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Decoding Cultural Heritage

A Critical Dissection and Taxonomy of Human Creativity through Digital Tools

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Preface

The concept of *cultural heritage* is one of the most complex, from the point of view of architecture, art, design, and literature, to name a few leading disciplines, which contemporary times are trying to address within a convulsive and rapidly changing social context. The Krakow Charter (UNESCO, 2000), a key document for restoration, defined heritage as follows: "*It is the set of human works in which a community recognizes its specific and particular values and with which it identifies. The identification and specification of heritage is therefore a process related to the choice of values*."

Undoubtedly, in this area, technology is relevant, both from a conceptual and instrumental perspective. The *digital tools* lead us to reflect, once again, on the triad "mythos, techne, logos," addressed for example by Martin Heidegger (2017), which cement a possible way of understanding any produced reality. Ancestral dynamics reiterated destructive protocols of "the old," without any brake, to erect new works, in accordance with the society of their time. At present, such dynamics are inconceivable. On the contrary, in Western Europe, consolidated criteria show that the need to preserve the remains of collective memory, of creations from earlier times, is still valid. Certainly, cultural heritage has oscillated between the extreme of disappearance and that of generalized protection, which on certain occasions was only supported by chronological and not qualitative reasons. In this historical sequence, arbitrariness is a feature that must be considered. The fire at Notre Dame in Paris revived a recurring debate around the figure of the architect Viollet-le-Duc and his restoration processes that sought to redefine, in accordance with his interpretation of the genuine spirit of the time of the great medieval constructions, all sorts of monuments. This ideological vector cleaned of additions and true historical strata, cathedrals, monasteries, giving birth to a new Gothic in the nineteenth century. The heritage underwent projects of interpretation and authentic creation, and even recreation, which sacrificed its natural becoming, sequentially natural, for the sake of a mythologized, but vigorous reality, far removed from the spirit of consolidation works such as those carried out in the Cathedral of Segovia after the Lisbon earthquake of 1755. Viollet's maxim states that "restoring a building is not maintaining, repairing or redoing it, it is restoring it to a complete state that may never have existed at a given time,”[1] and unequivocally it is his conviction that no civilization, in times before his, would have tried to make restorations as they were understood in the second half of the nineteenth century.[2] The impossibility of “raising the dead” (Ruskin, 1889, p. 194) will support the scathing criticisms[3] with which his own contemporaries and his successors will attack him to the point of eclipsing his solid theoretical foundation.

The previous examples present us with a delicate panorama, which in the twentieth century acquired a new dimension in light of documents such as the Venice Charter (ICOMOS, 1964) and the, already mentioned, Krakow Charter (UNESCO, 2000), which delve into the understanding of modern architecture initiated in the Athens Charter of 1931 (CIAM, 1954). Both texts are key to architectural restoration and to understanding how society could deal with inheritances received, dynamically, and from multiple spheres, covered with a series of values filtered by the eyes of contemporary times. It is at this point where we must quote out some paragraphs of the Venetian text:

> Restoration is an operation that must be of an exceptional nature. *Its purpose is to preserve and reveal the aesthetic and historical values of the monument and is based on respect for the ancient essence and authentic documents. Its limit is where the hypothesis begins:* at the level of reconstructions based on conjectures, all complementary work recognized as essential for aesthetic or technical reasons emerges from the architectural composition and will bear the mark of our time. The restoration will always be preceded and accompanied by an archaeological and historical study of the monument. When traditional techniques prove inadequate, *the consolidation of a monument can be secured using all modern techniques of conservation and construction whose effectiveness has been demonstrated on a scientific basis and guaranteed by experience*.

What happens to the restorative hypothesis if it can be developed, from contemporary times, in a precise and, at times, identical way, not only in the result but also in the registration of temporary patinas? What happens when the techniques of Consolidation have not been guaranteed by direct experience, but by the laboratory model? These considerations can be extended to painting, sculpture, music, and many other disciplines that in their day articulated a new sensibility based on technological developments, such as optics at the time. Given the challenges posed about the intervention in the heritage of the past, it became necessary to expand knowledge about it to explore and identify the possibilities of action, or not, for its conservation and restoration.

The digital realities of the twentieth century gave birth, among other events, to high-precision cartography or exhaustive material analysis, a precursor, in turn,

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[1] “Restaurer un édifice, ce n’est pas l’entretenir, le réparer ou le refaire, c’est le rétablir dans un état complet qui peut n’avoir jamais existé à un moment donné” (Viollet-le-Duc, 1866, p. 14).

[2] “aucune civilisation, aucun peuple, dans les temps écoulés, n’a entendu faire des restaurations comme nous les comprenons aujourd’hui” (Viollet-le-Duc, 1866, p. 14).

[3] “Do not let us deceive ourselves in this important matter; it is impossible, as impossible as to raise the dead, to restore anything that has ever been great or beautiful in architecture” (Ruskin, 1889, p. 194).

to other technological horizons. The development of Artificial Intelligence (AI) opens up, among other options, new ways to propose possibilities for finishing all kinds of unfinished creations. Specifically, with the recent appearance of tools such as DALL-E, capable of completing images guided by a textual description, you can count on the help of AI for recreation tasks. However, as was the case in the nineteenth century, when architects believed they were capable of deducing the right solution for unfinished projects, today, the expectations created by image completion tools seem to be leading us down paths of similar enthusiasm. The nineteenth-century conviction that it was possible to propose the correct solution to the enigma of an unfinished project (Mangone, 2018, p. 10) seems to have a second chance with Artificial Intelligence. However, the very approach of "the correct solution" presupposes an unequivocal result, alien to the natural processes of creativity, in which *pentimenti* and rectifications have always been the order of the day.

Today, different sensors collect indicators of temperature, humidity, and a long etcetera of conditions that determine the needs for preventive conservation of all kinds of artistic works. Systems that also have actuators that create atmospheres of protection that avoid the natural evolution of time are being used. A reality that today scales to all kinds of events and that effectively generates multiple data that are processed and analyzed to understand cultural heritage, from its genesis to its possible new controlled future. Point clouds, photogrammetries, reflectographies, and stylistic analysis become models, even prototypes, articulated by algorithms. Artificial Intelligence, inexorably present in our society, is colonizing all areas, from the economy to entertainment. Cultural heritage is a new enclave where critical progress is made in the knowledge of these tools and all its derivatives. The use of digital tools and techniques for cultural heritage is an emerging area in computer science that is expected to enable many new developments and applications. The book covers existing tools that have been extensively used for cultural heritage preservation, such as image processing, advanced sensing, or geomatics and for recreation such as virtual and augmented reality. The use of newer tools such as generative artificial intelligence for images and 3D or advanced natural language processing systems is also considered. The book also discusses new applications of digital tools and techniques that can be useful to better understand and preserve cultural heritage. Next, we briefly describe the contents of each part of the book.

The first part of the book focuses on how AI emerges as the final frontier in the workflow of a complex process that started decades ago, affecting heritage from various perspectives. An AI that is activated through different programs like DALL-E, but that cannot yet fully replace the designer or the critical thinking that this entails. Generative AI leads us to debate about design within a specific style and, especially, its ability to illuminate known realities, but never formally, graphically materialized in a reliable manner. This point takes us deeper into Pliny the Younger's Villa Laurentina and its virtual construction with the inherent contradictions of this process. The handling of data and the opening of an enriched dimension for the understanding of art, in general, materialize in the Yale Collections Discovery platform experience. Above all, there is a necessary reflection on replication and the conservation of the past where the supportive capacity of AI can be crucial for a new understanding of the values of the copy versus the original from a clear contemporary reading.

The second part of the book delves into a sort of meta-history of text and its supports: How does a digital era, like ours, connect with ancestral and foundational documents, in a sense, of our cultural context? The complex conditions of support for these writings and their linguistic dimension are addressed, which, in a way, reveals the complex reality of the word as a tool, consider the prompts, key to the relationship between man and AI. At the same time, the physical papyri can be deciphered or reconstructed thanks to digital technology and AI as shown by the first passages of rolled-up Herculaneum scroll recently revealed.[4]

The third part of the book analyzes the confrontation between digitalization and the visual arts, from their conceptualization to their restorative intervention. Processes that begin, again, with data and its management to uncover possible cataloging, open and accessible, and characterizations, precise, crucial in reading styles and authors that result in complex training for AI. Perhaps the example of Goya's Black Paintings synthesizes, in a superlative manner, these operations of visual and conservational order.

The fourth part of the book addresses examples of complete digital processes from an eminently architectural context. The debate around the question of the "monument" from the perspective of Alois Riegl serves as a prelude to works in high-value heritage contexts such as the Cathedral of Segovia and the National Archaeological Museum. An application of these techniques in a vernacular world like the Cathedral of Mejorada del Campo is also possible, and there is also room for considering heritage as a field to expand through Augmented Reality (AR).

The book ends in part five with an exploration of the urban heritage reality and its ties to digital knowledge and management. The "smart" concept is presented as a new way of optimizing the conservation and management of established historical sites, but also in modern neighborhoods in need of a deep sociological analysis, supported by digital tools. New socio-environmental cartographies have been materialized at the Venice Biennale using a wide repertoire of instruments that begin with the recognition of the urban context with all the physical and technological dimensions that this implies.

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[4] https://www.nature.com/articles/d41586-024-00346-8

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Contents

Part I
Cultural Heritage and Artificial Intelligence: A New Relationship Between Past and Future Times

Can Artificial Intelligence Mark the Next Architectural Revolution? Design Exploration in the Realm of Generative Algorithms and Search Engines

Karla Saldana Ochoa

1 Introduction

The evolution of computing has had a decentralized shift from one central computer serving many people (1943) to one computer per person (1974) and now to one person using multiple devices (2023). These devices constantly collect information about our daily activities. They are ubiquitous and create vast amounts of data through walking, shopping, traveling, and even when we consume entertainment (Rouvroy, 2016). This data, called Big Data, has various formats, such as images, videos, and text, and has been created in large quantities (Fig. 1). However, Artificial Intelligence (AI) algorithms can convert this digital data into numerical data for analysis. We can find patterns and make decisions using these numbers to make predictions (Saldana Ochoa & Comes, 2021).

The term "Artificial Intelligence" can be traced back to Ada Lovelace, often regarded as the first software engineer who made groundbreaking contributions in the nineteenth century (Essinger, 2014). She collaborated with Charles Babbage on the design of the Analytical Engine, a precursor to modern computers. Lovelace wrote the first algorithm intended to be processed by a machine. Ada translated Babbage's work from French to English and included her notes on the translation, which were three times longer than the actual text. Ada Lovelace's notes were labeled alphabetically from A to G. In note G, she describes an algorithm for the Analytical Engine to compute Bernoulli numbers. The algorithm involved"conditional branching," marking a significant milestone in the history of programming (Essinger, 2014). While the Analytical Engine was never built in their time, Lovelace's work laid the foundation for future developments in

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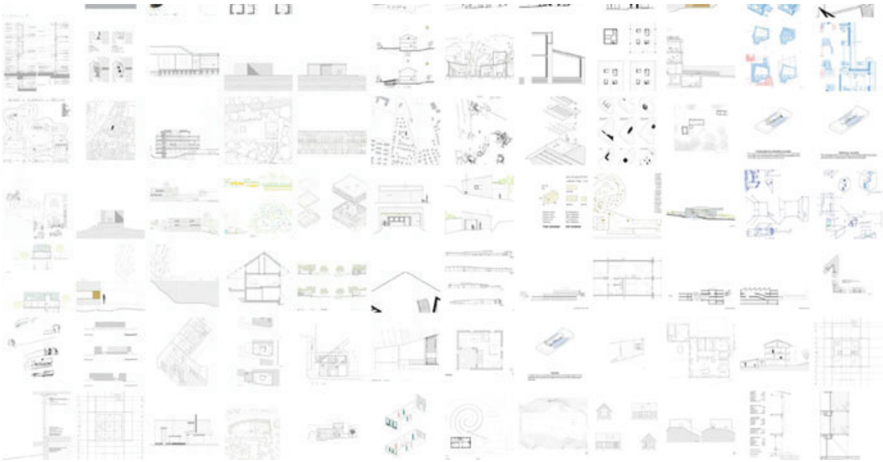

Fig. 1 Compilation of architectural drawings from the web

computing. The concept of the Analytical Engine was taken over by Alan Turing, who introduced it as a Turing machine in 1936 (Appel, 2021). The idea of a Turing machine is pivotal in understanding the theoretical underpinnings of computation. A Turing Machine is a mathematical model of computation capable of performing any computation that can be described algorithmically (Appel, 2021).

Turing proposed that machines can exhibit intelligent behavior by tricking people into thinking they are human; Turing tested his hypothesis with a question-and-answer game called the "Turing Test." In the test, a questioner tries to determine who is a human and who is a machine based on their answers. If a machine is mistaken for a human, it has passed the "Turing Test" (Hodges, 2009). This question-and-answer test has been adapted to many tasks, such as chatbots (Gupta et al., 2020), robotics (Murphy, 2019), and image recognition (Tian, 2020). Industry and academia have been competing for years to pass these "Turing Tests" with their AI-created systems. This competition has given rise to a diverse set of AI-based technology tools from which researchers and designers can choose to solve various problems in their field. Since this chapter is about AI algorithms and architecture, let us start by defining one of the most used AI algorithms in architectural practice today, generative algorithms. We will begin by asking what generative algorithms are and where they fit within the broader umbrella encompassing AI.

2 Generative Algorithms and Artificial Intelligence

To comprehend generative algorithms, let us juxtapose them with discriminative learning. Like a classifier, a discriminative algorithm models itself based on observed data, making fewer assumptions about distributions but relying heavily

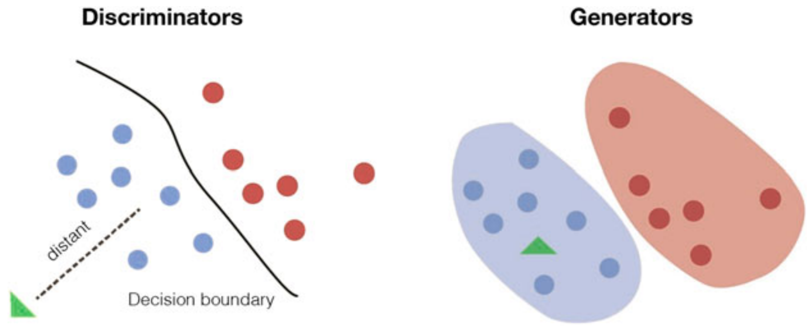

Fig. 2 An example of discriminative learning and generative learning

on data quality (refer to Fig. 2, left). Logistic Regression serves as an example of such a discriminative algorithm. In contrast, generative algorithms aim to construct positive and negative models, envisioning a model as a "blueprint" for a class (refer to Fig. 2, right). These models delineate decision boundaries where one becomes more probable, effectively creating models for each class that can be employed in generations.

In the context of supervised learning, both discriminative and generative algorithms presuppose a set of examples. This framework represents just one of the four types of learning that a machine learning (ML) algorithm can undertake. The other categories encompass unsupervised learning, semi-supervised learning, and reinforcement learning. This chapter will primarily delve into supervised learning, where the algorithm, armed with an array of features (e.g., week of the year, price) and a labeled output variable (e.g., sales), predicts the most accurate label for new input arrays.

It is crucial to discern that not all generative algorithms fall under the umbrella of machine learning (ML), and similarly, not all ML algorithms delve into deep learning (DL). Despite often being used interchangeably, these terms encapsulate distinct concepts. Artificial Intelligence (AI) is the overarching term encompassing ML and DL (Zhang et al., 2023). For instance, a rule- and logic-based generator qualifies as an AI algorithm but not a DL algorithm. Refer to Table 1 for a compilation of such algorithms and concise descriptions of their performance.

An example of a generative DL algorithm is Generative Adversary Network (GAN); the architecture of this algorithm has many layers (hence deep). GAN operates through a dynamic interplay between two key components: Firstly, the generator is tasked with learning how to create realistic data. The instances it generates serve as negative training examples for the second component, a discriminator. Conversely, the discriminator focuses on learning to differentiate between the artificial data generated by the generator and the actual data. In doing so, it penalizes the generator for producing deemed fake outputs. As the training process commences, the generator initially produces artificial data. In response, the discriminator swiftly hones its ability to discern fake creations from real ones.

Table 1 List of different AI generative algorithms using logic- and rule-based approach

Name	Description
Cellular automata (CA)	CA is a collection of cells on a grid of a specified shape that evolve over time according to a set of rules driven by the state of the neighbouring cells
Genetic algorithms (GA)	GAs and genetic programming are evolutionary techniques inspired by natural evolutionary processes
Shape grammars (SG)	SG is a set of shape rules that can be applied to generate a set or design language. The rules themselves are the descriptions of the generated designs
L-systems (LS)	LSs are mathematical algorithms known for generating factual-like forms with self-similarity that exhibit the characteristics of biological growth
Agent-based models (ABM)	ABM are often used to implement social or collective behaviors. Agents are software systems capable of acting autonomously according to their own beliefs
Parametric design (PD)	PD is a process based on algorithmic thinking that enables the expression of parameters and rules that, together, define, encode, and clarify the relationship between design intent and design response

This iterative cycle of improvement continues, refining the capabilities of both the generator and the discriminator over time.

Another prominent example is the diffusion model (the architecture used by the well-known mid-journey and DALL-e algorithms). These models operate on the premise of generating coherent and intricate outputs by diffusing information across multiple layers of a neural network. Mid-journey, in particular, demonstrates a unique architecture that integrates diffusion processes, allowing for the creation of visually stunning and contextually rich content. On a parallel note, DALL-e, another exemplar of diffusion models, showcases an architecture adept at generating diverse and high-quality images from textual prompts. The generative power of diffusion models lies in their ability to capture intricate patterns and details while navigating complex data spaces. Figure 3 shows what the diffusion model learns, which is the backward sequence of a process where noise is partially added to an image until it reaches total noise (Zhang et al., 2023).

In recent times, the proliferation of images and texts generated by advanced generative AI algorithms, including but not limited to DALL-E (DALL-e, 2023), mid-journey (Midjourney, 2023), and ChatGPT (ChatGPT, 2023), has been quite conspicuous. The ease with which one can conduct experiments using these algorithms is remarkable—a mere input of text effortlessly translates into a novel and articulate output (refer to Fig. 4). However, this surge in creative prowess has inevitably given rise to a certain level of skepticism within the creative community, specifically questioning whether the remarkable agility exhibited by these algorithms in producing images and text poses a potential threat to the conventional roles of designers and architects. This apprehension is not unfounded,

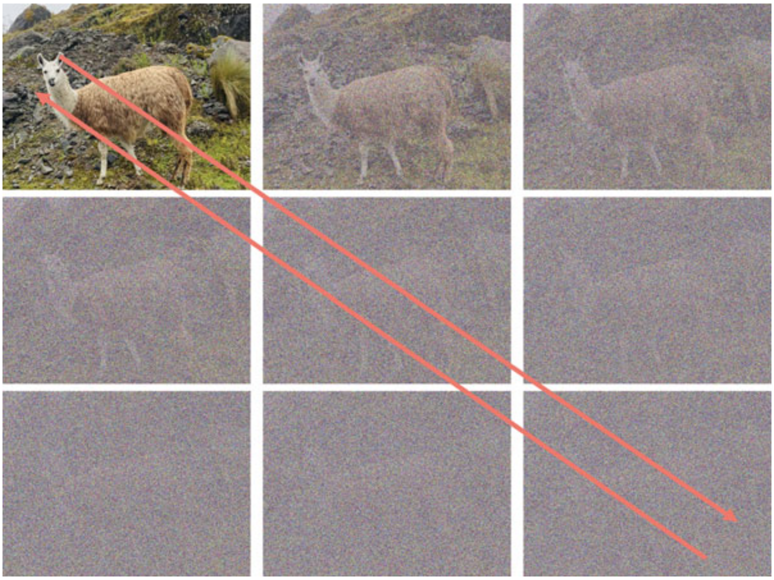

Fig. 3 An example of the diffusion process. Diffusion occurs in multiple steps. The model learns how to remove noise from an image and the steps it took to clean it up. The trained noise predictor can handle a noisy image and denoise it by following the denoising steps learned in training, generating a new noise-free image out of pure noise paired with a text description

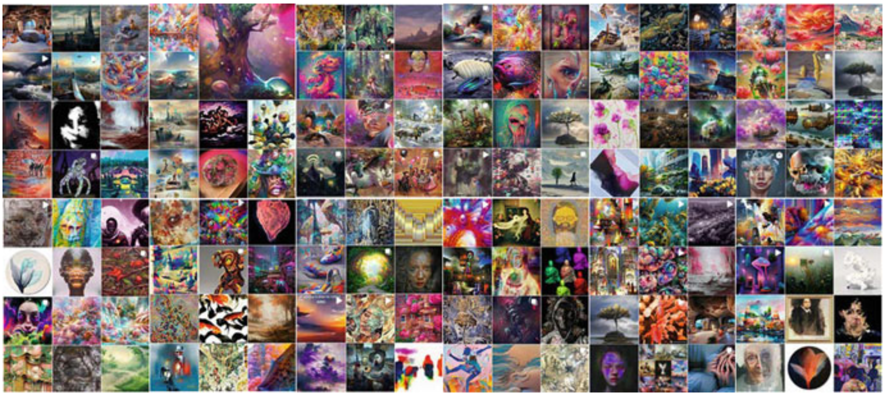

Fig. 4 Compilation of images from social networks with the AI art tag

as these AI systems' rapid and seemingly boundless creativity may prompt concerns about the potential displacement of human creators.

However, it is imperative to approach this skepticism with nuance. Rather than framing the rise of generative AI as a direct threat, it could be viewed as a transformative force that challenges creatives to reconsider their roles. While AI systems exhibit impressive creativity, they lack the intrinsic understanding, intuition, and contextual awareness that human designers and architects bring. The synergy of human ingenuity and AI capabilities could lead to a collaborative, symbiotic relationship. Designers could leverage AI algorithms' efficiency and rapid ideation capabilities, focusing on higher-order creative decisions, critical thinking, and the nuanced understanding of human experiences that AI currently lacks.

Furthermore, the concern over the potential threat to traditional creative roles raises broader questions about the ethical and societal implications of widespread AI integration in creative industries. Striking a balance between embracing AI's benefits and preserving human creators' unique contributions is essential. As we navigate this evolving landscape, it becomes crucial to foster a dialogue that addresses concerns and explores opportunities for constructive collaboration between human designers and the powerful generative capabilities of AI.

3 Search Engines and Artificial Intelligence

As seen above, the rapid advancement of AI algorithms and open-source datasets has revolutionized various industries, including architecture (Hovestadt et al., 2020). Open-source datasets provide vast information that enhances architectural projects, while big data plays a vital role in training generative algorithms (GA). However, the same phenomena have also aided in optimizing search engine (SE) indexing. GA generates new information through interpolation (Newton, 2019), whereas SE retrieves relevant results through efficient scanning and indexing based on specific keywords (Alvarez Marin, 2020). Search engines are pivotal in information retrieval, research, and inspiration in architecture. Architectural professionals and enthusiasts often leverage search engines to access various resources, including design ideas, project documentation, scholarly articles, and industry trends.

There is a significant focus on GA using diffusion models and Large Language Model (LLM) algorithms, such as ChatGPT (DALL-e, 2023). With these algorithms, it is crucial to carefully construct questions to counteract the algorithms' tendency for unjustified responses known as hallucination (Alkaissi & McFarlane, 2023). Hence, the following question arises: How can these technologies be utilized to overcome the hallucination problem? This is where SE introduces another methodology to address this problem. The output of a search engine is grounded in existing indices, always based on actual data, thus circumventing the challenges of hallucination encountered with GA and LLM (Chang et al., 2024). The critical factor lies in the dataset to be parsed, emphasizing the importance of curation and personalization to address project-specific inquiries.

4 Methodology

To describe how AI is revolutionizing architectural practice, this chapter presents examples of how the use of AI in various stages of design can enhance the creative capacity of a designer. First, it offers two examples of today's most commonly used algorithms (DALL-e and Chat GPT). Second, it presents four examples of other AI algorithms leveraging search engines applied to architectural design.

4.1 Images

Recent months have seen the ease with which architects embrace the mass production of images (Fig. 5). The former invites us to think that architects have taken on the passive role of curators of images. However, are they still the authors of those images? That is not the case, entirely. These images are not their creations but iterations of possible projects that serve to inspire future project ideas. Authorship of these images is shared with the researchers who create the algorithm, the people who produce the training data, and the designers who generate the images. That is, we must take responsibility for not assigning all design responsibilities to one algorithm and for ensuring that both the data used for training and the architecture of the algorithm are adequate to help us answer the question that every architectural project has because architecture is more complex than just the formal part that an image can capture; the final work results from all the agents involved in the production.

To leverage a diffusion model, one must understand the relationship between the input provided and how it will influence the algorithm's output. To explore the input-output relationship, let us examine the qualitative impact of the two primary

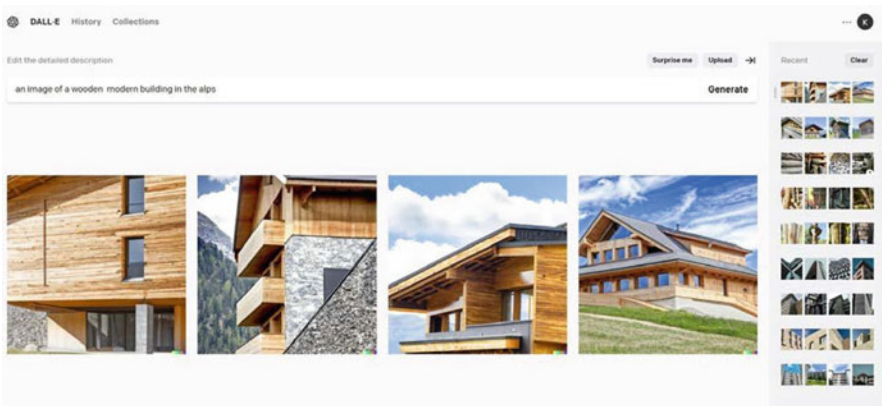

Fig. 5 Screenshot of Dall-e, a generative algorithm created by open AI

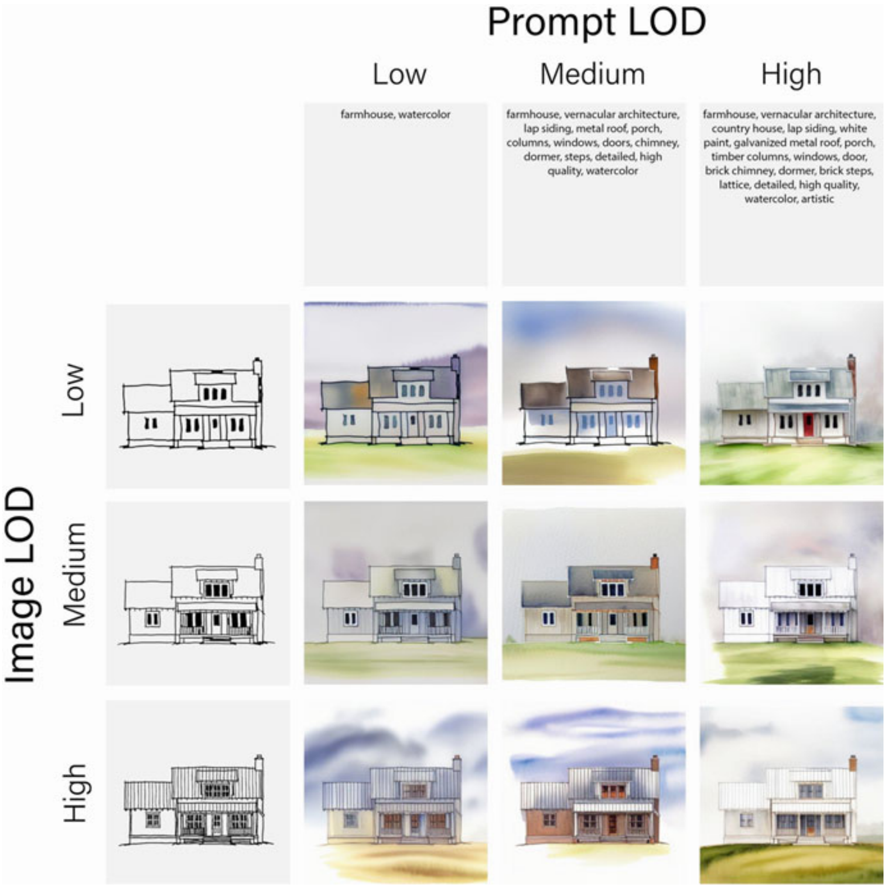

Fig. 6 Comparison matrix between Image and Prompt level of detail—artwork by Joel Esposito

inputs, namely the prompt and the control image, influencing the final output. The aim of the exploration is to assess different combinations of level of detail (LOD) for both image and prompt. The x-axis was designated for Prompt LOD, while the y-axis represented Image LOD (Fig. 6). This arrangement facilitates a convenient comparison of various combinations along both axes. Notably, the diffusion model's level of inference grows more sophisticated as each axis approaches a higher LOD. For instance, contextual shading becomes evident with the highest prompt specificity, whereas intricate details like fenestration are rendered more accurately with a high-detail input sketch. Given the diffusion model's rapid output capability, the number of generation cycles for each image needed to be regulated in this preliminary experiment, as the additional marginal time involved was deemed insignificant for business application in an architectural practice.

Fig. 7 Line with exploration from Light to Heavy, using the same text prompt—artwork by Joel Esposito

Continuing our investigation, let us focus on the image input and experiment with various line weights, ranging from light to heavy, with the same text prompt as input (Fig. 7). We notice a discernible correlation between stroke weight and the LOD. Notably, as the line weight increases, the LOD also increases. The algorithm perceives the thicker stroke as indicative of volume, subsequently introducing shadows and imbuing the image with a sense of perspective. When dealing with the control image as input, it becomes crucial to consider the intricacy of the detail invested in the drawing and the choice of line weight employed to depict various elements.

4.2 Text

Let us talk about another medium: text. A text allows designers to describe the design space and present ideas that they (the designers) still need to explore. In this case, we used ChatGPT to experiment. We prompted it with the following text, "write an architectural project similar to a Le-Corbusier project." After a few seconds, the following text appeared:

> This project is an architectural marvel that transcends time and trends, remaining true to the principles of modernism espoused by Le-Corbusier. The building presents an iconic silhouette characterized by sleek lines, geometric forms, and innovative use of raw materials such as concrete, steel, and glass. The open floor plan and large glazed walls offer an unparalleled connection to the outdoors, blurring the line between indoor and outdoor spaces and providing abundant natural light. Sustainability and environmental responsibility are key elements of this project, which specializes in using greenery and vegetation to create a harmonious balance between the built and natural environment. The minimalist color palette and industrial feel give the building a raw, modern feel, while the strategic

> placement of vegetation brings a touch of nature to the urban landscape. In short, this project is a contemporary interpretation of Le-Corbusier's timeless design principles, offering an unparalleled living experience in a harmonious balance of form and function. Prepare to experience the ultimate fusion of style, sustainability, and innovation.

After reading this text, the first question is: Where is the creativity in this process? Writing an architectural brief is not about listing the program but synthesizing design thinking translated into research about the place, the comfort, and the users. In addition, the description of an architectural project also connects with the future user at the level of their needs. To emphasize the approach, we need to have with these generation algorithms, let us analyze the text above. An architect immediately realizes that this text does not fit the work of Le-Corbusier. He did not focus on sustainability, inside-outside relationships, etc. These algorithms are powerful enough to answer any question we ask. Therefore, it gives us the responsibility to formalize a question where the hallucination of these algorithms is mostly suppressed or leveraged.

5 Other Examples of AI in Architectural Design

In this section, we want to focus on how AI can help architects and designers make better decisions, generate new ideas, and explore design spaces that were previously impossible. Architecture is not only about generating images focused on the formal part of a project, nor is it only about the description of the program. An architectural project synthesizes many layers: form, functionality, need, comfort, etc. For about 100 years, designing and constructing buildings has remained the same, which is not the case in other disciplines such as aeronautics, where the design of airplanes and aerospace ships is periodically re-invented. However, in architecture, we must recognize the tradition of the craft but also embrace the new paradigm that AI and data-driven design methodologies bring to architectural design. With these new technologies, we can change how architects design because they can access millions of design solutions ranked by AI algorithms based on the architect's preferences or automatic generators biased to follow a particular design style prone to satisfy the designer. AI could support, not replace, the creativity and expertise of architects and designers. To make this point, the following sections will show four projects using AI as an instrument to empower creativity.

5.1 Project 1

An AI search engine was used to organize thousands of images from users' social media networks, the same images describing the needs of a geographic location. Not being able to be at this location physically, the only source of information for this location is the data from social media. In total, more than 12,000 images and posts were collected. How do we make sense of this amount of data? The answer to this question is using unsupervised AI algorithms for automatic clustering; in this case, we used the self-organizing maps algorithm (Kohonen, 1990). This algorithm can group similar images and create a grid that summarizes the site's needs, allowing a designer to understand the general sentiments of the users about the place. From this grid (Fig. 8), other design exercises, such as collages, can be performed to represent the space. In this case, atmospheric images were made. These images capture designers' intentions through the concepts they want to capture in their design. Through this exploration, an architect can understand the site analysis differently, including a collective point of view characterized by the users and their

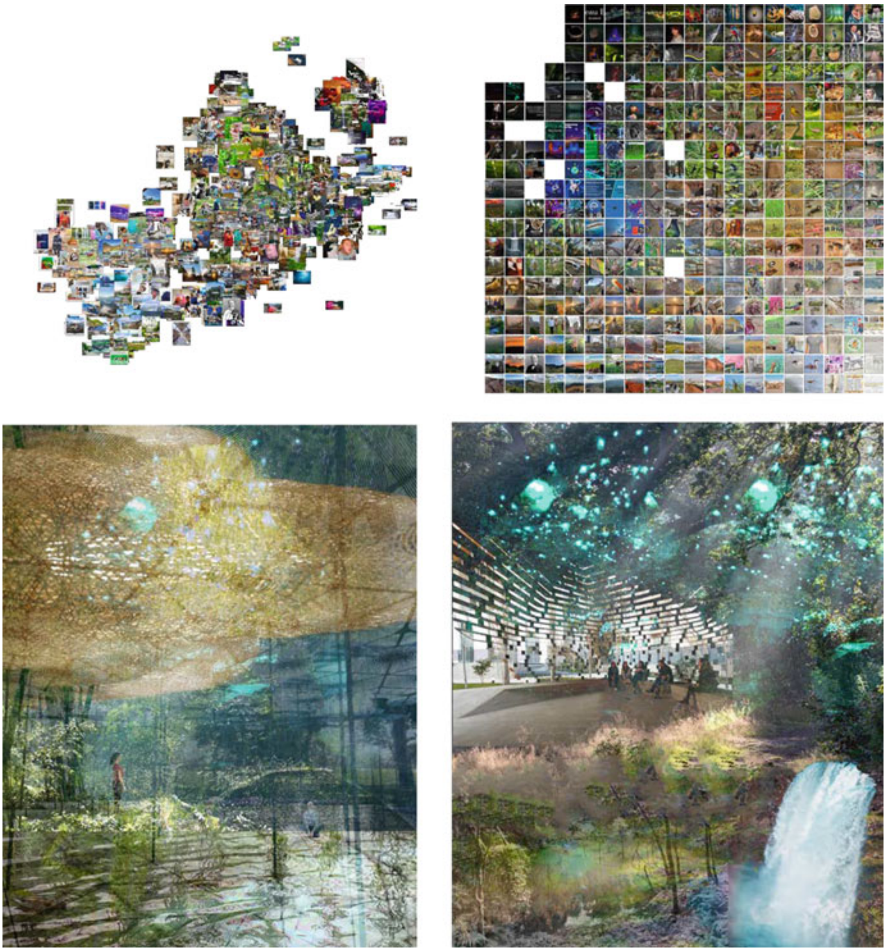

Fig. 8 Top left, representation of the collected social network data. On the top right are the commonalities achieved with AI clustering algorithms; on the bottom are the atmospheric images—artwork by Sarah Gurevitch

activities. This approach goes beyond the typical site analysis based on physical site visits, physical infrastructure mapping, and site-specific interviews (Saldana Ochoa & Huang, 2022).

5.2 *Project 2*

Figure 9 displays atmospheric images coupled with text. In this instance of image generation, designers employed the same social media grid, organized by the unsupervised clustering algorithm self-organizing map, to represent concepts and images associated with the site and users. These images and concepts served as inputs to a generative algorithm, specifically DALL-e, for the automatic generation of images. Designers utilized ALICE (Roman, 2021), an AI search engine grounded in architectural treatise libraries, to establish connections between the newly generated images and similarly themed concepts. By conducting searches, they curated relevant concepts. ALICE provides a set of paragraphs discussing these concepts within architectural treatises, referencing the generated images and search texts. The designers created an architectural idea to start a design project challenging the individualistic approach, transforming images and text into a collaborative discussion among multiple authors addressing the same topic to articulate a comprehensive description of design intentions. This project resembles

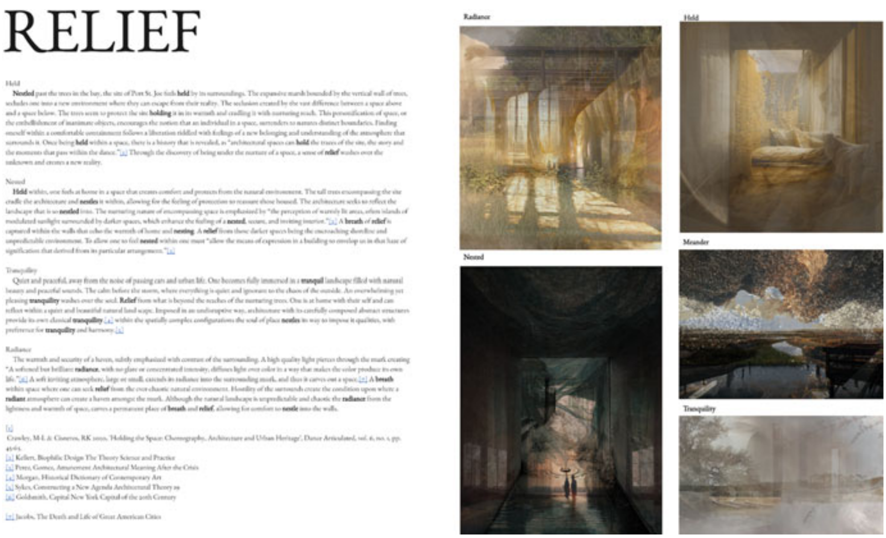

Fig. 9 On the left, the title of the work and concepts describe the design intentions; each concept was developed with ALICE to find quotes from prominent authors. On the right, atmospheric images are generated with diffusion models and social network data—artwork by Marc Kiener

a collaborative drawing and writing exercise, with the distinction that the co-authors are renowned figures from past eras who mastered the art of drawing and writing.

5.3 Project 3

This project presents a novel architecture design workflow that explores the intersection of Big Data, Artificial Intelligence (AI), and storytelling by scraping, encoding, and mapping data, which can then be implemented through Virtual Reality (VR) and Augmented Reality (AR) technologies. In contrast to conventional approaches that consider AI solely as an optimization tool, this workflow embraces AI as an instrument for critical thinking and idea generation. The workflow revolves around "Canonical architecture," where data-driven techniques traverse dimensions and representations, encompassing text, images, and 3D objects. The data utilized consists of 20,000 social media posts, including both images and text, which provide insights into user needs and site characteristics, and 9000 3D models of architectural details extracted from 38 different architectural projects. The primary objective is to assist architects in developing a workflow that does not suggest starting from scratch or a tabula rasa but working with already hyper-connected objects, be it text, images, 3D models, etc. This project also creates a search engine using an unsupervised clustering algorithm called self-organizing maps (SOM), similar to the two previous projects; the difference now is that 3D objects are added directly to the data to be organized (Fig. 10).

Organizing the data in such grids allowed architects to personalize their search and augment their design ideas to create architectural conceptualizations (Fig. 11). These conceptualizations were then enacted in game engines and experimented with in AR/VR platforms (Fig. 12). Through this process, the framework aims to develop a sensibility of working with large amounts of data without losing focus and letting the electric grounds of the Internet help us in articulating projects.

5.4 Project 4

This project delves into the realm of structural design, positioned at the intersection of architecture and structural engineering, using it as a focal point for testing the integration of AI within the design process (Saldana Ochoa et al., 2021). This project advances the interaction between human designers and AI, empowering the algorithm to comprehend semantic requests related to structural forms, transcending the conventional quantitative aspects of structural engineering. The research advocates a departure from the conventional deterministic form-finding approach, which optimizes forms solely based on structural criteria, towards an open, creative process. In this innovative paradigm, textual inputs from the designer are translated into spatial structures in static equilibrium. The key outcome of this project is

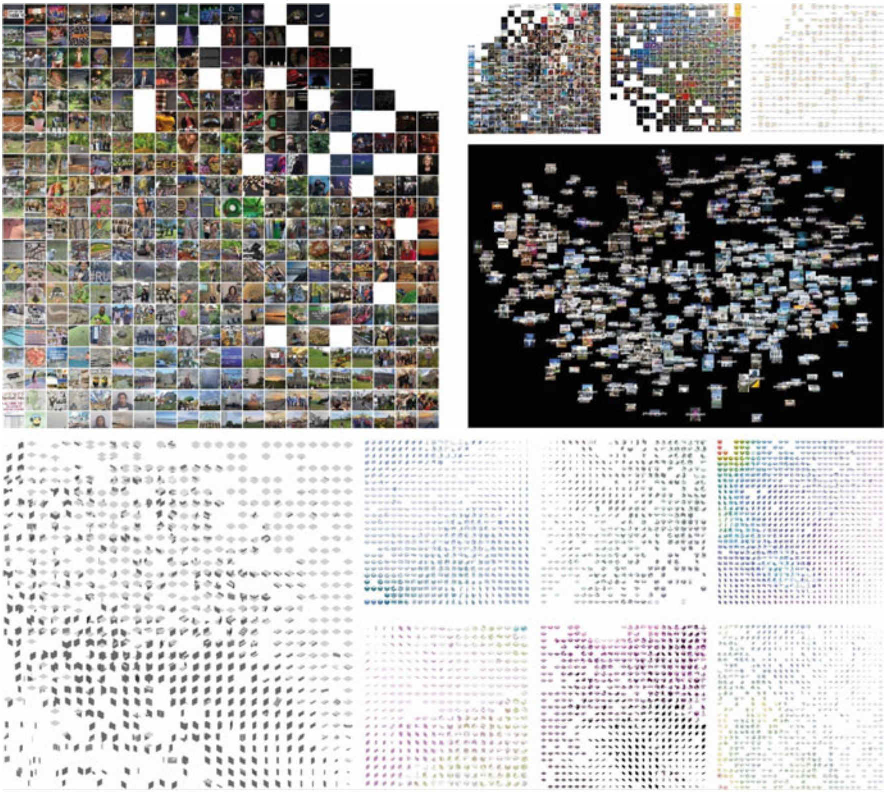

Fig. 10 SOM examples of images, text, and 3D objects

the creation of Text2Form3D, an ML-based design framework. Text2Form3D synergizes a Natural Language Processing (NLP) algorithm, which translates text into numerical features, with the Combinatorial Equilibrium Modeling (CEM) form-finding algorithm. This fusion enables Text2Form3D to propose potential design parameters based on the designer's textual inputs, thereby allowing semantic exploration of the design space governed by the CEM method.

Figure 13 illustrates the Text2Form3D initial pipeline. In the first step, the CEM algorithm generates a dataset comprising diverse structural forms with randomly initialized design parameters. CEM, an equilibrium-based form-finding algorithm rooted in vector-based 3D graphic statics, sequentially constructs the equilibrium form of a structure based on given topology and metric properties. The dataset encompasses both the design parameters and the resultant forms. In the subsequent step, self-organizing maps (SOM) cluster the generated forms. The SOM training uses user-defined quantitative criteria to capture formal metric characteristics. Moving to the third step, the designer employs the trained SOM to label numerous design options using vocabulary sourced from architectural and structural practice

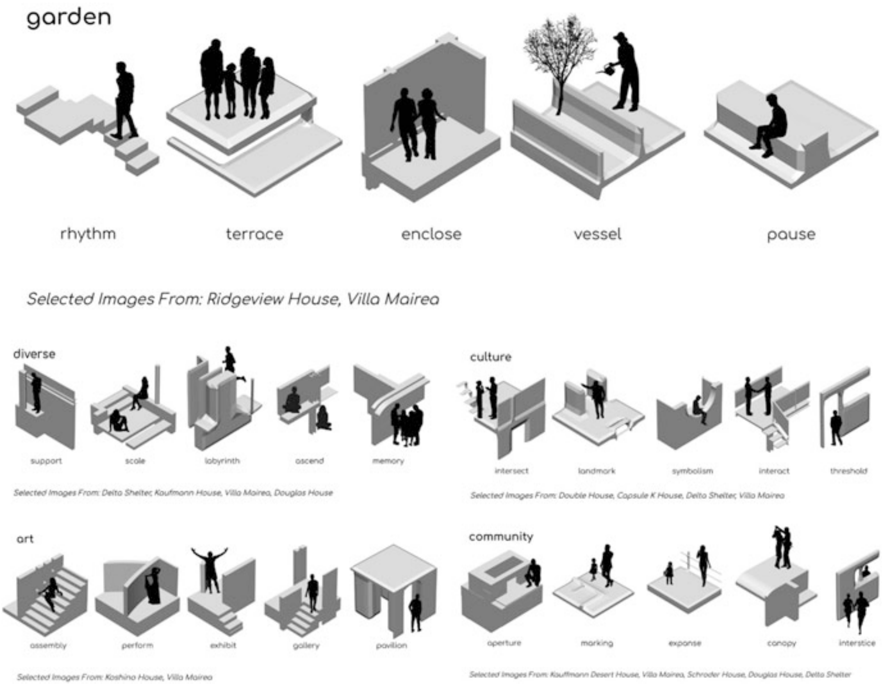

Fig. 11 Set of 3D objects as conceptual architectural ideas—artwork by Natalie Bergeron and Stephanie Roberts

Fig. 12 Staged scenographic storytelling settings

competition reports. These labels, manually assigned to each form, create data for training a machine learning algorithm.

Upon labeling, in the fourth step, text labels undergo processing using word embedding, a technique converting words into numerical vectors based on contextual similarities. These vectors encapsulate contextual information, enabling a comparison of words' semantic meanings. In the fifth step, a deep neural network is trained using text vectors as input and CEM design parameters as output. This trained network can generate CEM input parameters based on new embedding vectors derived from input texts. This comprehensive design workflow was experimentally tested in the generation of towers.

Figure 14 illustrates four clusters of 3D structural forms generated through distinct input adjectives using the proposed pipeline. Each cluster distinctly show-

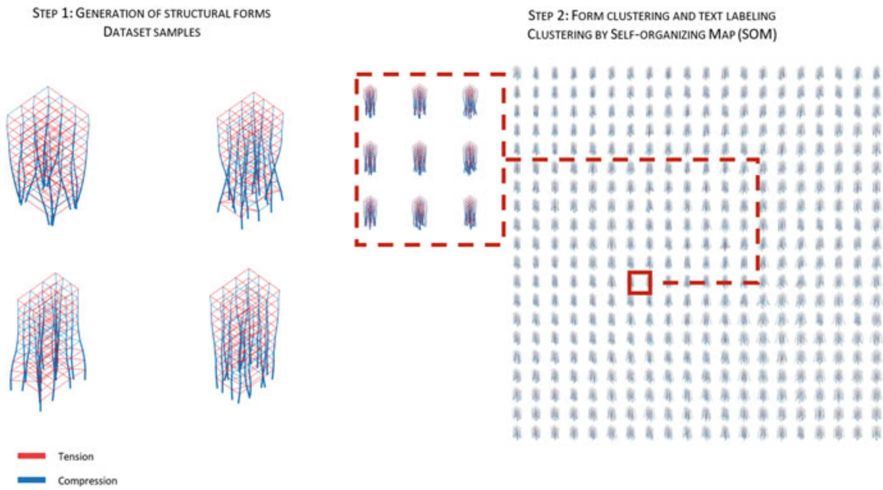

Fig. 13 Summary of tasks 1 and 2 of Text2Form3D, an algorithm that is based on a deep neural network algorithm that couples word embeddings, a natural language processing (NLP) technique, with Combinatorial Equilibrium Modeling (CEM), a shape search method based on graph statics

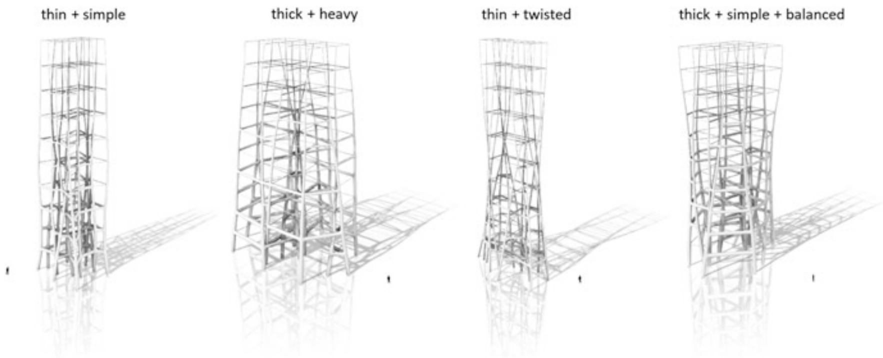

Fig. 14 Four examples of generated structures with different text inputs

cases geometric characteristics discernible from others, signifying the successful capture of semantic information by Text2Form3D, translating it into distinct output geometries. Within each group, the generated forms exhibit a consistent tendency in geometric features yet display substantial variety in geometric details. This outcome underscores the efficacy of normally distributed random vectors as a potent means to explore formal variations stemming from identical semantic inputs.

The suggested workflow underscores the effectiveness of the collaboration between human designers and AI, wherein structural forms are designed through a fusion of descriptive text and quantitative parameters as inputs. This study has explored and generated 3D structural forms using a text-based AI engine in conjunction with computational graphic statics. The project introduces a workflow