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The Algorithmic Mashrabiya: Reimagining the Traditional Islamic Screen

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MFA in Design

The Algorithmic Mashrabiya

Reimagining the Traditional Islamic Screen

By

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Abstract

Traditionally, a *mashrabiya* was an ornate wooden structure attached to the side of an Arabian building or house, with small, intricately patterned openings to provide both ventilation and privacy for the people inside. The patterns, following the geometric rules of Islamic ornament, lent a distinctive appearance to buildings in the region. A *mashrabiya* converted the house into a safe, private sanctuary, providing a magical scene inside, characterized by linear sun rays, filtered points of light and shadow. Over time, as building technology changed and the number of skilled craftsmen dwindled, the traditional *mashrabiya* has all but vanished. The aim of this thesis is to propose a new future for the *mashrabiya*, converting it from a stylistically preordained Islamic artifact to a culturally resonant architectural element expressive of Arabic culture and lifestyle. The research explores connections between culture and nature, using a generative design process powered by algorithms, to produce patterns inspired by nature reminiscent of formations found in the Arabian desert. A contemporary structure, *The Algorithmic Mashrabiya* is respectful of the Islamic principles embedded within the traditional *mashrabiya* but is newly aligned with the needs and capabilities of twenty-first century architecture.

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Introduction

I carry a memory from childhood: bursts of sunlight on the floor, barely touching the end of my bed, forming a mesmerizing, star-like pattern. I recall this scene, from the place I grew up, every time light comes through a window and touches the floor of my new home. The light conjures countless memories from childhood. I remember my deceased grandparents, who held and comforted me under that window. I remember staring at the wooden *mashrabiya* pattern, spellbound by the beauty of its geometric patterns. I remember deciding to be a designer one day, to share the simple joy of composed light and complex elements, designed to dazzle and inspire.

People's homes are intimately linked to their identities. Homes remind people of who they are and where they come from. The light of the sun wakes people up each morning, illuminating their surroundings and guiding their first thoughts. The shape and intensity of morning sun rays can affect a person's mood and awareness, forming different experiences over time and creating memories of home. By actively designing something to trigger an emotional connection to a place where someone grew up or used to live, design has the power to resonate with a person's memories. In fact, design actually contributes to shaping new memories, providing events with authentic details that people replay in their minds and relive, in the form of reverie. Thoughtful design evokes emotion, mining the subconscious and planting seeds that come to life later, fusing past, remembered events with new, more meaningful experiences.

Mashrabiya once covered entire facades in the Middle East. Regional design techniques and cultural practices tied these ubiquitous elements to Arabs' architectural identity. *Mashrabiya*, as a result, became a distinguishing Arabic design element and feature. *Mashrabiya* were used in public spaces as a buffer between—for instance—people eating in restaurants and others praying in mosques. In addition, the distinctive screens ensured women's privacy, allowing women to see the outside world from their windows and balconies without being exposed. For Muslims, privacy is a necessity, not a luxury.

And yet, the use of *mashrabiya* has greatly diminished in the contemporary era, because some traditional aspects of its design do not align well with contemporary architectural practices, which have been adopted from outside the region. The uncritical use of imported building practices is generating a crisis of identity, privacy and energy usage in Middle Eastern society. Most new construction in the region has adopted the open, glassy, Western-influenced approach to construction, even though underlying Arabic cultural traditions, practices and beliefs have not changed. For a *mashrabiya* to be considered a *mashrabiya*, the design must complement the architecture of the Middle East region.

One consideration shaping contemporary architecture in the Gulf region is a process of conceptual abstraction and adaptation inspired from natural elements. Since connection to nature is deeply rooted in traditional Arabian culture and lifestyle, using parametric design to simulate natural features can offer a promising bridge for connecting forward-looking architectural expression with forms and ideas that resonate with Arabian heritage. An abstract reference to a celebrated regional geographic feature or geological phenomenon, such as the desert rose, evokes memories and emotions from Arabic heritage, recalling the region's nomadic desert lifestyle and tent living. The National museum of Qatar, for example, intentionally recalls the form of this sophisticated natural element, and other celebrated buildings in the region are also inspired by nature. Nature produces complex forms and systems, but at the same time, generates order and structured patterns from elemental shapes.

Generative design, a method that uses mathematical relationships to produce complex forms and patterns, is a useful method for replicating nature's sophisticated forms. This research uses algorithms and functions as a primary design method to create parametric patterns that recall the rhythmic patterns and organic shapes of nature. Employing advanced fabrication technology, it is now possible to materialize the sophisticated parametric design inspired by nature and apply it in real life. A goal of *The Algorithmic Mashrabiya* is to offer a new symbol for contemporary Arabian architectural identity—forward-looking but resonating with the past.

By using parametric design to generate new forms inspired by nature, the *mashrabiya* can once again become the signature design element that defines Arabian architecture in the Middle East. The aim of this thesis is to reimagine the iconic Islamic *mashrabiya* and transform it into a modern cultural artifact that is uniquely tied to Arabian cultural heritage, specifically in the Gulf region. Beyond the traditional religious element, with proscriptive rules guiding its pre-ordained pattern language, this research seeks to produce an artifact that reverberates with Arabic heritage and showcases cultural characteristics that Arabs cherish and respect. The *Algorithmic Mashrabiya* breaks longstanding rules demanding symmetry and instead introduces new forms and patterns driven by algorithms, which recall distinctive natural phenomena of the Arabian desert. Sunlight passing through this asymmetric, non-traditional pattern, covering the floor with tiny points of light, will be able to inspire new memories—memories that echo with the desert traditions of generations past.

Background

Biomimicry

Biomimicry is a process of generating inventive new solutions by looking to nature for inspiration. It is the concept of learning to gracefully live and adapt on Earth by consciously emulating life's genius. Instead of thinking that technology and biology are two separate entities, it is the technology of biology.[1] This research, while it does not claim to be an example of biomimicry per se, is inspired by biomimicry, and it uses nature as inspiration to create parametric patterns inspired by the rhythmic patterns of natural phenomena found in the Middle East region.

Generative Design

Generative Design is an exploratory process in which designers program intended design goals into software, along with parameters such as spatial requirements, materials, manufacturing methods, and cost constraints. The software gives the designer easy control over specific variables, accelerating the ability to explore multiple options and leading to better-informed choices.[2] Designers can also use the software to manipulate form, creating custom parametric functions to control geometric criteria. With the change of any parameters, the whole design is affected, offering the designer multiple points of control and providing a pathway to the best design solution conceptually and practically. In some cases, the machine itself can be programmed to determine the best iteration, according to custom criteria.

Generative Art

Unlike most common design approaches, generative art does not mean for the work to express our individuality, but rather express the chaos and abandonment of the processes—which represents the unpredictable different outcomes, free of our control. Generative artists are able to utilize the unpredictable, harness it and convert it into pleasing forms. In the production process, the role of the artist is more of a curator and less of a creator. The artist creates a system, models it, refines it and nurtures it, but the system itself is creating the design.[3]

Generative Art and Biomimicry

The generative artist comes from the world of logic to look toward the natural world for inspiration. However, the question arises: "Is there an obvious contradiction in using computers to explore the realm of the organic?" Can someone create work that he calls art with the intention of exploring aesthetics and emotions using merely procedures, logic and mathematics?

In fact, simplicity and complexity, order and chaos, and the mechanical and the organic aren't necessary at the opposite sides of the spectrum—both of each are intertwined. The mere existence of human beings is balanced between order and entropy—between the hostility of a chaotic environment and the simplicity of purest nothing. The mechanical and the organic are similar to the ordered and the chaotic; they are codependent. One would not exist without the other. A person may appeal to the complex just as much as the simple, the organic just as much as the mechanical. Current mood may sway one towards the other, but we do not go completely with one side and abandon the other. Perhaps: For us to do that is to stop living—in order to eradicate chaos, one must be a robot, and to eradicate order one must be a savage. The aim of natural inspiration via generative art is to use the mechanical to create the organic, starting from order and heading toward chaos without leaning too much toward either one of the two directions.[4]

Two design precedents illuminate these concepts and methodologies. First, Zhoujie Zhang's *Mashing Mesh Mirrors* deploys algorithmic design to mimic water, providing an example of natural inspiration via generative design. Next, Lilian Van Daal's *3D-Printed Soft Seat* uses biomimicry to inform the project's functionality, while also generating a structural/ material aesthetic that recalls the shape of plant cells.

· Figure (1.1)

· Figure (1.2)

· Figure (1.3)

Zhoujie Zhang, *Mashing Mesh Mirrors*

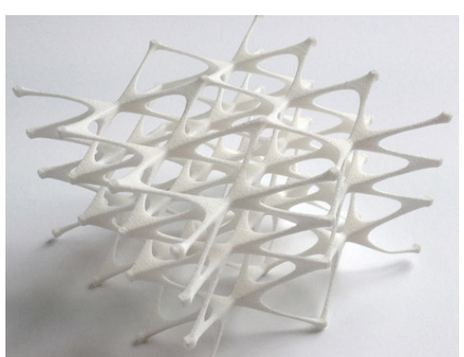
Derived from the natural movements of water, Chinese Designer Zhoujie Zhang uses computer algorithms to generate a dynamic surface. Modeling a series of dissimilar triangular meshes, Zhang uses parametric design to capture the unpredictable flow and movement of water. The sculptural surface is made from pieces of stainless steel, painstakingly polished and bent.

Zhang's exhibition includes five different wall mirror sculptures. Inspired by natural variety, Zhang's work produces five distinct variations, the light and shadow reflecting differently in different environments. Situated at different angles, the interlocking stainless-steel pieces present viewers with the precision of machine-made stainless-steel and also the unpredictable ebb and flow of nature, within each mirror.[5]

In this precedent, Zhang turns the water's movement into a frozen, still sculptural form. In Zhang's hands, natural inspiration is more of an expressive tool, as opposed to a method used to solve a design problem. The mimetic appearance is based on a hi-tech approach that puts algorithms to work at the center of the design process.[6]

· Figure (1.4)

· Figure (1.5)



· Figure (1.6)

Lilian Van Daal, 3D-Printed Soft Seat

3D-Printed Soft Seat, by Lilian Van Daal, rejects the ordinary approach to making a chair, where different materials and processes create the frame, padding and cover. Instead, inspired by nature, Van Daal investigates and adapts lessons from plant cells, creating a chair that is 3D-printed from a single material.[7]

Learning from the way structures in nature achieve varied properties from a single material, Van Daal imitates observed natural geometries to generate the aesthetic, structural and functional performance of the chair.[8] According to how the material is distributed throughout the design, the entire structure behaves differently. It allows some parts of the design to be soft and others to be rigid. The design is organic, with irregular density, to provide flexibility in the seat, while adding strength in the back, legs and joints, where structural performance is needed. Van Daal uses sophisticated optimization and stress analysis software to distribute material in the most efficient way possible.[9]

Generative Design and *Mashrabiya*

The name *mashrabiya* refers to a lattice screen, traditionally made from wood, located in front of windows. The word *mashrabiya* comes from an Arabic root used to describe the place where jars of drinking water were stored and kept cool.[10] Air flowing through openings in the *mashrabiya* cooled by evaporation as it flowed around and past the jars of water.[11] Due to this important role of controlling and tempering airflow within the desert climate, the Middle Eastern *mashrabiya* was constructed in a highly controlled manner, yielding a highly restrictive and consistent physical form. The careful craftsmanship required to build *mashrabiya*, in turn, required a high degree of technical skill and specialized labor.

Today, designers can access a custom Fast Fluid Dynamics (FFD) code in the 3D-modelling software Rhinoceros, powered by the computational plugin Grasshopper, to study airflow around buildings and related surface pressures. These studies allow the consideration of airflow during the conceptual design phase. Airflow has numerous effects on building energy performance, thermal comfort and occupant health. It impacts through-facade ventilation and passive ventilation techniques, and if designed carefully, natural ventilation can improve indoor air quality and thermal comfort while reducing energy consumption and building maintenance costs. Airflow analysis can greatly enhance the design of healthy, productive and energy-efficient built environments.[12]

By combining airflow analysis with the use of generative design to design *mashrabiya*, it is possible not only to make the design unique to a specific location's airflow, but it is also possible to generate a distinctive design aesthetic and identity of a specific region. This ability to customize creates new possibilities for the design of *mashrabiya*, moving beyond past aesthetic and functional limitations.

Hygro-Skin Meteorosensitive Pavilion, by Achim Menges Architect, in collaboration with Oliver David Krieg and Steffen Reichert, is an example of a project using biomimicry to naturally block or allow airflow through the building envelope.

Figure (1.7)

Hygro-Skin Meteorosensitive Pavilion

Hygro-Skin Meteorosensitive Pavilion uses the responsive capacity biologically embedded in a natural material to generate a naturally responsive physical system of airflow control. The pavilion skin contains clusters of spruce cones. As the spruce cones open and close, in response to changes in humidity and temperature, they act as small windows in the skin of the pavilion. The operation doesn't consume any energy and is intrinsic to the material's hygroscopic behavior and anisotropic characteristics—hygroscopicity is the material's ability to take in moisture when dry and yield moisture when wet, while anisotropic refers to the directionality of the material's characteristics. In simple terms, when the cones get dry, they open, and when they get wet, they close. Hence, the movement is dependent on the wood's intrinsic capacity to interact with the external

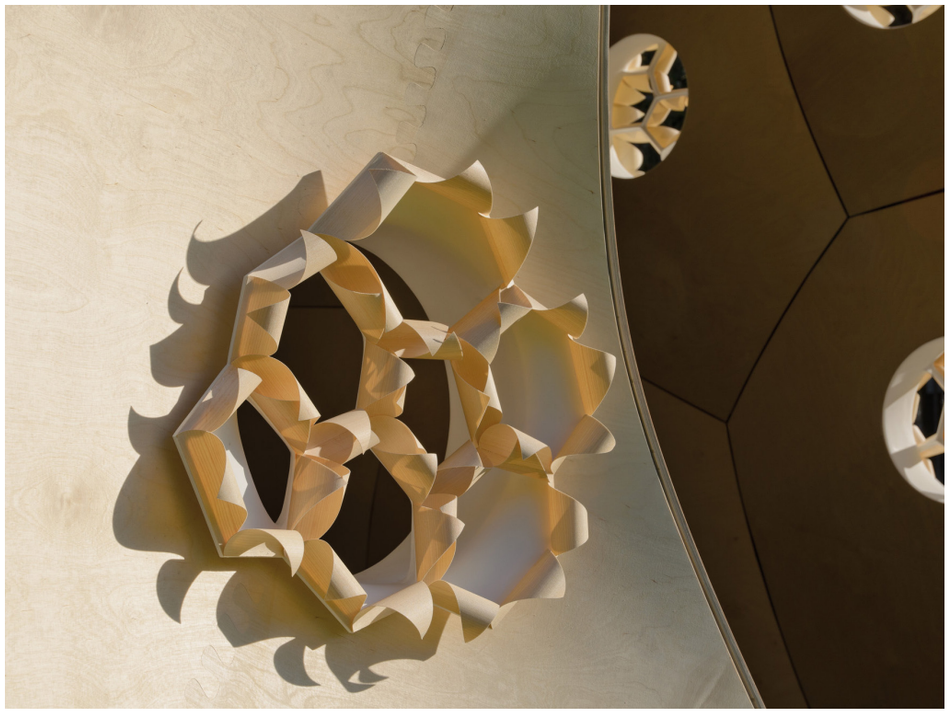


Figure (1.8)

environment. The shape of the pavilion itself is inspired by the bending behavior of the plywood sheets. The apertures on the structure respond to relative humidity, thus the entire pavilion constantly adapts to its immediate environment, with constantly changing degrees of openness and porosity. The most unique feature of the pavilion is that it provides a convergence of environmental and spatial experience. The delicate, constantly changing structure subtly moves, as the result of its meteorosensitive skin. The ability to react, sense and actuate are all embedded within the material itself. The project investigates biomimetic principles for responsive facades without using sensory equipment, motor function or energy input.[13] In contrast to Zhang's hi-tech approach to nature inspiration, *Hygro-Skin Meteorosensitive Pavilion* pursues a no-tech method to achieve airflow sustainably.

Mimicing Nature in the Middle East

The natural elements at the root of Arabic heritage in the Gulf Region are the desert and the water. From these two extremes traditional Arabs made their living: fishing and collecting pearls from oysters in the sea, and raising sheep, goats and camels in the desert.[14] Dependent upon nature, Arabic culture is deeply tied to the appreciation of nature—natural elements hold sentimental value to the Arabs, tied to an ancient lifestyle and way of living that Arabs cherish deeply. Contemporary architectural designs that recognize this cultural tie resonate with people who live in the Middle East. Two such buildings, inspired by nature, are the Qatar National Convention Center, by Arata Isozaki and the National Museum of Qatar by Jean Nouvel.

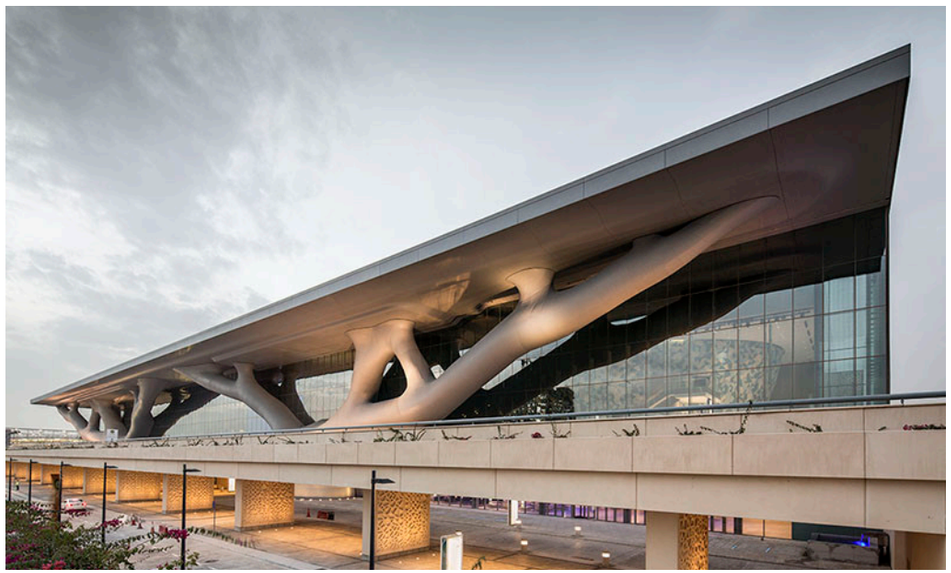
QATAR National Convention Center (QNCC):

The QNCC officially opened in December 2011 and is considered one of the most sophisticated convention and exhibition centers ever. Its iconic design features a giant sidra tree façade, a nod to the famously resilient tree that is the symbol of knowledge and gathering adopted by Qatar Foundation. Supporting the exterior canopy, massive organic columns, resembling two intertwined trees, form the building's distinctive façade.[15]

The sidra tree provides comfort and shade in the desert, offering a place to gather, fostering exchange between travelers, and becoming known as a haven for poets and scholars who shared knowledge beneath its branches. Isozaki 's design references the Arabic connection to nature by referencing this valued narrative. [16]

National Museum of Qatar (NMoQ):

Jean Nouvel's *National Museum of Qatar* draws inspiration from the desert rose, a mineral formation found in deserts of the Gulf region. A desert rose forms in the sandy soil when minerals crystallize beneath the surface of a shallow salt basin. The museum consists of large interlocking disks, circular in shape, with varying diameters. The finishes are monochromatic, and the floors are sand-colored polished concrete. The cladding and the sand-colored concrete illustrate the harmony between the building and its surrounding desert landscape. Exhibits focus on the environmental, political and cultural history of Qatar. The museum explains how people cultivated and lived in the surrounding harsh desert environment.[17]



Qatar National Convention Center, Figure (1.9)

National Museum of Qatar, Figure (2.0)

Investigation

Two main factors define the success of any design element: concept and function.

Concept

The traditional *mashrabiya* is known for its distinctive aesthetic and mesmerizing beauty. People admire the way a *mashrabiya* looks on a building's façade—the elegant wooden structure attached to the side of a building, the varied patterns in harmony with each other, the dazzling interior light show within, caused by desert sunlight piercing its openings. But there was never a concept organizing the collection of patterns, or creating meaning from the mathematical geometries derived from Islamic art. There is no record of a clear, consistent idea driving the aesthetics of traditional Middle Eastern *mashrabiya*. Functionality has always been the main concern, with a nod to formulaic ornamentation. Like so many things, the cultural and conceptual significance were not fully apparent.

This section defines the concept behind the aesthetic of *The Algorithmic Mashrabiya*. In order to do this, one has to explore the history of Arabic people in the Gulf region, to understand their traditions and define a concept that is relatable and understandable, a concept that will resonate.

In the past, Arabs' lives were dependent on nature. Nature, in this context, consisted of sand and water. Bedouin people lived in tents, raising sheep and goats for milk and meat, camels for transportation, and sometimes they fished to obtain an alternative source of protein. Sand was where they lived—they slept, walked and ate on sand every day. For this reason, sand retains an irreplaceable sentimental value among Arabs. As part of their nature, Arabs are very religious and spiritual people. Religion plays a huge role in shaping Arabic culture and tradition. Arabic people pray to God yearly for the rain to fall, rain that provides for their essential needs and brings prosperity. Rain represents prosperity, as it is the primary source of pure drinking water, nourishing animals and plants in this region without rivers or other means to obtain clean water in the immediate environment. In fact, the rain prayer takes place annually—to the day—at the beginning of winter. If God does not send rain, Arabs perform good deeds and pray again until rain comes to the land. This behavior is part of what makes Arabs unique. It is what makes them proud of their origin and religion. It is what makes them spiritual people who value natural elements.

Cracked Sand

Because of the crucial roles that sand and rain play in the lives of Arabs, the concept of *The Algorithmic Mashrabiya* is derived from the combination of these natural elements: rain plus sand. When rain hits desert sand, it sometimes produces a phenomenon known as cracked sand. Cracked sand occurs after rainfall, when wet silt is exposed to the sunlight and quickly dries on its surface. Tiny particles draw close together and aggregate into a compact layer, trapping moisture beneath, creating tension. The drying silt endures internal stresses, which act around focal points as the material contracts, initiating irregular cracks around seemingly random, vaguely cellular clusters. The resulting action carves the sandy surface into a network of irregular islands, separated by crevasses that relieve the tension and allow the underlying moisture to evaporate.[18] An underlying unpredictability gives the network of cracks a distinct characteristic—at once geometric and chaotic. Randomness and disorder within the structure provide a background "noise." Anyone familiar with the arid desert.

Figure (2.1)

Mimicing Cracked Sand

Since cracked sand is random and irregular, it is a perfect example of a natural feature that can be replicated using algorithms and functions. Drawing such irregular shapes using traditional manual drawing techniques would be tedious, or impossible, due to the infinitely variable shapes and sizes needed to replicate such an irregular organic form. Algorithmic functions, on the other hand, allow a designer to create a framework to generate the design parameters needed for a randomly generated, organic-feeling pattern. Also, algorithmic functions allow the designer to control the level of apparent chaos and randomness within the design, while at the same time manipulating the scale of the network of cracks. In order to capture the character of cracked sand as closely as possible, *The Algorithmic Mashrabiya* uses Grasshopper, which is a plugin for the 3D-modelling software platform Rhinoceros.

Grasshopper

Grasshopper is parametric design software that allows designers to create within a digital space functions that are strategically selected and connected in sequence. In Grasshopper, to create *The Algorithmic Mashrabiya*, I created a series of points, next to and on top of each other. Each point represents the center of one island of cracked sand. Next, I used the command “Voronoi” in Grasshopper. Voronoi is a command that creates geometric shapes by creating a system of dispersed points. Each point relates to a surrounding radial, area; these areas, around different points interact to form cells. At the place where neighboring cells meet, they form a boundary. In 2D space, the boundary forms a bisection line, which partitions the planar surface. [19] Using this command allowed me to create a series of asymmetric geometrical shapes around a series of points, distributed in an irregular manner to intentionally resemble the appearance of cracked sand (Fig 2.2). I patiently adjusted the parameters of the functions, focusing on capturing the randomness of shape and the degree of variation between cells and the overall scale and pattern density (Fig 2.3).

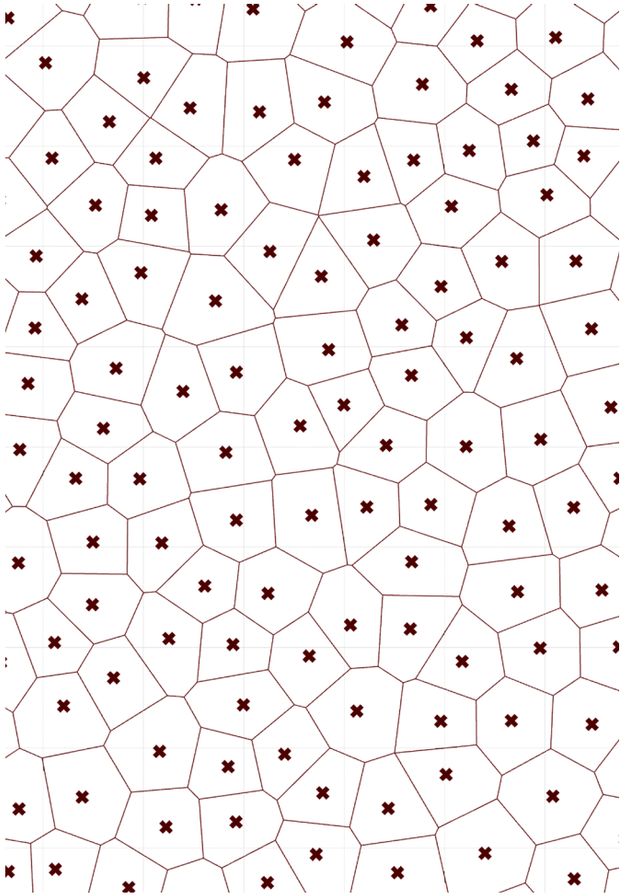


Figure (2.2)

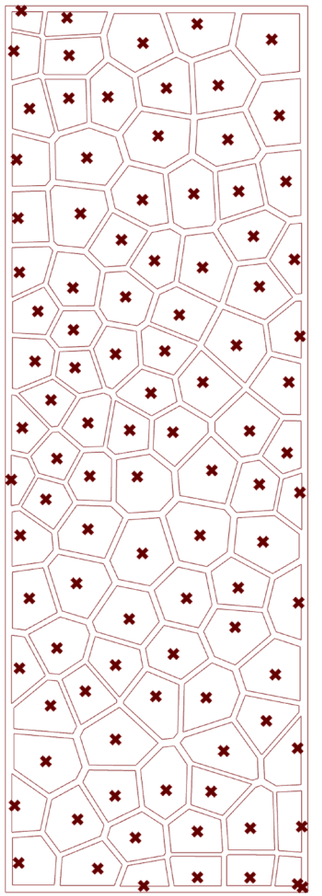


Figure (2.3)

Attractors

After adjusting the parameters to arrive at settings that best approximated the appearance of cracked-sand islands, I added a new component to provide control over the scale of individual cracked-sand islands, fine-tuning the relationships from one to another. As the islands rhythmically and fluently varied in scale, the appearance became both more natural and also—paradoxically—more intentional. As illustrated in Figure (2.4), there is a certain flow one can feel, related to the changing scale of the islands. To achieve this, I added an additional crucial component in Grasshopper, called attractors. Attractors are sets of points that influence the whole design. I defined the distance between the attractors and the cracked sand islands to be the factor determining the scale of each island. I drew a curve that cut through the entire design and then divided this curve into a series of points, defining them as attractor points. As a result, the distance between these attractor points and the points within each cracked-sand island determined the scale of each cracked-sand island. The smaller the distance, the bigger the cracked-sand island. This set of relationships added a degree of ordered randomness to the overall pattern. The goal was to balance order and disorder, and to intentionally generate a design that appeared as organic as nature. The cracked-sand islands become the openings in *The Algorithmic Mashrabiya* with ribs between, to hold the structure together.

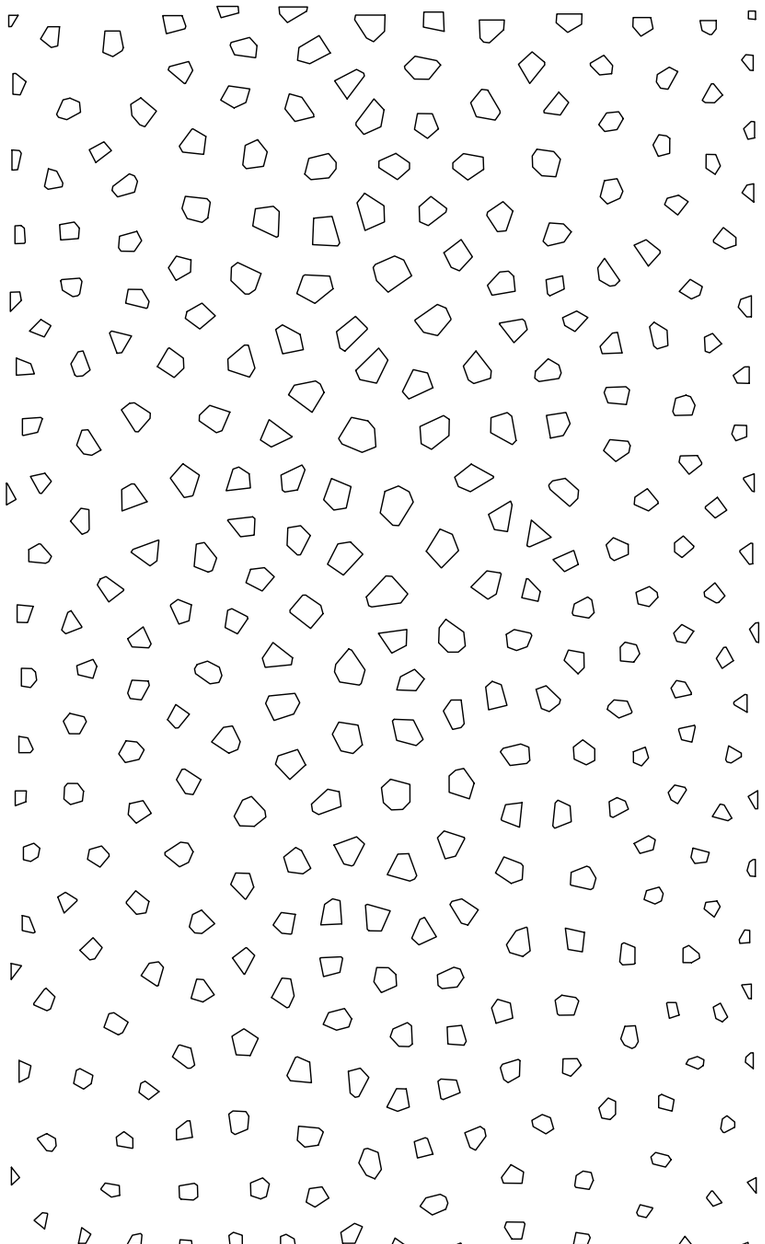


Figure (2.4)

A Second Set of Cracked-Sand Islands

After creating algorithms to represent the cracked sand phenomenon, and after manipulating parameters to control the scale of its many openings, I developed a second set of algorithms to add an additional layer of detail and refinement. The first set of algorithms created holes that go all the way through the *mashrabiya*; these holds relate to a user's vision—the closer the openings are to the center of the structure, the larger they become. The second set of algorithms created a recessed pocket on the surface of the mashrabiya, but did not penetrate all the way through the material (Figure 2.5). Together, the two sets of actions provided control over the degree of privacy, while adding a second layer of detail that added control over the pattern's density. The result provided unity to the design, and aesthetic continuity on the outward-facing side of the *mashrabiya*, while maintaining a simple and elegant interior surface. The resulting contrast between the two sides of *The Algorithmic Mashrabiya* generated two different user experiences, depending on which side is visible. The outer side, facing the street, has the second set of recessed cracked-sand islands, in addition to the smaller openings. The effect this has on one's experience is that the inner part contains only small openings, offering clear vision and privacy to the inside inhabitant, while observers on the outside see a dynamic scene, consisting of two interwoven patterns—an low-relief sculptural surface, in addition to the smaller center holes providing discreet views from the personal space within.

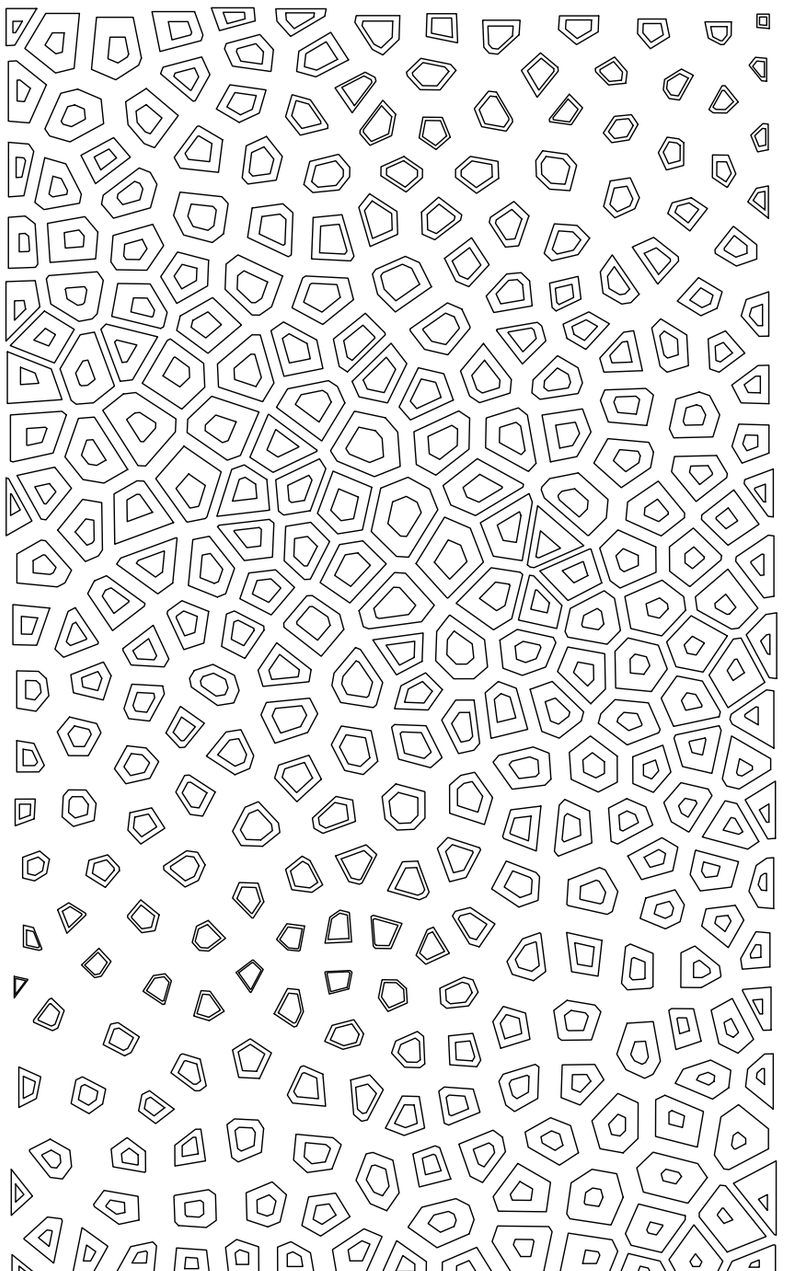


Figure (2.5)

Functionality

Parametric design allows designers to fine-tune variables that not only affect appearance, designers can also make adjustments to make the design as practical and functional as possible. For *The Algorithmic Mashrabiya*, functionality consists of four main features: privacy, structure, sustainability and user experience.

Privacy

Privacy has always been a primary concern within Arabic society and households. The need for privacy between men and women is especially keen in the Middle East. Islam offers clear guidance on the topic of privacy and strongly advises against exposing the private lives of other people. Every Muslim takes privacy into account when building a house. A key reason for the development of traditional *mashrabiya* was to prevent people outside in the street—particularly men—from gaining views into the interior of the home—especially spaces where women spend time. The patterns prevented people outside from seeing inside, while still allowing those inside to have a protected view. As traditions developed, however, the Islamic patterns of typical *mashrabiya* began being repeated, expanding across the entire structure for the sake of continuity, but leading to a degree of inflexibility, preventing designs from achieving different levels of functionality in different parts of a building.

To allow a discreet view out, a hinged triangular window swings out, giving an inside occupant control over her environment, allowing the occupant to look out into the street. The triangular window coincides with an area of the surface where the openings are small and spaced apart from one another, ensuring enough material between openings to cut the joint that creates the window.

With the cracked-sand motif of *The Algorithmic Mashrabiya*, the pattern is less rigid than traditional Islamic *mashrabiya*. The shapes and sizes of the cracked-sand islands are able to vary and change as needed. No two openings are the same. In *The Algorithmic Mashrabiya*, openings at eye level are larger than others. Openings below the view line of interior occupants are much smaller, to maximize privacy and create a sense of safe sanctuary within the household. There is no mandate for hole size, instead, an organic flow controls the size of the openings across the surface of the structure.

Sustainability

Islam strongly advises against wasting resources. Prophet Muhammed taught people to value their resources and to avoid wasting money on frivolous things. A primary goal of *The Algorithmic Mashrabiya* is to save energy by blocking direct sunlight and reducing heat gain. In the extremely hot desert climate of the Middle East, shielding glass windows from direct sunlight can significantly reduce energy consumption. With parametric design's ability to make dynamic adjustments, *The Algorithmic Mashrabiya* models a careful balance of solid and void openings, creating a pattern solid enough to prevent direct sunlight from entering during the hottest parts of the day, but transparent enough to allow views at the eye level and the middle part of the *mashrabiya*.

Structure

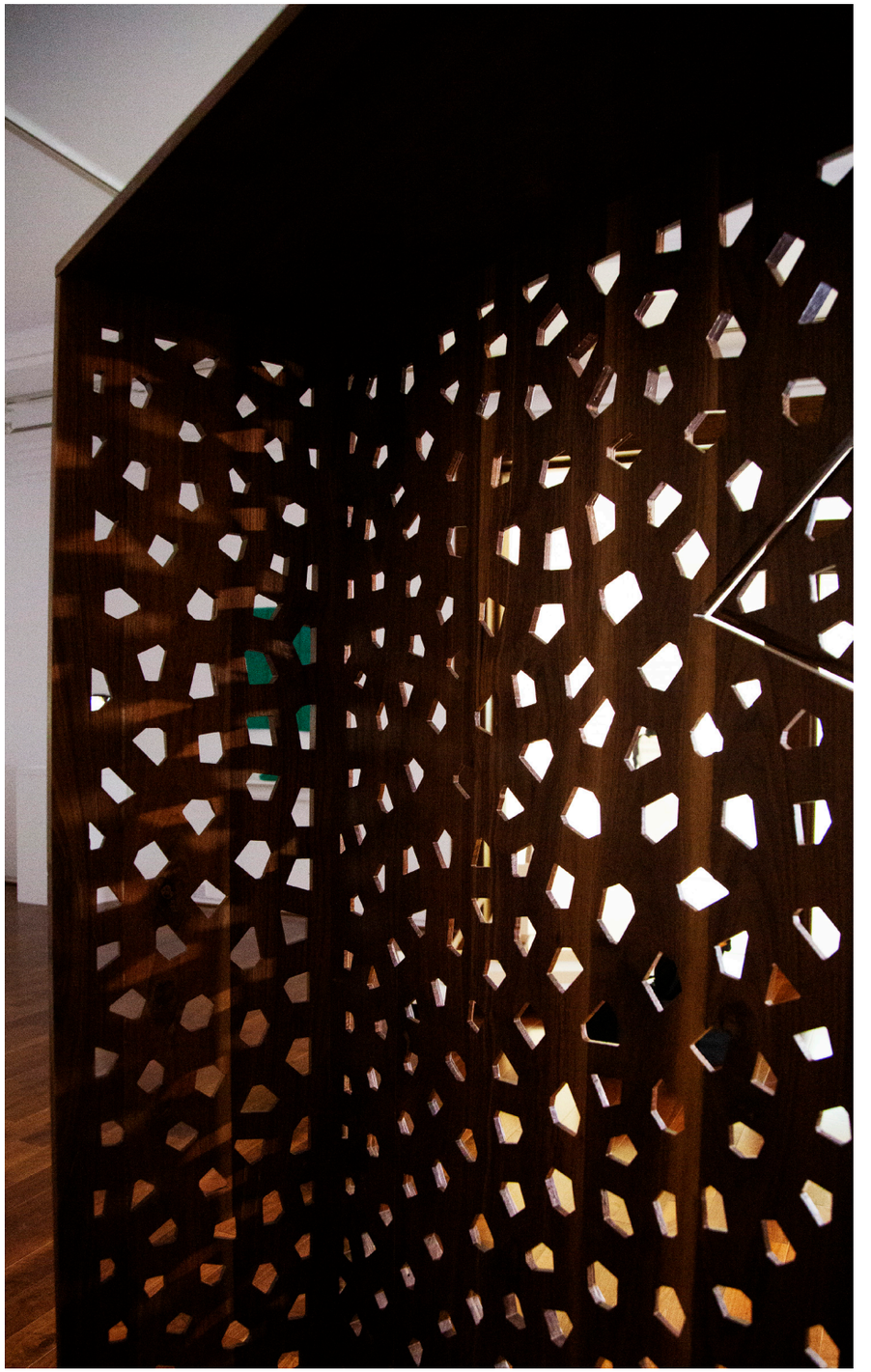
The Algorithmic Mashrabiya consists of three joined panels—front 1.2 x 2 meters and two side panels 0.45 x 2 meters. With an additional top surface and thick base, dovetail joints connect these five elements—made from solid walnut—into a sturdy, stable box. Openings near the bottom of *The Algorithmic Mashrabiya* are smaller, where the sides join the base, at the location where the stiffness of solid material is needed most. At the edge of each panel, a 2-centimeter zone remains solid, providing support for the joints and adding stability to the finished structure.

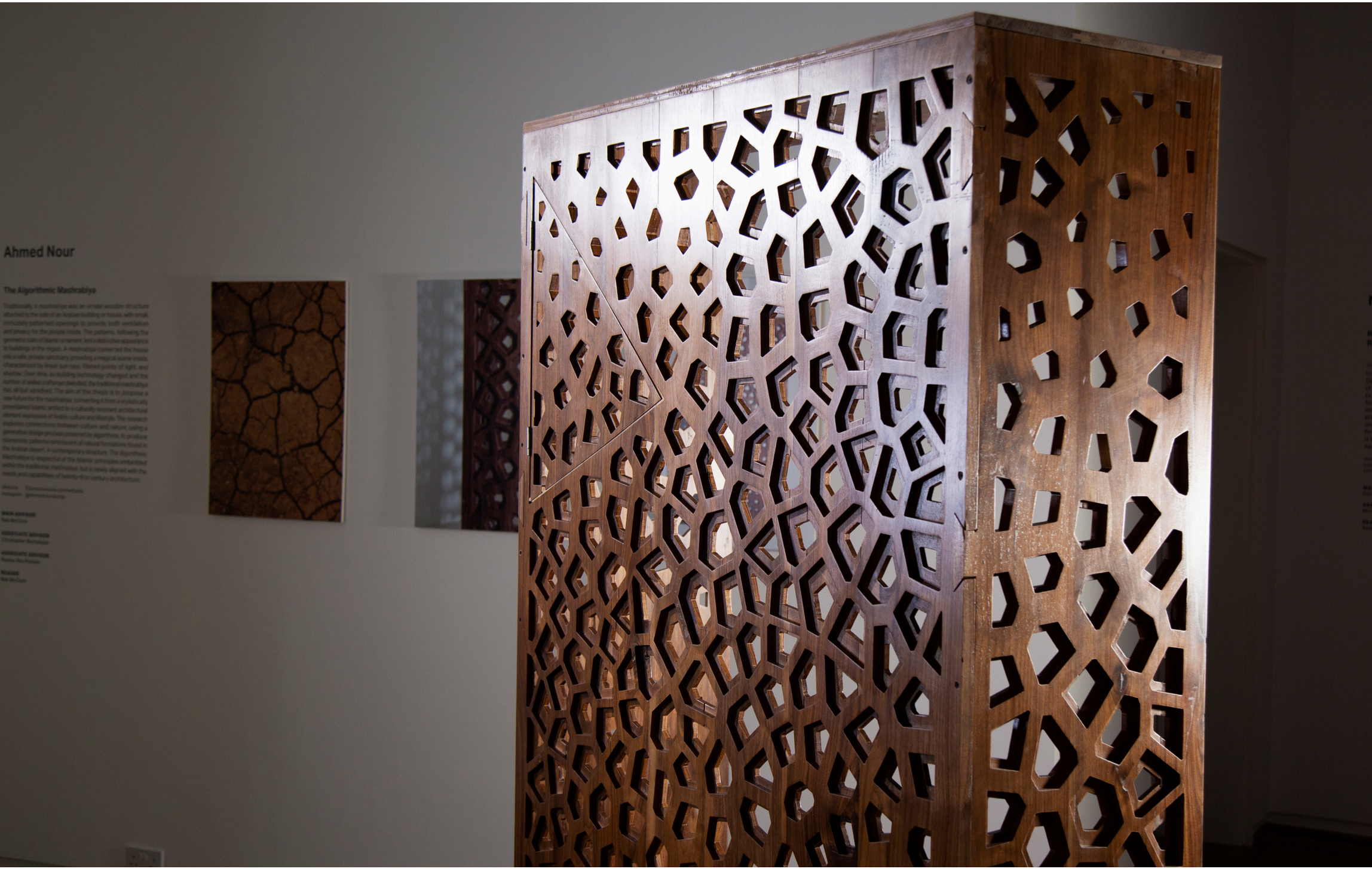
User Experience

The Double-Sided *Mashrabiya* Design

Unlike traditional *mashrabiya*, *The Algorithmic Mashrabiya* offers duality. The occupant inside feels a completely different experience from the outside observer. The inside occupant sees the outside street clearly, while at the same time benefitting from a concealing pattern that provides privacy, shields the interior from direct sunlight and features patterns made from points of light in high contrast with the shady, protected interior (Figure 3.2). The outside observer sees a rich, sophisticated patterned surface filled with light and shadow, designed to complement and embellish the supporting architectural façade. The outside observer sees a patterned sculptural building feature, which conceals the occupant inside and protects the privacy of personal space.

Using algorithms to create layered effects, the designer can easily adjust the parameters that control the randomness, rhythm and scale of carved surface patterns. In other words, one can produce varied outcomes that appear very different from the outside, while maintaining the same hole pattern, with its inherent structural, sustainable and privacy benefits. *The Algorithmic Mashrabiya* can be customized to meet the needs of each individual user. *The Algorithmic Mashrabiya* benefits, on the one hand, from ordered randomness, which yields a richly varied, but calmly simple pattern of porous openings. The second layer of control offers the dynamic additional option of irregular, carved geometric shapes. This dual nature provides each perspective—occupants and observers—a completely different spatial experience, based on one's point of view.

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The Algorithmic Mashrabiya

Conclusion

The Algorithmic Mashrabiya is designed to be unique—to be asymmetrical, irregular, chaotic and random, but at the same time rhythmic, parametric, and organized by an organic flow and order. The project proposes a new type of *mashrabiya*, adapted to better suit the needs of the contemporary world. New fabrication technology, driven by parametric design, achieves results that would have seemed inconceivable in the past. Inspired by natural features that are distinctive to the Middle East region, *The Algorithmic Mashrabiya* is designed to resonate with Arabian heritage and the collective cultural memory of Arabic people. The dual design allows the exterior building façade to be uniquely tailored, without changing the sizes of the actual openings or reducing functionality. By changing the design settings for just the exterior-facing, recessed layer of cracked-sand islands, the design's appearance changes for the observer. The complexity of the two interwoven cracked-sand patterns allows for a wide range of possibilities. The flexibility of parametric design offers new aesthetic and functional design possibilities that promise to ensure *mashrabiya* will continue to provide fascinating architectural facades for users to experience and appreciate.

Future Directions

I intend for this design to be replicated and customized mainly in the interior and on the exterior of residential buildings, though it would also have useful applications in public buildings. Unlike the traditional *mashrabiyas* that were added to windows ad hoc, without coordinating design motifs across multiple, adjacent *mashrabiyas*, I intend for *The Algorithmic Mashrabiya* to be able to complement other design elements on the same façade. I intend to utilize the organic flow of the cracked-sand islands to relate all *mashrabiyas* across the building façade. The project's parametric design features allow simple adjustments that instantly change the design, meaning each piece can be unique. But by drawing a hidden line that passes through all of the *mashrabiyas* on one house or building, the rhythm of all of the *mashrabiyas'* patterns will be related, across the entire façade. This feature, of added design flexibility, could allow the *mashrabiya* to once again define the architecture of the Middle East Region. In addition, because Arabs are known for their hospitality and frequent gatherings, the design features of *The Algorithmic Mashrabiya* could operate within interior spaces as well, where parametric screens could distinguish between personal interior spaces and public open spaces in buildings such as restaurants and mosques. *The Algorithmic Mashrabiya* could bring distinctive aesthetic value to the region's interior spaces, serving as artistic sculptural pieces that also serve crucial functions within the space. By addressing the cultural and functional needs of Arabian society while also recalling patterns and formations from the surrounding natural world, *The Algorithmic Mashrabiya* promises to convert sunlight into patterned points of light that will shape the memories of future generations.

List of Figures

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