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THE DIGITAL AND THE SOUTH: QUESTIONINGS VOL. 1

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O DIGITAL E O SUL: TENSIONAMENTOS VOL. 1

LO DIGITAL Y EL SUR: QUESTIONAMIENTOS VOL. 1

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FROM CELLULAR AUTOMATA TO AI AND FABRICATION
DESDE AUTÓMATAS CELULARES HACIA AI Y FABRICACIÓN
ALBERTO FERNÁNDEZ GONZÁLEZ

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Abstract

This paper presents research on workflows for architectural design through the integration of Cellular Automata (CA), Artificial Intelligence (AI), and Digital Fabrication. This study aims to explore how these technologies can optimise both structure and aesthetics in architectural design, providing an efficient and innovative framework. The methodology combines the generation of complex patterns with CA, the use of AI diffusion models for geometry optimisation, and the digital translation of these designs using Autodesk Fusion, enabling comprehensive project management and facilitating interdisciplinary collaboration. The methodology focuses on generating Cellular Automata (CA) patterns using a combination of bespoke and existing algorithms (e.g., Langton's Ant). CA patterns are developed within the Processing environment, leveraging local rules to create complex configurations. AI models, specifically diffusion models, are employed to iterate and optimise these geometries, facilitating continuous refinement of architectural designs and ensuring precise adaptation of the CA-generated patterns. This work develops a workflow aligned with the adoption and transformation of technologies in the Global South, particularly by integrating AI into the creative process. It opens pathways for adapting these methodologies to resource-constrained contexts, proposing a comprehensive framework that combines innovation and efficiency. The study significantly contributes to the future implementation of these technologies, promoting their accessibility and adaptability.

Keywords: Cellular Automata, Artificial Intelligence, Digital Fabrication, Workflows, Architectural Design

1 Introduction

The field of architecture is constantly evolving, seeking innovative methods to enhance design processes, particularly in structural optimisation and aesthetic refinement. In the context of the Global South, these emerging technologies present significant potential to overcome infrastructural and resource limitations, offering adaptable and accessible solutions that address specific local challenges. This approach encourages a rethinking of how adopting computational design technologies, such as Cellular Automata (CA), Artificial Intelligence (AI), and Digital Fabrication, can contribute to more inclusive architectural design and foster decolonial debates within the discipline.

Traditional practices, often reliant on manual drawing and static models, are laborious and limited in their capacity to explore complex forms and dynamic systems (Ball, 2011). The advent of digital technologies has triggered a substantial shift towards computational design methods, which offer greater flexibility, precision, and efficiency (Batty, 2007). One of the most promising advancements in this area is the integration of complex computational strategies, such as CA and AI. CA, a discrete model in computational mathematics, involves a grid of cells evolving through simple rules based on the states of their neighbors (Beigy & Meybodi, 2004). This method can generate intricate patterns and structures that mimic natural processes, proving to be a powerful tool for architectural design (Beigy & Meybodi, 2006). Similarly, AI, mainly through machine learning and diffusion models, can analyse large datasets to identify optimal design solutions that balance form and function (Gilpin, 2018).

This research aims to explore the effectiveness of CA and AI, specifically diffusion models, in generating architecturally appealing geometries that are both structurally and aesthetically refined (Glover et al., 2021). Diffusion models in AI simulate the propagation of particles or information over time, refining architectural designs through iterative enhancement of initial concepts (Beigy & Meybodi, 2007). This iterative process can lead to innovative solutions that may not be immediately evident through traditional methods (Beigy & Meybodi, 2008).

The study emphasises the use of depth map technologies for translating 3D models, bridging the gap between conceptual design and structural performance (Beigy & Meybodi, 2010). Depth maps represent the distance between surfaces in a 3D space and are key for converting 2D patterns generated by CA and AI into three-dimensional structures (Berlekamp et al., 1982). With the support of these technologies, architects can create detailed and precise models ready for structural analysis and optimisation (Betka et al., 2020).

Additionally, different studies have examined how these technologies can be applied in the Global South to address resource constraints and adapt to local contexts (e.g., Oxman, 2017). The integration of CA, AI, and depth-map technologies enables architects to push the boundaries of traditional design, creating buildings that are both aesthetically interesting and structurally strong (Fernández González,

2023b). This approach can potentially revolutionise architecture across diverse contexts, offering new pathways to develop sustainable and efficient designs inspired by organic forms or nature-inspired patterns.

2 From Generative CA to AI

This research represents a significant improvement in the field of architectural design. It demonstrates the practical application of Cellular Automata (CA) and Artificial Intelligence (AI) in form-finding processes, with a particular focus on structural optimisation. By integrating these advanced computational tools, the study provides a coherent framework for exploring new architectural forms while enhancing efficiency and creativity in the design process (Fernández González, 2023a), as illustrated in Figure 1.

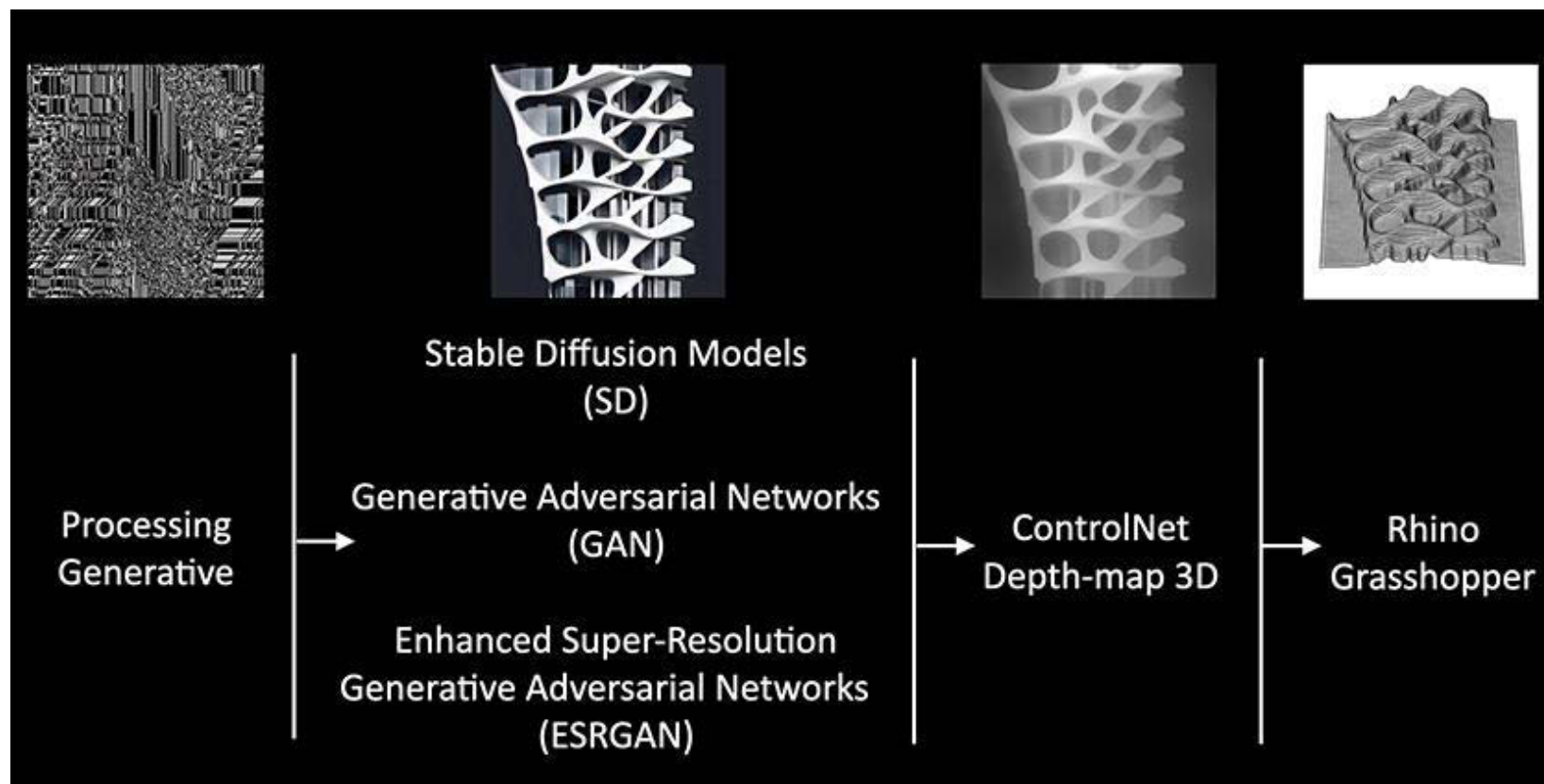


Fig. 1: Proposed workflow from Generative CA to AI. Source: Author, 2024.

The integration of CA and AI demonstrates the transformative potential of combining computational design techniques with AI algorithms and depth map technologies. Cellular Automata, as a computational model, enable the generation of complex patterns and structures that mimic natural processes (Beigy & Meybodi, 2004). This ability to simulate growth and form through systems based on simple rules provides architects with a powerful tool to explore innovative and efficient structural solutions. Diffusion models, which simulate the propagation of particles or information over time, facilitate the iterative refinement of architectural designs. This iterative process allows for continuous improvement and optimisation, leading to design solutions that balance aesthetic appeal with structural performance (Beigy & Meybodi, 2007).

Figure 2 demonstrates how depth map technologies play a crucial role in translating 2D designs generated by CA and AI into 3D models (Beigy & Meybodi, 2010). This process bridges the gap between conceptual design and structural performance, ensuring that aesthetic innovations are supported by practical viability (Berlekamp et al., 1982). The ability to accurately model and analyse complex geometries in three dimensions is essential for developing designs that are not only visually compelling but also structurally efficient and sustainable (Betka et al., 2020). Depth maps enhance the precision and detail of architectural models, enabling a more comprehensive understanding of spatial relationships and structural dynamics. This capability is critical in high-resolution architectural design, where intricate details and complex interactions must be represented and analysed precisely (Christen & Del Fabbro, 2019).



Fig. 2: Translation of an AI-generated image from a CA pattern to a 3D depth map using ControlNet. Source: Author, 2024.

By facilitating a deeper integration of these technologies, this research opens new pathways for developing sustainable, efficient, and aesthetically appealing architectural designs (Oxman, 2017). The combined use of CA, AI, and BIM enables the creation of structures optimised for both performance and resource efficiency, contributing to broader sustainability goals in architecture. This approach can lead to more energy-efficient buildings, produce less material waste, and are better adapted to their environmental context (Glover et al., 2021). The study's focus on high-resolution architectural design, incorporating intricate details and complex interactions, aligns with the principles of sustainable design. By leveraging computational tools to optimise both form and function, architects can create buildings that are not only beautiful but also environmentally responsible and economically viable (Beigy & Meybodi, 2008).

The study underscores the relevance of computational methods in addressing contemporary architectural challenges. As the demands of architectural design grow increasingly complex, encompassing sustainability, resilience, and adaptability, the need for advanced computational tools becomes more evident (Ball, 2011). This research demonstrates that the integration of CA, AI, and BIM can meet these demands, providing a comprehensive framework for innovative and practical design solutions (Mitchell, 2009). The ability to simulate and analyse complex interactions within architectural designs enables more informed decision-making and enhances the overall quality of the built environment, where innovative design solutions are essential (Kolarevic & Malkawi, 2005).

3 Methodology

The study adopts a multi-stage methodological approach, beginning with the generation of 2D patterns using customised Cellular Automata (CA) algorithms based on the Langton Ant model. These algorithms were modified with specific repetition rules to promote Class 4 distribution patterns, according to Wolfram's classification, enabling the creation of complex and adaptive configurations. The resulting patterns are exported in .txt format, with each point described by x, y, and z coordinates, and subsequently imported into Grasshopper, where they are reinterpreted as point maps ready for further exploration and transformation.

The next phase of the process involves the integration of Artificial Intelligence (AI) models, specifically stable diffusion models, which reinterpret the patterns generated by CA. This integration allows the conditioning of prior patterns, creating bio-inspired architectural

representations with continuous forms and a high level of detail. The ability of diffusion models to produce precise and detailed variations facilitates creative exploration in architectural design, enabling the discovery of solutions that balance aesthetics and structure.

To translate the designs into 3D models, depth map technologies are employed in Grasshopper, allowing the transformation of 2D configurations into detailed three-dimensional geometries. These 3D models are then exported to Autodesk Fusion for structural analysis and final optimisation. This iterative process of translation and refinement combines computational design with AI knowledge and Building Information Modeling (BIM) coordination, ensuring that architectural forms meet aesthetic and structural criteria.

Comparison with similar studies: Unlike previous approaches that focus solely on exploring CA patterns without deeply integrating AI, this study stands out for its innovative methodology combining CA and diffusion models, achieving a cohesive and adaptive workflow. This combination offers new possibilities for generating bio-inspired architectural structures, positioning this research at the forefront of innovation in computational design.

Summary of Methodological Stages:

A Initial Design Exploration: 2D patterns are generated in Processing and Grasshopper using CA algorithms based on Langton Ant, with modifications to create Class 4 patterns. This process establishes a rich geometric foundation for subsequent refinement stages.

B AI Integration: AI diffusion models reinterpret the CA patterns, expanding design possibilities and guiding the results toward bio-inspired and highly complex configurations.

C Translation to 3D Models: Using depth map technologies in Grasshopper, the 2D patterns are transformed into 3D models, which are then optimised in Autodesk Fusion to ensure structural feasibility and architectural precision, as illustrated in Figure 3.

This methodological approach enables a unique synergy between CA, AI, and digital fabrication technologies, establishing an innovative and adaptable framework for diverse architectural contexts regardless of available resources.

4 Digital Experiments and Results

By applying CA algorithms within the Processing and Grasshopper environments, initial 2D patterns were generated as the first step of this experiment, serving as a foundation for developing more complex geometries. Governed by simple local rules, these patterns evolve into intricate forms that can adapt to diverse architectural needs. The iterative nature of CA allows for the continuous refinement of these patterns, as indicated in Figure 4.

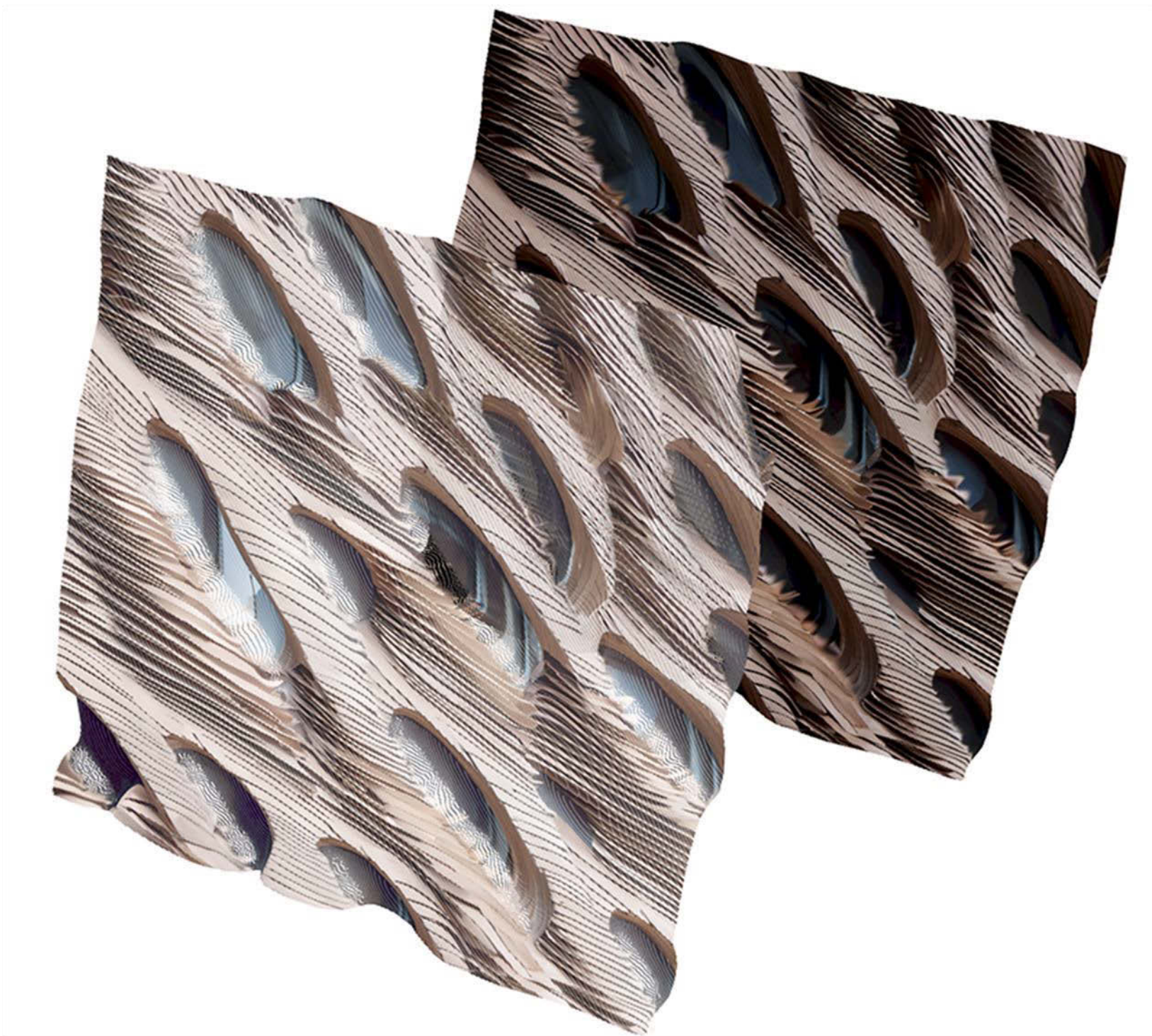


Fig. 3: Translation of a 3D CA model to AI-generated images using a custom Processing node based on depth map data. The results are saved as a point cloud and an OBJ file for Rhino. Source: Author, 2024.

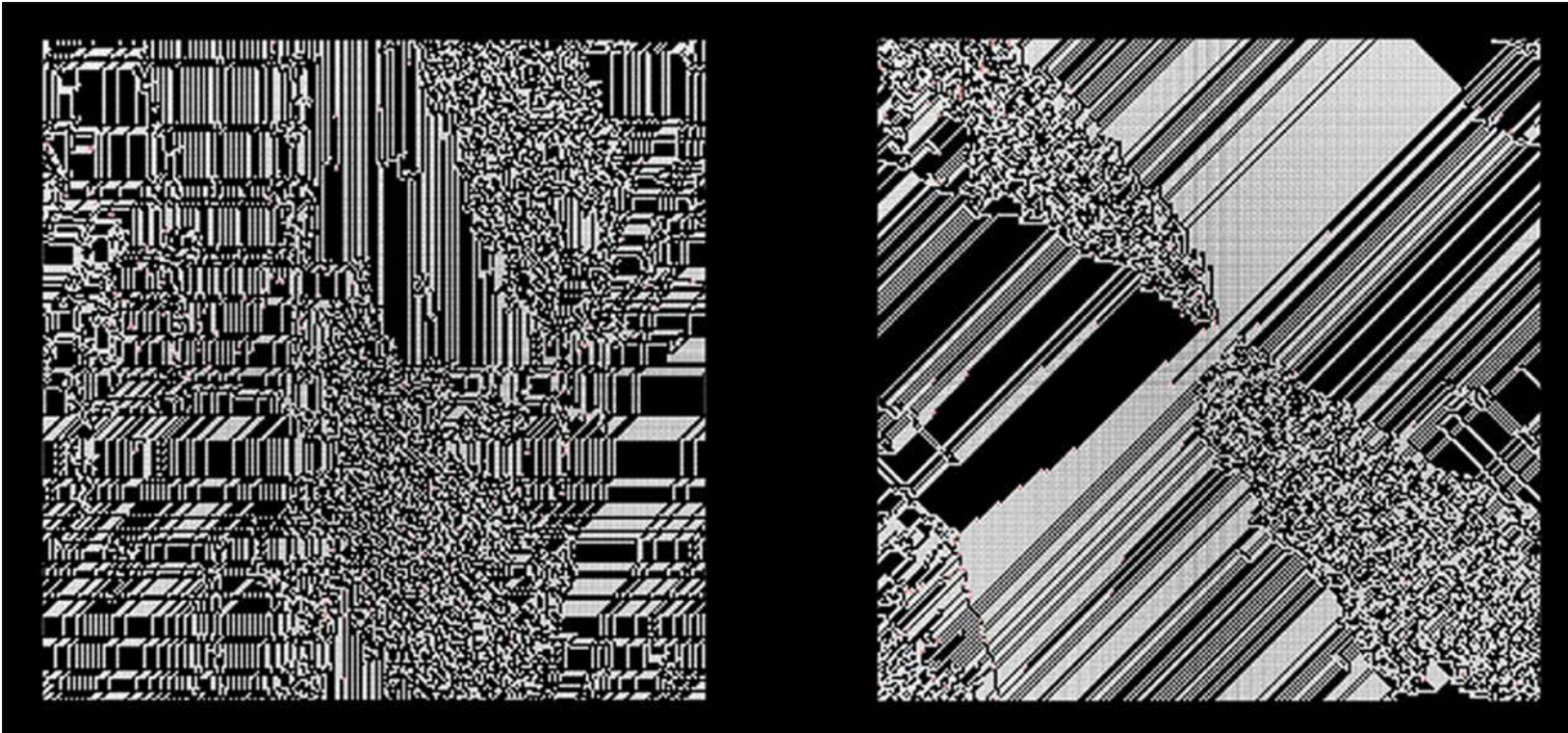


Fig. 4: Patterns generated by CA as the first step in this workflow. Source: Author, 2024.

Step 1: The first step in this workflow involved generating 2D patterns using Cellular Automata (CA) algorithms within the Processing and Grasshopper environments. The initial patterns, structured by simple local rules, were developed from algorithms based on the Langton Ant model, customised with modifications to repetition rules to generate Class 4 patterns, as defined by Wolfram's classification. This class of patterns offers high adaptability and complexity, which is crucial for architectural applications where functional and aesthetically unique configurations are sought. The resulting patterns were exported in .txt format with x, y and z coordinates, enabling easy import and manipulation in Grasshopper.

An important advantage of using CA is its ability to produce results with low memory and processing requirements, making this approach particularly suitable for resource-limited environments. This stage lays a foundation for creating more complex geometries, adaptable to various architectural needs, from facade creation to internal structural optimisation.

Additionally, the research examines how these technologies can be applied in resource-constrained environments and adapted to local contexts. The CA algorithms employed consume minimal computational resources, making them easily adaptable to pre-existing patterns in local realities, potentially serving as the basis for future work. In such environments, CA's ability to generate complex configurations from simple rules is especially relevant, enabling design exploration without reliance on sophisticated or expensive technologies (requiring no more than 16GB RAM and simple processes). Governed by basic computational principles, these patterns can be implemented in resource-limited contexts, allowing architects in the Global South to experiment with architectural configurations that respond to local specificities. The iterative nature of CA allows for continuous refinement of generated patterns, which is crucial for achieving solutions that are not only visually appealing but also functional and feasible within these contexts.

Step 2: The next step in the experiments involved integrating Artificial Intelligence (AI) diffusion models, which significantly expanded the design exploration space. These AI models, particularly diffusion models, simulate the propagation of particles or information through a medium, enabling a more sophisticated exploration of form and function. This capacity to explore a wide range of design possibilities is fundamental to architectural innovation, as it allows architects to discover configurations that may not be apparent through traditional methods (Gilpin, 2018).

Through thousands of iterations generated by these diffusion models, the process identifies optimal configurations that balance aesthetics with structural performance. In contexts where resources may be limited, this approach allows for adaptive experimentation, maximising material efficiency and tailoring the design to specific environmental conditions. In this sense, AI becomes a tool not only for optimisation but also for creative exploration, enabling specific adaptations to local needs and promoting decolonial and sustainable design practices.

The AI diffusion models also facilitated the exploration of various design scenarios, including the impact of different materials and diverse contextual conditions. The application of depth map technologies in translating these designs to 3D is essential for creating complex architectural forms that meet subsequent spatial analysis and material performance requirements.

Depth maps, which represent the distance between surfaces in a 3D space, are critical for converting CA- and AI-generated patterns into detailed and precise three-dimensional structures. This translation process bridges the gap between conceptual designs and their practical manufacturability, enabling the creation of structures that are not only visually appealing but also structurally coherent and economically viable in resource-limited contexts, as indicated in Figure 5.



Fig. 5: Set of variations of a CA pattern in the search for a potential architectural-structural solution. Source: Author, 2024.

Step 3: The application of depth map technologies proved to be a critical component in translating the 2D patterns generated by CA and AI into detailed 3D models within Grasshopper. Depth maps, which represent the distance between surfaces in a three-dimensional space, allow precise control over the final shape of the 3D model. This control is essential to ensure that architectural models are not only aesthetically appealing but also structurally robust and manufacturable. In the experiments, depth maps were generated to translate the 2D CA patterns into detailed 3D models within Grasshopper, as shown in Figure 6. Figure 7 shows how this technology provided precise control over the three-dimensional form, enabling the creation of highly detailed and accurate architectural models. Additionally, depth maps facilitated the integration of complex geometries into the overall building design. By accurately representing spatial relationships and the interactions between different structural elements, depth maps ensured that the final designs were not only aesthetically innovative but also structurally viable (Christen & Del Fabbro, 2019).

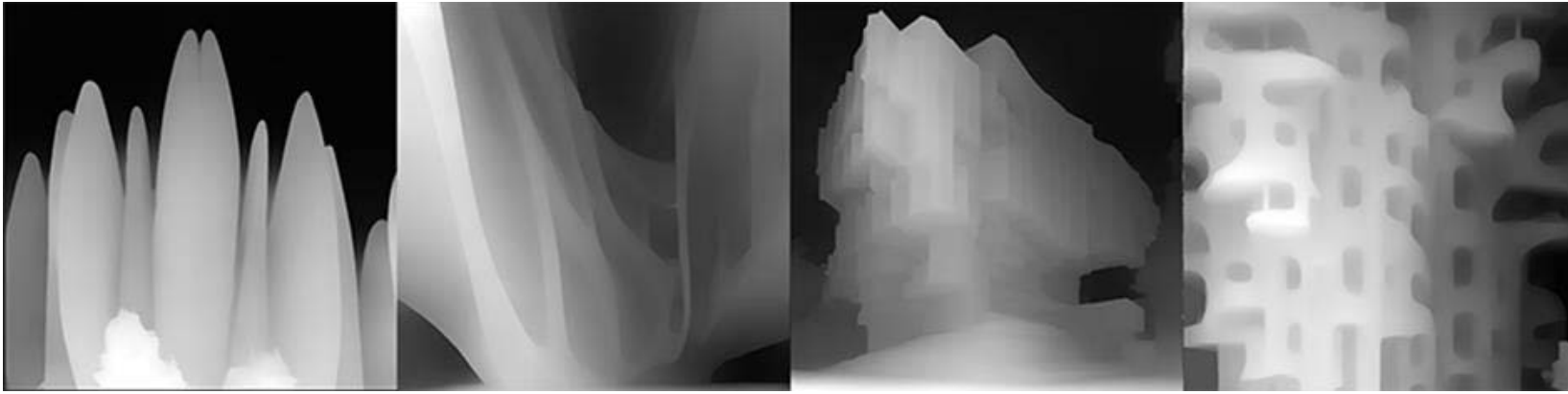


Fig. 6: Set of depth map variations based on a CA pattern in the search for a potential architectural solution. Source: Author, 2024.

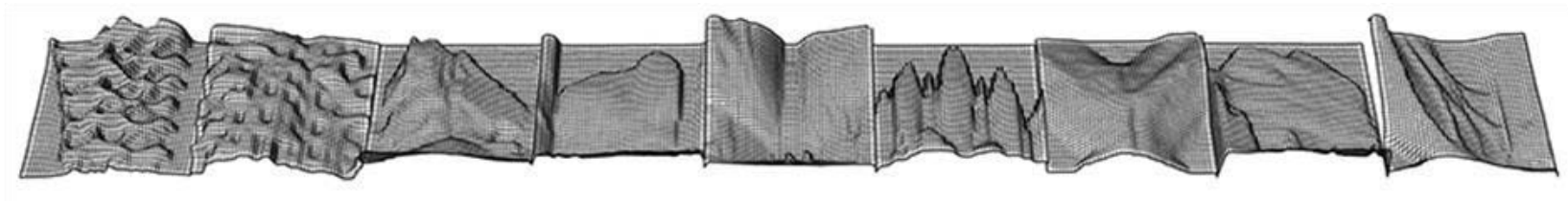


Fig. 7: Set of depth map translations with varying densities into Rhinoceros as a preliminary step towards the final 3D translation. Source: Author, 2024.

Step 4: The 3D models generated using Cellular Automata (CA), Artificial Intelligence (AI), and depth maps were subsequently refined and analysed using Autodesk Fusion, an advanced tool that facilitates precise evaluations of structural feasibility as the final step in the process. At this stage, Autodesk Fusion provides a robust platform for assessing the structural integrity of architectural designs, enabling designers to identify and address potential weaknesses in the structure before proceeding to fabrication. This analysis is critical to ensuring that the proposed architectural configurations are not only visually appealing and conceptually innovative but also capable of withstanding the loads and conditions they will face in real-world environments.

During this refinement process, aspects such as load distribution, material strength, and overall model stability were evaluated. The simulation in Autodesk Fusion illustrated in Figure 8 enabled iterative adjustments to optimise the model, modifying structural parameters and improving design efficiency in terms of material usage and strength. This iterative approach ensures that the final model is ready for implementation in the fabrication phase, minimising risks and guaranteeing that the design meets the safety and performance standards required in architectural practice.

Although work with Autodesk Fusion is typically conducted within an academic setting where the cost of the tool is mitigated by educational licenses, this reliance represents a limitation in research, particularly when considering its applicability outside academia. Future research proposes the use of Rhinoceros and Grasshopper as viable alternatives, simulating the structural evaluation processes currently performed on the Autodesk platform. This approach would allow broader access to the techniques developed in this study, facilitating their adoption in professional contexts and regions where access to Autodesk Fusion may be constrained by economic restrictions.

Depth map technology played a crucial role in this process, facilitating the conversion of 2D patterns generated in earlier stages into detailed 3D geometries that were then integrated into a 3D printing and fabrication workflow. This transition from flat patterns to three-dimensional structures enables architects and designers to explore complex configurations and test their structural feasibility in a digital environment before physical fabrication. The results of this evaluation and optimisation process demonstrated not only the feasibility of the design but also its structural integrity and visual uniqueness, highlighting how the integration of CA, AI, and digital fabrication can produce innovative architectural solutions tailored to the current demands for sustainability and structural efficiency (Fernández González, 2023b).

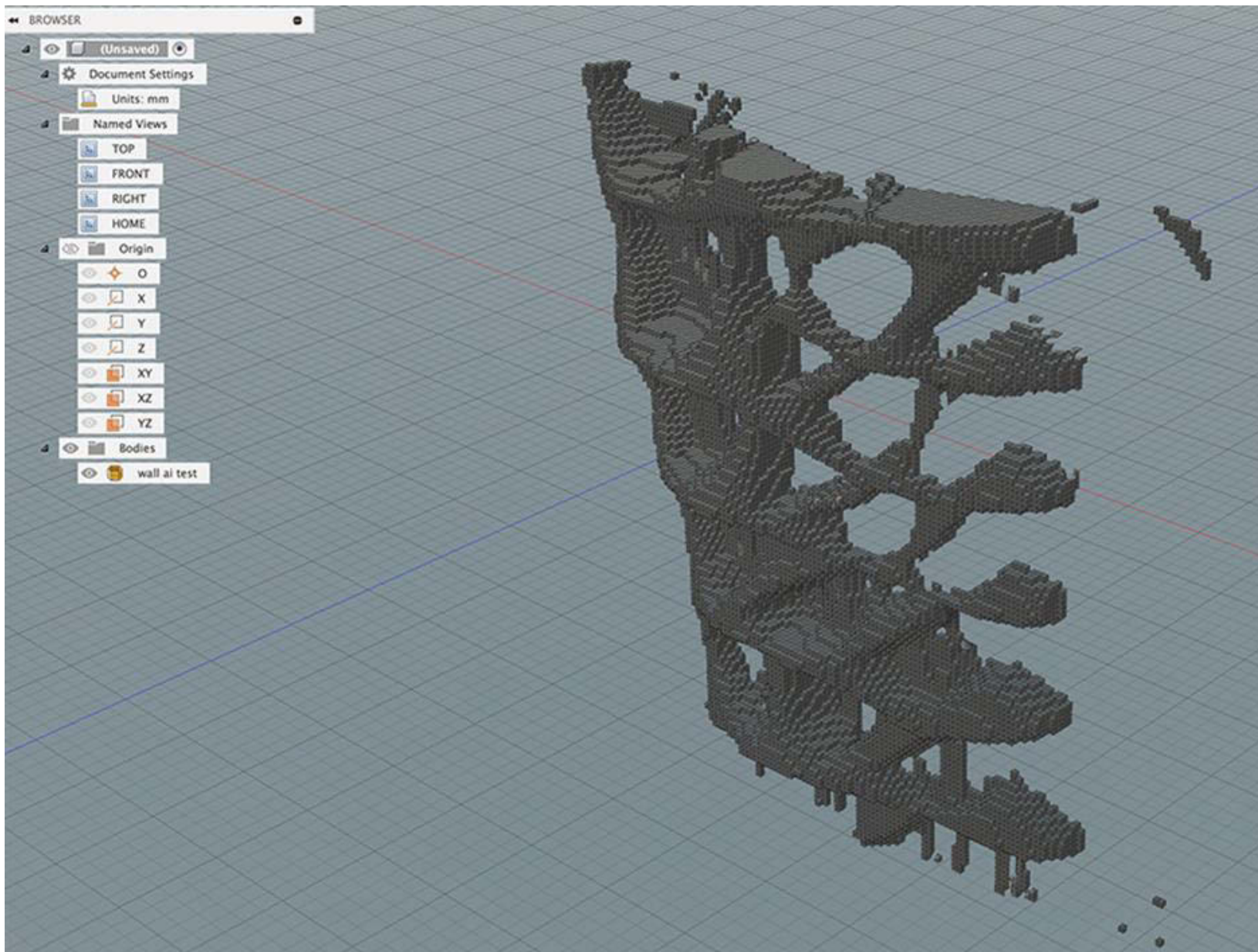


Fig. 8: Autodesk Fusion: Discrete Continuity of the 3D Model. Source: Author, 2024.

Finally, the refined 3D models were integrated into a digital fabrication process using PLA filament 3D printing techniques, allowing the complex geometries developed in earlier stages to be materialised. A key step in this phase was the discretisation of the form in Autodesk Fusion, which simplified the structures into modular and consistent components. This discretisation not only facilitates 3D printing by creating geometries tailored to the fabrication process but also significantly reduces the need for additional supports, thereby optimising the time and resources used during printing. By minimising the use of supports, the resulting model is not only more material-efficient but also higher in quality, avoiding imperfections caused by excessive support use in complex structures.

The fabrication phase, demonstrated in Figure. 9, not only validated the feasibility of the design but also highlighted its visual uniqueness and the structural integrity of the created models. The 3D prints, such as the one shown in the reference image, capture the precision of patterns generated through Cellular Automata (CA) and Artificial Intelligence (AI), demonstrating how these technologies can produce detailed and visually striking structures that maintain consistency during the printing process.

The results demonstrate that combining CA, AI, and digital fabrication offers an innovative and efficient approach to architectural design, capable of producing structures that are both aesthetically appealing and structurally sound. The implementation of discretisation and the

reduction of supports enables the exploration of bio-inspired forms optimised for printing, resulting in sustainable and resilient models that meet contemporary architectural demands.

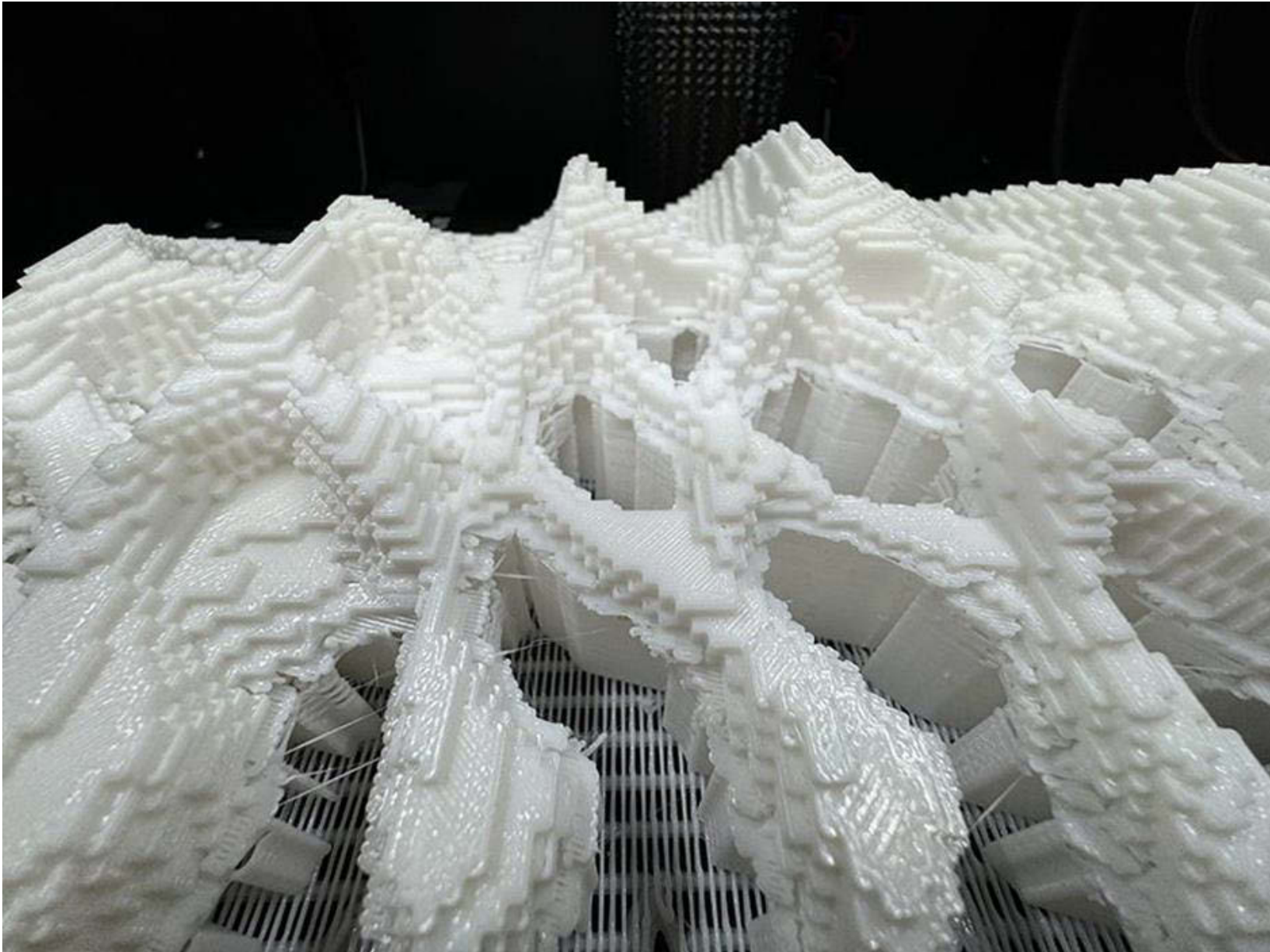


Fig. 9: Discrete 3D Model Printed in 3D. Source: Author, 2024.

5 Concluding Remarks

This study demonstrates that integrating Cellular Automata (CA), Artificial Intelligence (AI), and digital fabrication into a coherent workflow provides an innovative and robust approach to architectural design. This process enables an enriched exploration of forms, spaces, and structures, facilitating the creation of complex designs that maintain consistency throughout fabrication. Specifically, using CA for generating intricate patterns, combined with AI for optimising geometries, offers an adaptable and efficient method that addresses contemporary architectural demands for sustainability and aesthetics. Additionally, the discretisation of models in Autodesk Fusion simplifies forms for 3D printing, reducing the need for support and optimising resources, a feature particularly relevant in resource-constrained contexts.

Applying this workflow in Global South contexts opens new possibilities for architectural design in regions with limited infrastructure and access to advanced technology. CA's capacity to generate results with low memory and processing requirements makes this methodology viable in such settings, enabling architects and designers to experiment with innovative solutions tailored to local needs. This approach

fosters decolonial design practices by adapting advanced technologies to be accessible and relevant to the Global South. As such, this workflow becomes a tool for democratising access to advanced design methods, promoting a more inclusive and contextually appropriate architecture.

Future steps include exploring Rhinoceros and Grasshopper as alternatives to Autodesk Fusion for structural simulation and evaluation, potentially expanding the applicability of this approach in non-academic environments where Autodesk Fusion's educational licenses may not be available. Further research could also focus on developing more advanced AI algorithms to enhance adaptability and customisation in the design process, optimising CA-generated models to better respond to the material and structural load conditions of specific projects.

The results of this study suggest that combining CA, AI, and digital fabrication not only enriches the formal, spatial, and structural exploration process but also provides a consistent framework for creating viable architectural structures. This workflow enables architects and designers in the Global South to overcome accessibility barriers and explore new design forms that are both aesthetically innovative and functionally robust, contributing to the development of an architecture that meets contemporary challenges sustainably and efficiently.

References

- Ball, P. (2011). *Shapes: Nature's patterns: A tapestry in three parts*. Oxford, UK: Oxford University Press.
- Batty, M. (2007). *Cities and complexity: Understanding cities with cellular automata, agent-based models, and fractals*. Cambridge, MA: MIT Press.
- Beigy, H., & Meybodi, M. R. (2004). A mathematical framework for cellular learning automata. *Advances in Complex Systems*, 7(3), 295–319. <https://doi.org/10.1142/S0219525904000202>
- Beigy, H., & Meybodi, M. R. (2006). Utilizing distributed learning automata to solve stochastic shortest path problems. *International Journal of Uncertainty, Fuzziness and Knowledge-Based Systems*, 14(5), 591–615. <https://doi.org/10.1142/S0218488506004217>
- Beigy, H., & Meybodi, M. R. (2007). Open synchronous cellular learning automata. *Advances in Complex Systems*, 10(4), 527–556. <https://doi.org/10.1142/S0219525907001413>
- Beigy, H., & Meybodi, M. R. (2008). Asynchronous cellular learning automata. *Automatica*, 44(6), 1350–1357. <https://doi.org/10.1016/j.automatica.2007.11.018>
- Beigy, H., & Meybodi, M. R. (2010). Cellular learning automata with multiple learning automata in each cell and its applications. *IEEE Transactions on Systems, Man, and Cybernetics, Part B: Cybernetics*, 40(1), 54–65. <https://doi.org/10.1109/TSMCB.2009.2030786>
- Berlekamp, E. R., Conway, J. H., & Guy, R. K. (1982). *Winning ways for your mathematical plays*. Academic Press.
- Betka, A., Terki, N., Toumi, A., & Dahmani, H. (2020). Grey wolf optimizer-based learning automata for solving block matching problem. *Signal, Image and Video Processing*, 14(2), 285–293. <https://doi.org/10.1007/s11760-019-01554-w>
- Christen, P., & Del Fabbro, O. (2019). Cybernetical concepts for cellular automaton and artificial neural network modelling and implementation. *Proceedings. 2019 IEEE International Conference on Systems, Man and Cybernetics (SMC)*, 4124–4130. <https://doi.org/10.1109/SMC.2019.8913839>
- Fernández González, A. (2023a). *A neo-postnatural high resolution aesthetic by cellular architecture*. Blucher Design Proceedings.
- Fernández González, A. (2023b). Autómata celular. ¿Un nuevo modelo de diseño participativo? *AREA - Agenda de Reflexión en Arquitectura, Diseño y Urbanismo*, 29(2), 1–12.
- Gilpin, W. (2018). *Cellular automata as convolutional neural networks*. arXiv preprint arXiv:1809.02942.
- Glover, T. E., Lind, P., Yazidi, A., Osipov, E., & Nichele, S. (2021). The dynamical landscape of reservoir computing with elementary cellular automata. In *ALIFE 2021: The 2021 Conference on Artificial Life*. Cambridge, MA: MIT Press.
- Kolarevic, B., & Malkawi, A. M. (2005). *Performative architecture: Beyond instrumentality*. London: Spon Press.

Mitchell, M. (2009). *Complexity: A guided tour*. Cambridge, MA: Oxford University Press.

Oxman, R. (2017). *Thinking difference: Theories and models of parametric design thinking*. 52, 4–39. *Design Studies*.
<https://doi.org/10.1016/j.destud.2017.06.001>