

AI in Architecture: Is It a Good Match?

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As the GPU-based machine learning revolution has gained pace over the last five years, popular headlines have concentrated on the ways in which AI automation might replace human effort in a number of sectors.

The targeted industries or occupations tend to be either mathematical and formulaic by nature, or else in some way repetitive and potentially quantifiable — and therefore susceptible to analysis and reproduction by machine learning systems.

On the face of it, the precise and exacting structures of the architect's trade are prime candidates for automation through [AI software development](#), promising a transformative impact similar to the new CAD applications of the 1980s and 1990s. Yet an oft-cited study¹ by The Economist places architects among the least-threatened professional group facing the onslaught of AI, with a mere 1.8% chance of being replaced by machine learning algorithms.

In this article we'll take a look at some of the concrete and abstract reasons why the architectural process is unlikely to be entirely supplanted by AI; but also at some of the ways in which machine learning is beginning to offer new tools, processes and analytical techniques to aid the architecture and construction sectors.

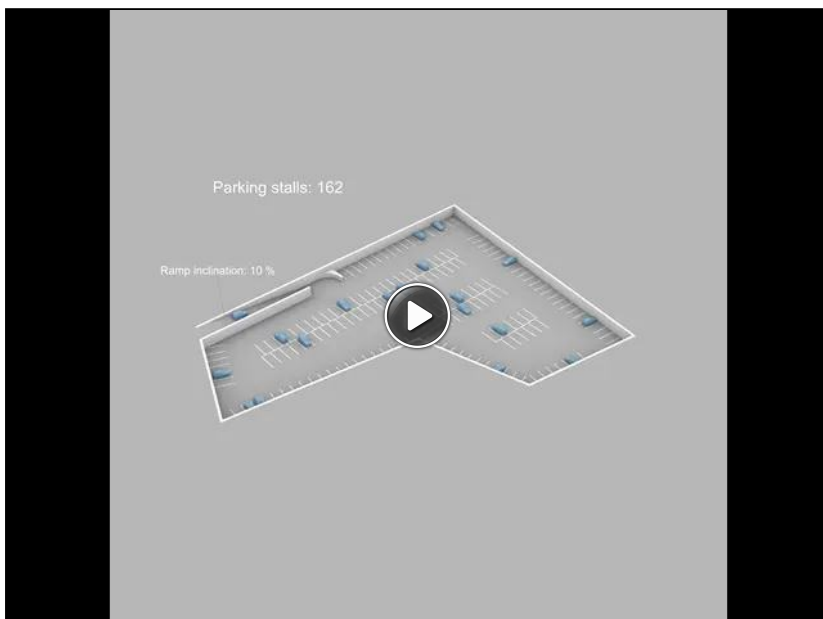
We'll see later that the outer layers of the architectural process represent a difficult target for the AI revolution, for political and economic reasons. In terms of the core mathematical processes, however, machine learning has a freer reign to provide useful new tools for development.

Automating Architectural Ideation, Drafting and Development

AI-Enabled Parametric Exploration

One notable new application of this type is Finch, a parametric architectural planning application that not only uses algorithmic rules to provide adaptive re-modelling of floor plans, but also employs a neural network capable of learning the habits of an architect over time and gradually adapting its processes and methods to suit the specific habits and preferences of the user.

According to the project's founder, the system is intended as an aide in the earlier, more conceptual stages of the design process².



To similar effect, the startup Higharc uses machine learning algorithms to dynamically formulate possible architectural layouts, taking into consideration a broad range of environmental and ancillary factors that would normally represent a time-consuming manual task³.

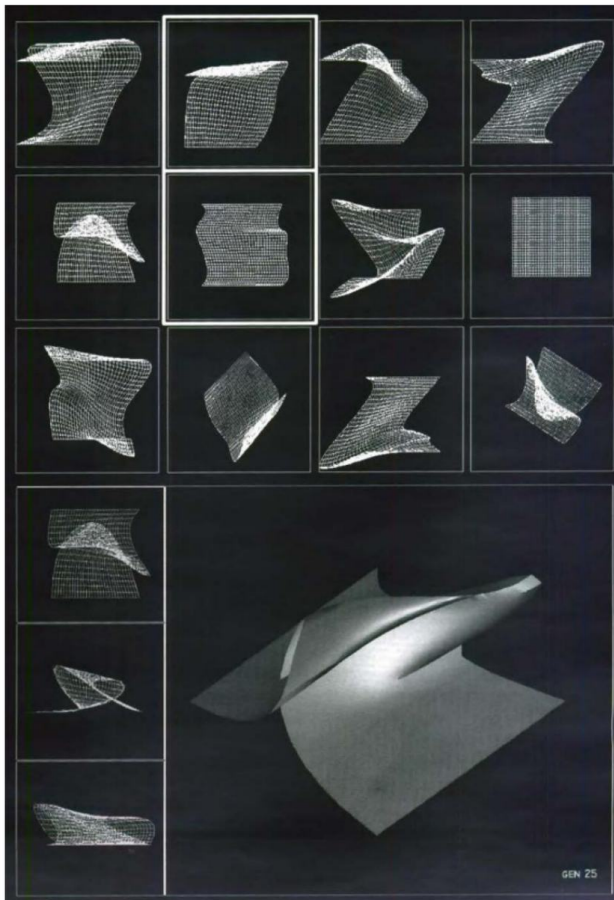


Data source: youtube.com—Higharc automatically generates 3D home plans based on your needs

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A number of recent and historical projects have similarly experimented with parametric and semi-automated design generation. Besides earlier and simpler iterations of machine learning technologies, such as Support Vector Machine (SVM), some of these have used generative genetic algorithms⁴ and other automated ways to iterate through possible structures.

THE USE OF GENETIC ALGORITHMS IN DEVELOPING CONSTRUCTION SURFACES



Data source: issuu.com—An Evolutionary Architecture

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The Karamba 3D parametric tool offers similar flexibility to Finch and is informed by machine learning⁵, while an AI-derived tool in the LadyBug suite offers a machine learning model to calculate thermal efficiency in an architectural project⁶.

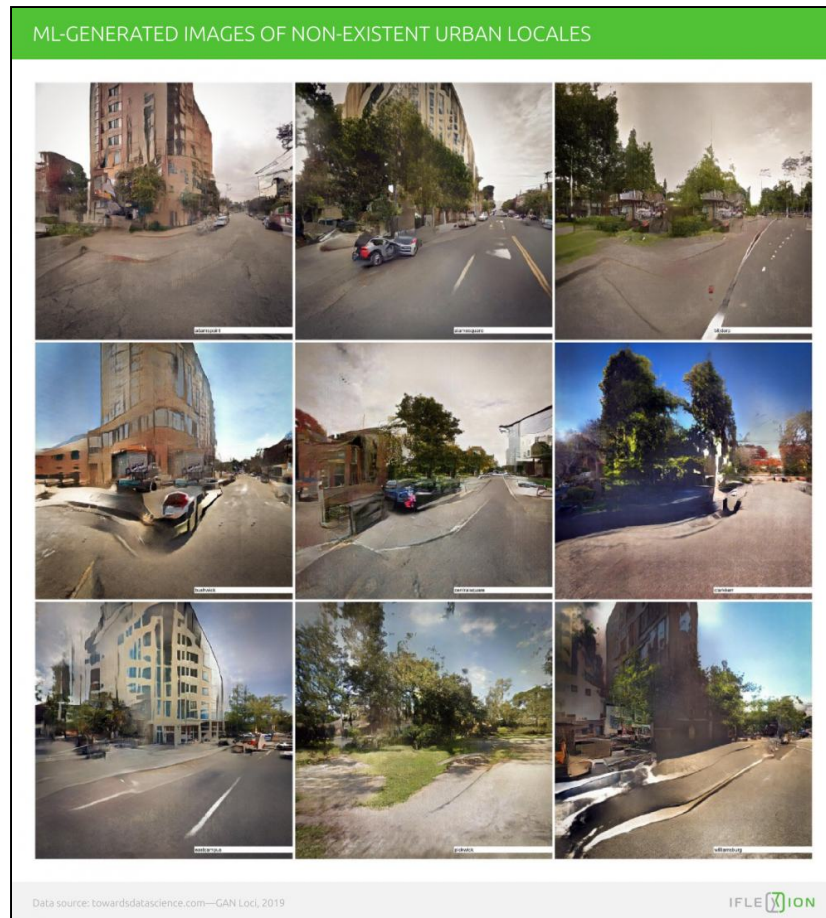
Exploring and Re-Crafting Architectural History

The strength of more recent GPU-enabled machine learning is in the discovery and exploitation of architectural configurations and in generating new inspiration from large datasets.

When Apple added facial recognition features⁷ to its iPhoto software in 2009, one architect noted that the software could now confuse the characteristics of buildings with the features of human faces. The phenomenon is known as Pareidolia⁸ — the tendency to individuate human faces from non-human sources.

This software glitch eventually led to the foundation of architectural biometrics⁹, an ongoing study at the University of Rochester to provide new tools for analysis of spatial data in architecture, and to understand better the anthropomorphic aspect of the way that humans create and relate to buildings.

On a similarly off-beat note, a recent research¹⁰ out of UC Berkeley has applied generative adversarial networks (GANs) to create non-existent urban spaces:



The project uses NVIDIA's StyleGan2 and a high-definition version of Berkeley's own Pix2Pix to distil features from massive datasets of urban imagery.

The core intent of the work is to help architects to transcend their own vision and their own transformative power and to re-evaluate the ways in which their work should strive to be contextual to an existing area or location, rather than impose a new visual dynamic on the area.

The project uses Google Street View data as a primary source, and exploits the little-known fact that many of Street View's explorable panoramas contain depth map information¹¹ that allows three-dimensional description of the scene objects, providing a valuable new parameter for machine learning exploitation.



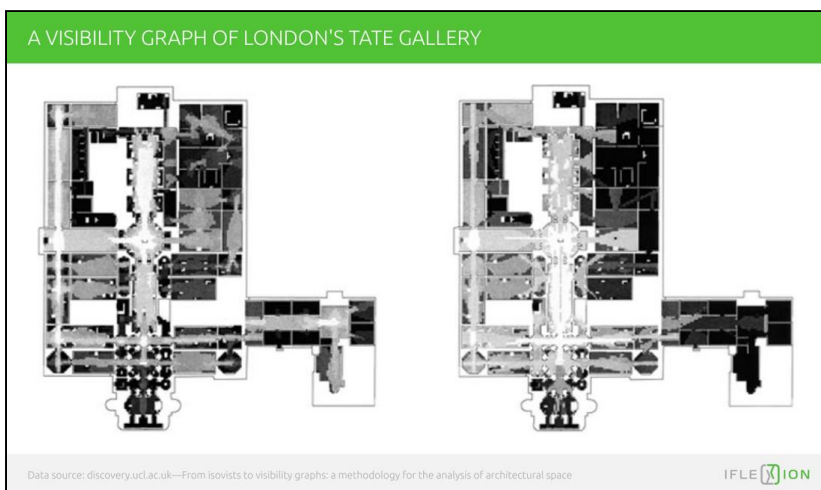
The resulting simulations also allow of rudimentary animation:



Composing and Exploring Internal Spaces with AI

In recent years, [machine learning](#) has been turned towards internal building layout as a facilitator for greater productivity. Practitioners of performance-driven design seek to evaluate optimum 'spatial connectivity' in a workplace environment by calculating the intersection of several theories and approaches.

One influential theory¹² which emerged from University College London in the early 2000s has fueled the move towards open-plan offices over the last two decades by positing a relationship between productivity and visibility in the workplace, and in public spaces.

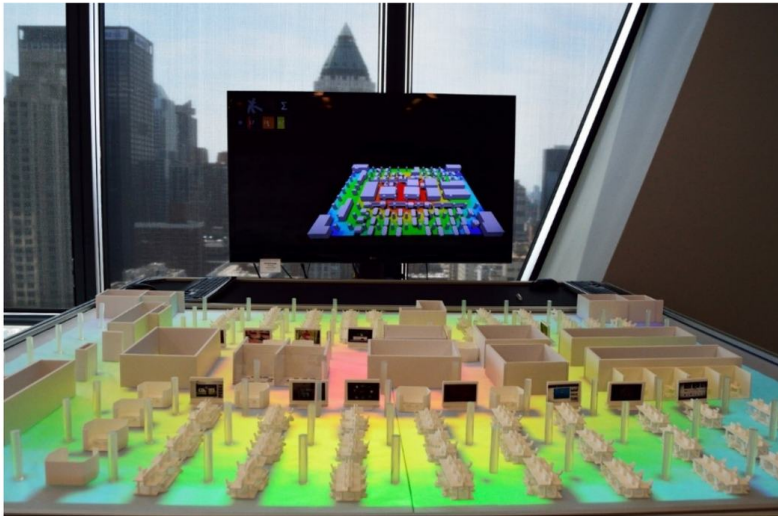


Since spaces may be physically close together without being visible or obviously accessible to someone walking through that environment, a fruitful exploration of floor-plan possibilities will need to be informed by psychological and event-driven data derived from actual use cases, and not just by the 'best-optimized' use of available space.

This is one example of the complex ways that architecture is bound up with society and human psychology, and resists the reductionism that characterizes many of the recent headlines around AI-enabled automation.

Incorporating several such theories into one floor-plan evaluation has always been computationally expensive and time-consuming. One British architectural design company has therefore developed¹³ a neural network model to assimilate the various possible approaches into an interactive framework.

FOSTER & COMPANY'S INTERACTIVE SPATIAL MODELLING ENVIRONMENT

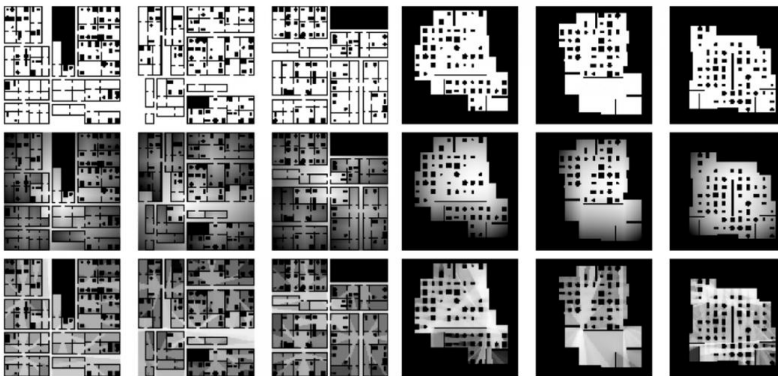


Data source: arxiv.org—Deep learning surrogate models for spatial and visual connectivity, 2019

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The system is capable of approaching useful outcomes from a number of directions. In the image below we see two groups of output: generated floor plans on the left and spatial and visual connectivity analyses on the right. The plans generated represent both open-plan and compartmentalized spaces.

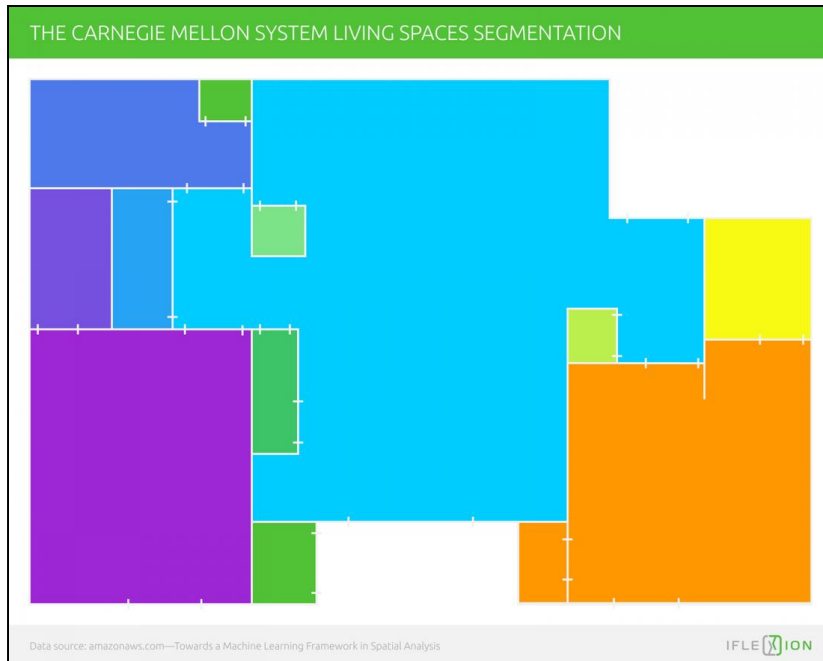
ML-GENERATED FLOOR PLANS



Data source: arxiv.org—Deep learning surrogate models for spatial and visual connectivity, 2019

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Visual connectivity also has a major role to play in [the development of retail environments](#). Recent research¹⁴ from the University of Kentucky pits various machine learning approaches against each other in search of the optimum retail floor layout; a WeWork research group has used neural networks to generate improved meeting space layouts based on historic usage patterns¹⁵; and a neural network framework proposed by Carnegie Mellon researchers¹⁶ offers feature extraction for models that are capable of balancing spatial features against more abstract considerations, such as privacy.



Further AI-Based Architectural Design Applications

Older technologies such as genetic algorithms are now incorporated into an emerging sphere of architectural machine learning, called Compositional Pattern-Producing Networks (CPPNs)¹⁷.

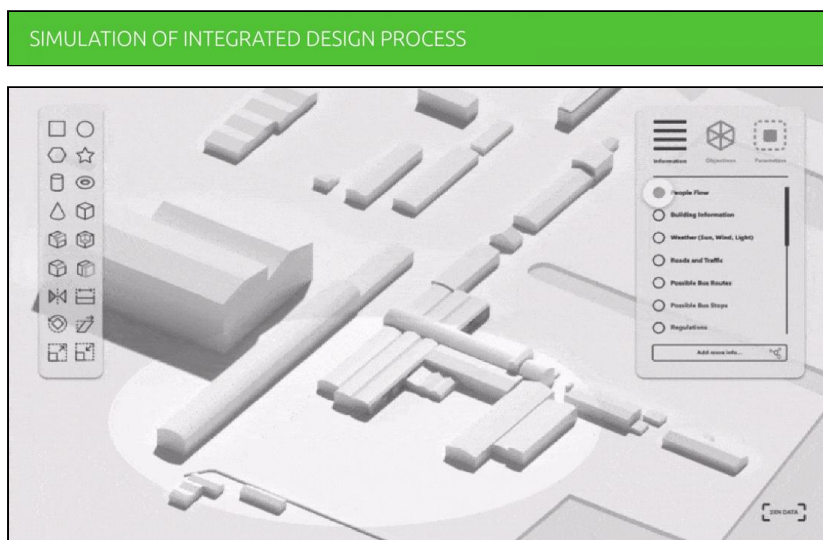
While most machine learning networks rely on changing models weights in order to identify possible new relationships, CPPNs can actually suggest new, potentially more fruitful configurations for the neural network itself.

An 'altered' generation of a neural network created in this dynamic way may have additional or more interconnected nodes than the seed design. This is equivalent to a factory constantly re-designing itself to improve its own end product.

The resulting iterations can be so divergent from the original settings that CPPNs are designed to only pit the more complex derivations against each other as the network and content designs mutate and advance — a true paradigm for 'architectural evolution'.

Well-known products that make use of CPPNs include Picbreeder¹⁸ and Cornell's 'Soft' Robots¹⁹. Other notable projects of recent years in the field of AI-driven architecture ideation and design generation include:

- The Hybrid Sentient Canopy²⁰, a discursive machine learning project from the Living Architecture Systems Group and the Philip Beesley Architecture company. The project explores the ways in which people react to and interact with architecture, and proposes hardware, firmware and software solutions to generate new architectural concepts derived from machine learning analyses.
- A collaboration between the department of architecture at the University of West Hartford, CT, USA, and Raytheon, which used a deep neural network to adapt a 16thC Spanish architectural experiment into a machine learning model that can ingest multiple designs and break elements of architectural constructs into reusable building blocks²¹.
- Danish architectural practice 3XN, which envisages a new integration of architecture with AI, prototyping new interfaces (see image below) where machine learning can suggest alterations in a current design. The company suggests that Building Information Management (BIM) will be one of several new data streams contributing to machine learning models and derived algorithms in the architectural pipeline in years to come.



Architectural Mapping and Measurement with Machine Learning

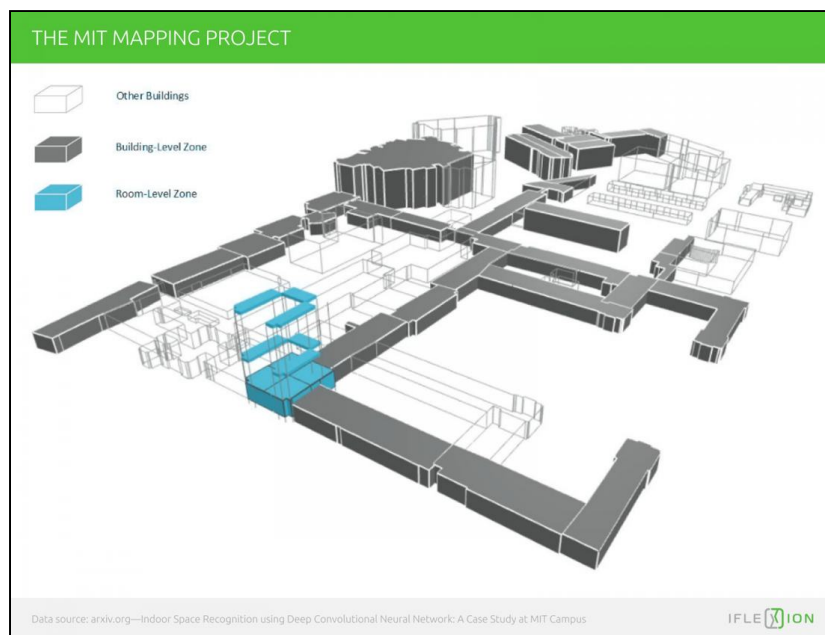
Architecture and [augmented reality applications](#) have recently begun to align in a number of ways, with machine learning a pivotal factor in emerging approaches to mapping and simulating real-world spaces.

In addition to the growing demand for interior space mapping and measurement, autonomous systems such as self-driving vehicles may also need to map their environments dynamically²², for purposes of obstacle detection and changes to the real world that are not yet reflected in pre-mapped locations.

Reflective approaches to dynamic measurement include sonar²³, radar²⁴ and LiDar (Light Detection and Ranging), with the latter now an integrated technology in Apple iOS devices²⁵ — and a growing market emerging for all kinds of measurements, from terrain mapping through to the generation of dynamic AR environments.

Emission-based mapping approaches such as radar and LiDar depend on relatively costly sensors and operate within distance constraints²⁶, whereas systems that can map and measure based on image input only can potentially function without these limitations; for instance, in a large architectural space that mobile emission-based sensors lack the power to traverse.

One example of this is a 2016 study in computer vision-driven mapping at MIT, which used a deep convolutional neural network (DCNN) to parse a large database of images of the campus interior spaces, and generate an abstract architectural model for navigational purposes²⁷.



Google's [ARCore platform](#) allows Android and iOS devices to perform dynamic environment measurement by calculating the host device's position against the video stream of its cameras and other sensors, enabling the mapping of 3D spaces without the need²⁸ for the specialized hardware that was a pre-requisite of its predecessor, Project Tango²⁹. ARCore has been used in a number of high profile outings, such as Sotheby's International Realty AR showcase platform³⁰.

Apple's ARKit for iOS, recently updated to reflect the availability of the new LiDar sensor, has offered AI-driven interior space measurement as a default native app for some years. Various architectural applications have been developed from ARKit to generate floor plans³¹, though public offerings of this type are generally for casual consumer use rather than industry applications.

A study out of the Lawrence Berkeley National Laboratory in 2018 acknowledges that the high dimensionality of 3D representations in machine learning space makes it difficult to produce generalized models with wide applicability, but nonetheless offers a system capable of providing real world measurements from machine learning analysis of 3D object data³². The project was developed with Princeton's ModelNet CAD data sets.

At the current state of the art, the confluence between AI-driven architectural measurement and augmented reality applications that are informed by [computer vision techniques](#) is tending towards systems where the architectural domain supports AR rather than methods by which machine learning can map spaces reliably enough for real-world architectural construction projects.

However, this is a nascent sub-sector of architectural AI, and one which is set to evolve further as gaming and consumer-level products drive and fund research and products (such as architecture-oriented offerings around the Unity gaming engine³³) that will ultimately benefit both sectors.

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Why Architecture Is an Elusive Target for AI Automation

Even by the standards of big tech, the stakes are extraordinarily high in this particular transformative space.

Unlike more abstract and volatile tech sectors such as cryptocurrencies and platform development, construction and [real estate](#) touch everyone's life directly. The more attention these sectors draw as drivers of affluence for the world's super-rich³⁴, the more they become deeply personal,

political and even divisive across all cultures.

Additionally, notwithstanding the effects of the pandemic on industry and commerce, it's estimated³⁵ that the global construction industry will increase by 10% in value to \$11,093.7 billion USD by 2024. Just as real estate was a prime driver of recovery in a post-industrial west after the banking crisis of 2008³⁶, a COVID-afflicted world seems once again to be relying on land and building development to provide an engine of recovery in the world's newly-stricken economies³⁷.

Protectionism vs. AI in Construction

The World Bank Group acknowledges³⁸ that the construction industry, which accounts for one-third of all gross capital formation, is one of the most consistently corrupt sectors on the planet, notably regarding the diversion and misuse of state funding³⁹.

The mechanisms of corruption and favoritism depend on a certain level of civic and legislative opacity. Since these 'exclusive' business processes would be threatened by the creation of transparent and automated frameworks, and since the assets involved represent the core wealth of some of the world's most powerful entities, the automation of the sector faces extraordinary challenges in comparison to similarly high-profile industries.

As with other core economic sectors, machine learning is capable of deducing optimum paths and approaches from vast volumes of data; but factors ranging from the quality of building materials to the expenditure of brick or concrete in a wall are economic, often even political in nature.

Therefore such improvements as AI may bring to the creation and maintenance of private and public spaces are likely to be only in proportion to the emphases that people assign to different types of contributing data: where end-user considerations such as noise-damping or seismic resistance come up against budgetary constraints, zoning restrictions, pressure from lobbyists, or other non-mathematical factors relating to private and regulatory interests, the architectural process itself is likely to remain a very human and fallible one.

Conclusion

In this glancing overview of AI in architecture we have looked at ways that machine learning may directly help the architecture profession in ideating, exploring and realizing new designs through the manipulation and processing of big data.

It remains to be seen whether the emerging tranche of machine learning tools will ultimately achieve more than leavening the repetitive aspects of the architect's trade — and whether there is an industry appetite to allow AI further into one of the most secretive and lucrative of human pursuits.

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