EMERGING POSITIONS OF PARAMETRIC METHODS AND ARTIFICIAL INTELLIGENCE IN ARCHITECTURAL DESIGN

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CAL POLY

INTRODUCTION

In architectural design, the spillover effects of parametricism have been observable primarily in (i) formal explorations (i.e. form making) and (ii) performative analyses in design processes. As a result, the connections between parametric decision making and built environment related data increasingly empower design decision making.

More recently, artificial intelligence (AI) has been enabling making sense of vast amounts of data possible in a short amount of time. Nevertheless, the number studies on AI's potential contributions to parametric empirical data-based design decision making is limited. Most of the published work on artificial intelligence in architecture seems to focus on idea generation and conceptual development, as opposed to data-based decision making. With the abundance of publicly and freely available data in the- twenty-first century, it is critical for architectural research to contribute to a deeper understanding of novel technologies and their positioning in advanced design decision making.

The objective of this study was to systematically explore the potential contribution of AI in relation to parametric design methods beyond idea generation and conceptual development in three areas: (i) form development, (ii) performative analysis, and, (iii) by relating the two to one another, environmentally conscious design decision making.

METHODOLOGY

Step 1. A standard set of problem definitions were selected in three areas: (i) form making, (ii) environmental performance analysis, (iii) form making to enhance environmental performance.

Step 2. The researchers solved each problem definition in two phases: (i) first, by creating human developed scripts, and (ii) second, by asking artificial intelligence to reason its own solution, then write a corresponding script.

Step 3. The resulting human and AI-developed scripts were systematically compared in terms of parametric definitions and their solutions.

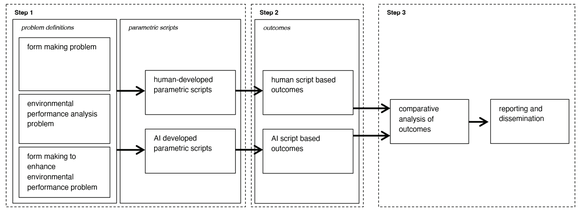


Figure 1. The study will be conducted in three steps.

RESEARCH QUESTIONS

(i) How does AI perform in the development of parametric scripts for solving human-defined form development problems?

(ii) How does AI perform in the development of parametric scripts for solving human-defined environmental performance analysis problems?

(iii) How does AI perform in the development of parametric scripts for solving human-defined environmental performance-oriented form making problems?

SELECTED DATA COLLECTION OUTCOMES

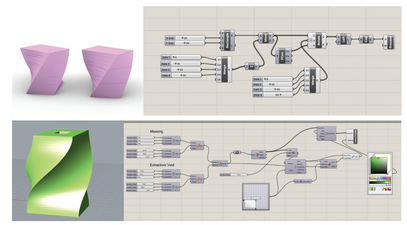
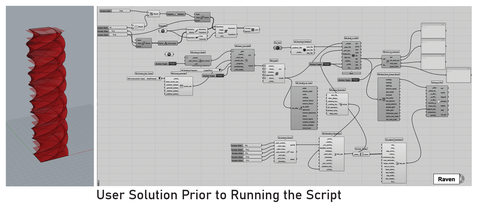
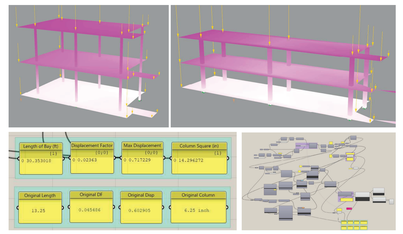
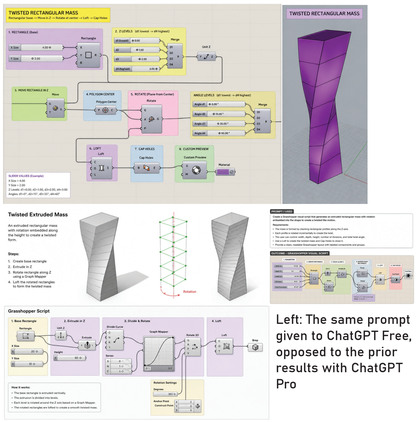
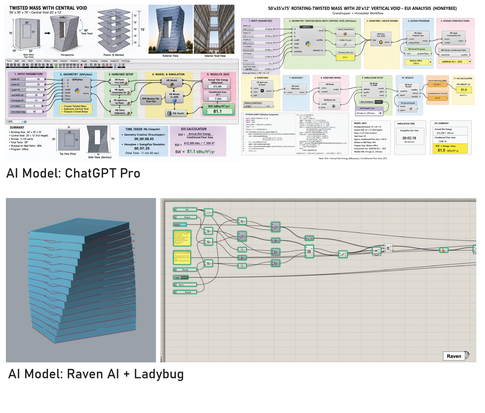
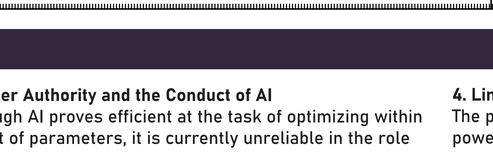
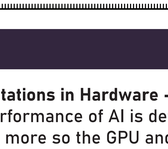
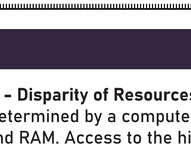
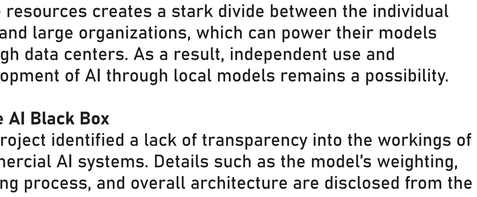
	EXPLORATION OF FORM	ENVIRONMENTAL PERFORMANCE	STRUCTURAL OPTIMIZATION
USER SOLUTION	TWISTING TOWERS: Create an extruded rectangular mass with rotation embedded into the shape, giving twisted-like motion. 	TWISTING TOWERS: Using a 50'x35'x75' rotating-twisted mass with a 20'x12' void place in the center vertically, estimate the tower's EUI using HoneyBee  User Solution Prior to Running the Script	OPTIMIZATION: Using Le Corbusier's Domino House, maximize the length of each structural bay, while maintaining a relatively low value of displacement 
AI SOLUTION	PROMPT: Create an extruded rectangular mass with rotation embedded into the shape, giving twisted-like motion. Provide script and visual of Grasshopper  Left: The same prompt given to ChatGPT Free, opposed to the prior results with ChatGPT Pro	PROMPT: Design ***Using a 50'x35'x75' rotating-twisted mass with a 20'x12' void place in the center vertically, analyze the EUI with honeybee ***. Use Rhinoceros and Grasshopper. show the grasshopper script and time it took  AI Model: ChatGPT Pro  AI Model: Raven AI + Ladybug	Claude + Rhino MCP AI Massing Model  User Correction of Model  Simplification  **RESULT (Claude + Rhino MCP Script)** Software limitations prompted simplification of the structure to a single story, so we ran both human and AI scripts again. AI's optimization reduced each bay to half its length  Results of AI and Human Optimization, Side by Side

Figure 2. A selection of data collection outcomes from the research process.

LITERATURE REVIEW FINDINGS

ISSUES

Suhyung, J., Hyunsung, R., Ghang, L. (2025). Generative AI in architectural design: Application, data, and evaluation methods
Through a systematic overview of the development of AI use in architecture, this paper study concludes that architects are in urgent need of an augmentable framework. Without it, AI usage has been limited to one-off experiments: rapidly outdated, lacking in computational literacy, and without a standard bar of evaluation.

Kemkomnerd, W., Tirapas, C., 2025 | The Silicon Architect: Transformation Towards a Data-Centric Mindset
Whereas parametric architecture was geared towards exploring variations, today's data-centric architecture pushes design towards optimization. The speed at which AI can design an algorithm, scan through every variable, and pinpoint the mathematical zenith is unmatched by human efforts. This paper raises the question: can the extent of design evolve beyond the human brain's capacity?

Figen, L., Delikanli, B., Üneşi, O., Gül, E., 2024 | Development and Applications of Generative AI in Architectural Design Studios
Over the course of five semesters, researchers conducted a series of AI-implementation workshops, supplementing a standard architectural design studio. This experimental curriculum recorded the students' creative process, outcomes of using the institution's GAI-A platform (a collage-to-render ideation tool), and whether the students would continue to utilize this workflow. Despite positive work outputs, students expressed conflicted feelings over a perceived loss of authorship.

APPLICATIONS

Zhang, J., Liu, N., & Wang, S., 2021 | Generative design and performance optimization of residential buildings based on parametric algorithm
This paper reports on a study of a performance-driven parametric framework schemes to replace conventional, inefficient residential design workflows with AI-supported Grasshopper design strategies, structured into five operational phases: target input, layout generation, performance evaluation, decision-making, and final scheme selection.

Jaechang, K., Ajibefuna, J., Wei, Y., 2024 | Experiments on Generative AI-Powered Parametric Modeling and BIM for Architectural Design
Researchers propose a new framework for integrating AI into BIM modeling. Using ChatGPT, Rhino, and Grasshopper, the team asked LLMS to rewrite given problem definitions as mathematical algorithms (i.e., code). The AI's code was then run through Rhino using Grasshopper's script components, resulting in parametric NURBS geometries.

Uhrík, M., López, J. C., Sánchez, C. E., Hajtmanek, R., Demčák, J., & Kupko, A., 2026 | Prompt choreographies: Dialogues between humans and generative AI in architecture.
Examining how human-AI collaboration patterns shape ecologically integrated "environmental interfaces," this study evaluates multi-agent generative workflows to address gaps between design intent and machine output while identifying distinct human design weaknesses, finding that AI best enhances ideation when guided by curated, process-driven frameworks.

FINDINGS

Our explorations indicate three current models of artificial intelligence use for environmental performance analysis and form generation tasks in architecture. While the first two models rely on cloud based services (i.e. running data at off-site locations such as servers in data centers), the last model relies on local hardware and software available to the user. Figure 3 provides a visual summary of the three models as follows.

Model 1: Use of commonly available generative AI engines such as ChatGPT and Claude along with CAD software such as Rhinoceros 3D, Grasshopper and Revit. In this model, the user requests information about specified tasks from the AI engine and can interpret / input findings into the CAD tool. Reponses from AI engine are composed of text instructions and visual descriptions.

Model 2: Use of purpose specific AI engines such as MCP and Raven along with CAD software such as Rhinoceros 3D, Grasshopper and Revit. In this model, the user requests information about specified tasks from purpose specific AI engines that CONNECT commonly available generative AI engines and CAD tools. for example, through MCP, one can have software such as Rhinoceros complete modeling tasks. Or, using Raven, a Grasshopper-native AI plugin, the user can verbally describe tasks and receive descriptions of Grasshopper definitions.

Model 3: Use of Independent Local AI Engines such as Ollama and LMstudio to run LLMs (Large Language Models) and purpose specific AI engines such as MCP along with CAD software such as Rhinoceros 3D, Grasshopper and Revit.

1. User Authority and the Conduct of AI
Though AI proves efficient at the task of optimizing within a set of parameters, it is currently unreliable in the role of defining those parameters itself. Proper usage of AI requires the user to (i) provide a problem definition, and (ii) delineate a set of rules and independent variables through which the AI should solve it. I.e., the user provides something akin to a verbal equation. Without fixed inputs, there is nothing for the AI to weigh, causing it to steer off or be trapped in logic loops. This all comes to say that the user cannot use AI aimlessly- they must conduct full authority over the way AI thinks.

2. AI's Impacts on Cognition
AI has been discussed as a tool causing cognitive offloading: the reduction of a task's mental requirements. Within architecture, the main pitch has been to use AI for numeric, tedious tasks, sparing the architect's mental energy for the creative design process. On the contrary, the heavy usage of AI throughout this project's timeline brought up frequent notes of mental fatigue. As the current state of AI is far from infallible, the user is forced into a state of active monitoring, fatigued by the task of constant troubleshooting and fact verification.

3. The Language Barrier Between Human and AI
Architects rely on a visual form of communication, both in the literal representation of their work, and in the use of spatial metaphors. This stands at odds with AI's rigid, computational processing, causing frequent mistranslation in the beginner-stages of collaboration. To resolve this setback, architects must establish and train towards a baseline of AI and computer literacy. Regardless, this only solves one end of the dialogue. AI cannot meaningfully produce visual representations of its internal processing, much less educate the user through diagrammatic means.

4. Limitations in Hardware - Disparity of Resources
The performance of AI is determined by a computer's processing power, more so the GPU and RAM. Access to the higher end of these resources creates a stark divide between the individual user and large organizations, which can power their models through data centers. As a result, independent use and development of AI through local models remains a possibility.

5. The AI Black Box
The project identified a lack of transparency into the workings of commercial AI systems. Details such as the model's weighting, training process, and overall architecture are disclosed from the public, making them hard to evaluate objectively. This limits the development of independent AI usage.

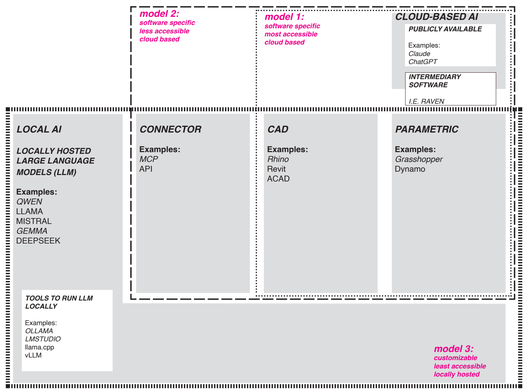


Figure 3 provides a visual summary of the three models.