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Digital Ornaments

Preface

The use of artificial intelligence (AI), digital tools and fabrication technologies in architecture has followed a paradigm shift, enhancing its design and construction processes and performances. While it has enhanced the performability and efficiency aspects of architecture, it has removed the aesthetics and symbolism of ornamentation and individuality of buildings. This research questions what the new relationships and arrangements for architecture and ornament are, specifically focusing on the use of AI and digital technology, to understand how these instruments can be used to bring craft, structure, functionality, and symbolism back to contemporary ornamentation in architecture.

Introduction

Ornamentation has long been a topic for debate. Historically, it was integral in creating a sense of craft in the design. In classical architecture, ornamentation was the key component to constructing buildings that symbolized a sense of beauty as well as expressing social values, hierarchy, and order (Picon, 2013, pg. 11). Throughout time, the meaning and use of ornament has transformed, with each movement in architecture adding influence on its definition. Historical, cultural, social, and technological circumstances were factors that have significantly impacted the way ornament has been defined over the years. The defining moment of this change occurred during the second industrial revolution. Throughout this period, the concept of mass-production and an effort to reduce cost and increase efficiency became a primary focus for construction (Retsin, 2019, pg. 8). Although these technological evolutions were vital in the development of the construction industry, the push for mass-production meant the focus was steered away from ornament and craft, and therefore was no longer seen as a necessity to design. In present architecture, there is an immense amount of new technology used to design and construct buildings, where AI has become the latest movement within it. This is “increasingly challenging the historic relationship between architecture and its means of production” (Kolarevic, 2005, pg.4), as this relationship has exponentially developed since its earliest days, where it was completed through physical labour. The availability of such technologies allows architecture to no longer be bound by the limitations of standardization and mass-production, bringing forth new opportunities for modern day architecture to be redefined, and in turn to redefine ornament.

Definition of Ornament

The term ‘Ornament’ is defined as “a useful accessory that lends grace or beauty” (Ornament, Def. 2). It is “a thing used or serving to make something look more attractive but usually having no practical purpose” (Ornament, Def. 2). Details on the other hand, can be defined as “a part considered or requiring to be considered separately from the whole” (Detail, Def. 2b), which contains “information about something” (Detail, Def. A2). The above-mentioned definitions for both concepts refer to both terms as being additional elements whose main roles are to serve their carriers. Although they are defined to be serving their carriers, they do so in different ways. Ornaments mainly provide an aesthetic purpose, occasionally mixing in with practical characteristics, whereas details entirely fulfill practical purposes. Ultimately, a detail can be an ornament, however, an ornament cannot be a detail. This thesis will thus focus on the term ornament, as it will encompass the idea of ‘detail’ when studied.

The way ornament is defined in the dictionary and other academic sources of literature does not characterize and portray the *contemporary ornament* appropriately. It is an outdated definition, focusing on a historical perspective, undermining its capabilities and possibilities in the design of buildings. Based on such definitions, it has been heavily scrutinized by many architects and historians throughout the ages, negating its existence in the contemporary built environment. Adolf Loos argues that architecture “should correspond to the spirit of [its] time” (Loos, 1998, pg. 222). He criticized ornamentation because it did not progress with society and its changes, so there was a loss for it. However, with the industrial revolution exponentially advancing the possibilities of technology, making it part of everyday tasks, reintroducing ornamentation through such tools can become very much rooted in the ‘spirit of our time’. This re-establishment of ornamentation back into our buildings is not setting architecture back but celebrating the digital and technological culture that is present within our society and demonstrating its capabilities of producing unique, complex, yet still efficient, functional, and customizable architecture. Within contemporary times, the need to reevaluate the characteristics and functions of ornaments are present.

Contemporary Ornament

The following thesis aims to explore the ways that artificial intelligence can change the way we think about and design *contemporary ornamentation*. In order to do so, the need to define the term ‘ornament’ in contemporary architecture is necessary. Ornaments in contemporary architecture are open to interpretation. There is a variety of ornaments from architectural details to art to urban texture. It can be applied “from a graphic composition to a flat image, from a relief to a three-dimensional structure” (Dal, 2021, pg.101). One of the results of contemporary ornament has been that it “now lacks a simple definition, it cannot be understood as it was in classical terms” (Picon, 2013). The advancement of digital technology has created an ornamentation that lacks a deeper meaning and is only seen as an effect of their processes. Within this thesis, *contemporary ornamentation* should seek to be designed with structure and functionality as the driver but should “never be reduced to [only] a question of function” (Levit, 2008, pg. 3) or “an artifact of construction or craftsmanship” (pg. 3). It emerged as a concept to explicitly express the symbolic dimension of form it holds. “Form is interpreted symbolically, and ornament is a primary device of its expression” (pg. 3). Thus, it should also express something other than its material existence—a dimension that people understand symbolically, whilst still playing a pivotal functional role as a structural component.

The *contemporary ornament* must be structural. In the past, ornaments were either applied as decoration, thus bearing no structural qualities, and seen predominantly as décor, or they were integrated into the structural framework of the building, resulting in 'expressive' columns and beams, rather that intricate visualizations. This is what was valued by society at the time and demonstrated the wealth and hierarchy of the owners of the building. Currently, societal values have greatly changed, where beauty and craft have been sacrificed for efficiency, cost-effectiveness, and practical construction, which results in mundane and simple designs. Ornamentation was removed because it was deemed to serve no other purpose or function but to be an aesthetic additive piece to the building. Implementing ornaments was costly, time-consuming to produce, and became an inefficient and unsustainable element in the world of architecture. Thus, contemporary ornaments need to relieve these barriers, by being structural and having a functional quality within the building.

The *contemporary ornament* should also be able to create a bond between people and their surroundings, where it seeks to captivate the viewer to something else, a vision that will create an appreciation for the space. The qualities of the *contemporary ornament* sought will be both distinct and blunt, as well as illusory and unfounded; form, structure and material reinterpreted by the observer. To further define the attitude of its expression, it should strive to be the equilibrium of all things. It should exist between chaos and order, both the natural and the artificial, both tangible and intangible, as neither foreign nor familiar. It merges structural performance and aesthetics; it merges the synthetic and the organic; it merges human creativity and technological performance. It is composed of layers, where it becomes a symbiosis of all of them entangled into one form. With the capabilities and possibilities of digital tools, ornaments should "create an architecture that defies classification and reductionism, [exploring] unobserved levels of resolution and complexity in architecture" (Dillenburger, 2013) with the use of mathematical and geometric processes.

The question may result as to why such a description? Why are there so many layers and complexities within the design of an ornament? To put it simply, the design of the ornament within the digital revolution allows for such complexities. Artificial intelligence and digital tools can take on the complexity that humans cannot, and the intricacy and craft that came with ornamentation in historic times can be brought back without the worry or need for it to be inefficient and costly. *Contemporary ornamentation* also requires a set of rules in our image driven society for it to be successful in its design. Such a set of rules leave enough freedom and ambiguity to formulate interesting proposals, having purpose and functionality, and not become just an added piece of décor or afterthought. "It is clear that in a multicultural and increasingly cosmopolitan society, symbolic communication is harder to enact as it is difficult to gain a consensus on symbols or icons. Representational tools are less coded and unable to produce convergence with culture" (Moussavi et al., 2007, pg. 5). By creating such ornaments within these set of guidelines, it creates spaces and "features that exceed the threshold of human haptic or visual perception that would be entirely undrawable using traditional means" (Dillenburger, 2013). Any allusions to literal imagery or styles are not evidently "integrated into the design process but are evoked only as associations in the eye of the beholder" (Dillenburger, 2013), allowing them to be accepted by a larger population. Users today also contain short and limited attention spans, by producing such complexities, it is more likely to evoke pauses, contemplation, and engagement, attracting individuals to experience or determine the ornaments semblance. Taking longer to perceive the complexity of such creations is proven to be engaging. The bewitching impact of detailed ornamentation can hold the interest of curious onlookers for extended periods of time, due to their perplexity and association. With such engagement, the ornament creates a lasting impression, allowing the users to engage in an architectural conversation with the building.

The History of Ornaments

In a historical context, ornament was integral in creating a sense of craft in the design. It was the key component to constructing buildings that symbolized a sense of beauty, as well as expressing social values, hierarchy, and order. Throughout history, "each and every detail has a place, origin, and order of its own" (Vitruvius, 1960, pg. 93). The historical creation of ornament "was interwoven with the history of style, each of which produced its own ornaments per se, with a clear definition and set of rules for its design, production, and application" (Allmer et. al, 2016, pg. 157).

Until the 19th century, before the industrial revolution of decorative elements began, ornaments were produced by hand. Stemming from their beginnings, they were often designed using analog tools. Such tools included freehand sketching, painting, physical model making, drawing with the use of drafting boards, and manual rendering techniques. With their additional complexity, people of different trades, like artists, architects, and craftsmen, were required for the ornaments to be completed, taking on large costs and being labour-intensive. Such ornamentation existed in two forms; they were either integrated into the design of the building or applied as a decoration. The first method exhibits how ornament is integrated into the framework of the building, through the façade, walls, ceiling, or among other components of the building. These types of ornaments stem from the structure or materiality of the building and are most appropriate when trying to stay true and not mask the building. The applied ornament is seen as decor. In comparison to the scale of the building they often seem very small, and are depicted as paintings, sculptures, carvings, etc. However, through the applicative form of ornamentation, it could also aid to provide a more human scale building, that is able to communicate to the public. Its function would allow it to speak and seek connection to its viewer.

As time progressed, new technologies arose, aiding in the design and construction of ornaments. The last two decades have seen a profound transformation in the design of architecture. Every so often, "our world encounters a relentless and unstoppable force that changes everything in every industry, overturning the old and replacing it with innovation. Such were the effects of the industrial revolution and are that of the digital revolution" (Aiello, 2014, pg. 45). With such developments, architecture evolved, and ornaments grew out of style in design, bringing a drastic change to the appearance of buildings, by becoming minimalistic. The meaning of ornaments as well as their purpose was changed and discarded during this era. The designs strived for usefulness and functionality over ornamentation. With this strong belief, the beauty of a structure became the simplest achievable form.

Later came innovations like CAD, which were big developments in the architecture industry, transitioning from hand drawings to computer-generated drawings. However, these were fundamentally just a "post of the old drafting process to a new technology" (Pg.45). Shortly after followed 'parametricism', which had a huge impact of the reintroduction of ornamentation into architecture, after the years of it being decreased in use. "The widespread return of ornament that can be observed today is actually inseparable from the massive diffusion of the computer in the architectural world" (Picon, 2013, pg.26). The parametric process that informs design demonstrates the potential of immense computational powers regarding 3D modeling and rapidly producing multiple variations of a design. At its core, "parametric design uses large sets of data with detailed constraints and algorithms to precisely and quickly automate user-defined tasks, thus generating a design" (Aiello, 2014, pg. 46). The resultant designs, however, are more often exhibited as having a lack of control, where architecture appears to have happened rather than been designed. With such movements, ornamentation was more inclined towards blending factors like sustainability, functionality, and beautification as a result for user appreciation.

Now we are in the era of AI. The history of AI can be read as a history of visibility and invisibility. Most people are largely unaware of AI and have little understanding of what it does. And often even those who do understand what it does, do not understand quite how it does it (Leach, 2022, pg. 58). During the mid-17th century, "Gottfried Wilhelm Leibniz, Rene Descartes, and Thomas Hobbes devoted themselves to the systematic study of rational thinking" (Xiaoyao, 2020, pg. 1). Such studies led to the emergence of the formal symbol system that became the beacon of AI research (Pg. 1). The birth of artificial intelligence was a slow and long process, but improvements in AI have kept pace with the development of human knowledge and, in some ways, surpassed human wisdom (pg. 1). The development of stricter reasoning in the earlier days was meant for the mechanization of human intelligence, however it has now taken over many disciplines.

> "It is on our phones, opening them up through facial recognition, identifying friends on Facebook and feeding us news and advertisements; on our computers, reminding us of meetings, finishing off sentences and filtering out spam; in our homes in the form of Alexa, Cortana and other AI assistants, controlling robotic floor cleaners and regulating environmental control systems; and in our cars, giving directions, finding parking spaces and notifying us if we stay out of lane" (Campo et al., 2022, pg. 7).

No other era in history has seen this momentum in the evolution of technology. With the "continuous development of new technologies and its rapid integration into the design fields it is only possible to imagine what the future of our built environment will be in the next few decades" (Aiello, 2014, pg. 7). It is transforming every aspect of our existence, including the architecture discipline. It is heading in the trajectory of being embedded in every architect's toolkit, changing the nature and process of design. AI has become a source of creation in architecture. Although it has become the source of creation in architecture, ornamentation has yet to be defined in the era of AI. There is also no depiction in constructed works of architecture, of what the contemporary ornament looks like, using AI as a main means of design and production. Being a recent innovation, all its current applications in architecture are seen through render visualizations and 2D imagery, which have been populating the web within the last two years. New information about AI is found daily, adding to its better understanding and possibilities. It cannot be said what its full potential is, as the information discovered only scratches the surface of its capabilities. Thus, there is an unknown stance in architecture, as to how today's ornamentation relates in comparison to the remaining eras of ornamentation. This thesis is an exploration of this idea, as well as its possibilities based off the current knowledge available about AI, and how the contemporary ornament can integrate and compare itself to its counterparts of the past – through design and construction.

AI & Architectural Processes

As mentioned earlier, the process of creating ornaments historically originated with physical labour. The ornament was designed on paper, iterated, and then completed by skilled labourers. Historically the ancient and cultural techniques of creating ornaments were created based off the tools and techniques available to them, with the threshold being the capabilities of the human mind and human hands. From the moment of its conception humans designed it, from start to finish. As new information in technology came to life, it altered the design process and reflected the technology of its time through design. With the emergence of each new technology there is a shift in the design process. AI has this same potential, although it is a bit more drastic than previous technologies. Contrary to historical and present processes of designing, AI uses a different method in the creation of objects. The way computers think, and the way humans think, and design are different. Computers do not contain the capacity to be creative and have consciousness of what they are doing. They need to be trained. To understand the relationship between the process of design in architecture and the process of designing in AI, a better understanding of AI needs to be discussed.

A common definition of *Artificial Intelligence* (AI) is that it is a technological tool that seeks to do what human minds are capable of (Boden, 2016, pg. 1). However, this definition is now obsolete, as it already has the potential to outperform human beings. “Human intelligence does not constitute the absolute pinnacle of intelligence” (Leach, 2022, pg. 15) After all, there have already been instances where AI outperformed human intelligence. In the 1997 chess championship, the world champion of that time, Garry Kasparov, was defeated by the machine DeepBlue (Campo et al., 2022, pg. 7). Similarly, in 2016, a machine called AlphaGo defeated the top player, Lee Sedol, at an intricate game of Go, “in which there are more potential moves than atoms in the universe” (Campo et al., 2022, pg. 7). There is no sense in contending against Al, it will outperform humans in most cases; its immense power and knowledge should be instead applied to bettering tasks and processes. Typically the tasks it performs involve learning and problem solving, but not all tasks require intelligence. They do however, all relate to our cognitive abilities, involving “psychological skills- such as perception, association, prediction, planning, motor control- that enable humans and animals to attain their goals” (Leach, 2022, pg.15). Whilst defining AI, it is important to distinguish that although ‘intelligence’ is used for both humans and machines, AI intelligence is different from human intelligence. It does not possess consciousness. In the example of the chess championship, DeepBlue may have defeated Kasparov, but it was not aware of playing the game.

AI can be subdivided into three types of categories: AI itself, machine learning, and deep learning. These different forms of AI focus’ “can be seen to be nested within each other – somewhat like a series of Russian dolls, or layers in an onion” (Leach, 2022, pg. 16). The ‘classical AI’ is programmed to process a set of data, only carrying out the tasks that it is programmed to do, thus the machine itself could not learn (17). By contrast, ‘machine learning’ can train itself “using vast quantities of data” (17). The term ‘learning’ within machine learning, should not be understood the same as the way humans learn. In this context, learning is “improving your ability to do the right thing, as a result of experience” (Russell, pg. 40). Deep learning on the other hand, is the most recent development but has the most promising form of AI, making significant advances in the field. It is the “subfield of machine learning that designs and evaluates training algorithms and architecture for modern neural network models’” (Kelleher, pg. 252). To put it into perspective, while machine learning is trying to put knowledge into computers by allowing computers to learn from examples, deep learning is doing it in a way that is inspired by the brain.

The most current versions of AI can learn and improve over time and adapt in certain ways, due to the neural network it is comprised of. The “neural networks are composed of information processing units that are called 'neurons', and connections that control the flow of information between these units that are called 'synapses'” (Leach, 2022, pg. 21). Each synapse has “a direction and a weight and the weight defines the effect of the neuron before or the neuron after'” (Alpaydin, 2016, pg. 178). They need to be trained by being supplied with a sequence of input-output pairs as a form of training examples. Over a period, the system 'learns' and aims to find the ideal weighting for each connection, so that when it is fed an input, the output result matches the training examples, as best as possible (Leach, 2022, pg. 22). The easiest way for a neural network to handle an image is

> “to operate in one direction, known as 'feed forward'. A network consists of an 'input layer', an 'output layer' and - in between – multiple internal layers known as 'hidden layers'. Each layer consists of simulated neurons. These neurons each 'compute' their input based on the weight' of the input's connection, applying a threshold value to determine its "activation value'. In doing so, each neuron extracts and filters out certain 'features', before passing on its activation value to neurons in the next layer. Each subsequent layer computes progressively higher-level features, until a classification output is generated based on its probability of being correct” (pg. 22-23).

The neural network within AI is named after the neurons in the human brain. Although comparisons between the two exist, they should not be equated as the same. Neural networks are inspired by the human brain; however they are not as sophisticated, and they are not as numerous as the countless amount in humans. They also do not possess certain qualities that the human brain does.

Within the current design process, determining a building’s shape and spatial qualities is the principal task of the conceptual architectural design process. It is required to produce a building that is simultaneously aesthetically pleasing, structurally stable, and functional. It is common within contemporary architectural design processes for architects to begin a design with a vague idea and concept image of its shape, forming the underlying notion and basis for the proposal. The initial form and geometries will affect the buildings costs, performance, inherent traits, and spatial qualities, among other characteristics. Therefore, the search for its final form becomes an important key step in the conceptual design phase because it defines the inputs for the next steps based off its results. The designer gains inspiration from the analysis and brainstorming they conduct, developing a better understanding of the requirements for the physical, spatial, and material qualities of the project.

Afterwards, multiple iterations are conducted, basing it off different factors and constraints the project might have. These explorations are done through sketching, drawing, creating digital models, and through physical model explorations.

With regards to AI, the conceptual design process begins with the computer, the hand is only used as a director, guiding, and supervising the computer so it completes the task at hand. AI changes the creation and concept stages of designing ornaments, regarding visualizations. Free online platforms such as Mid-Journey and DALL-E can rapidly generate photo-realistic architectural visuals, using text services, which draft written technical descriptions in seconds. The exploration of describing ornamentation enables the derivation of their functioning principles from the information collected across multiple observations. Rather than sketching or modeling ornaments using specific “context-agnostic rules” (Chaillou, 2022, pg. 200), AI can help study architectural patterns in context, which could relate to an improved understanding and juxtaposition to the distinctive role of singular conditions. These advancements have also permitted the consumption and analysis of large amounts of data within a shorter time span; being able to significantly speed up the early stages of an architect’s work.

Architectural design is a complex process that draws on experience and creativity to develop new designs. Creativity, being a very complex human trait, plays a large role within design thinking. AI’s take on creativity is interesting, because it enables and enhances the cognitive strategies and skills of creativity, whilst not containing any of its own. AI cannot be creative, as it follows a mathematical construct. It uses a trained set of data and algorithmic organization to complete the tasks that are requested by the designer. The process of AI by using a logical and mathematical approach, can still create unique and beautiful results, because architectural beauty is found in mathematical regulations, such as symmetry and the golden ratio. AI generates such unique and beautiful images, which in turn become a starting point in the process of the design and have viable potential to be developed in further stages of the project. In comparison to the existing architectural process that has been used throughout decades, it is inverted, in the sense that traditionally the most detailed image of the building/design comes at the end of the conceptual design process before the construction phase begins. Therefore, the use of AI within this process should not be oriented to finding a solution in a defined search space, but instead be viewed as a process of exploration of the requirements and potential solutions. In design, elements are chosen based on the consideration of varying quantifiable and non-quantifiable features simultaneously. Even if a problem can be expressed numerically, articulating design objectives is challenging due to the absence of defined and accepted evaluation standards, especially since the design requirements are not yet well defined within the conceptual stage.

In the conceptual design phase, AI still has a limited capacity for autonomous decision-making. Even though the designer inputs the relevant data into the software, it does not possess the responsibility of evaluating the results and making subsequent decisions as to proceed with such ideas or change them to lead to the desired result. Also, a generated digital image is no more than an initial concept idea, leaving the architect to assess the feasibility of the design and make the necessary adjustments, and translate it to functional architectural drawings and spaces. The outcomes generated are also dependent on the knowledge of the user. They need to have the ability to formulate accurate and intricate prompts for the results to be successful.

Relationship of the Two

The two distinct elements of this thesis, ornamentation and AI, are being explored and are present everywhere. They both appear in our cities carrying out opposing functions. Ornamentation takes physical form acting as an additive aesthetic to the architecture (from a historical conception), whereas AI has an intangible presence aiding in the functioning of various tasks and processes that the city relies on. So how can such opposites be merged to rethink and redesign architecture presently? And more specifically, its impact on contemporary ornamentation?

The connection between architecture and digital technology is neither recent, nor have they been a stable reality. Despite having quite distinct agendas, their respective histories display moments of alignment and mutual enrichment. Either by inspiring one another, or by sharing entire frameworks with each other, their discussions have brought significant contributions to both worlds (Chaillou, 2022, pg. 33). With the emergence of artificial intelligence in the past decade, it has resulted in research and wealth of its applications across different scales in the architecture industry, providing tangible signs of its dissemination in the field (pg. 63). It is within this context that we can begin to explore its potential in the scope of architecture and more specifically ornamentation.

I. AI and Architectural Representation

One of the ways that AI can redefine the process of designing and creating ornaments is through its capacities of visualization and representation. AI can 'hallucinate' potential designs, by using a system called generative adversarial networks (GANs). GANs is a "technique for training a computer to perform complex tasks through generative process measured against a set of training images" (Leach, 2022, pg. 26). This process generates results rapidly, with significantly high resolution, and has become a breakthrough in synthesizing images. This system is based on

> "A competition between two different neural networks. It consists of a bottom- up generator- or 'artist'- that generates images, and a top-down discriminator- or 'critic'- that evaluates those images. In the competition, the generator attempts to fool the discriminator by producing images so realistic that the discriminator would be unable to distinguish them from a real data set. […] The two work in tandem and improve over time, so that the 'artist' trains the 'critic' and the 'critic' trains the 'artist'. Once the artist has been trained, the 'critic' can be removed" (pg. 26).

An example of this, is a project called DeepHimmelblla (Figure 1), generated by Daniel Bolojan. The intent behind the project was to discover a way of 'augmenting' design processes, as well as adding an additional layer to already existing designs. These design processes 'span from physical models' interpretations to real time analysis, real time render, domain translations 2D and 3D, [and] design space explorations" (pg. 104). Its resulting explorations demonstrate how this project outperforms designers with "regards to the speed of interpretation and representation, and the amount of coherent interpretations that it can generate" (pg. 104). With machine learning the computer can learn from itself. The results within projects can become closer to the creativity and imagination that the architect beholds, immediately translating the ideas onto ‘paper’, amongst numerous iterations that come with it, when described properly into the system. However, it can also create new and un-envisioned imagery, ideas, and approaches for the design that the architect might have not thought of. This is significant to the process of creating ornamentation in architecture, as ornaments are experienced visually and require such an imaginative presence to capture its visitors. It is important to note that AI is not taking over the role of the architect or limiting it but is working alongside to create a more efficient and prosperous process. It is a point of initialization to brainstorm, visualize and enable architects to expand from those 2D ideas and reach another level of complexity. These generated hallucinations are quite convincing and opened a new medium for ideas and creativity, as well as for new ways of designing, helping to communicate ideas in a quick visual form. The design process shifts to “a delicate balance between the expected and the unexpected, as well as between control and relinquishment” (Dillenburger, 2013).

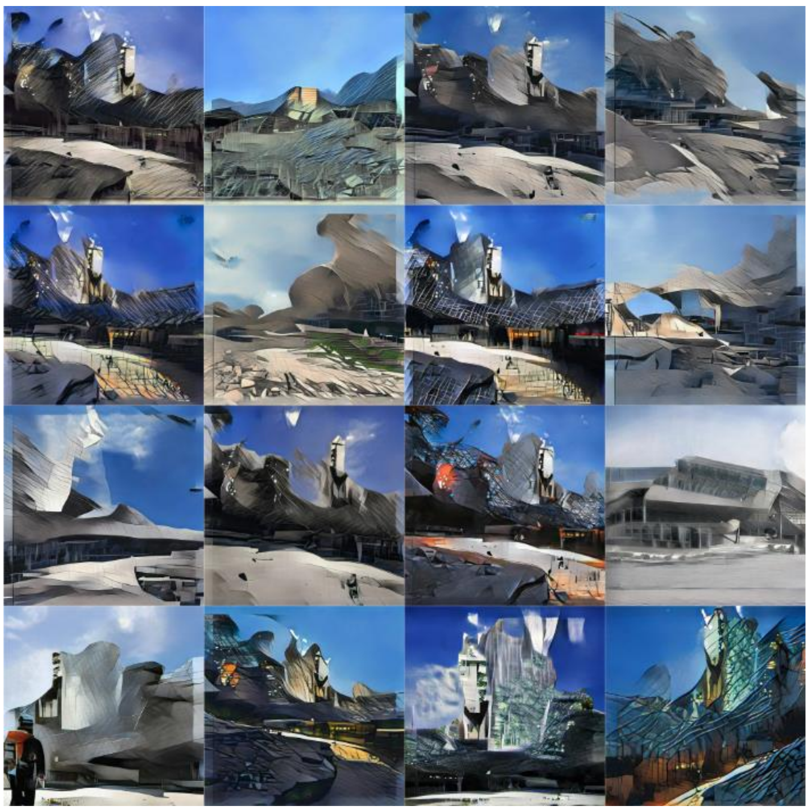

Figure 1 The results of the cumulative research effort undertaken by Daniel Bolojan and his office.

Ornaments are rooted in culture and symbolism, ranging in appearance based on different eras. Each of these time periods has a set of rules and characteristics that emulate what ornament was intended to represent within it. “The understanding and exchange of symbolic values is inherently connected to language and code, which ultimately form the ingrained texture of any form of coded environment, including the coded structure of Neural Networks” (Campo et al., 2020, pg. 89). Neural networks can greatly enhance image classification tasks. They have the ability to recognize and understand architectural ornamentation and extract visual representations of key elements (both geometric and stylistic features) with higher accuracy and sophistication than a human could. By doing so, they capture new ways of 'seeing' finding nuances in building structure and aesthetics. The learned feature sets from the networks can be used to achieve novel representations of form for standard architectural motifs. Specifically when it comes to certain patterns that the human visual system disregards when it performs classifications.

Such a tool is also capable of generating solutions that combine patterns from different cultural and historical contexts without the influence of human personality or emotion, which can become an overpowering factor and the driver in creating designs and making decisions. Because of this the AI "algorithms are deterministic as they do not incorporate randomness, but the results are not necessarily entirely foreseeable" (Dillenburger, 2013). Alternatively, "they have the power to surprise" (Dillenburger, 2013), and produce playful and dreamlike ornaments whilst maintaining optimization, refinement, and ultimately accuracy, creating really astounding ornaments "that go far beyond what one could have traditionally conceived" (Dillenburger, 2013). AI has the potential to give architects new means of refining the adequacy between "their design and the specificity of contextual or cultural factors" (Chaillou, 2022, pg. 200). They can play off the porosity between research and practice, even more so than previous technological revolutions did. The synergies between the "practice's project-based mindset and AI's research-based culture can be the bedrock of a new approach to Architecture" (pg. 200), allowing for both practitioners and researchers to create meaningful bridges between both worlds, allowing and promising more from technology than the mere promise of automation.

II. AI and Architectural Form

AI possesses many strengths that other tools and software cannot do in the industry. While other software like grasshopper "can generate multiple outcomes, [the scripts ultimately] have to be produced manually one by one over a period of time[.] The beauty of more advanced AI tools is that they can generate an almost infinite number of options instantaneously" (Leach, 2022, pg. 107), however, currently only in a 2-dimensional format. AI privileges the aesthetic potential of architecture, producing visually stimulating images. However, its success is likely to be judged through other means, specifically through its ability to compute 3D forms, as well as finding the most efficient solutions to a design task from the performance perspective. Al is certainly not limited to representational concerns. The issue and the future of AI in architecture, and more specifically ornamentation, is how to generate these forms in 3D, as well as how to control them sufficiently to make them useful within an architectural framework. Research has shown that tests of translating 2D to 3D in AI have already begun. The use of Deep Neural Networks (DNN) has been used to imitate brain plasticity. They are "able to receive, 'give' and 'explode' form, yet are also inscribed with a conceptually similar fallibility for their capacity to generate forms" (Campo et al., 2022, pg. 88). Similarly to how two humans conceive forms differently, no two DNNS can 'give' or 'train' forms that are exact, even if they have received the same form at the starting point.

Ornaments are 3D forms and are experienced as such. In AI, there are a variety of different ways to denote 3D information for a neural network. Some of which include depth maps, 3D reconstruction with multi-view RGB image sets, voxels, point clouds, and polygon meshes. However, the additional spatial dimension "creates a huge computational burden as a result of the increased input size and intermediate network representation sizes, which ultimately renders 3D vision/perception infeasible for many vision problems" (Campo et al., 2020, pg. 95). Due to this, the resulting images must be kept to a low resolution to be able to process the thousands of images necessary to teach a neural network. This is a problem that needs to be overcome in order to make more detailed and precise models that allow for further elaboration in the complexity of contemporary ornaments. There are pros and cons of each type of data format, as well as the choice of which type you use will directly impact the features learned and extracted by the neural network. For instance, point clouds in comparison to voxels, are much sparser and thus take up much less computer memory. However, they do not capture a sense of faces or surfaces, making it difficult for the input or manipulation of texture, thus making it more complex, as it cannot be 3D printed or rationalized into components for fabrication. A watertight mesh is necessary to process the file for digital fabrication. Regarding 3D reconstruction with multi-view RGB image sets, this process requires having images of an object from varying views/perspectives in order to be recreated into a 3D form. This process only works for objects or buildings that already exist, as these views need to be derived from something that already takes on a physical form. Such a process can be useful for areas of restoration and conservation in architecture.

The majority of neural networks have been created to handle 2D visual information in the form of images. They can also be expanded to work on varying 3D representations of the world, which fall under two main categories. The first takes the 3D object and projects it into a 2D representation, such as depth images (Campo et al., 2020, pg. 95). The second category uses neural networks "whose connectivity structure has been modified directly to operate directly on 3D information" (pg. 95). Employing the methods of the first group of algorithms, 2D neural network-based image editing techniques can be utilized to make aesthetic changes to 3D objects "based upon the learned representations of neural networks trained on 2D image data" (pg. 96). As mentioned earlier, these point clouds and voxels have no form of connected structure or smooth surfaces, which are necessary to generate continuously closed polygon meshes and create ornaments. Instead, object meshes are a good medium between point clouds and voxels, as they are "computationally more efficient than voxels but have enough visual information about surfaces that can be manipulated with interesting aesthetic edits" (pg. 96). With such approaches of AI available, the 3D explorations discussed are not easily translated into visible and understandable forms, each containing benefits and drawbacks to their method. Currently the translation of the 2D information and imagery that AI produces is where it is the most deficient. Few successful explorations have been conducted, and those that come close still have difficulty translating such information entirely through AI. Thus, requiring the additional support of other tools to post-process the information that it provides, and translate it to usable spatial models that can be used within the scope of ornamentation and architecture.

An example that explores the 3D potentials of AI is Immanuel Koh's 3D printed GAN Chair (Figure 2). GANs was trained to synthesize a design based off 3D geometric models of thousands of chairs at different scales and resolutions. It is an attempt to address the specific hierarchical structure of DNNs for architectural design beyond its two-dimensional representations. The neural sampling in this project, "proceeds by directly sampling from the discrete 3D vertices and faces of its training dataset - a slow, generative process that samples sequentially, one vertex after another, and then one face after another" (Campo et al., 2022, pg. 90). Thus, its plasticity does not lie in a dormant space, "but in a probabilistic sequence, much like in language" (pg. 90). This project begins to bridge the gap between these two realms, however it also changes the process of form-finding and designing that currently exists in the architecture profession. It is a counterpoint to the current prominent 'form finding' method found within the architectural process of "topological optimization that seeks to arrive at a structural and material ideal via physics-based and constraint-based simulations" (pg. 90). With this method forms are able to 'dream', without becoming an automatic response pattern or habit of the past, as well as without being constrained to particular goals. The results show that 3D GAN shows a shift towards including more complex architectural ideas of spatial interiority, program, and contextual bias with greater granularity.

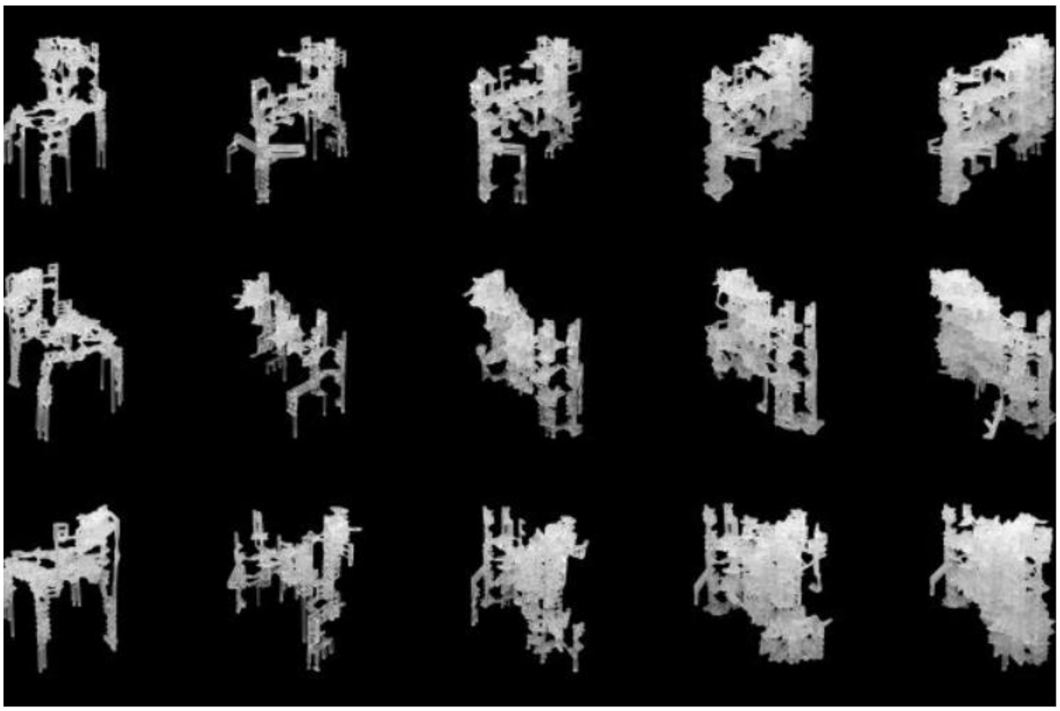

Figure 2 Immanuel Koh's 3D printed GAN Chair

III. AI and Architectural Materiality

Contemporary ornament, within the definition of this thesis, relies on creating a 3-dimensional object that acquires symbolism, structural functionality, and a material form. This report has already explored AI's potential in the creativity and symbolism of ornament, thus, looking at how it can help in its physical realization is critical. Artificial Intelligence specifically in the form of coding has expressed a new style of architecture, one where an object with the help of an architect, designs another object. Ornaments are material objects, whereas computation is immaterial. The use of intelligent computational techniques, such as AI, can aid in informing the intelligent design of an ornament and make our designs even more 'materially intelligent'. "Architectural intelligence therefore stands not only for the intelligent use of materials and the use of 'intelligent materials' in the construction of a building, but also for the use of intelligent computational techniques to design the material form of that building" (Leach, 2022, pg.

174). Such expressions can be seen within the Dragonfly Wing Project, completed by Hao Zheng and Masoud Akbarzadeh (Figure 3). The dragonfly wing project uses 'machine learning', which is programmed to process a set of data, by training itself "using vast quantities of data" (Leach, 2022, pg. 17). The project "used graphic statics to analyze the structural features of the convex only networks of a dragonfly wing and create a data set for machine learning" (Campo et. Al, 2022, pg. 132). After effectively studying the features of the dragonfly wing, the same process is used to study structures from other species. This method not only creates structural geometries that are merely identical to the original species, it also successfully "predicts the thickness of the bodily structure" (pg. 132). This study shows potential in having an effective design method for varying manufactured structures, with similar or different performance needs, opening possibilities to other investigations. Through such methods, it can also help improve the understanding of "various design parameters needed to craft human-made systems dealing with similar boundaries conditions and enhance the performance of the design" (pg. 132). Through this technology, it can aid in the creation of architectural features, such as ornaments, by producing structural and material forms that are intelligent in their entirety, containing multiple performance traits and more of a function than they had in the past.

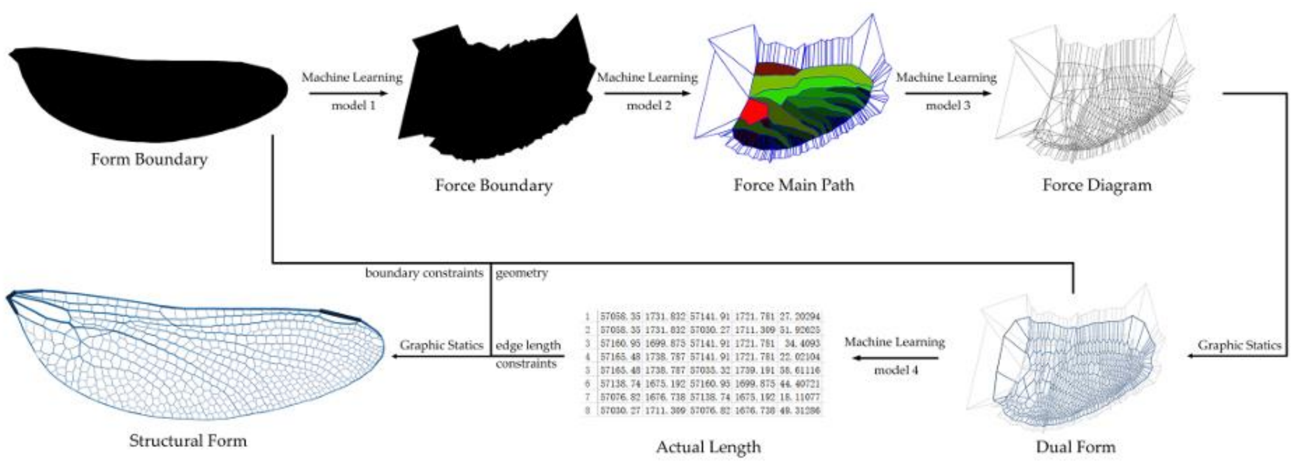

Figure 3 Dragonfly Wing Project Process

With today's global concerns about improving the material performance of architecture and reducing carbon emissions, performance has long been a concern within the field of architecture and is seen to be implemented in all aspects of design. With the establishment of advanced informational systems drawing upon satellite information and data mining, there are more opportunities to model and test the performance of designs with far greater accuracy (Leach, 2022, pg. 36). One key area where AI is being utilized gradually for performance-driven design is structural and material design, using an established GOFAI technique, of topological optimization. An example that has already implemented such a form of AI is Project Dreamcatcher. Project Dreamcatcher is "a generative design system developed by Autodesk, that allows designers to generate a range of designs by specifying goals and constraints, such as functions, materials, performance criteria and costs restrictions, allowing them to trade off different approaches and explore design solutions" (pg. 36). Another example would be Ameba, "a bi-directional evolutionary structural optimization (BESO) technology developed by Mike Xie of Xie Technologies" (pg. 36). Such examples hold the alluring potential of creating "optimal" forms for a given situation, for instance solving for the greatest strength per unit of material (Levin et al, 2021, pg. 124). These examples have the ability to aid with creating an efficient use of material and minimal weight, while remaining strong enough to withstand the forces applied. This use of less materials and creation of less waste, while delivering a structurally sound building is important in architecture, as it contributes to a large portion of greenhouse gas emissions, which are created by the making of these materials for buildings. By optimizing the amount needed for the project, less material is needed, less emissions are created, less time to construct is required, whilst still maintaining greater complexity and structural intelligence.

Explored Methods from 2D to 3D

The following section will discuss the various methods explored of how to use AI and digital tools to realize the *contemporary ornament*, in translating its 2D state into 3D forms. All the methods contain the same beginning steps, where a prompt is generated using text, that is then implemented into text-to-image generator models, which create the aspired images for the next steps. Within this thesis the creation of prompts to visualize 2D images is an important aspect of the design process in creating ornamentation. With the way a prompt is structured it can transform the designers' ideas on to paper, in a matter of seconds. Prompts require a textual description of a desired image to be created. They can be short and brief or long and descriptive, containing multiple nouns, adjectives, verbs amongst other parts of speech. The results will create an image that aims to match that description. Within the text-to-image generator, key words are entered into the command section, resulting in four generated images from the input data. If the results created are unsatisfactory to the overall vision, further variants can be developed based off the initial four images. If none of the results are deemed satisfactory, the process can be repeated based off the same key words or by altering the prompt until the desired image is attained. It is worth highlighting that re-entering the same phrase within the generator will never create the exact same results. This is because the images that source the final generated images are chosen at random in each case, generating an infinite number of possibilities. Furthermore, its continuous evaluation of itself based off user choices allows the algorithm to evolve, learning to produce better visualizations over time.

Within this section of designing, AI provides vast amounts of unique images that are attributed to the moment it was created. It can generate everything and anything that a human imagination translates into text. However, the drawback of this process is that the generator does not do well with ambiguity. If the text prompt is not specific enough within the framework, as to what needs to be described, it will be difficult to achieve the desired result. It will require doing several iterations, adjusting the text prompt to retrieve the closest possible physical image that was envisioned by the designer. For this thesis the main generators used were Mid-Journey and DALL-E, however, others were also explored to catalyze the differences and benefits of each. Each generator creates images based off the images that it was trained off; thus the results are specific and limited to them. Some of them contain limited images, which results in a similar output in terms of characteristics of the images, although the typed prompt is specific and intricate.

I. Methods 01 & 02

To determine the best approach of translating 2D images to 3D forms for this thesis, different methods were explored. Within all the methods the process requires the use of an AI software to generate an image, to be then translated into the following methods. The first method explored taking the image from the AI text-to-image generator, and transferring it into rhinoceros, where the information of the image is extracted through a heightfield function (Figure 4). Heightfield is a function in the software that deforms the 2D planar image by extracting parts of the image to different height points based off the image's colour value, to translate it into a 3D form. The lighter the colour in the image the higher those points move, whereas the darker the colour the lower the location of the points. Heightfield in Rhino creates a more fluid and continuous image with a natural sculptural presence. It does not create a subdivided effect on the surface, but instead acts as one uniform object. However, the drawback of this method is that the image created is more of an extrusion of the original image that was projected onto a flat surface, rather than a structural composition; making it harder to assess its structural capacity. It is also more difficult to manipulate the surface as the user has less control over the computer's extrusions based off the image's colours. The more colours the image has, the harder it is for the computer to decipher the height field due to the complexity of the image. With such an approach the results are not always successful, based on the image used. In some instances, specifically complex and detailed images, it becomes easier to manually manipulate and generate the form, than to use such a process.

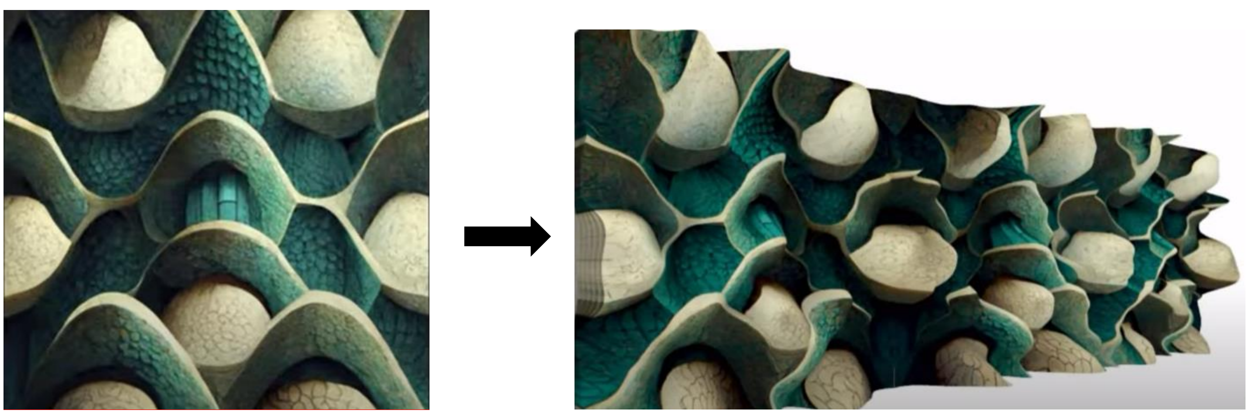

Figure 4 Results of Heightfield Method

Another method explored consisted of breaking down the AI image into pixels, and gradually extracting those subdivided surfaces to create a pixelated sculptural presence in comparison to the previous method. Within the second method, the gradual extrusion technique is used to translate the 2D images to 3D architectural elements that form the ornamentation. The image that contains ornamentation is implemented into a grasshopper script, which is a plug-in for Rhino, where it samples the image and subdivides it into smaller squares (Figure 5). These squares are then extruded based off the colour value of the image. Through this method, it also allows for the design to have smaller sub-geometries, that can be manipulated to adjust to the complexity of the image. However, the drawback of this method is that the image created contains a pixelated result, which is vaguer and more stylistic than the original AI input image. The ornamented element would also require more material in the production process, as the extrusions of the pixels (now voxels) would create additional surface areas around it.

Figure 5 Potential Results of Pixel Method

II. Chosen Method

When starting to work on bridging the gap between 2D and 3D elements, an exploration of 2D surfaces was conducted in ways they can be transformed or manipulated into 3D objects. Before screens there was paper in architecture. In its natural states it takes on a flat two-dimensional form, possessing no aesthetic, structural, symbolic, or functional qualities. However, once you start playing around with it, it can be folded and manipulated into various forms, and representation of objects. Even with a single fold it develops a level of structural stability, where it can now stand upright, without falling over. This exploration became the inspiration for the main method of this thesis in developing contemporary ornamentation. With such a method it is inspired by origami and mathematical process of subdivision. Within this method, the folding technique of origami is used to translate the 2D images to 3D architectural elements that form the ornamentation (Figure 6). The images generated in the previous steps are the first part of the process and are then translated into the second part which is the post-production. The image that contains ornamentation is implemented into a grasshopper script, which is a plug-in for Rhino, where it samples the image and extracts the information via image sampler and creates simple sub-geometries. These sub-geometries are, specifically triangles, as they contain the strongest structural stability and can be joined to formulate other geometries. Through this method, it also allows for the design to embody a natural structural quality. The vertices of the triangles will be extrapolated to apply a collapsible function to create the folding effect of origami, resulting in a 3D ornamented geometry that resembles an idea of a design that could take form as ornamentation. This can then be transferred into Karamba (a grasshopper plug-in) to be assessed structurally and optimized to provide the best structural performance for that element.

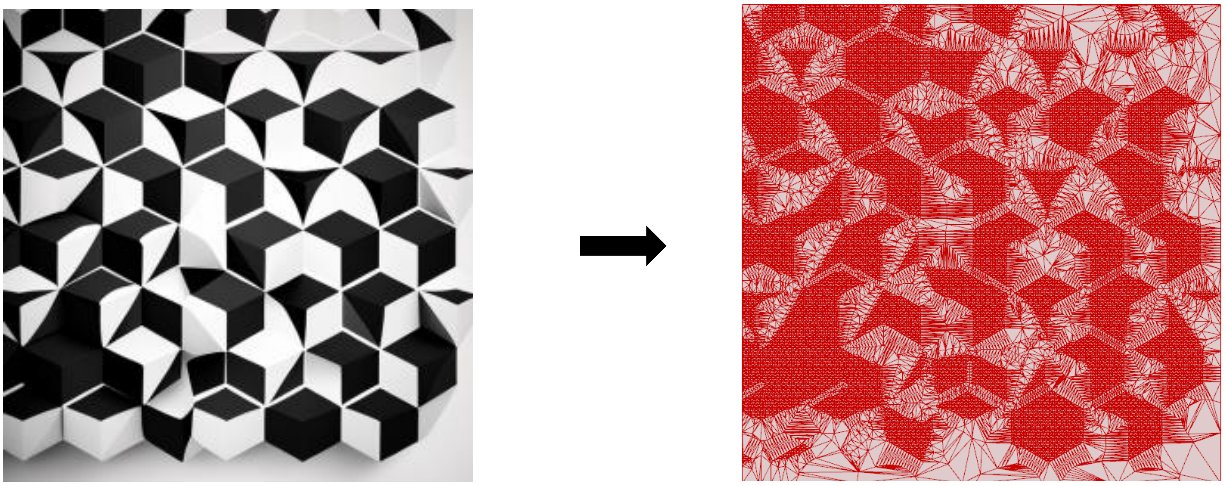

Figure 6 Results of Origami Method

This method of designing ornaments is deemed successful in its output results. However, it is still not the smoothest transition from taking 2D elements and creating 3D geometries. It requires complex levels of post-production and deeper knowledge of software like Grasshopper. The creation of sub geometries creates a very heavy file making it difficult to generate the folding action within the software. It requires a strong processing computer to handle more complex imagery. Also, for the most successful results, the images used should be transformed into black and white images, in order for the image sampler to better read the image and extract the image's details for it to be readable. Currently the example shown within this paper, demonstrates the simple translation of a 2D image into an ornamented wall. This approach can also be used to generate varying architecture spaces and elements that are not only rectilinear but contain curved surfaces and varying forms. The script would just have to be adjusted to either manipulate the wall to be bent, curved, or transformed to the desired spatial qualities, or the initial image can be mapped/projected to separately generated geometries and then be transformed within the script to generate a 3D structurally ornamented form.

III. Origami & Mathematics

The study of origami and its principles in mathematics is an important topic within the exploration of merging the 2D with the 3D, as the act of folding and subdividing is how the AI images can be realized in 3D ornaments. Origami has been taken as a source of inspiration due to its variety of applications. Origami is the art of paper folding which is an ancient technique that originated from Japan. The word 'Origami' "comes from Japanese, and is a combination of 'oru', which means 'fold' and 'kami', which means `paper'" (Schenk, 2012, pg. 1). Although origami is associated with simple folding models such as the origami crane, it has the capacity to reach unprecedented complexities, with a single sheet of paper. Many of the "recent advances in origami design are a result of the growing mathematical understanding of origami, and newly developed computational design tools" (pg. 1). The visual patterns which contain creases enable a form finding process that creates complex geometries generated in an economic way. Designers can make use of the "of the ability of folding patterns to increase the bending stiffness of a sheet" (pg. 5), which allows it to span greater distances and areas. They can also undergo large changes in shape and deformation as a result of the opening and closing of the folds, while still providing flexibility in certain deformation modes. This" combination of flexibility and rigidity is of interest in morphing structures, such as the skin of morphing aircraft wings" (Thill et al., 2008). Thus, the visual patterns used within this thesis are used for the improvement of structural properties. These logical and mathematical principles can be applied in larger scale designs, such as the construction of a wall. Traditionally "origami folding makes use of straight fold lines, but curved folds open up new avenues of shapes and designs" (Schenk, 2012, pg. 1). They can be "designed with an intrinsic global curvature and can be continuously manufactured with minimal material deformations" (pg. 5). This is useful in architectural applications within this project, since it can be used as cladding material and a secondary structure for varying curved surfaces, or even on the façade for a larger scale approach. Using origami as a primary method within this thesis captures the important behaviour of creating complex imagery whilst integrating structural properties. Based on such a technique, origami exhibits remarkable properties which allows for astonishing richness and variability, whilst using such a simple means of folding to create complexity.

In terms of the preliminary results of the design, by getting acquainted with AI software and combining it with the processes of other digital software used within architecture, it allowed me to find initial iterations of how AI can be integrated to explore and optimize new forms of ornaments. The design focuses on generating text-to-image visuals, which will be then inputted into a software or script which will transform them into 3D forms, and architectural spaces. The evolution of creating the ornament from text in the AI software, to Rhino or Grasshopper to be experienced 3-dimensionally, uses generative techniques, which provide a more flexible design process, where the result no longer has a definitive form, but rather a form based on descriptive visuals, mathematical function, and rule-based reasoning. The final forms are created with a complexity that would be impossible to create otherwise or requiring hours of work. Every component of the images produced is generated through these customized algorithms with minimal human intervention. The different techniques can be merged and combined to create varying images and constructs. Using multiple and mixed approaches, it enables even more methods and possibilities to be generated, creating the potential to have a library of varying results, with unique and different styles. Due to the constraint of time of this thesis, the combination of techniques was not assessed and compared to the main method used for the design.

Image Complexity

The following section determines the successfulness of the grasshopper script, in extracting information from different images with varying levels of complexities. Three explorations will be done in order to test different forms of imagery the script can process. These will include simple geometric patterns to complex and realistic images, and the scripts capacity to translate them into legible sub-geometries for further development into ornaments. The proposed design process to create *contemporary ornamentation* requires a lot of post-production in other software because AI currently does not provide a seamless translation of images to form. The design is also based off dividing the image into basic sub-geometries, which creates a more sub-divided image, rather than a clear translation of what the ornament is to be as if it were a 2D image. This requires strong computer processors that can handle such levels of complexity and subdivision, where most stationary computers do not. To create legible images, the final images within this section were not folded into an origami form, due to the complexities of the image and number of sub-geometries created by the script. Based off the exploration conducted earlier on a simpler image, an assumption will be made that with a stronger computer, the script could manage to create such forms with more complex imagery.

The first exploration will focus on simpler geometric patterns, which contain more distinct boundaries of objects and shapes, rather than realistic images and photography (Figure 7). The prompt used to generate this image consisted of the following words*: complex pattern, black, white, advanced, detailed, white background, line drawing, simple illustration, flat design, ornamentation, unrepetitive.* The script, in accordance with this image, was proven to be successful. It could easily formulate images that contain an engrained geometric nature. With clear geometric forms, the script easily extrapolated the boundaries of the image, whilst maintaining its clarity and created legible geometries to be used as creases for the folding mechanism. A coloured geometric image was also explored to determine if the same level of success would be achieved if the contrast of the colours and hues was not so evident (Figure 8). The prompt used to generate this image consisted of the following words*: complex pattern, colour, advanced, detailed, colour background, line drawing, simple illustration, flat design, ornamentation, unrepetitive.* With regards to this image, the script had a more difficult time deciphering the image, as the contrast between the colours and hues did not create as large of a contrast, making the boundaries less evident for the script to understand. The image was thus post-processed to a black and white scale and the contrast was increased. It was run through the script again to determine if better results would be achieved. With such intervention, the script managed to create a more legible result than the previous iteration. The result does not reach the successful nature of the previous exploration; thus it can be concluded, that for the best results the image inserted into the script must be a high contrasted black and white image.

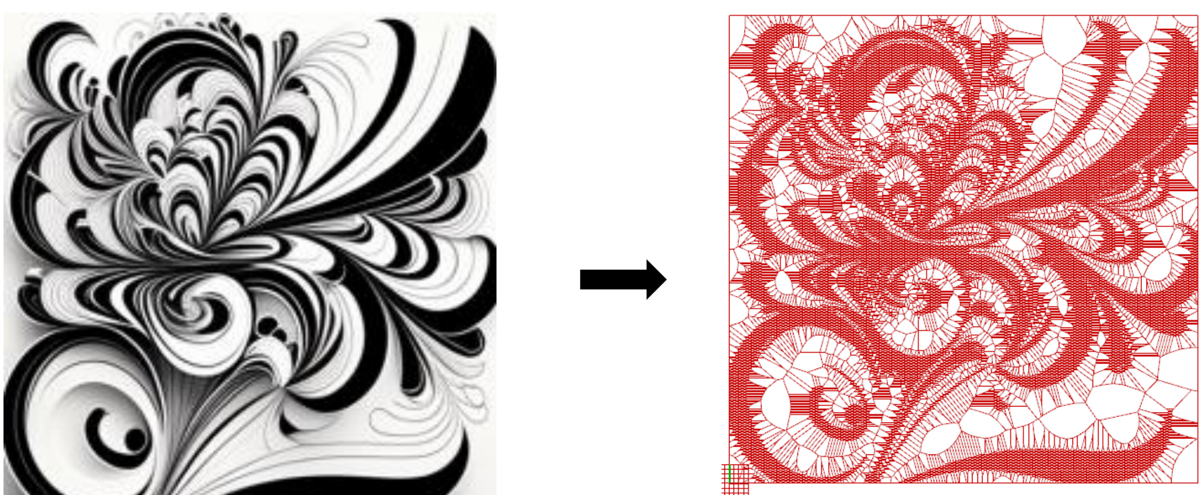

Figure 7 Simple geometric pattern exploration - Black and White

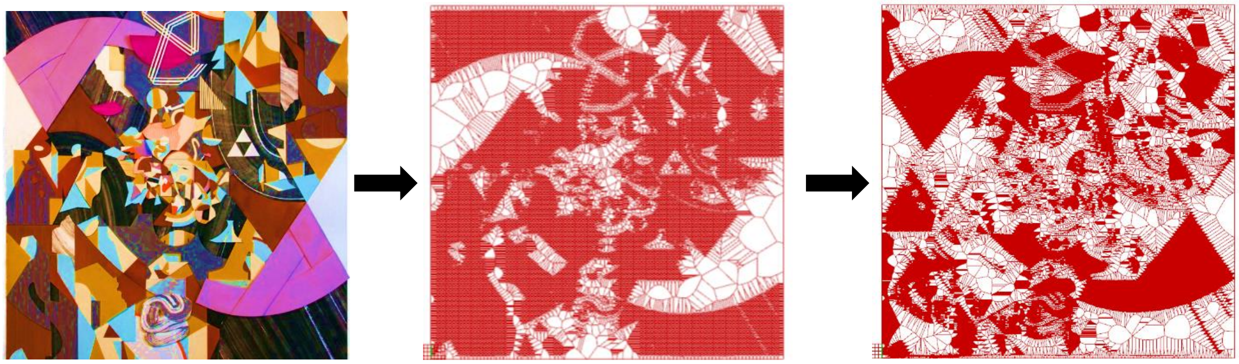

Figure 8 Simple geometric pattern exploration - Original vs Colour vs BW

The subsequent images will investigate the possibilities of translating realistic images of objects and people to determine if ornamented 3D forms can truly be created out of any image, that is input within the script. The second exploration will focus on a realistic image of a person, which contains more ambiguous boundaries and higher levels of detail and complexity compared to geometric images (Figure 9). The prompt used to generate this image consisted of the following words*: high texture, high contrast, full face, quality portrait of a young woman with freckles and crystal blue eyes.* The script, in accordance with this image, was proven to be successful, in deciphering the face and female attributes of the image. It easily extrapolated the boundaries of the image, and the present characteristics of the face whilst maintaining clarity and creating legible geometries to be used as creases for the folding mechanism. The drawbacks of this process is that the sub-geometries created within the image are not as precise as the details of the original image, creating a final output that represents an ambiguous portrait of a woman, alluding to certain characteristics but not being easily identifiable to the eye.

Figure 9 Person/Portrait exploration

The final image will investigate the possibilities of translating realistic images of scenes to determine if ornamented 3D forms can create clear pictures of multiple objects within the same image. This will show and compare the AI capabilities to the remaining results. The third exploration will focus on realistic images of a scene, that contains multiple elements of detail, along with various levels of depth within the image (Figure 10). The prompt used to generate this image consisted of the following words*:*

dog with a bone in his mouth, sitting in the forest, with lots of trees. The script, in accordance with this image, had a harder time deciphering the boundaries of the objects within the scene, which contains more depth and elements in a single image. The geometry of the image must be subdivided into numerous and smaller sizes in order to get a large level of definition and accuracy for the image of the ornament to be visible and legible, otherwise it looks very ambiguous and unrecognizable compared to the starting image. The following result was reached after many trial-and-error runs. If a stronger computer was used for the process, other conclusions, with potentially better results could have been reached. In such instances, for the best results the image should be broken down into subcomponents, for the script to subdivide them into geometries separately and then merged afterwards.

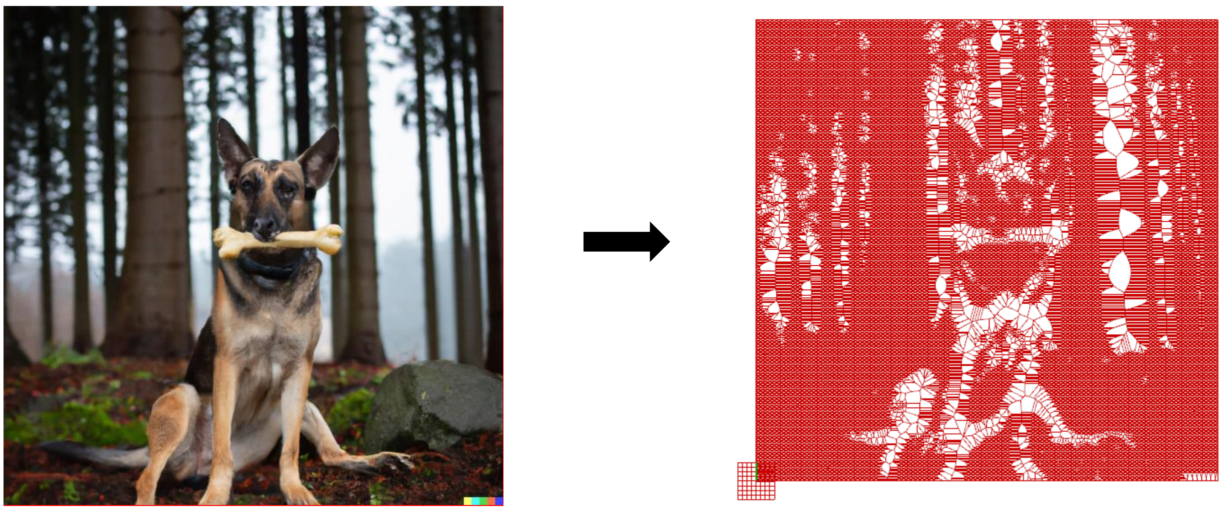

Figure 10 Complex scene exploration

The beauty of this project's results is that based off such findings and explorations, the script generated can be applied and transferable to any project, using any image, creating an infinite number of results and iterations. The script can adapt to varying levels of complexities of images, requiring small adjustments within the number sliders of the script to enhance the resolution of sub-geometries to create a more decipherable image. Although it has a harder time deciphering more complex images and scenes, it can still translate the boundaries to create an ambiguous idea of the original image, maintaining the theme of the image. This thesis research is the beginning of the discussion and exploration of such topic and can be used to further future research.

3D-2D-3D

The following section will explore the outlined methodology (which includes the AI process and grasshopper script) and compare its results to existing real world examples of architectural ornamentation. An exploration will be done to test the successfulness of recreating existing ornaments. Within this exploration, Michelangelo's David sculpture will be used as a ground root and will be compared to the generated AI image of itself and its translation to an origami folded architectural element. This sculpture was chosen as the focus because 3D human sculptures were prominent and reoccurring forms of ornamentation in historical architectural typologies, especially in religious and worship spaces. Figure 11 depicts the existing sculpture of David, in Florence, Italy. Figure 12 demonstrates the AI image generated of Michelangelo's David, and the resulting ornamented form after being processed by the grasshopper script. Examining the results in comparison to the original demonstrates a similar resemblance of the two sculptures. The origami folded David in Figure 12 generates a familiar silhouette that depicts the true existing sculpture, deciphering the male body attributes of the image. It easily extrapolated the boundaries of the image, and the present characteristics of the sculpture, however, lacking clarity and creating legible geometries to be used as creases for the folding mechanism.

Figure 11 Real World Ornament- Statue of David by Michelangelo

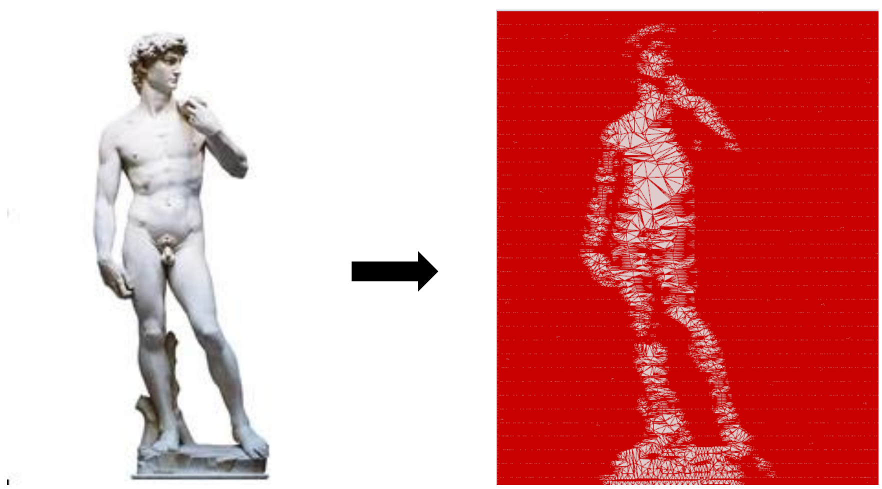

Figure 12 AI Image vs Folded Ornament

The results did have difficulty reaching the level of detail that the original sculpture holds. Its level of detail is also distributed differently than the existing sculpture. This is because it must break down the image into sub-geometries so it can be folded for structural purposes. The generated result is also not as fluid and natural in comparison to the original sculpture. The ground root David does not contain many harsh edges and vertices; however, the origami fold is composed of such. These vertices can be further postprocessed to be made smoother, however, the overall generated form will contain more subdivisions at a closer glance and will embody such look because of the geometric computation and mathematical process it is composed of. Analyzing the results further, the resultant form in Figure 12 generates only a portion of the sculpture. This is due to the fact that the back and sides of the original David sculpture are not clearly visible, thus it can only be compared to the side that is discernable. Being that in the context of this thesis, the generated origami David sculpture would have to act as a structural element, (i.e. a column), where all sides are visible, the following geometries would have to be stitched together based off images that encapsulates all the sides of the original sculpture. If it were to be integrated as a portion of a structural wall, then such elements would be less of a concern. With such a script it shows that ornamentation can be replicated, however, the results will contain a certain level of detail and style. As mentioned previously, such a result could differ if a stronger processing computer was used, to further subdivide the image to create a more seamless translation of the original to the fabricated.

Conclusion

The following thesis is an exploration on the topic of *contemporary ornamentation* in architecture through the lens of *Artificial Intelligence* (AI). Being that AI is a recent technological innovation, and being implemented into many aspects of varying industries, the scope to explore it in the realm of architecture and design, is an opportunity for this graduation thesis to properly assess its value within the discipline, as well as create a clear definition and set of rules for the current period of design. The goal is not to resurrect the ornament from the past and look back on it as it was, but instead to find a deeper abstraction of the lost craft situated in the digital era. Based off the research, ornamentation has the potential to be reintroduced into architecture, especially with the capacities of AI and digital tools. Through its capabilities it alters the way we design and implement ornaments by creating structural and functional architectural elements, whilst maintaining the symbolism and aesthetics of the past. It bridges the gap and spectrum of where ornament was throughout the years, to a new interpretation that can encompass it all. The availability of such technologies allows architecture to no longer be bound by the limitations of standardization and mass-production, bringing forth new opportunities for modern day architecture to be redefined, and in turn to redefine ornament. This thesis also shows through its explorations, the possibilities that can be further developed into creating a unique language in architecture, as well as the way the architectural process can be changed with regards to generating conceptual designs and new visuals. Studying ornament in relation to AI is unavoidable based on the trajectory and acceleration AI has had within every facet of our lives. Undoubtedly, writing and drawing skills will begin to fade and AI will begin to integrate itself within architecture and will become an indispensable tool and invisible assistant to the design and construction process.

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Appendix

Figure 01

Nonstandard Studio. (2019) Daniel Bolojan Nonstandard Studio [The results of the cumulative research effort undertaken by Daniel Bolojan and his office] [Image]. AIARCHITECTS.ORG. https://aiarchitects.org/portfolio/daniel-bolojan/

Figure 02

Koh, I. (2021). AI Sampling: On Plasticity and Form [Immanuel Koh's 3D printed GAN Chair] [Image]. Melbourne School of Design. https://msd.unimelb.edu.au/events/msd-at-home/ai-sampling-on-plasticity-and-form

Figure 03

Campo, M. del, Leach, N., Prix, W. D., Schmidbaur, K., Crespo, S., Manovich, L., Farahi, B., Menges, A., Wortmann, T., Andrasek, A., Steinfeld, K., & Spiller, N. (2022). *Machine hallucinations: Architecture and artificial intelligence*. [Dragonfly Wing Project Process] [Image]. John Wiley & Sons. Pg. 133

Figure 04

Kgm. (2022). *AI generated Image into Layered Skin - Midjourney + Rhino* [Results of Heightfield Method] [Video]. Youtube. https://www.youtube.com/watch?v=fqe_FNDD6m0&ab_channel=kgm

Figure 05

Lashbrook, J. (2017). *Jennifer Lashbrook Demo at JCO's* [Potential Results of Pixel Method] [Image]. Marie Cameron Studio. http://mariecameronstudio.com/tag/jennifer-lashbrook/

Figure 06

Panus, P. (2023). Geometric, pattern, black, white, advanced, detailed, [Results of Origami Method] [Image]. MidJourney.

Figure 07

Panus, P. (2023). Complex pattern, black, white, advanced, detailed, white background, line drawing, simple illustration, flat design, ornamentation, unrepetitive [Simple geometric pattern exploration - Black and White] [Image]. MidJourney.

Figure 08

Panus, P. (2023). *Complex pattern, colour, advanced, detailed, colour background, line drawing, simple illustration, flat design, ornamentation, unrepetitive* [Simple geometric pattern exploration - Original vs Colour vs BW] [Image]. MidJourney.

Figure 09

Panus, P. (2023). *High texture, high contrast, full face, quality portrait of a young woman with freckles and crystal blue eyes.* [Person/Portrait exploration] [Image]. MidJourney.

Figure 10

Panus, P. (2023). D*og with a bone in his mouth, sitting in the forest, with lots of trees.* [Complex scene exploration] [Image]. MidJourney.

Figure 11

Lama, M. (n.d.). [Real World Ornament- Statue of David by Michelangelo] [Image]. Melbourne School of Design. https://cdn.britannica.com/77/196577-050-1101EEBD/Michelangelos-David-Goliath-one-statues-world.jpg

Figure 12

Panus, P. (2023). *David statue by Michelangelo isolated on transparent background.* [AI Image vs Folded Ornament] [Image]. MidJourney.