Logic to Artefact

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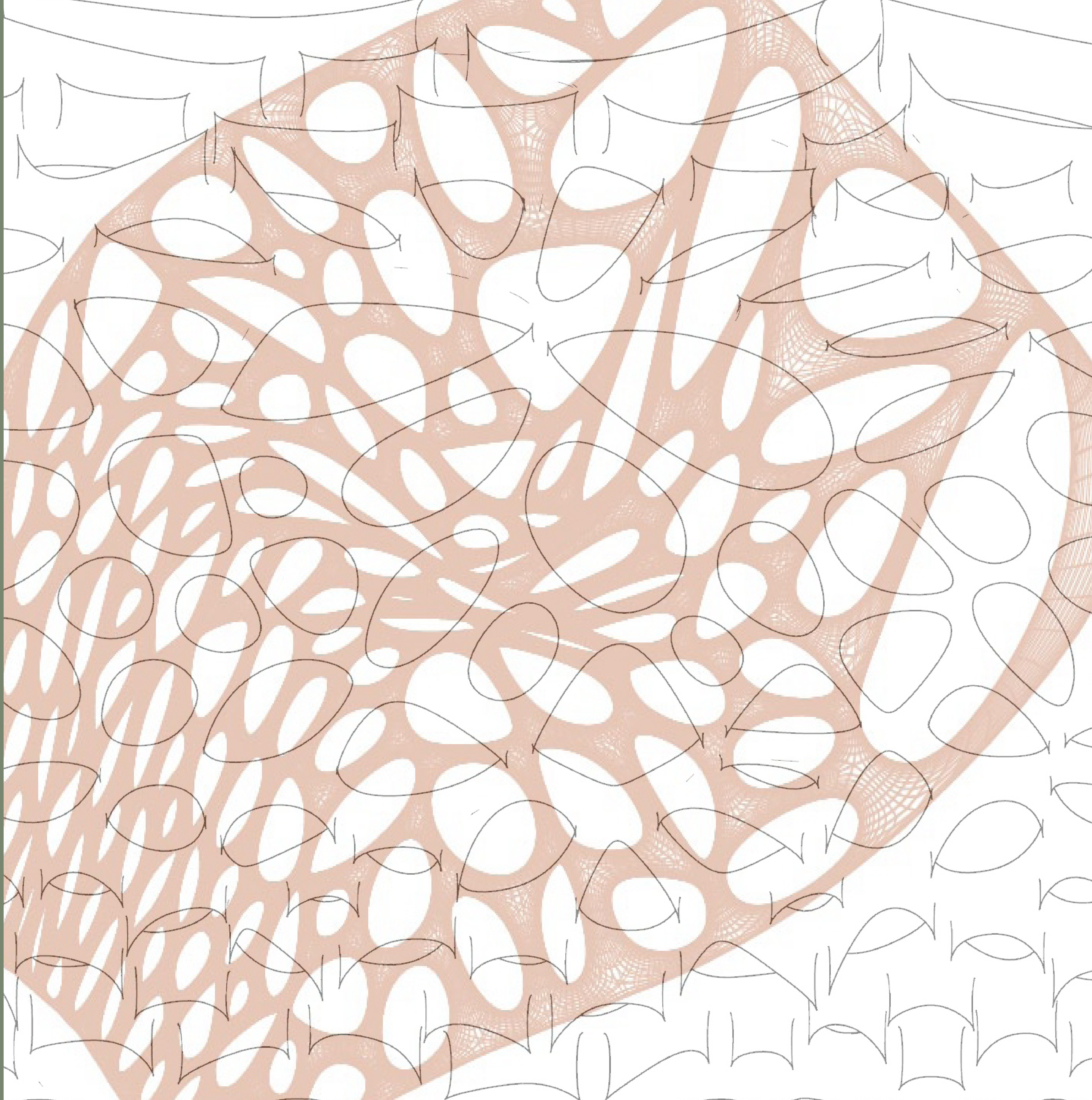
22057680



PATTERN LANGUAGE
Introduction

Pattern Systems

Patterns can be described as specific recurring events and repetitive material formations. This implies that patterns can range from energy to matter. In natural systems most patterns are generated by the interaction and mutual modulation of both energy and matter (M. Garcia, 2009).

My book review was on Branches by Philip Ball. He states that there are fundamental patterning processes that recur in nature, operating identically in many different settings. What nature uses is not a Law of Patterns but a set of principles which repeat but not necessarily regularly or with defined symmetry (P. Ball, 2009).

Mark Garcia explains that patterns are neither an exclusive material or appearance condition because this ignores the processes that underlie the formation of patterns. Both form and pattern can arise out of processes of self-organisation. This follows a logic of interaction rather than a logic of one-way causal effects. Therefore, the design process can involve pattern generation for both material conditions and form-finding. (M. Garcia, 2009).

The Importance of Patterns in Architecture

A pattern can provide a well-proven solution to a recurring design problem that arises within a specific design context. The solution is specified by describing the roles of its constituent participants, their responsibilities and relationships, and the ways in which they collaborate (F, Buschmann et. al, 2007). The pattern describes the core of the solution to that problem, in such a way that you can use the solution a million times over, without ever doing it the same way twice (C. Alexander (1977).

Kengo Kuma declares that completely new patterns can be generated and they will produce entirely different spaces and architectures. He follows on to say that pattern making holds the greatest promise for the next generation (A. De. Looz, 2006).

The ideas behind pattern formation are not new but we can start to understand design pattern morphologies in digital reworkings of ancient patterns in nature (e.g. waves) or new ones (e.g. DNA). They are designed using genetic algorithms and simulated with new visualisation techniques. Some examples of these patterns are soap bubbles, swarms/ flocks, voronoi cells and fractals (M. Garcia, 2009).

Image: Frank Gehry, Ungapatchket, Venice Architecture Biennale, 2008.
The voronoi patterns of material, environment and time appear in the hand-applied clay surface of Gehry's installation.

THE BRIEF
Introduction

Self-Replicant Form-Finding

The output of this project is to define the rules of an L-system as a foundational logic for a small structure (capacity of 1-3 users). This project is going to be built on a simple set of rules that, when repeated, create a complex structural system.
There will be 3 computational methods that can come together to create a small structure or stay as individual elements to create 3 separate structures.

By the end of this project I will have learnt to:

- Interpret Pattern Language theory and form-finding methods and recognise the interrelationship with computation design processes in academia and practice.
- Flexibly and creatively select appropriate computational and fabrication methods by proactively undertaking substantial investigations to address an architectural system design.
- Present an interpretation of fundamental Pattern Language and form-finding theories in a crafted artefact, graphical and verbal illustration at a high level of abstraction, arguing from competing perspectives (Logic to Artefact Brief, 2022-23).

Biophilic Hide (Group)

This project proposes a nature hide, for the purpose of connecting and integrating humans more closely with nature. The aim is to abstract patterns and structural formation from the natural environment, such as bird murmurations, predator/ prey relationships and Voronoi patterns. These abstractions are utilised with the goal that the structure will disguise the human build as an organic formation, developing a symbiotic environment.

Concept Model (Group)

This physical prototype model was developed to present the overarching logic of this shelter, showing how void forming and surface wrapping will be used to generate the space. The modelling process informed the design, helping realise the movement and deformations of the surface when wrapped.

BIOPHILIC HIDE

3 Computational Methods

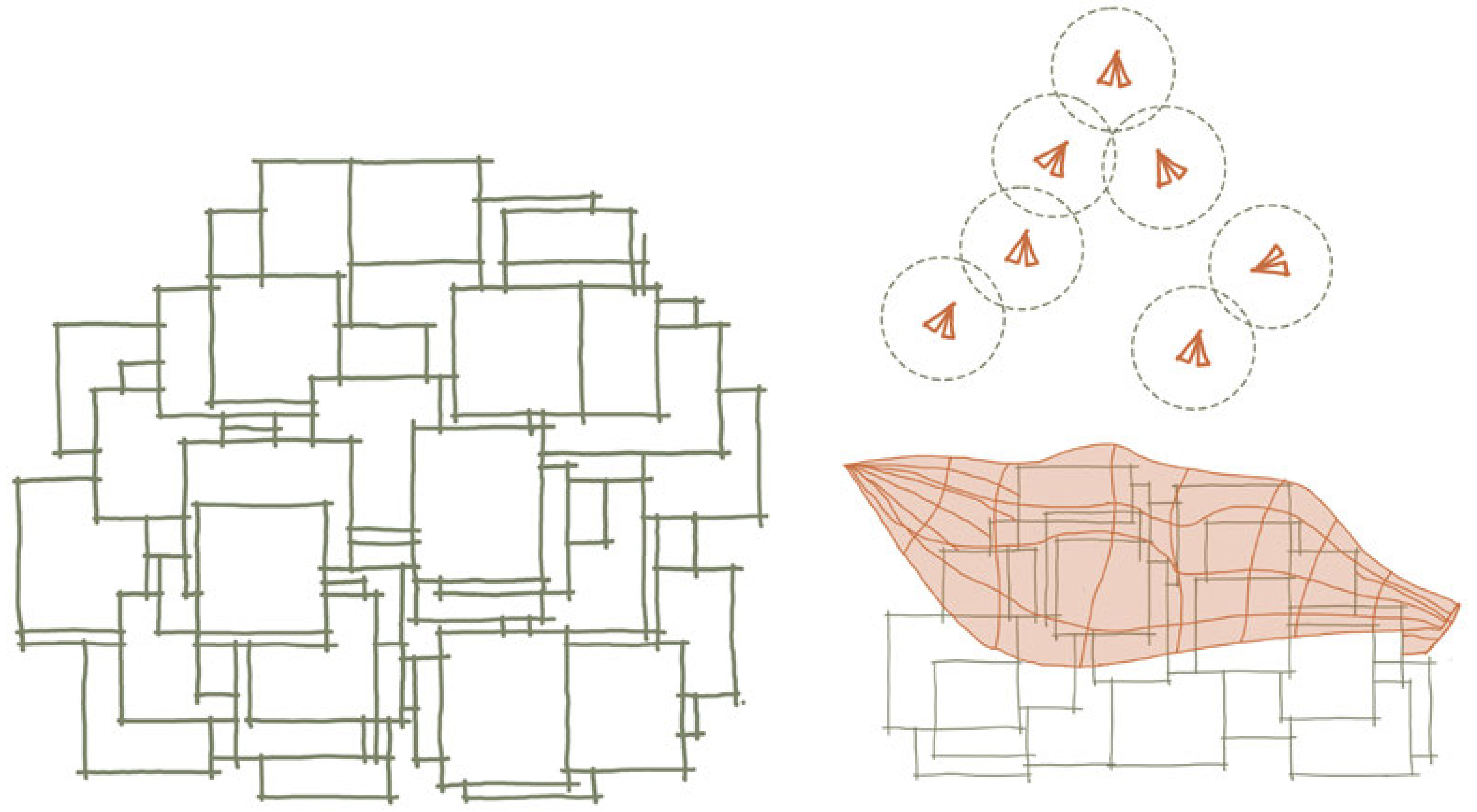
1. Agent Based - Form Finding (Felix)

The form finding process for the hide will be generated through an agent based modelling method. The intent is to use a flocking system to mimic the movement of starlings in murmuration and the dispersed density form. The intention of this methodology is not to dictate the design but to inspire the form. This practice is similar to the works of 'Agent-based modelling for early-stage optimization of spatial structures' (S. Zagar, et. al, 2022).

The actions of the agents will be dictated by the following three laws:

1. Attraction
2. Repulsion
3. Alignment

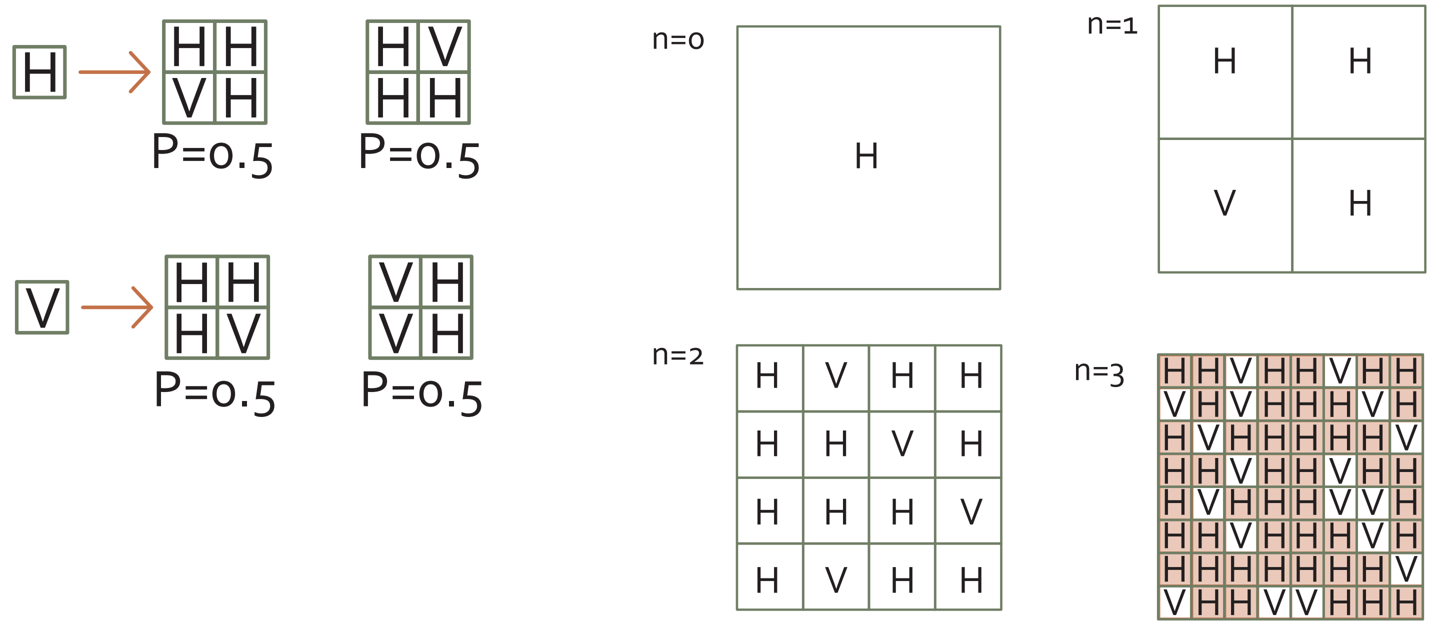
The algorithmic approach to these actions is extracted from 'An all-leader agent-based model for turning and flocking birds' (E. Cristiani, et. al, 2021).



2. L-system - Surface Structure (Zak)

Relating to the oscillation of the BZ reaction, the predator-prey model shows L-systems within nature. The initial theory of this design was to represent prey as H: Hide and predator as V: View allowing the predator (V) to perforate through the prey (H) creating viewpoints within the surface.

The rules assigned resembles there being more prey than predator. Each iteration takes the result of a cube and presents one of two possible outputs for either result. Each cube in the iteration will be divided into 4 equal segments closely following an exponential pattern within the number of cubes.

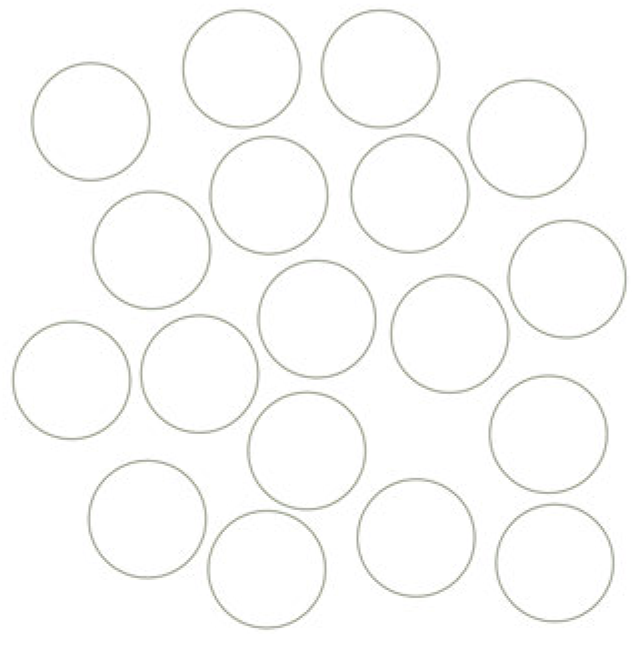


3. Voronoi Algorithm - Surface Design (Myself)

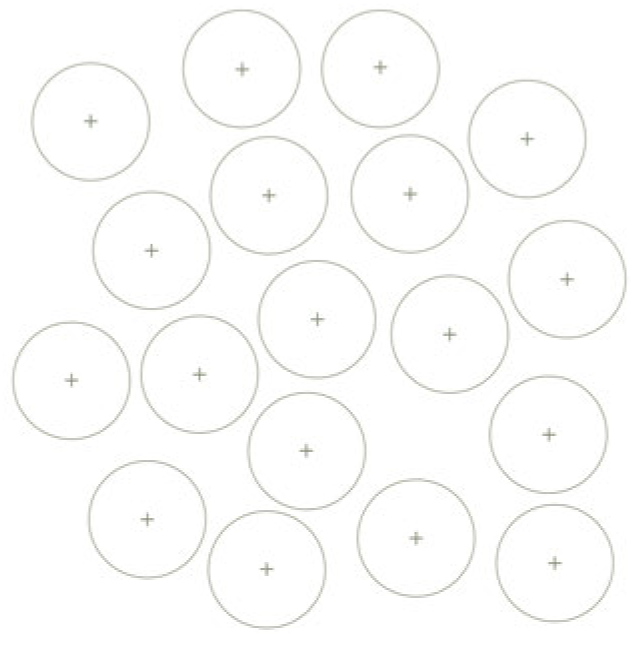
The Voronoi algorithm is the partitioning of a plane with n points into convex polygons so that each polygon contains one generating point and every point in a given polygon is closer to its generating point than to any other. If all the points are on a grid, each region will always be the same and is sometimes known as a Dirichlet tessellation.

Voronoi diagrams are applicable whenever there is growth, in all directions at the same speed, from n points. There are many uses for the Voronoi diagrams of irregularly distributed seed points. In 2D they can be used in studies of retail store utilisation, animal territories, and dividing a city into districts. In 3D they can be used as models of foams, grains in solids, biological cells and cosmic web patterns.

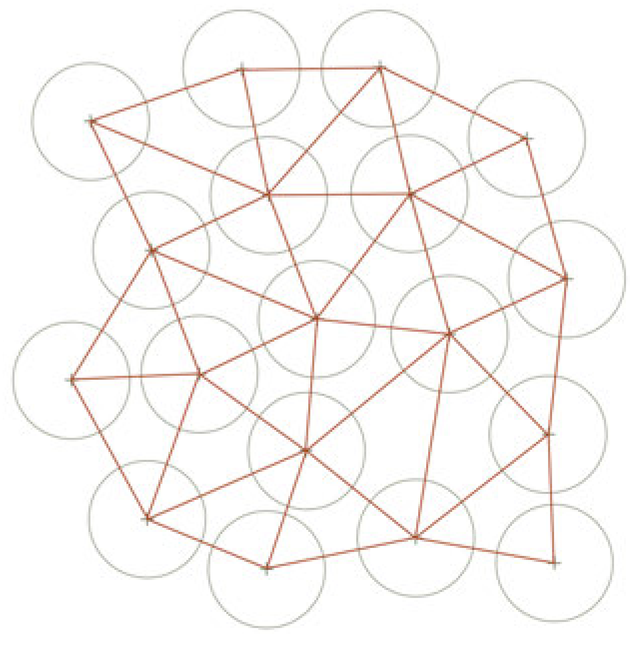
Efficient algorithms for constructing Voronoi patterns can now be produced by modern computational methods. This has allowed them to be used in mesh generation, point location, cluster analysis and many other computational tasks (S. Wolfram, 2002).



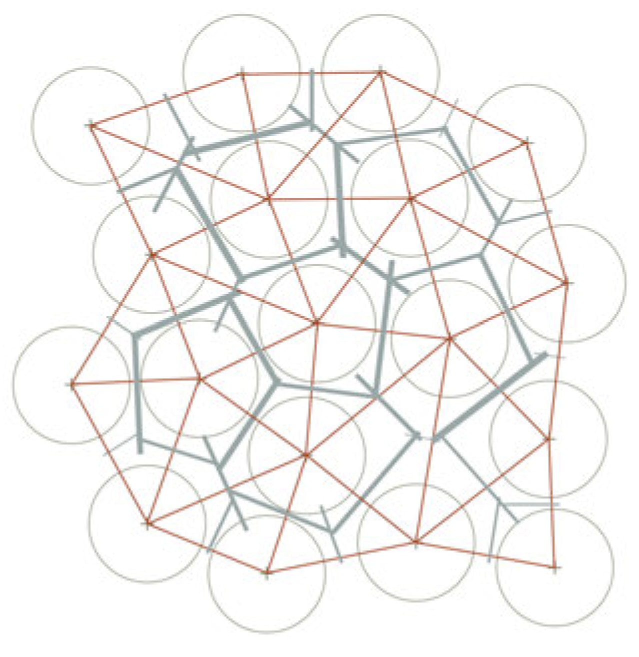
1. Circles with the same radius



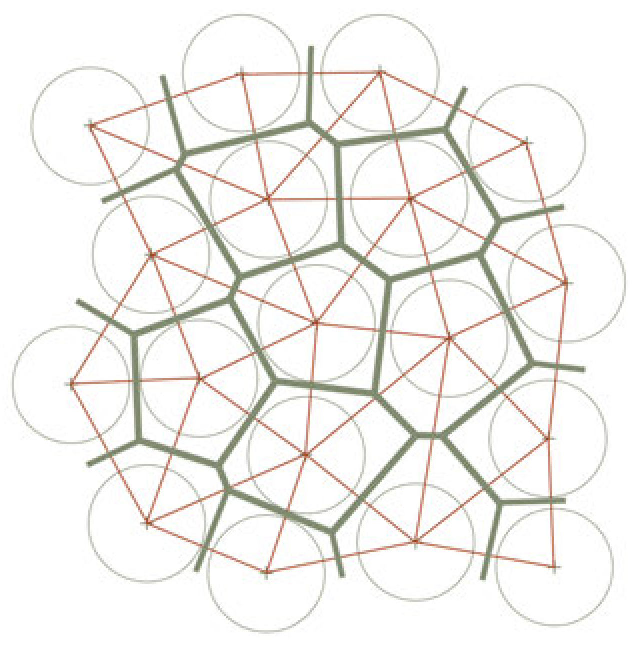
2. Centres of the circles



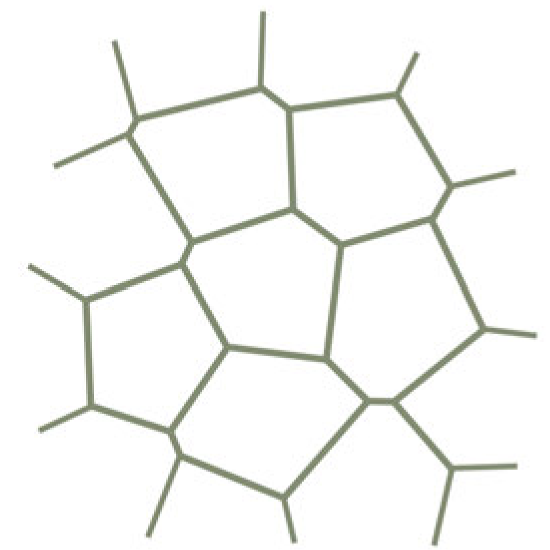
3. Find nearest neighbours (Delaunay Triangulation)



4. Bisect the connected lines



5. Connect the dots



6. Final Voronoi pattern

Voronoi Pattern
In Nature

Voronoi patterns are found in nature in many forms, as we can see in the images on the right.

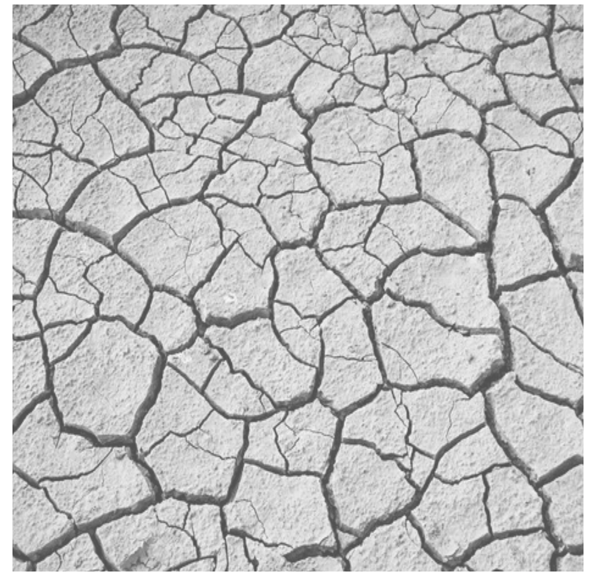
Branches by Philip Ball (Link to my Book Review)

In his book Ball has a chapter about Cracks. Some cracks don't form from a single point but all at once. This creates a reticulated web. An example of this would be the mud at the bottom of a dried pond. The whole surface contracts but it cannot shrink, like dried fruit, because the dry layer adheres to the wet mud underneath. This causes stresses to build up everywhere across the surface. When these stresses become big enough the surface cracks and fragments into a series of islands. This is an example of a naturally occurring voronoi pattern. (P, Ball, 2009).

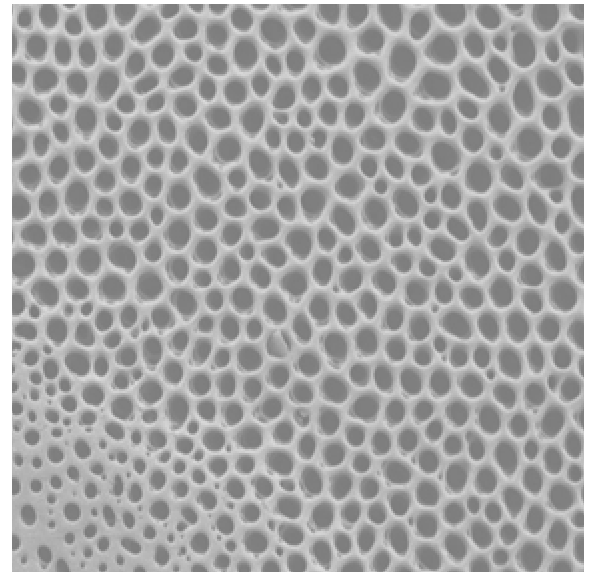
Why Voronoi?

I wanted to use Voronoi to assess configurations of different shapes and sizes, as well as various degrees of surface area.

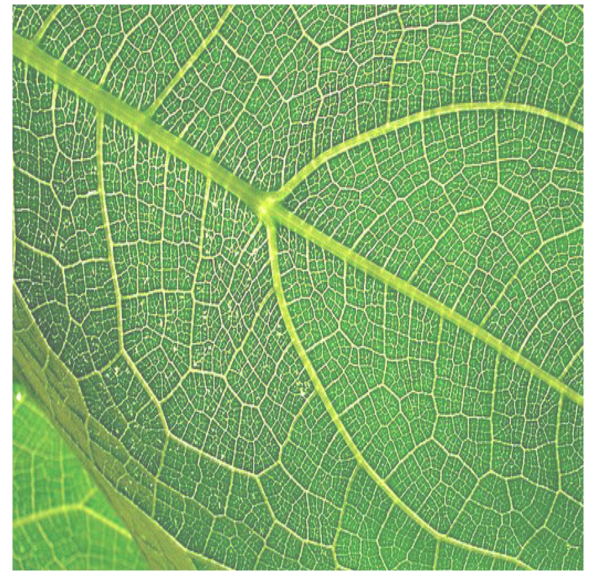
This gives a final design which appears organic and is not intrusive to the external context, allowing the user to observe nature in its natural habitat.

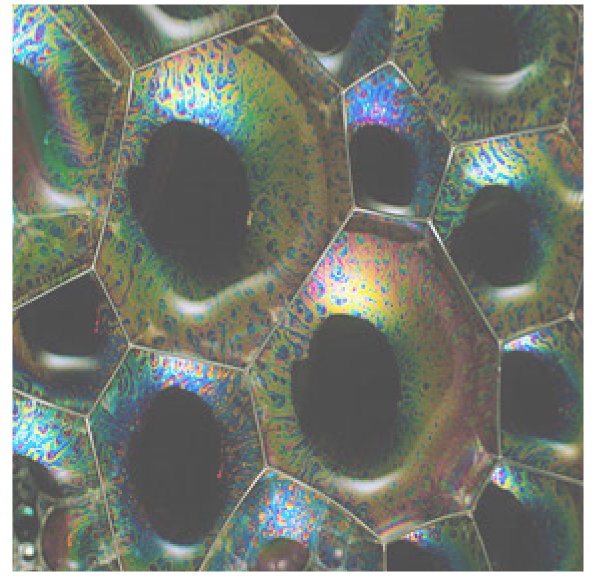

1. Dried Mud


2. Dragonfly Wing


3. Sea Urchin


4. Giraffe Skin


5. Leaf


6. Soap Bubbles

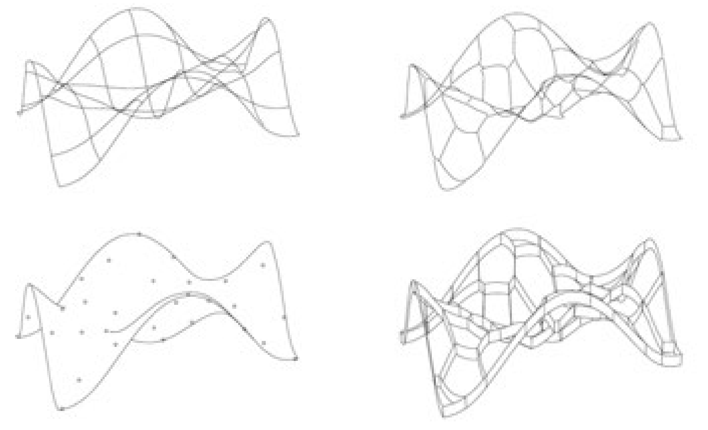
Voronoi Pattern
Precedents

ROOF STRUCTURE - Barkow Leibinger Architects (BLA)

Voronoi diagrams can be used in the formation of a roof structure, as shown on the Campus Restaurant and Event Space project in Stuttgart. The design formed a polygonal leaf-like canopy that can stretch over long spans using groups of columns. The structure includes a steel frame and columns with glulaminated wood-cell infill. These cells can have different uses such as skylights with solar-glass, perforated wood acoustic planking, or as artificial lighting cells modified by an aluminium-honeycombed deflector. The most economic way to build this complex structure was to use CNC routing and sawing to accommodate the many unique honeycomb joints (B, Leibinger 2008).

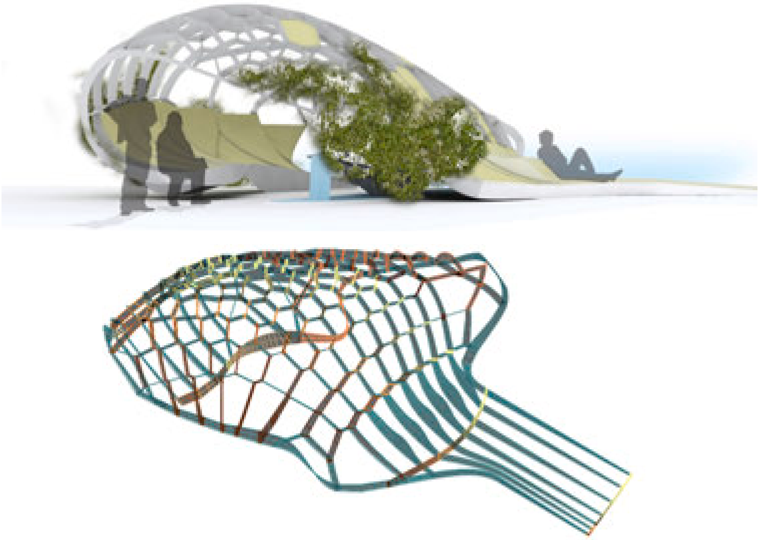
PROCESS - Design Study by Liang Gao et al

This project experimented with a Voronoi algorithm, which is similar to the process that I want to go through. The first stage was to use physical modelling to access different configurations of the pattern as well as various degrees of extrusion. The second stage moved to digital modelling, examining the Voronoi pattern parametrization and understanding the outcomes of applying it to 3D geometries. The result created a timber frame structure providing shelter for a ferry terminal (A. Agkathidis, et. al, 2015).



PROGRAM - Metalab Architecture + Fabrication

New Harmony Grotto is a reinterpretation of Frederick Kielser's Grotto for Meditation. The structural surface divisions were generated as minimal surfaces, based on the Voronoi diagrams, constituting natural formation processes. The structural grid is made of steel and each frame has a foundation made of concrete. The next phase of the project is to select and infill some of the cells with concrete to create seating and stability along with material in other locations to encourage the growth of vegetation onto the structures surface (A, Nowak 2015).



Methodology
Surface Design

This proposal seeks to investigate how Voronoi Pattern can be utilised in the surface design of a structure. I want to be able to control how private the structure is by the facade design. This is to allow the users to observe nature in its natural habitat by disguising the human build as an organic formation, developing a symbiotic environment

The first step is to identify a key statement that I can explore and test with iterations of probability logics. The statement is:

The smaller the voronoi hole the more private the structure.

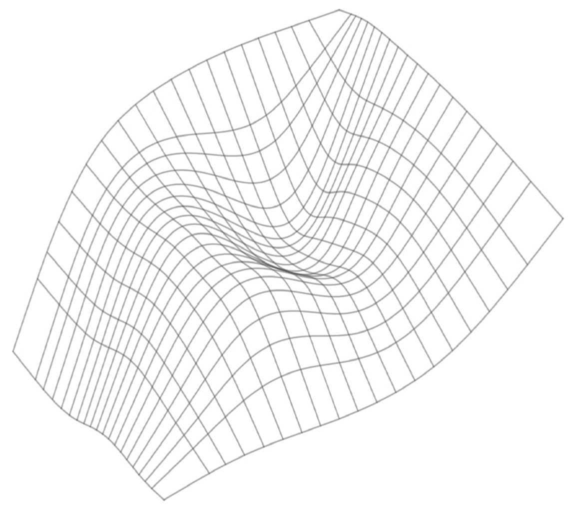
I am going to explore this statement using 3 probability logics:

1. Z Axis
2. Normals
3. Combining the Z Axis and the Normals

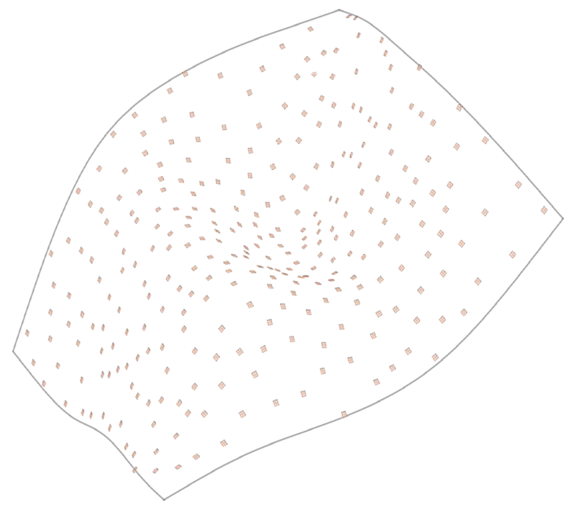
The process will start by using an early iteration of Felix's form finding method to use as my surface and populate the surface with points.

The next step is to apply a logic to the points which will calculate the probability of each point getting culled. Then, compare that probability with a random number to see whether or not to act on that probability. After that, use the culled points as seed points to create a Voronoi Pattern.

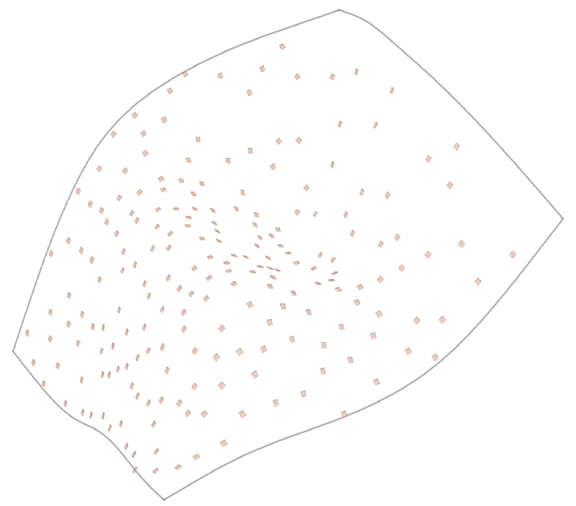
Weaverbird is then used to create openings, add thickness and smooth out the pattern design.



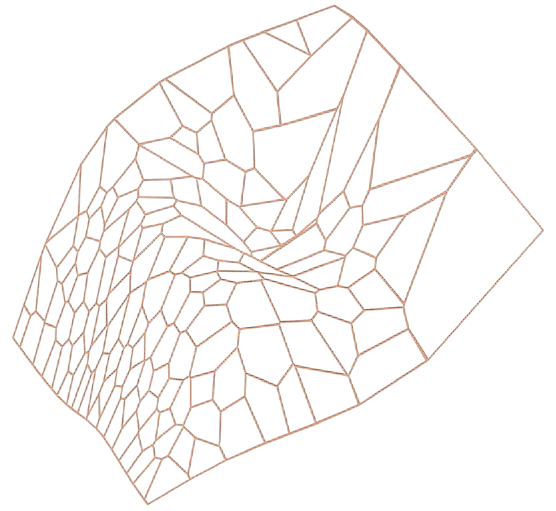
1. Start with a surface



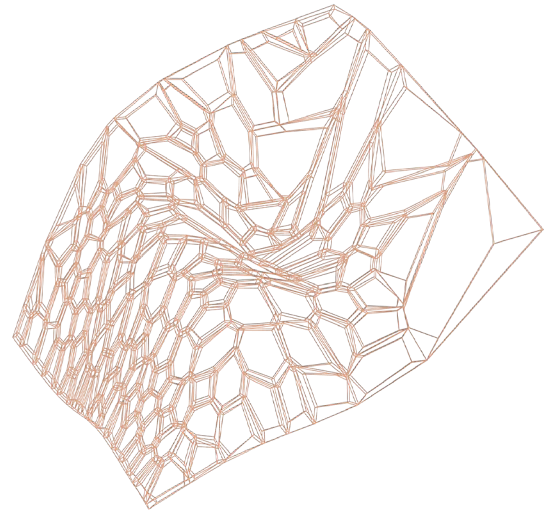
2. Map random points to surface



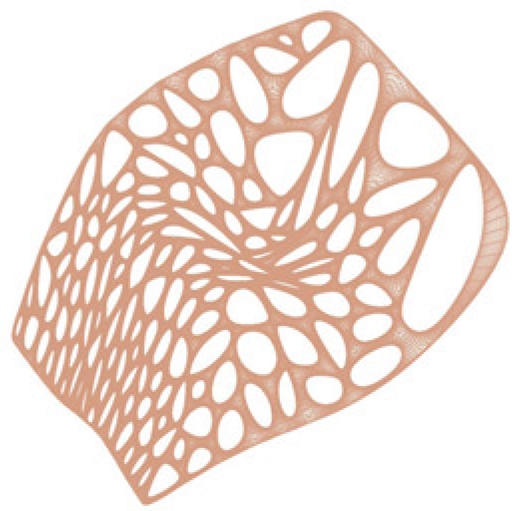
3. Cull points according to Probability Logic



4. Apply Voronoi algorithm



5. Create openings using Voronoi pattern



6. Smooth openings

Logic
Development

Using what I had learnt when interpreting the Voronoi pattern language and understanding the theory for my methodology, through precedents, allowed my logic to develop.

I needed a statement for each probability logic to understand what I wanted to try and achieve. These became the principles of my surface design.

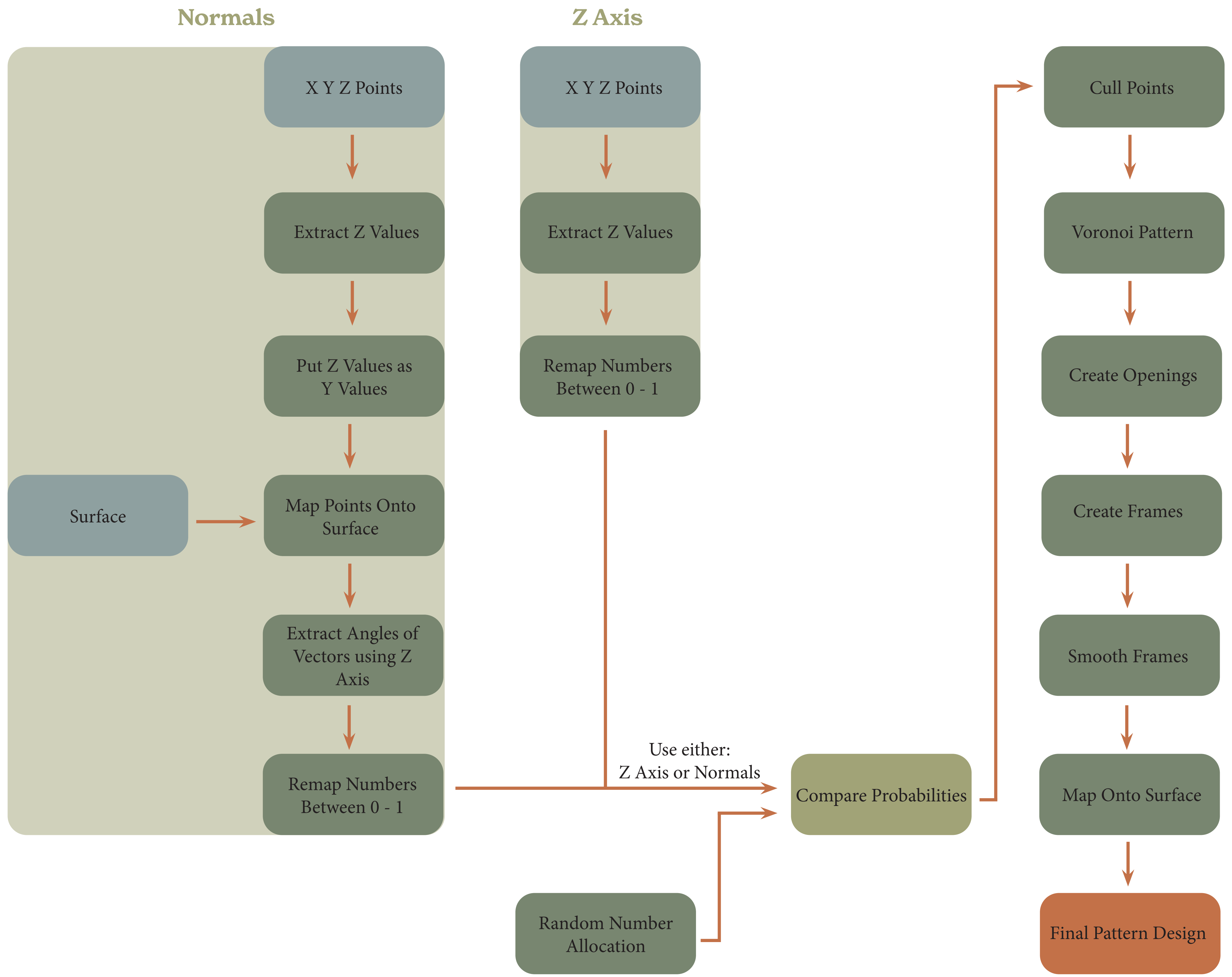
1. Z Axis:

The larger the z value is for each point, the more likely they are to be culled.

2. Normals:

The more horizontal the vector is for each point, the more likely they are to be culled.

These will be tested using a number of variables for multiple iterations to find the best solution.



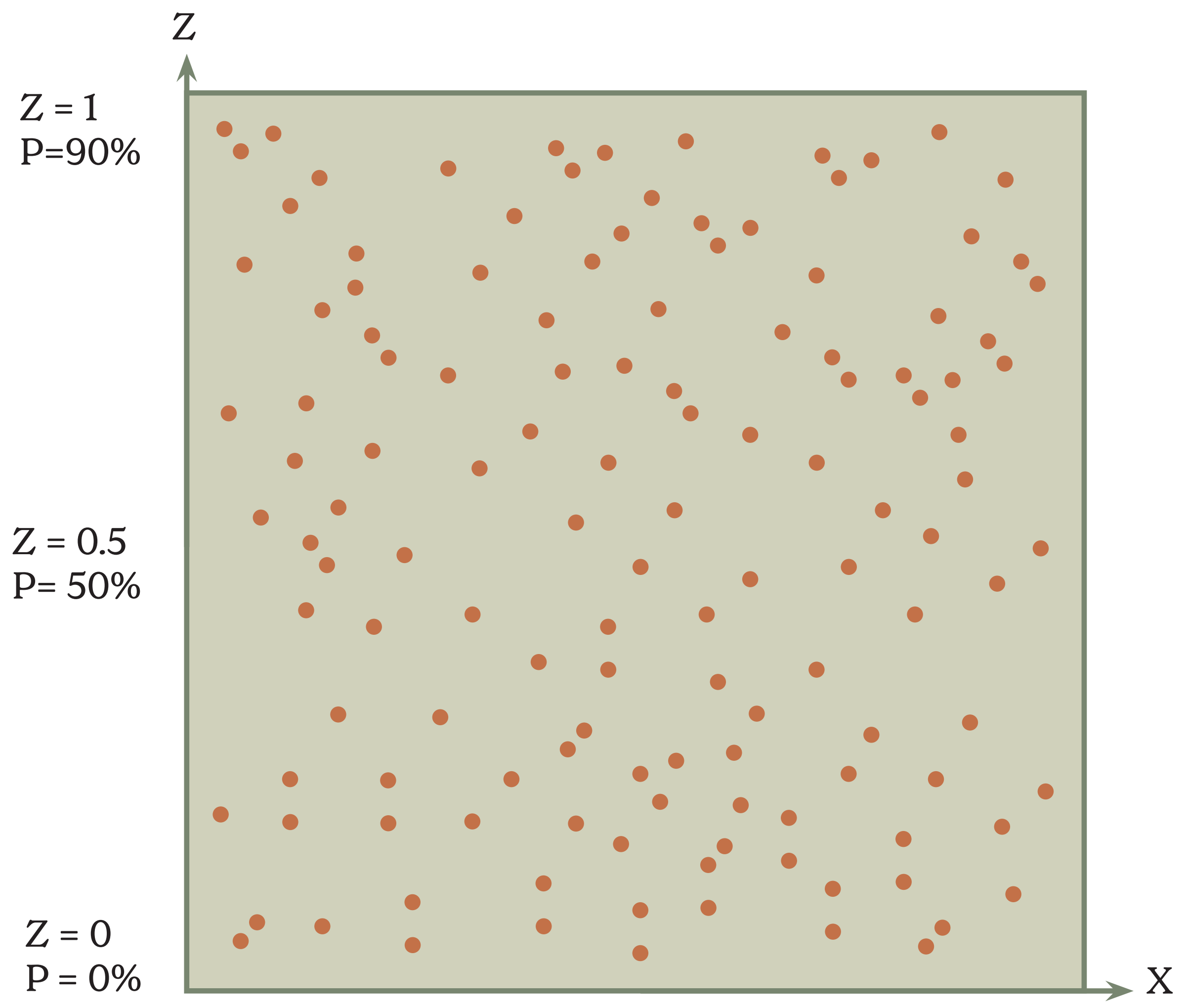
Iteration 1

Z Axis

This iteration explores the probability logic of the larger the Z value for each point, the more likely the points are to be culled.

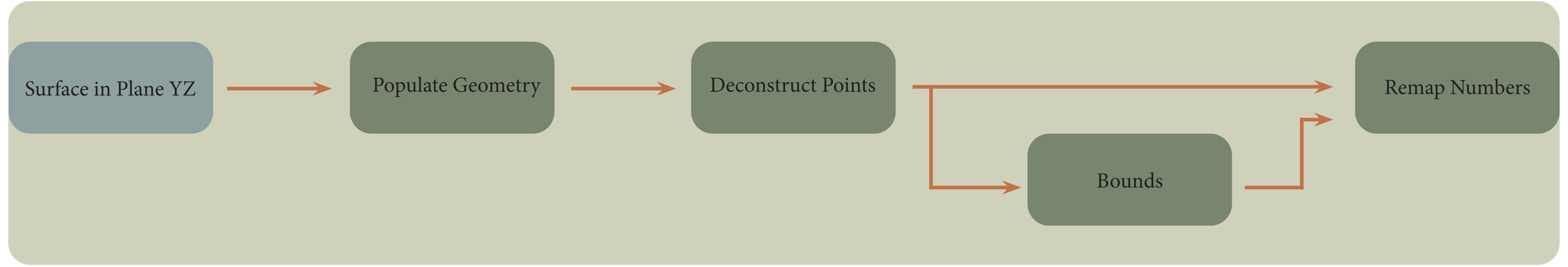
The parameters that will be altered are:

- The number of points
- The location of the points
- The random number allocated to each point



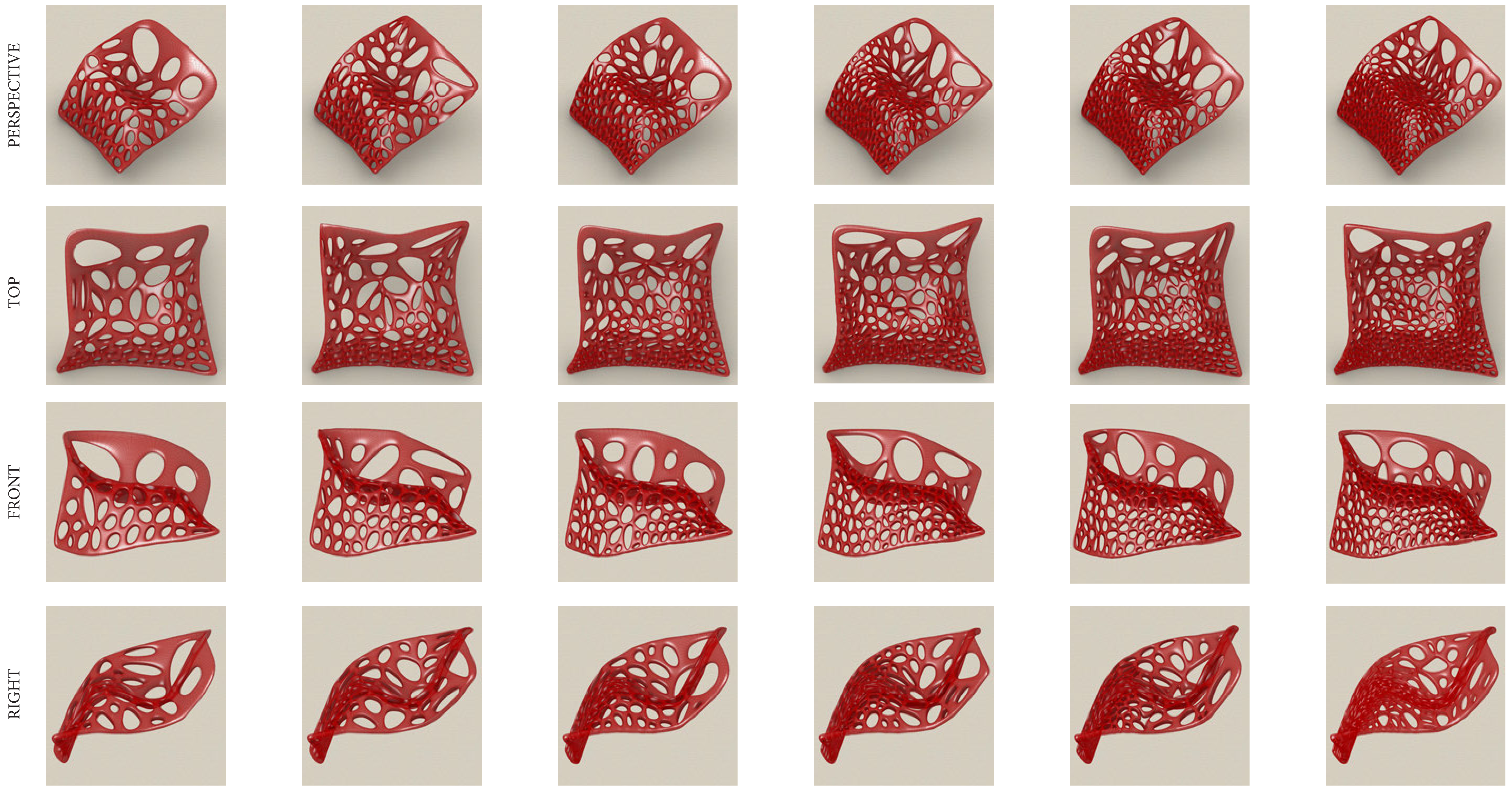
Z = Z Axis Co-ordinates
P = Probability of being culled

Z Axis Probability Logic



Parameters

No of Points: 100	No of Points: 200	No of Points: 300	No of Points: 350	No of Points: 400	No of Points: 500
Random Location of Points: 0	Random Location of Points: 300	Random Location of Points: 500	Random Location of Points:1000	Random Location of Points: 2000	Random Location of Points: 3000
Random Number Allocation: 0	Random Number Allocation: 300	Random Number Allocation: 600	Random Number Allocation: 2500	Random Number Allocation: 5500	Random Number Allocation: 8500

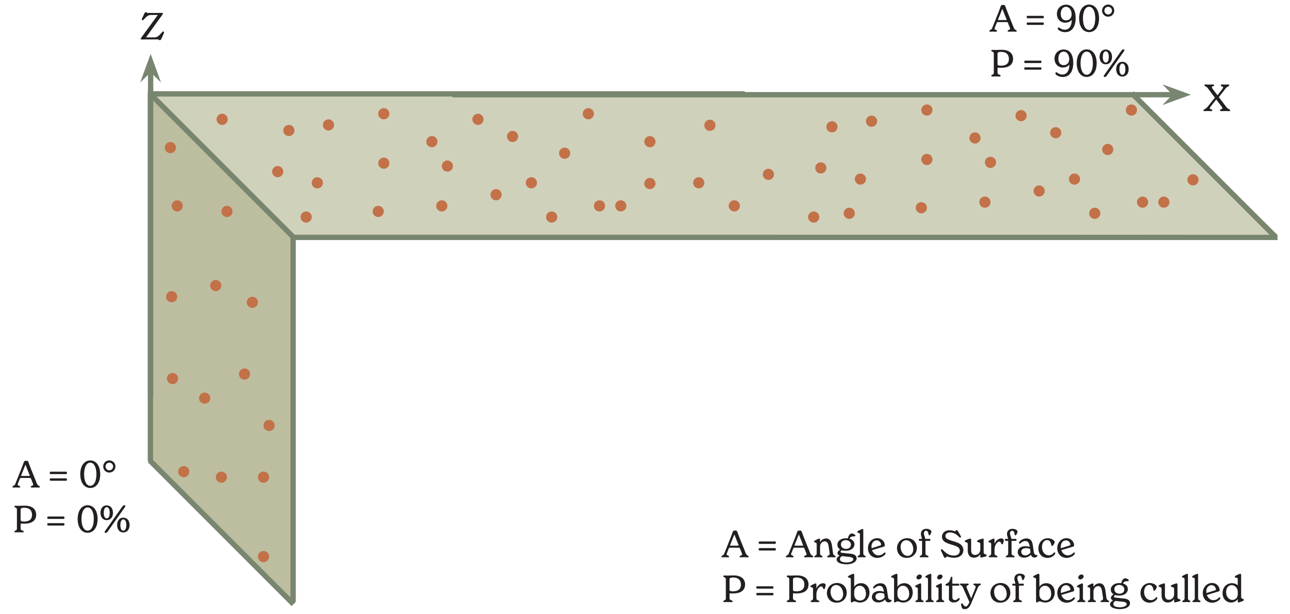


Iteration 2
Normals

This iteration explores the probability logic of the more horizontal the vector is for each point, the more likely the points are to be culled.

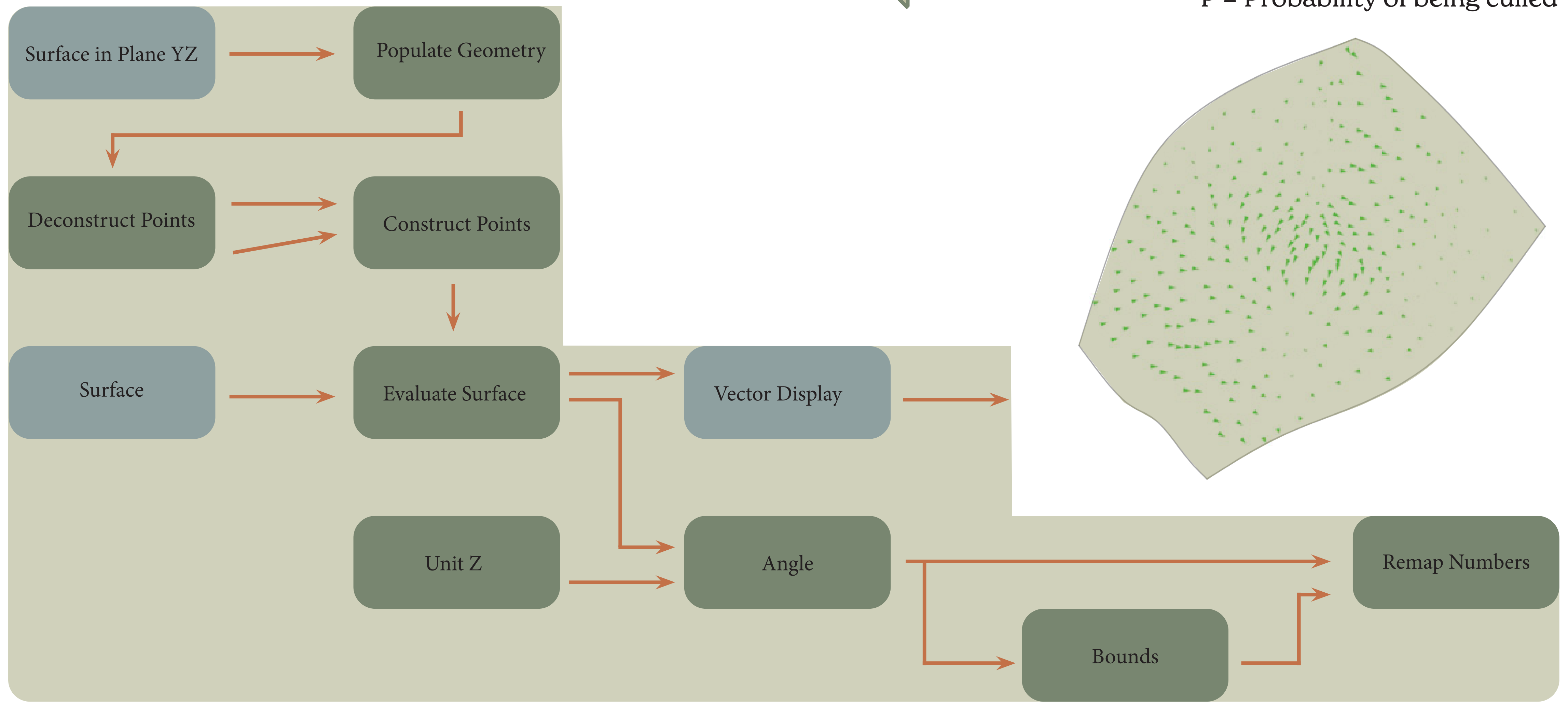
The parameters that will be altered are:

- The number of points
- The location of the points
- The random number allocated to each point



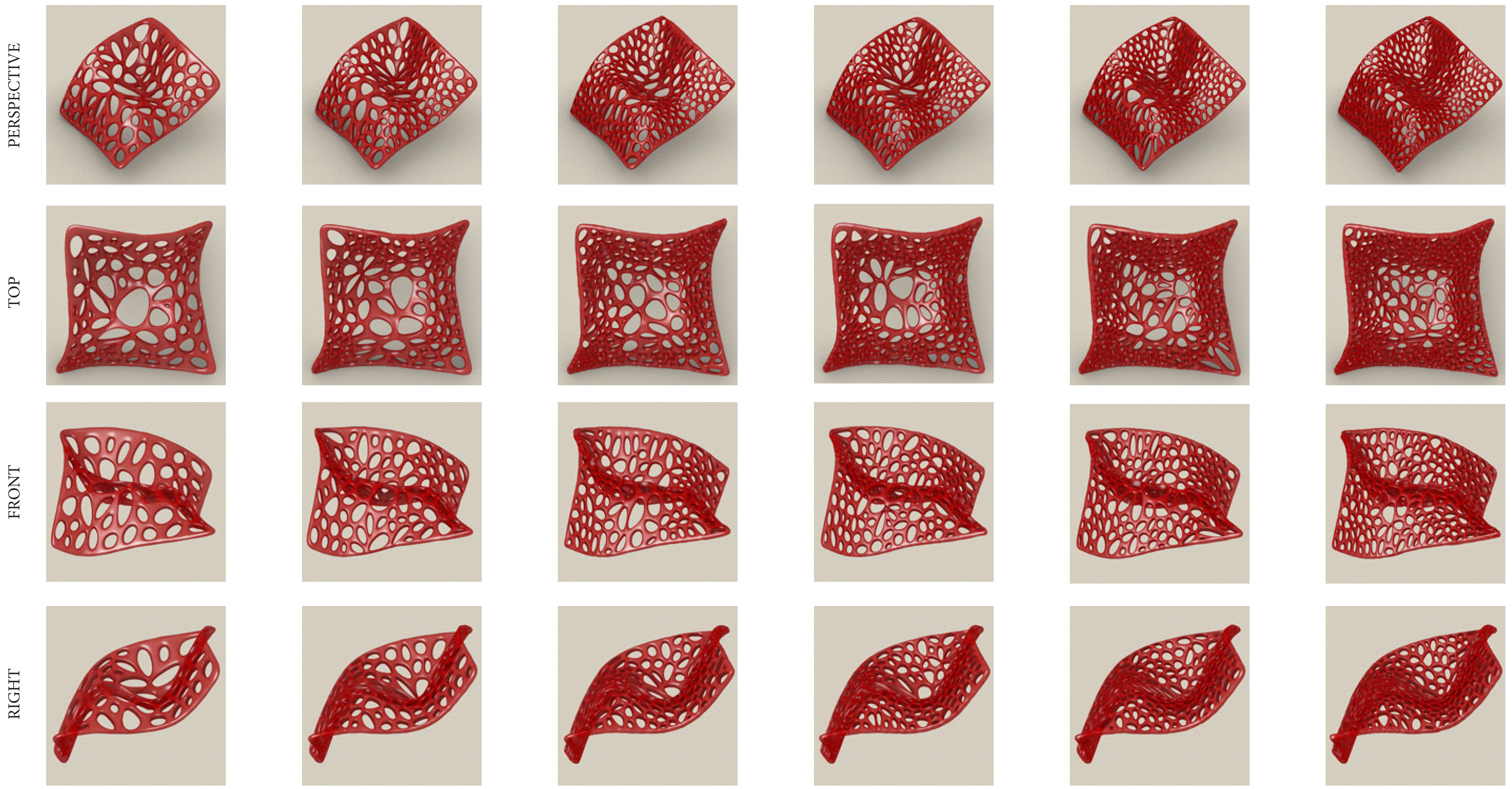
A = Angle of Surface
P = Probability of being culled

Normals Probability Logic



Parameters

No of Points: 100	No of Points: 200	No of Points: 300	No of Points: 350	No of Points: 400	No of Points: 500
Random Location of Points: 0	Random Location of Points: 300	Random Location of Points: 500	Random Location of Points:1000	Random Location of Points: 2000	Random Location of Points: 3000
Random Number Allocation: 0	Random Number Allocation: 300	Random Number Allocation: 600	Random Number Allocation: 2500	Random Number Allocation: 5500	Random Number Allocation: 8500



Iteration 3

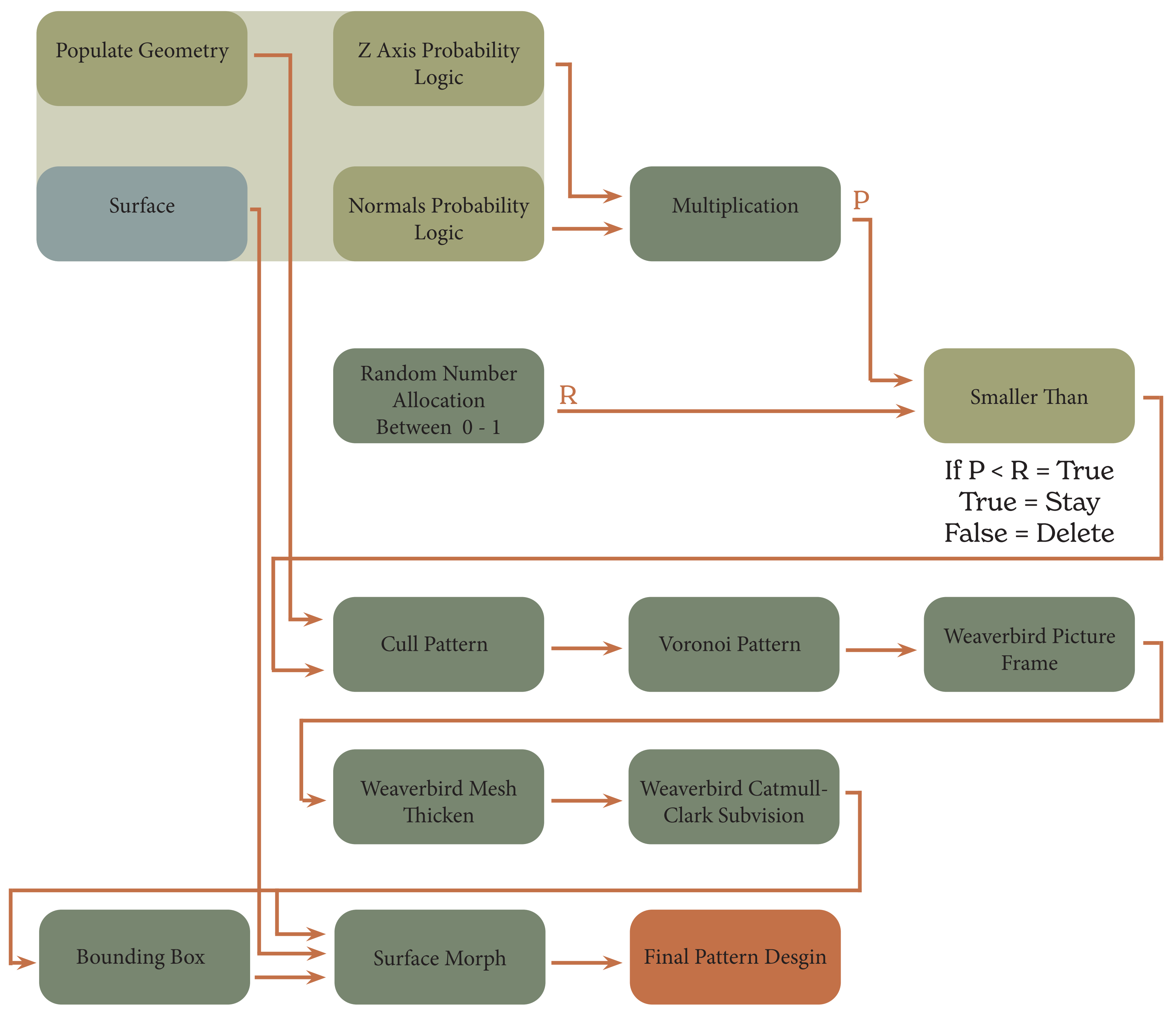
Combining Z Axis and Normals

This iteration explores the probability logic of combining both previous logics together and applying them to each point.

The parameters that will be altered are:

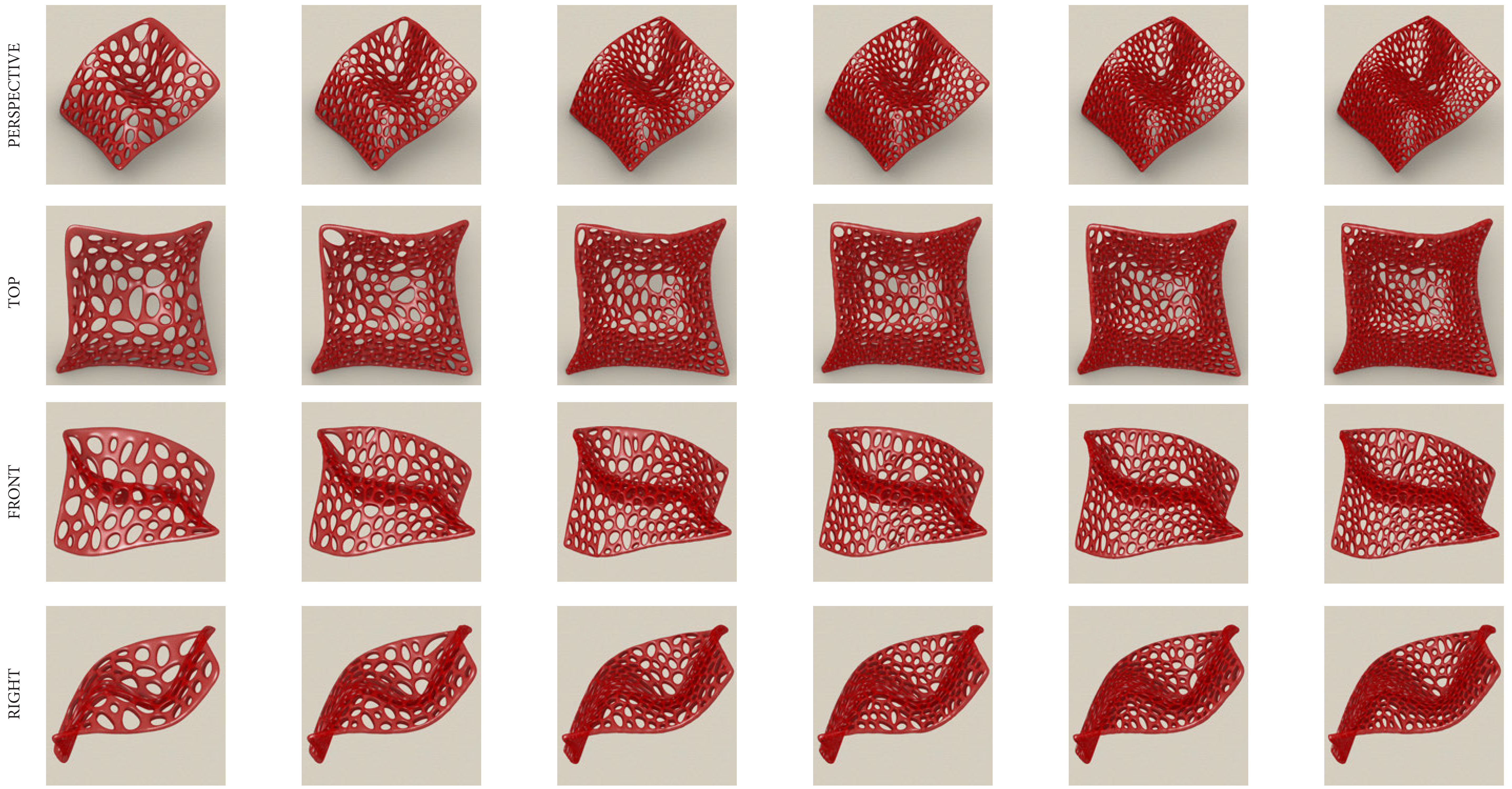
- The number of points
- The location of the points
- The random number allocated to each point

I used multiplication to combine these two logics. This is because their domain is between 0 - 1 and multiplying these domains keeps the domain between 0 - 1. I explored other options of combining these domains such as set union or addition however, addition would have changed the domains between 0 - 1 to 0 - 2 which is not the outcome I wanted.



Parameters

No of Points: 100	No of Points: 200	No of Points: 300	No of Points: 350	No of Points: 400	No of Points: 500
Random Location of Points: 0	Random Location of Points: 300	Random Location of Points: 500	Random Location of Points:1000	Random Location of Points: 2000	Random Location of Points: 3000
Random Number Allocation: 0	Random Number Allocation: 300	Random Number Allocation: 600	Random Number Allocation: 2500	Random Number Allocation: 5500	Random Number Allocation: 8500



Final Iteration

Z Axis

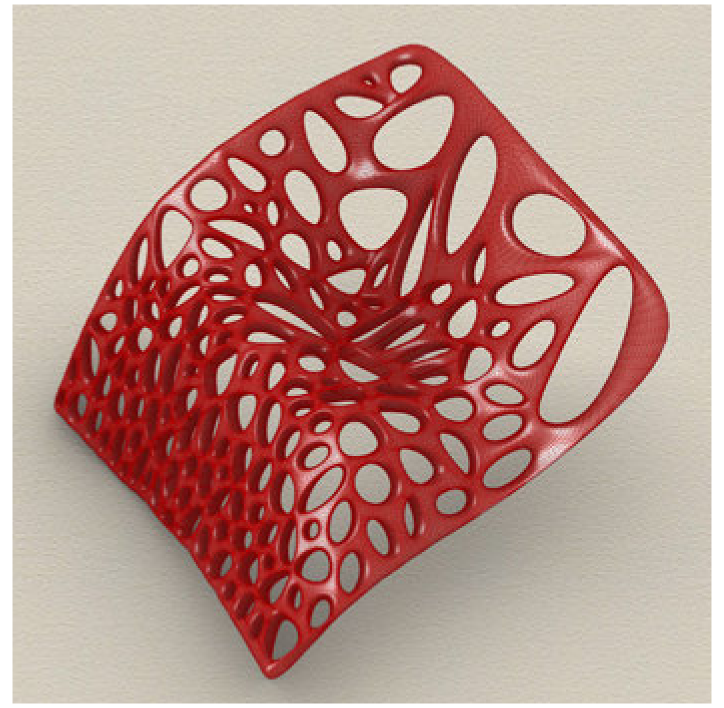
For my final iteration, I chose the Z Axis probability logic because I felt that this was the most successful solution in achieving my aim for my design.
Just to reiterate, the aim for my design is that I wanted to be able to control how private the structure is by the facade design. This is to allow the users to observe nature in its natural habitat.
The Z Axis probability logic worked well as there were smaller holes towards the bottom where the users will be standing and looking out. They would still be able to look out through the holes but be camouflaged by them. Subsequently, higher up in the structure the holes were larger to allow natural light to come in and use less material.

I tested the Z Axis probability logic on two different forms to make sure that the same effect occured. This would allow the desgin to be used for different sites.

No of Points: 290

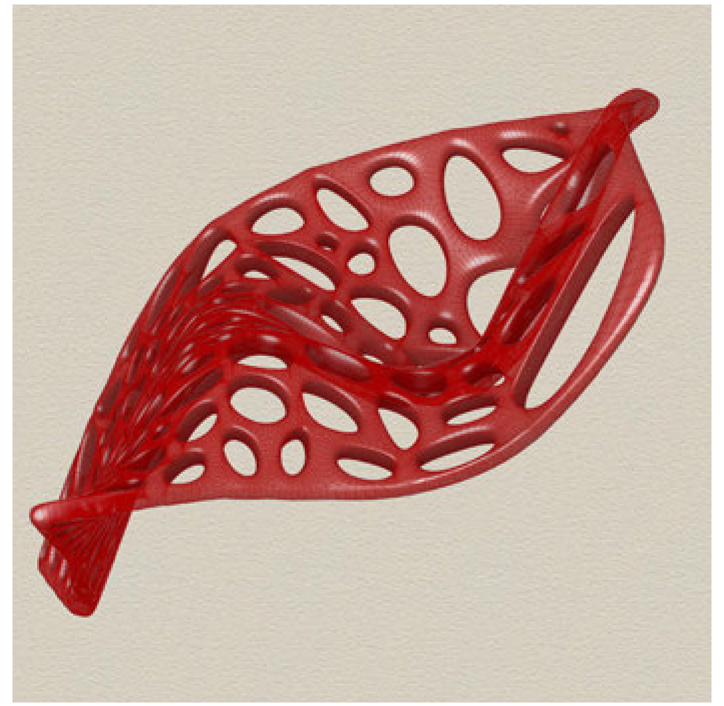
Random Location of Points: 1287

Random Number Allocation: 9305


PERSPECTIVE


TOP

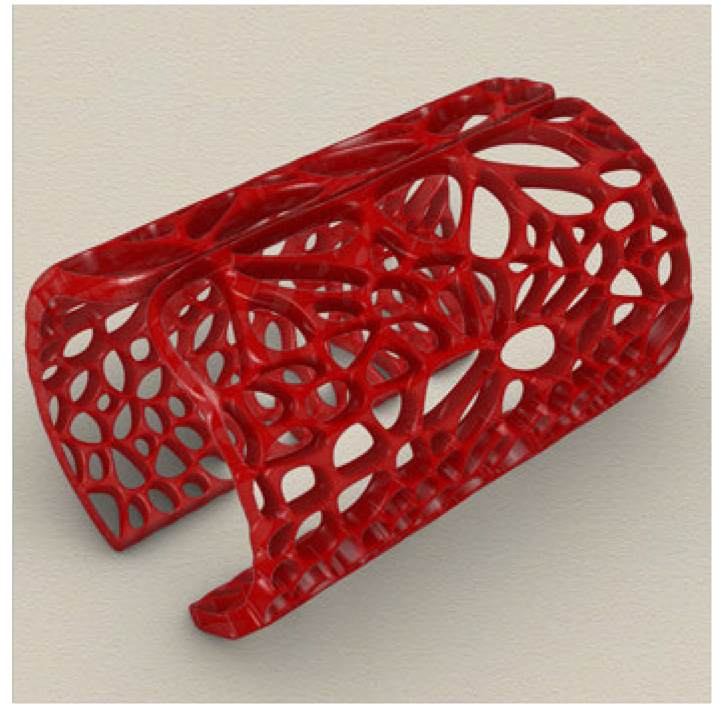

FRONT

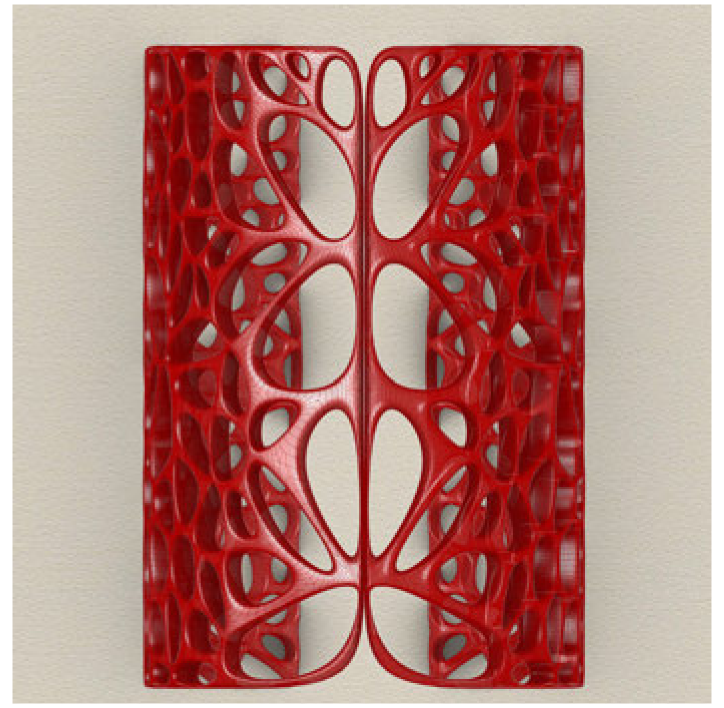

RIGHT

No of Points: 290

Random Location of Points: 1287

Random Number Allocation: 9305


PERSPECTIVE


TOP


FRONT


RIGHT

1:50 Scale Model

I decided to 3D Print a physical prototype because it is the most successful fabrication method to achieve complete accuracy with my surface pattern whilst keeping the complicated form.

This is one way to construct my structure and I explore some other options in more detail on the next page of this document.

Using a bright light I was able to see how sunlight and shade would play a role in the atmosphere of the structure. It highlighted the denser areas of holes with the amount of shade that was produced. This is where the user would observe and become obscured.







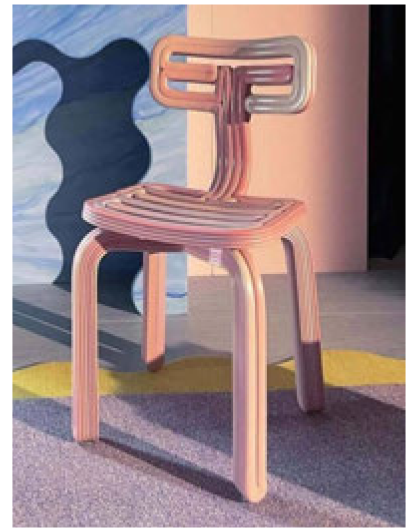



Construction
Precedents

Dirk Van Der Kooji - 3D Printed Chairs (2011)

I went to the Design Museum in London to visit an exhibition called 'Age Waste: What Can Designers Do?'. In this exhibition there were lots of examples of different types of waste material and how can we reuse it to create a closed loop system. One of the examples were these 3D printed chairs made from recycled plastic from discarded fridges. A computer controlled robotic arm extrudes a continuous thread of molten plastic to build the chair in three-and-a-half hours. Each chair is printed from 10kg of chipped, recycled fridge interiors which equates to one standard fridge. I could scale up this technique, materials and process to use it to 3D Print the Biophilic Hide.



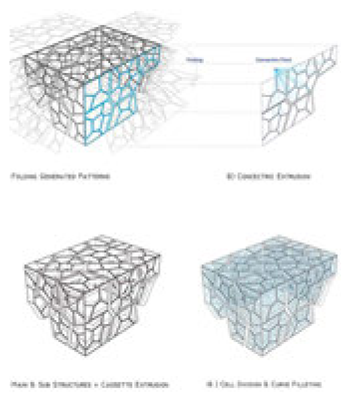


Marcos Cruz - Poikilohydric Living Walls

This research project explores different forms and materials to increase vegetative growth on buildings and improve the environmental quality of cities. It encourages the use of self-regulated biological systems on building façades by integrating poikilohydric species – algae, moss, lichen, etc. – that can switch their photosynthetic activity on and off without the help of man-made irrigation and maintenance. Corkcrete with larger-scale cork aggregates and a higher presence of cork on the surface was found to be successful in becoming biocolonised with algae (M, Cruz, 2022). Another way to construct the Biophilic Hide could be to 3D print a mould and fill it with Corkcrete, so not only does the surface pattern camouflage the user but the material encourages vegetative growth, so that the structure becomes part of the context.


Nex Architecture - Times Eureka Pavilion

This project is based on an algorithm that simulates the process of L-systems and Voronoi diagrams. The formation of the pavilion structure was inspired by the principle of natural structures, their development and growth of plants. It was constructed using a 5-axis milling machine for the wooden structure and laser cutting of plastic elements. (A, Nowak 2015). For the smooth shapes in my design I could lasercut plastic sheets to attach to the Voronoi strucutre.

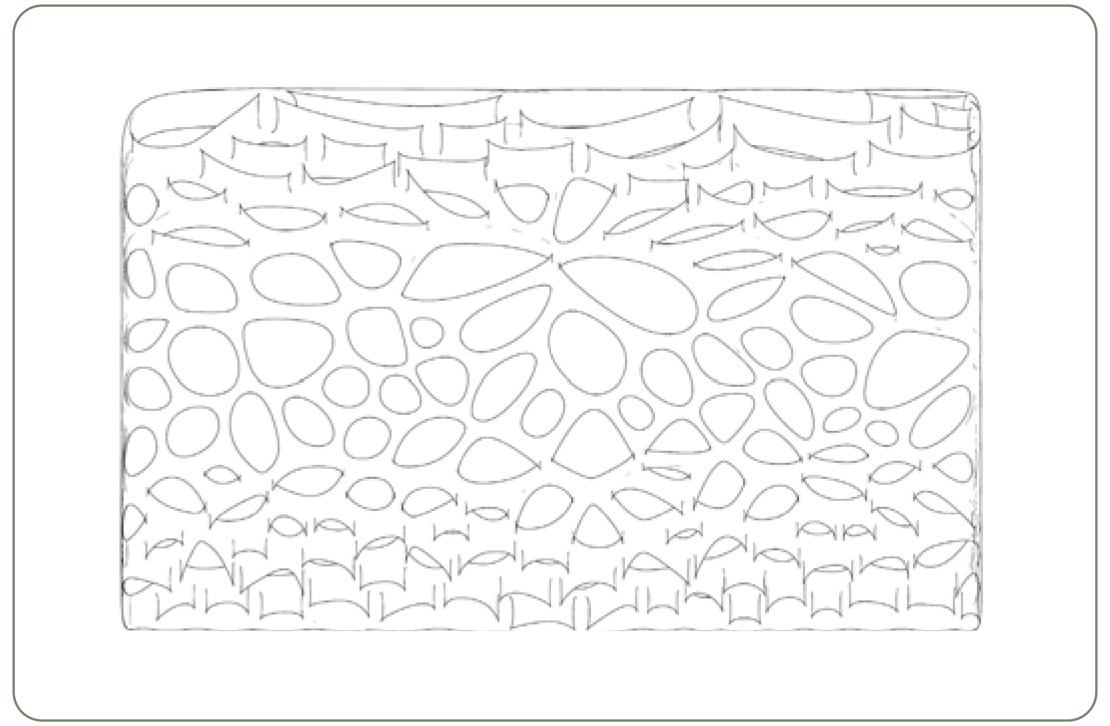



Construction
Storyboard

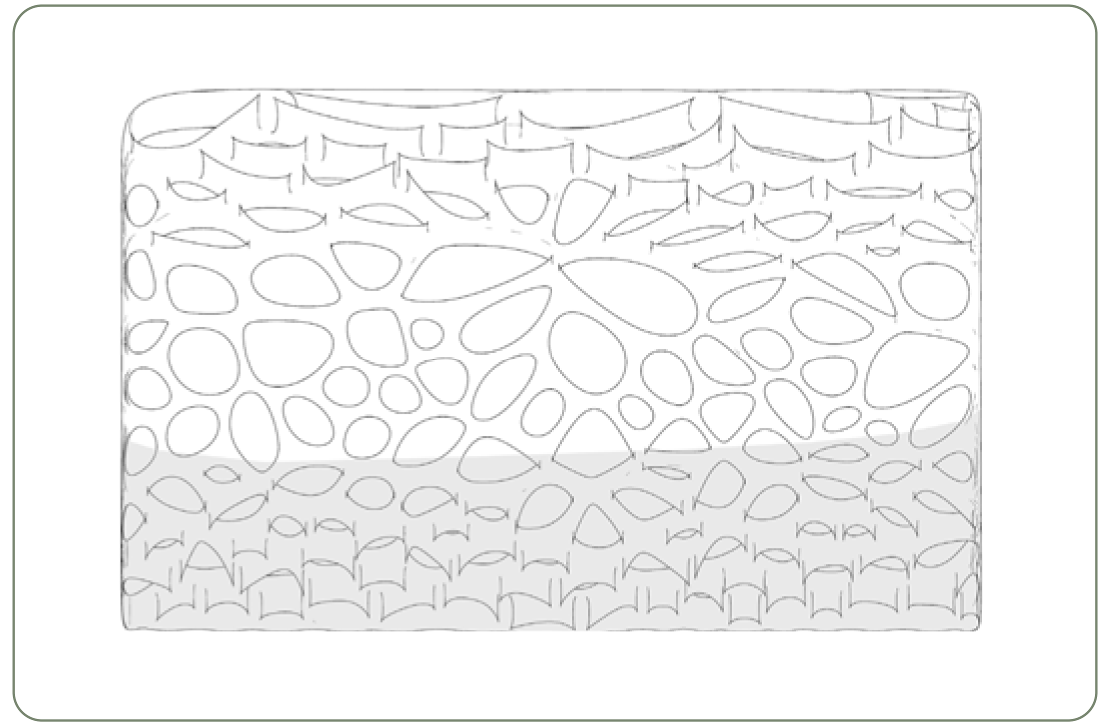
3D printing using recycled plastic would be my first choice in constructing this Biophilic structure.

However, after finding out about Corkcrete, if I went on to construct this structure using Corkcrete this is the basic process I would go through to construct it.

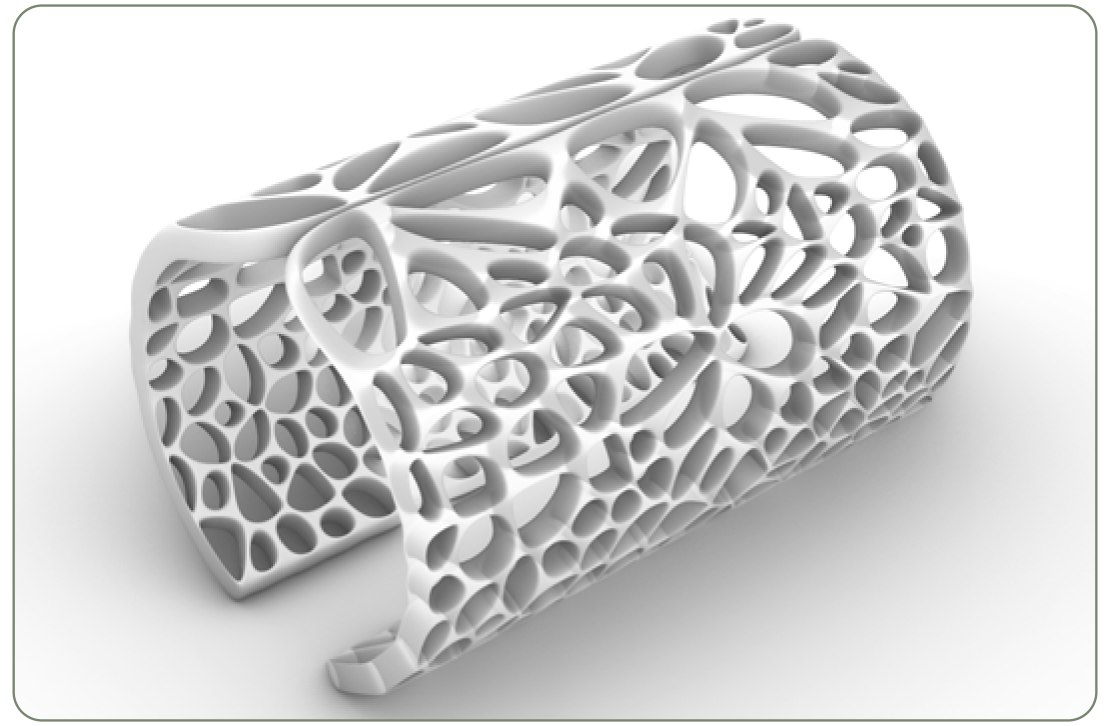
The reason I would want to use Corkcrete is because this also adds to my design aims of using the structure to disguise the human build as an organic form, developing a symbiotic environment. This will allow the user to observe nature without being intrusive.



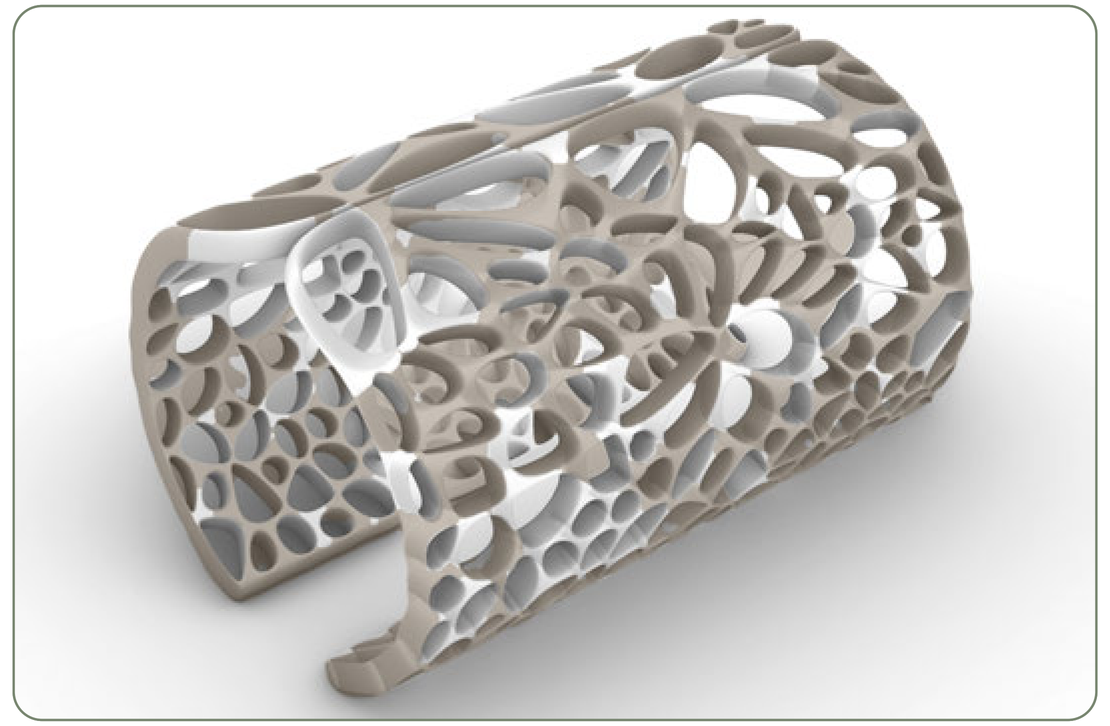
1. 3D Print a mould for the Surface Pattern (the ridges of 3D printing will also encourage poikilohydric growth)



2. Fill the 3D Print mould with Corkcrete



3. After waiting for it to set, take the structure out of the mould



4. After 12 months see the poikilohydric growth

Conclusion

In conclusion, the process of this project has produced a structure that responds to the brief in many ways:

- Branches by Philip Ball highlighted examples of where Voronoi patterns occur in nature and explains how and why it forms. This helped in deciding to use Voronoi pattern as the method for the surface design.
- The use of Voronoi pattern reinforces the design aims of the structure, which are to hide the user from nature, so it can be observed without being disturbed.
- A couple of logics have been defined and tested, by being built on a simple set of rules and when repeated have created a complex surface design.
- The use of academic resources have informed the concept of interpreting a pattern language and more specifically Voronoi pattern.
- Precedents have informed different areas of the project e.g. the process and construction methods.

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APPENDICES

Z Axis

Normals

Combined