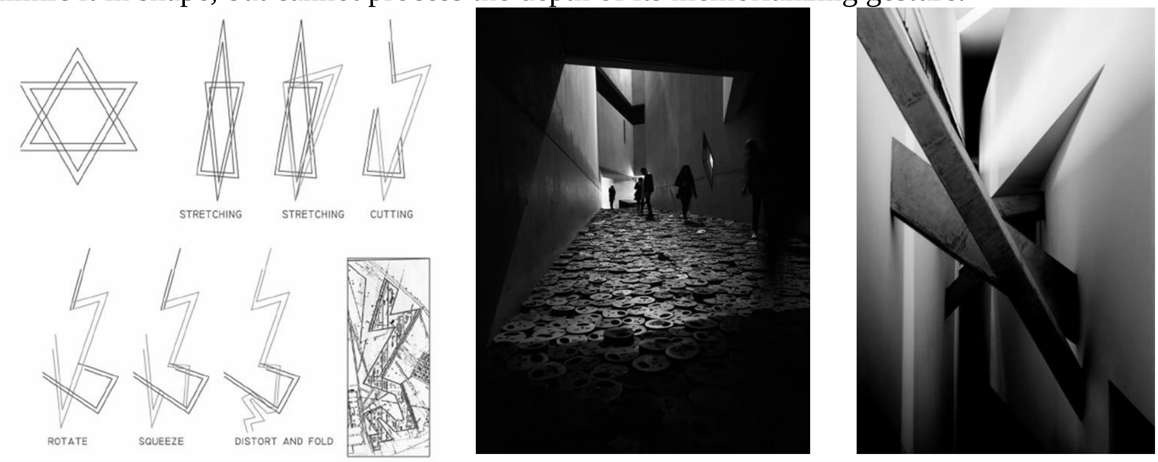


Figure 8. Jewish Museum in Berlin by Daniel Lebeskind

Moreover, memory is not static (Norberg-Schulz, 1980). It changes over time, affected by politics, trauma, and celebration. A public square may earn its sanctity from what took place in it at some time in the past, or a ruined wall may become a symbol of resilience. These layers of meaning are not found in architectural plans but in people's connections to them. AI has no access to this dynamic field of memory and meaning. It can represent the form but not the feeling.

AI, operating on datasets and pattern recognition, may identify recurring motifs or layouts, but it lacks cultural embeddedness. It does not know what a veranda means in Balkan domestic culture, or why the organization of a courtyard may signal hospitality in one context and hierarchy in another one. Form has meaning. A dome, a veranda, a courtyard – these are not neutral – they carry symbolic, ritual, and cultural weight. These meanings vary, shift, and grow far beyond the grasp of pattern recognition. In Hassan Fathy's New Gourna, vernacular mud-brick domes are not a stylistic choice, but a cultural statement – a return to collective knowledge – shared heritage, climate sensitivity, and regional independence.

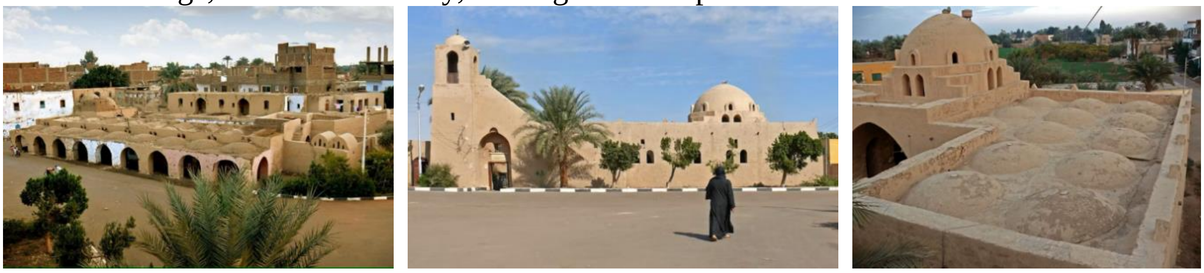


Figure 9. New Gourna by Hasan Fathy

4.5 Tectonic Poetics and the Intelligence of Making: The way architecture is made – the tectonics of it – is also unquantifiable. Kenneth Frampton's notion of tectonic poetics refers to how material and structure transfer ideas, ethics, and traditions (Frampton, 1995). A well-crafted joint, a weighty lintel, or a wall that reveals its construction speaks to a kind of embodied knowledge passed through generations of builders. (Robinson & Pallasmaa, 2015)

The Kimbell Art Museum by Louis Kahn: The vaulted concrete ceilings are not just structural – they channel natural light in ways that honor the art and the visitor. A generative algorithm may optimize light levels, but would it choose this serene rhythm of daylight with the same instinct?

Figure 10. Kimbell Art Museum by Louis Kahn

AI may assist in optimizing material use or calculating structural load, but it does not know how it feels to place stone upon stone. It cannot understand the patience of craftsmanship or the subtle pride in a hand-finished surface. Even in digital fabrication, where machines carve forms from code, the designer's intent and material sensibility remain exceptional.

In addition, tectonic expression is not always in line with what is reasonably logical. A beam may be oversized to convey strength, a joinery detail may be concealed not for efficiency but for mystery. These gestures, rich in symbolic meaning, transcend utility and defy algorithmic grasp.

4.6 Temporality and the Life of Buildings: Architecture is not a fixed object – it is a participant in time. A building changes as light moves across it, as seasons shift, as people inhabit and transform it – it is a living thing (Pallasmaa, 1996; Zumthor, 2006). The same space can feel radically different in the morning and evening, in rain and sunlight. Alvar Aalto's Villa Mairea plays with changing openness, filtered light and the warmth of wood, creating a constantly

shifting intimacy that changes with the day and the seasons. Its design holds time in its very bones.
AI can model time-based phenomena, like solar paths or pedestrian flows, but it cannot experience them. The reality is that architecture gains meaning as it ages. Patina (weathering, aging), decay, adaptation - these are not failures but narratives. A worn threshold speaks of decades of footsteps, a tree grown around a column tells a story of coexistence. These slow processes of change resist design, let alone algorithms.
In a world obsessed with novelty and optimization, the temporal depth of architecture reminds us that value often lies in persistence, resilience, and re-interpretation. No AI, no matter how advanced, can anticipate how a community is going to value a space fifty years from now.

5. The Future of AI in Architecture

As AI becomes more sophisticated and integrated into design process, architecture faces a critical cross-road: will it evolve into a purely computational discipline driven by data and optimization, or will reaffirm its humanistic core while leveraging the best of what AI can offer?
The most plausible future lies in collaboration, not replacement. AI should be understood as a design assistant - powerful, precise, and tireless - but not as a creative member. It can generate multiple iterations of a floor plan, simulate energy performance, detect spatial inefficiencies, and optimize building systems. Yet it cannot decide whether a space feels sacred, dignified, or serene. It can suggest, but it cannot judge. It can automate, but it cannot imagine.
To harness AI effectively, architects must recover authorship. This means not deferring to machine-generated proposals as if they were final, but rather treating them as raw material for critical interpretation. Designers must intervene, edit, contextualize, and reimagine - using AI outputs as provocations, not prescriptions.
Furthermore, architectural education has to change. Future architects need AI literacy, but this should not come at the expense of knowledge in spatial design, theory, history, philosophy, or even phenomenology. Students must learn how AI models are trained, what preconceptions they carry, and where they fall short. Just as previous generations learned structural systems and environmental controls, the next will have to learn to “read” algorithmic patterns.
Equally important is the ethical dimension. AI-powered tools are often imbued with the values and preconceptions of their creators. If left unchecked, they may perpetuate existing inequalities, spatial monocultures, or aesthetic flattening. Architecture has always been a site of social negotiation – who is included, who is excluded, what is celebrated, and what is erased. Architects must ensure that AI supports inclusion, diversity, and cultural richness, rather than undermining them through uniform metrics or one-size-fits-all templates.
Hybrid design processes can be innovative as well. AI can extend rather than replace human intuition. Imagine a diagram in which an architect sketches a spatial concept by hand, feeds it into a generative model that returns multiple optimized variants, and then reinterprets the results through refinement. These workflows respect the voice of the author and extend the range of experimentations.
Some architectural firms are already adopting this mentality. Rather than framing AI as a threat, they see it as a tool that liberates architects from tedious tasks - code checking, documentation, thermal analysis - allowing more time for conceptual development and on engagement with a building’s end user.
In this scenario, the role of the architect transforms - not into a coder, but into a curator of complexity, a mediator between systems and stories, between data and desire. In other words, it is a shift from drawing buildings to organizing processes, from designing objects to arranging relations.

But for this shift to be meaningful, architecture must resist the temptation to fully instrumentalize itself. If it cedes too much to automation, it may lose its capacity to surprise, to provoke, and to inspire. The strength of architecture lies in its capacity to hold contradiction, to manifest emotion, and to create places where people can belong - not just perform.

6. Discussions

This paper has explored the evolving relationship between architecture and artificial intelligence, framing it not as a binary of human versus machine, but as a complex entanglement of capabilities, limitations, and philosophical orientations. AI, for all its processing power, is stuck on the stuff that's measurable, repeatable, data-driven. Architecture, on the other hand, finds its richness in the immeasurable - the poetic ambiguity of space, the emotional resonance of materials, the cultural layering of place, and the ephemeral interplay between buildings and life.

We have traced this tension through historical design rationalism, current AI applications in space layout planning, and most importantly, through the central paradoxes and unquantifiable dimensions that assembly architectural thinking. From atmosphere to memory, from tectonics to temporality, architecture claims a realm that exceeds optimization. It resists closure and thrives on multiplicity - it refuses to close and it wants to be many. This does not mean AI has no place in architecture. It's not that it's not important, but its position is essential but contingent. It has to be subservient to architectural intention, not the other way around. AI can support but not replace the interpretive labor of the architect. It can enhance, but not replace creativity; it can generate, but not comprehend.

As we move into a future shaped increasingly by digital intelligence, architecture must hold its ground - not by resisting innovation, but by anchoring itself in the very qualities that machines cannot replicate: empathy, imagination, contradiction, and care. The challenge for architects is not simply to master new tools, but to ask better questions. What does it mean to dwell? What makes a space feel alive? How can architecture remain a vessel for memory, identity, and transformation in a world of increasing abstraction?

The answers will not come from algorithms. They will come from architects - still, and always, human.

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