Application of immateriality

-Using virtual objects as architectural elements and design tools

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Abstract

The research of mine in Cornell AAP for this one year is mainly about the relationship between the material and virtual object. In all four territories of investigation, my research matches Architecture + Discourse most. It is not about urbanism, nor ecological sustainability. Representation is related, lots of the parts of the research related to the computation design or the digital visual representation, but Architecture + Representation does not show the core idea of my research.

Material is the essence of the reality, and virtual object relates to virtual. The relation between these two concepts has a far older history than the computer. It is even older than the fresco or other forms of art. A dream perhaps is the first virtual object we created and ever saw. Materialism poses the question of identity in terms of formation and how the actions of making and doing constitute both consciousness and things as a process and the positing of “a world out there.” Therefore, a world of the virtual object is created after the setting up of a material system. Also, the experience and the expectation of a virtual object world is based on the experience of the material world. Marx states the existence of materiality separate from being, and it is the praxis, and the consciousness build and change all these worlds together. Discourse is more than just history, and it is a handful of several statements or arguments that work in conjunction to develop a more complex idea, usually in an extended form. Therefore, in my opinion, Architecture + Discourse is the right territory to conclude my research.

Which material are we using when we decorate our room with an oil painting? It is the media, the canvas the paints and the frame? Alternatively, the virtual object or we called images of things embedded in the media? In my opinion, it is virtual objects, the images of things, the virtual objects created by the media is the material we use, because the things we perceive in our mind instinctively are always not the media.

History of using the virtual object as architectural elements used

Virtual (Latin, virtus, for strength or power) of, relating to or possessing a power of acting without the agency of matter; being functionally or effectively but not formally of its kind.

Virtual objects are images of things. When we decorate a house with a landscape painting, it is the images of trees, mountains, and clouds to decorate the house, rather than the canvas or the paints. As Edgar Degas once asserted, art is not what you see, but what you make others see. What we see in a landscape painting is the diffuse lights from colorful paints on canvas; therefore, we can notice the texture, the strokes, and the variation of colors. However, the things we perceive in our mind are the leaves, trunks, the fur of animals, dim lights, etc. And it is these images of things for us to make the room have a window of there. Therefore, the decoration was completed by these paintings, the images of trees and mountains, the virtual objects, the virtual object.

In this perspective, we as human have a long history or using a virtual object.

These frescos and legends create virtual spaces for the homo sapiens to communicate without the limits of time and the existence of the speakers. During the war between

homo sapiens and Neanderthals, this virtual space helped to create an intangible concept of society which will not vanish for the elimination of the individuals. The space for virtual communication gave this society the ability to assimilate others. So far, there is no conclusion what reasons make the homo sapiens to win the war and why the Neanderthals disappeared. However, the virtual space makes the group of homo sapiens break the population limits of 150 and maintain the relationships among society without the help of close relationships.

In the medieval church, the stained glass window has a similar function as frescos. In simple, the cathedral glass helps people who cannot read understand the bible stories. By reading the figures and scenes in the window glasses, the readers are connected to the world and stories, not in their time. Since these worlds are not the real world at the time, they are a virtual world. Furthermore, the virtual had huge influences on the people at that time.

Also, in the east, Buddha temple created a virtual world by the statues, frescos, and stories behind. The religions in different regions and cultures rely on visual methods to spread their ideas of philosophy. Moreover, the visual method means using statues, frescos as the media to illustrate a virtual world for people to interpret the stories or the concepts.

In short, virtual objects or virtual objects are widely used in a different culture to make communication between people spanning the time. Virtual objects cannot stand-alone; they need media as a window to show them in the real world. However, the virtual object is not isolated from the real world, and they have positive impacts on the real world for a particular purpose it is designed for.

The development of meaning of virtual

The virtual is a substitute— “acting without the agency of matter”—an immaterial proxy for the material. Virtual refers to the register of representation itself, but representation that can be either or directly mimetic. In seventeenth- and eighteenth-century optics, virtual was used to describe an image that was seen by looking through a lens or that appeared in a mirror.

At the end of the nineteenth century, the notion of “the virtual” played a crucial role in the philosophy of Henri Bergson. In Matter and Memory (1896), Bergson uses the term “virtual” to depict the immateriality of memory.

Later in computer terminology, people invoke “virtual” to refer to a digital object or experience without physical existence. Once the term virtual is free from its enforced association with the digital, it can more accurately operate as a marker of an ontological, not a media-specific, property.

Triumph of the Name of Jesus, *by Giovanni Battista Gaulli*

Methods in using virtual objects as tools in enhancing reality

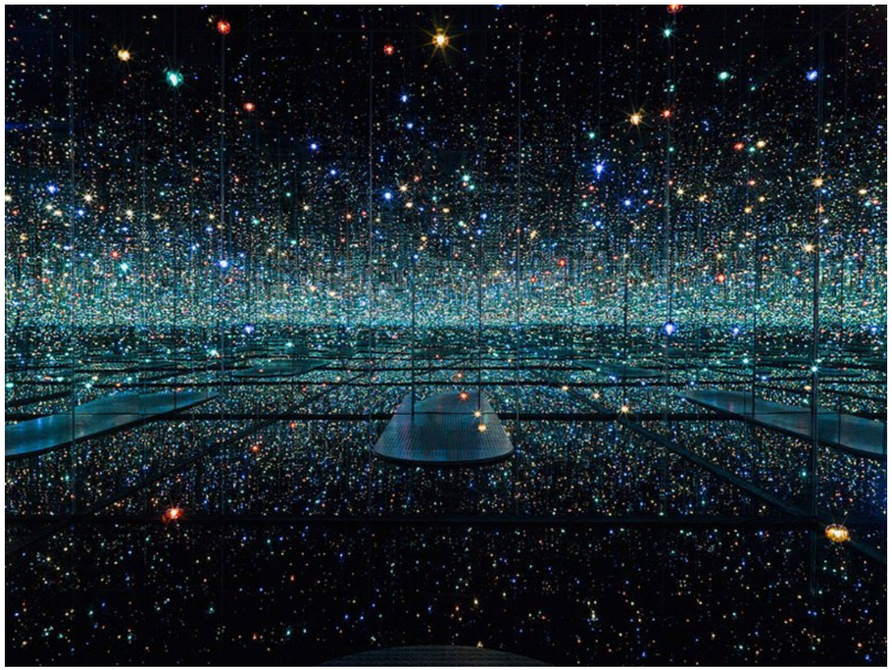
With the updates of the media, virtual objects become more and more vivid and real. The boundaries between virtual and reality are getting thinner and thinner. However, the media will always exist if the virtual objects are not realities, or we communicate directly mind to mind. But the updates of media certainly liberate the genre of the content.

Since the essence of the virtual material is immaterial, the contents can be freely created without limits, the discussion of the specific contents of this material seems pointless. However, it is crucial to examine the media. In some aspect, the contents' genre is largely decided by the media, such as some material we can see only sketch on it, for some we can see still but the vivid and colorful image on it, and some we can see moving images with sound on it. Then, it is an obvious clue to examine the material of the virtual object via its media.

From the purpose the virtual objects affect architectural meaning, I classify them into three categories. The first one is showing the observer a modified real world. The second one is showing a virtual world for adding more context. The third one is changing the connections among spaces.

In the first category, three examples can be referred to.

The first one is illusionism fresco. By using the rule of perspective, the artists created a deceivable fresco to illustrate a virtual space in the extending direction of a ceiling or wall. In Triumph of the Name of Jesus, by Giovanni Battista Gaulli, on the ceiling of the Church of the Gesu. Angels are flying into the room through the hole in the dome. The artist wanted to effect a real continuity between painting and sculpture. The virtual objects made the dome look like decorated by gold with an amazing span vault.



The Souls of Millions of Light Years Away, by Yayoi Kusama

The second example is the Infinity Mirrored Room – The Souls of Millions of Light Years Away, by Yayoi Kusama. She used mirrors to form a labyrinth. The walls, the ceiling, the floor are all mirrors. The reflection of the LED lighting system multiple the number of lights to infinite, as a mimic of the galaxy. The space the audience perceived was not decided by the walls. They felt space was a boundless infinity, which means it was the virtual objects that telling them the sense of space, rather than the physical wall.

Virtual reality is a digital approach to do a similar thing. Like the Brain in a vat, we react to things we perceive. Virtual objects change our sense of reality directly.

Another two examples for the second category.

Farmland North Coast, by Douglas Fryer

Firstly, as mentioned before, a landscape painting is adding a scene of the wild into a room. In an exhibition of Barbizon school, a gallery with these paintings is like a room with windows to the different wilds. Gallery space has more meaning than a simple box.

Secondly, in the Notre-Dame light show in 2018, people project different color and pattern onto the façade of Notre-Dame. The white stone façade, therefore, showed more potential than purely itself. So does the interior light show. The vault of the church was illustrated by the projected animation as a city under the sea, etc.

In the last category, several examples show the virtual objects change the connections among spaces. First, it is the screen. We are not talking directly to our friend via facetime. We are facing the images of them and talk to the screen. However, in this way, the space we are in and the spaces our friends are in are connected. We can see what is happening in their space, share details in the view of the camera. In some sci-

Notre-Dame light show in 2018

fi movie, like Dr. Strange, the portals in the New York temple connect other temple and wild to New York directly. So far it is only sci-fi, but one day it may become a reality in a real way or a virtual way.

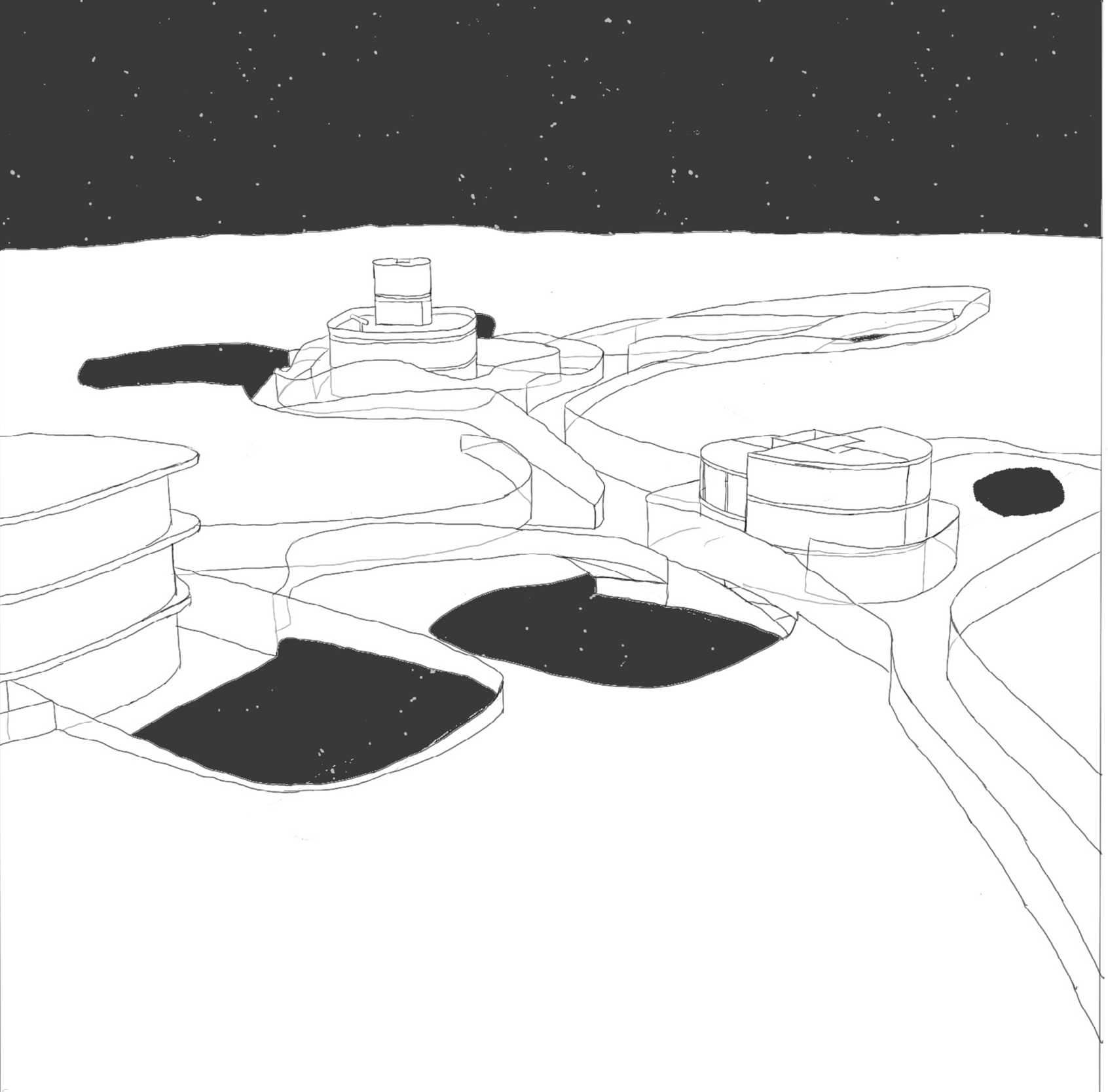
Methods in using virtual objects as tools in designing phases

How we use both material and virtual object to create a design exists in both the world of materiality and immateriality?

Four types of trying are categorized during my researches at Cornell.
They are ***using the virtual object to reorganize the relationship among realities; creating a new matter from an old matter via the virtual; Computation design; Virtual Reality.***

In my first practice, **Library of illusion** (taught by Rubén Alcolea), I examine the relationship between virtual object and material of media through three phases. The first phase was named as goggle of Pygmalion. The aim in this phase is building a goggle which can change the way you perceive the realities. The material of the media is the clue I followed. Glass is the most typical material of making the virtual object. Mirror or lens shows the world we cannot perceive naturally. In the first trying of this phase, I used the edge of Glass to blur the view while at the same time the light can still pass through the Glass, and then made a goggle which can help people see things unclearly. I mounted two sensors of light on the sides of the goggle which are connected to an Arduino board. The Arduino board will calculate the difference between the two sensors in real time and tell the light on both sides on or off. The light will be on in one side which has stronger input light or is on on both sides if the input light is strong in front. The virtual object created by Glass, sensors and LED here is the blurred view with navigating lights. And this virtual object help wearer follows the direction of light.
In the second trying of google, I mounted two pieces of half transparent half reflective acrylic onto a steel frame. Each piece of acrylic has 27 degrees to the face, and overlap

the view in backward onto the front view by reflection. The virtual object here is the mix of all three views to forming a reality not commonly perceived.
In the second phase, the transparent acrylic work effectively as the simulacra of glass walls. Multiple layers of this material created the copies of the observer. When a figure waved to its copy, the copy waved to it as well. The virtual object gave the figure a concept of itself.
In these two phases, I examined the basic ways to use virtual objects. In the last phase, I tried to use the virtual objects of the sky to build a library of the sky. Library of the sky means the sky is preserved in a“book” in this building. Book usually is a media which has text and pictures made by paper. But as I mentioned before, the genre of virtual object shift from material to material. In the observatory of this library, the distance between sky and observer is narrowed down by the telescope. The sky is not closer, but the virtual object of the sky is closer, etc.



Library of Illusion

Narrative of a transparent and reflective material

What is reality? What is illusion? And what is the reality? What is the relationship between the reality and the illusion? Is the illusion tangible or intangible?

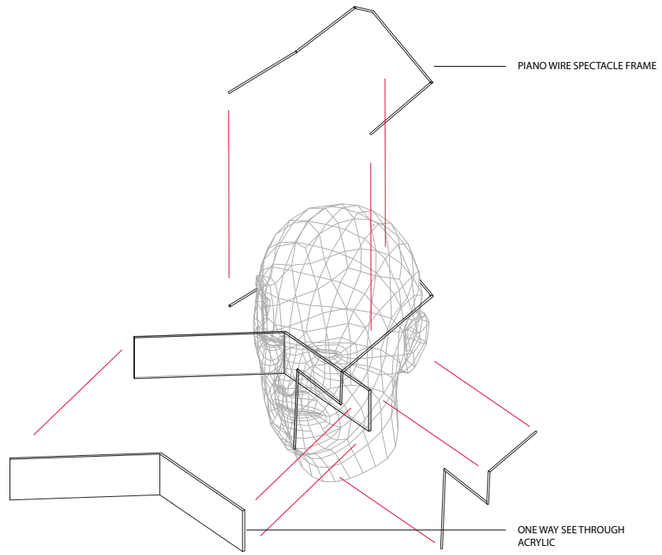
And then what is a book? What a book can mean? What is the relationship between a book and illusion?

Finally, what is the llibrary? What is the relationship between library and book, and the illusion?

My library is called library of sky. The site is in inner mongolia, where people believe sky is the destination of human being. The connection with sky is connection with the ancestors and people themselves

I started research the answer for the question along the clue of material. through the research of reflective transparent material-mirror acrylic, I got the answers.

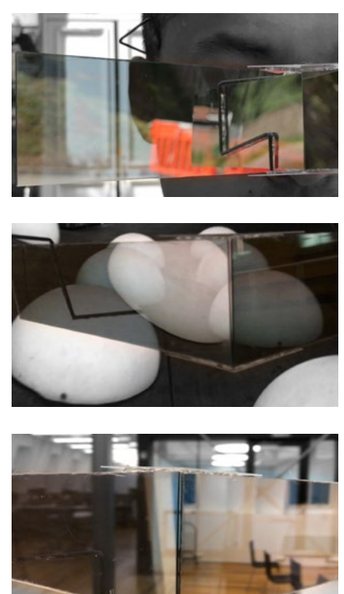
Instructor: Rubén Alcolea

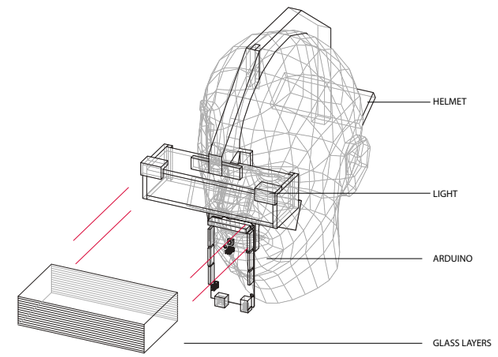


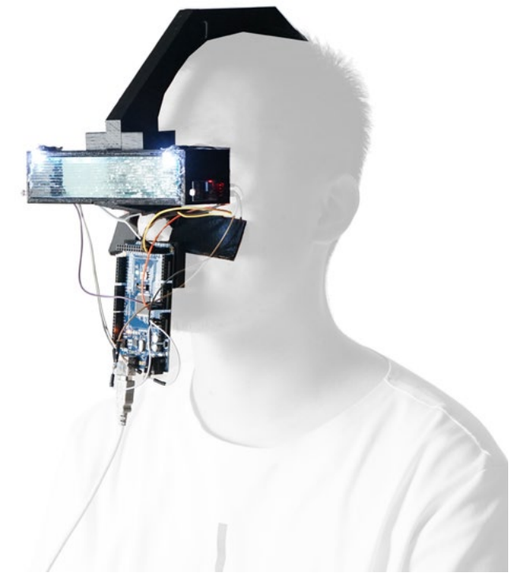
Spectacle-Mirror:

When I degined the goggle, the backwards views are displayed and overlapped on the view of front, for the material I used is both transparent and reflective. Due to the material property, the way I obeserve things changed. A obivious change can be made with only a single layer of this material.

The research with goggle is the start point with the material. A goglle change our view of the the world as the story indicated, which is provided by Ruben, Pygmalion's spectacles

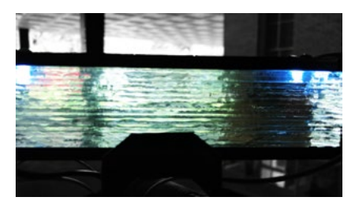


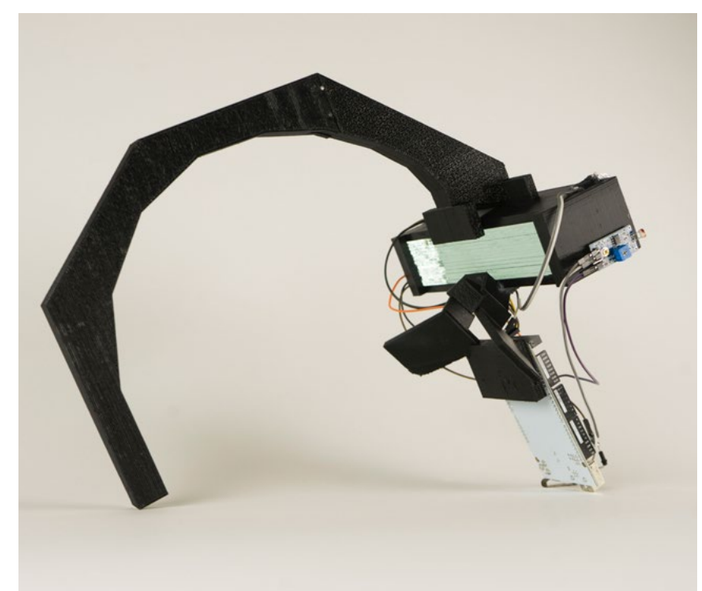




Spectacle-Navigator:

The other spectacle I made is using a stack of cut glasses to blur the view of people, and then use a pair of sensor and LED lights, which are controlled by an arduino board, to tell the wearer which is the direction has the stronger illumination, left or right, or just foward.





In the futher research, I try to figure out what would the visual effects change when I multiple the layer quantity of the matierial with reflective and tranparent features.

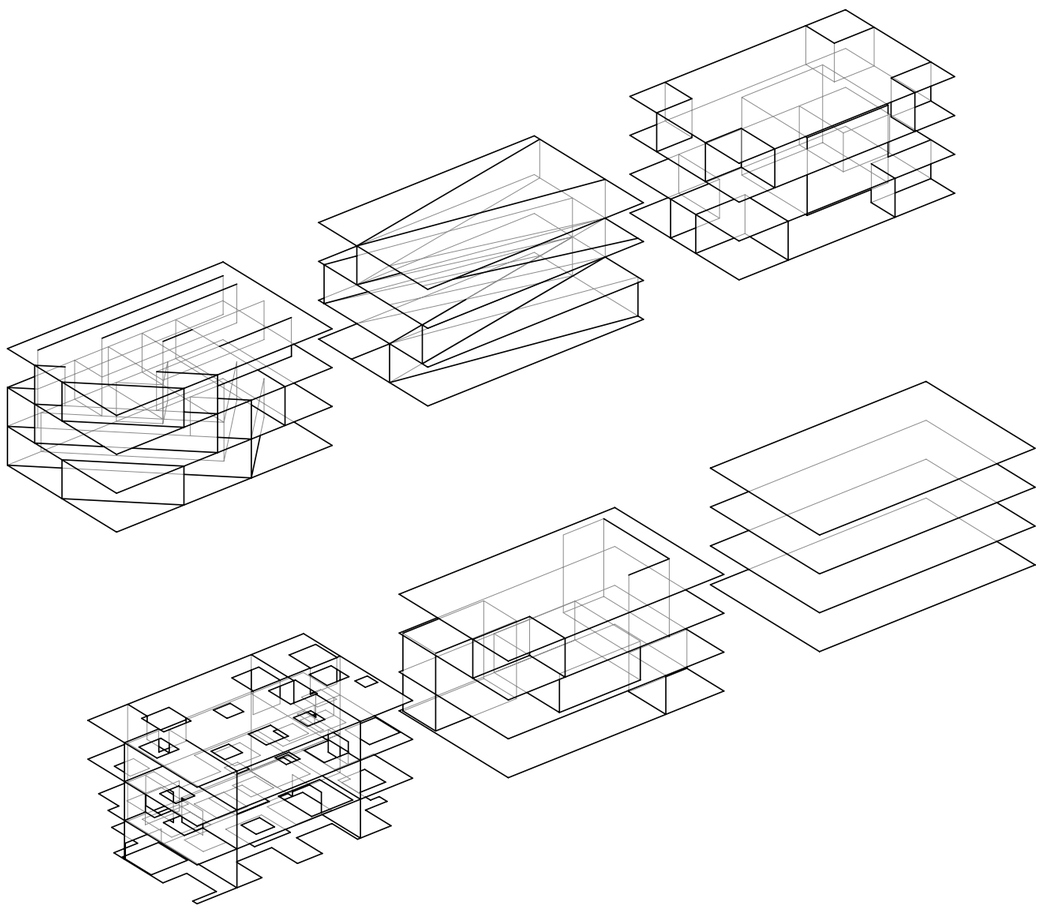
Then, as can be imaged, the infinity came in to view. Every two sheets of mirror can refelct each other, so that create an endless space. This is the prototype of the book- a book made of transparent and reflective material.

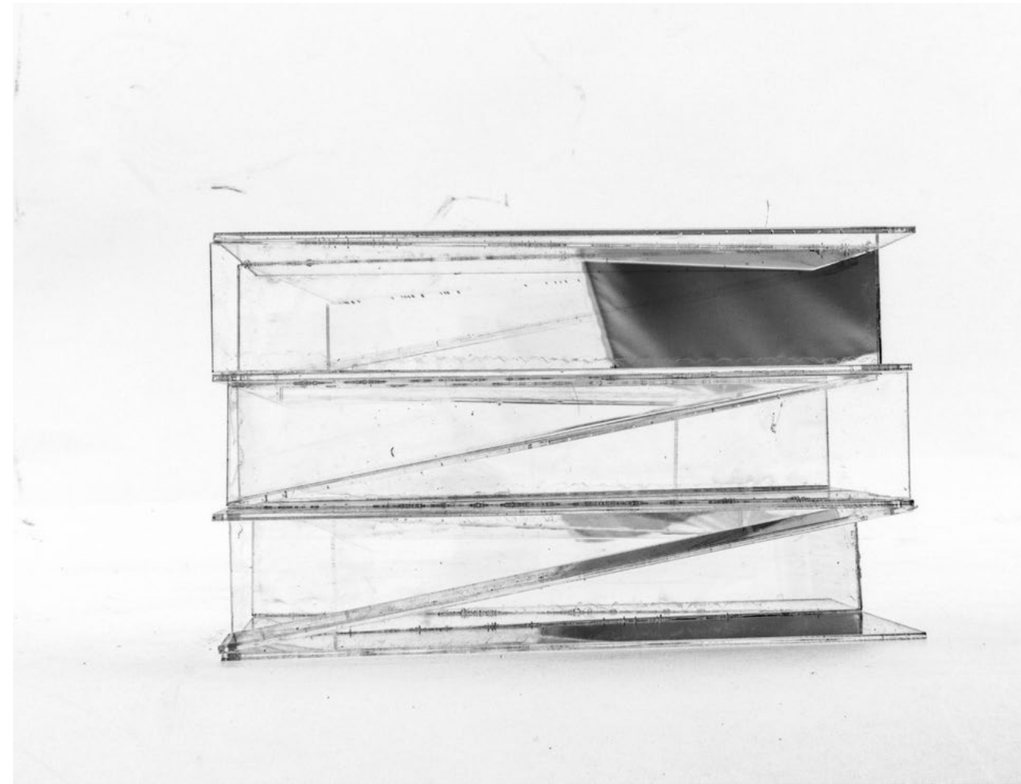
But what story can this book contain? What is the thing/ story can be stored in the glass book but not in a paper book?

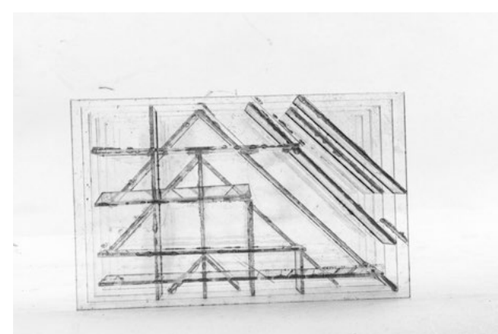
The answer came from the capacity of the glass book. Since the book can store sth infinity, it should be the book of telling the story of greatness. The stars, the stella, the universe, all these things we can see in the SKY should be describe in this book of infinity. Then the book is the book of Sky.

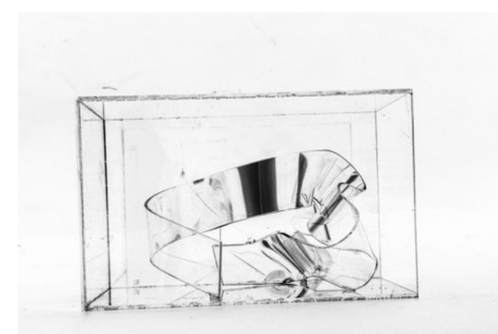
Book is something make connections between the readers and author or things described in the book. Book doesn't always contain the realities themselves unless the realities themselves are intangible concepts. In most circumstances, book only contains illusions, the projection of the realities.

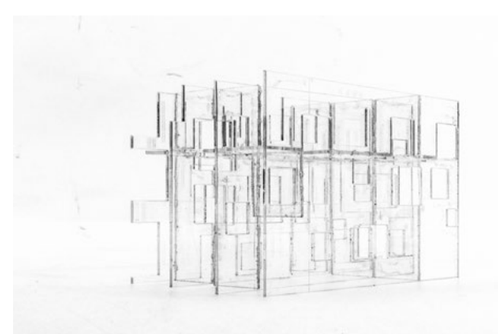
Then, a book of sky means a way of connection between sky and the reader.

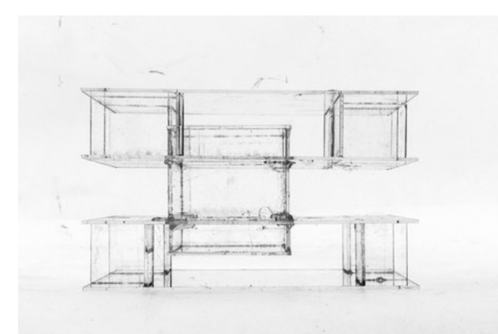


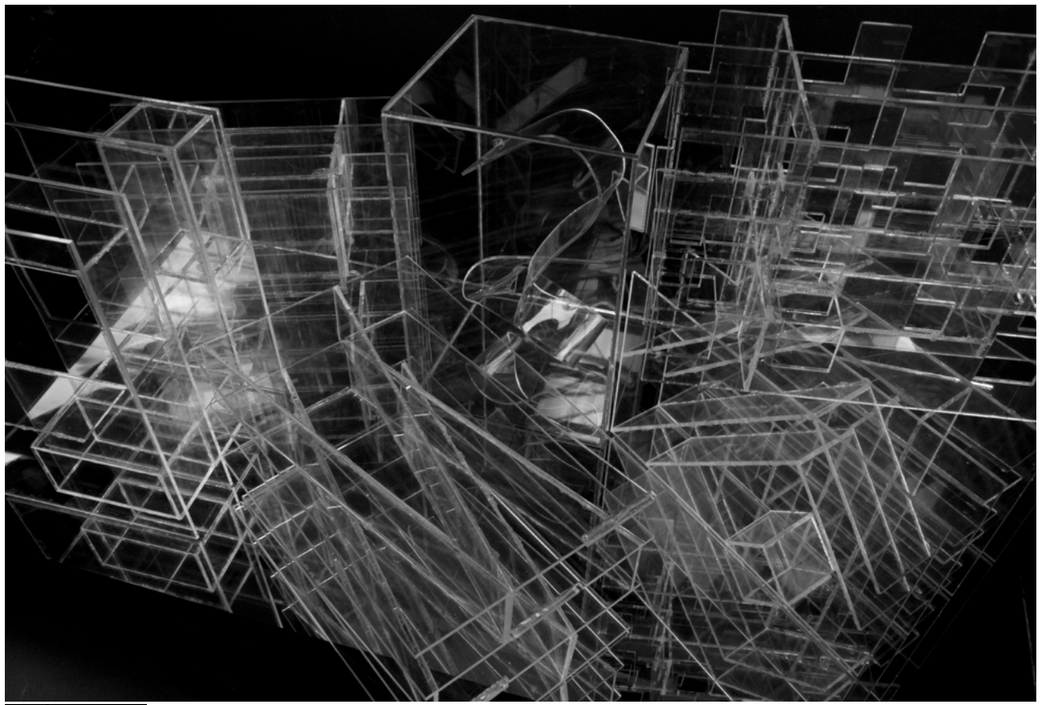




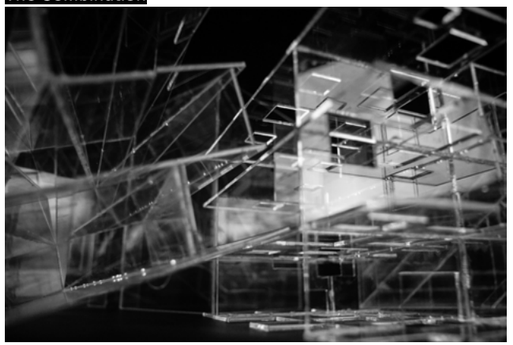


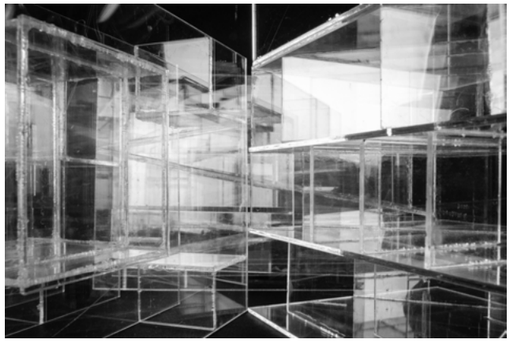


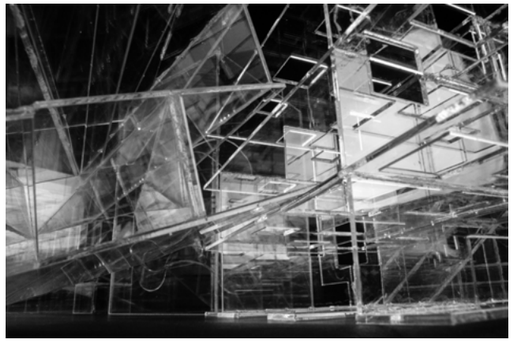


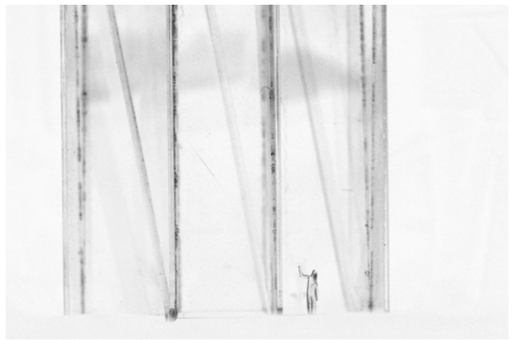


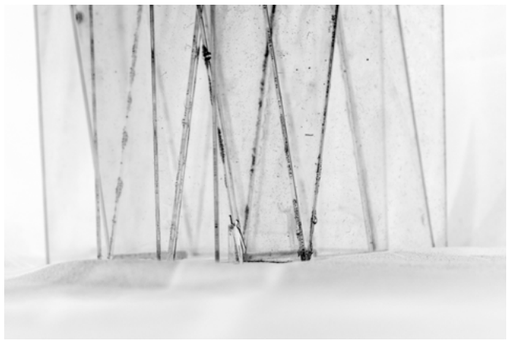
The Combination

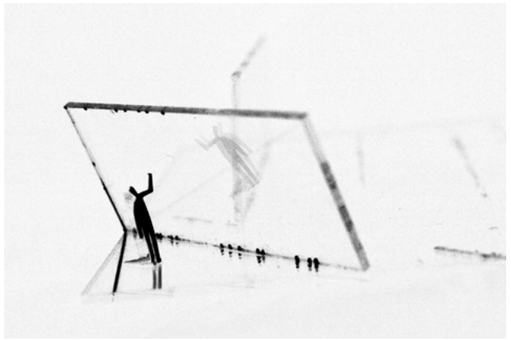




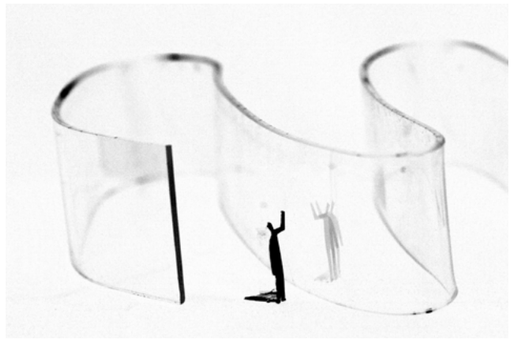


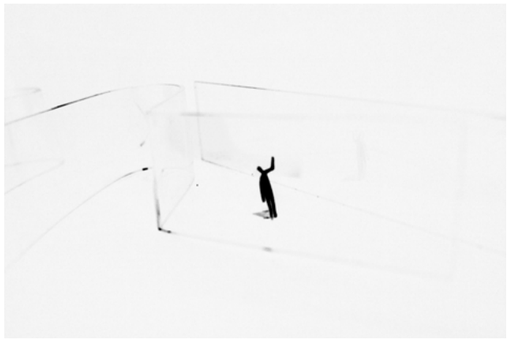






The connection between a visitor and its illusion

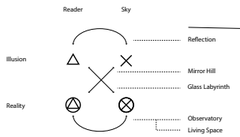




How many types of connections can be?

Reader Sky

The connections/books between Sky/ Reader and Illusion/ Reality



Illusion

Reality

Reflection

Mirror Hill

Glass Labyrinth

Observatory

Living Space

Narrow the distance

See the changing

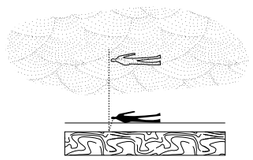
Library of Sky

Book of Sky is a way of connection between readers and sky, and there are many types of connections among illusion/ reality of reader/sky in still/motion. The assemble of these types of books is the Library of Sky.

A book is a connection between the readers and author or things described in the book. A book of Sky is a way of connection between sky and the reader.
The original thing is a reality, and the projection in the book is an illusion of the reality. In terms of the information they contain, there is no difference between realities and illusions.
Library is the set of books. Therefore, the properties of books define the property of library. A library of fine art always contains lots of collections of art/design albums.
As the result, the definition/form of books decides the form of library.

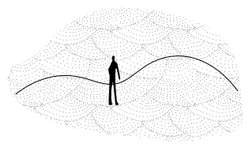
A book of sky can have many forms. "Optical telescopes which narrow the distance, glass labyrinth which mix the figure or both sky and readers. So does the living space and the land form arts, they all give new views of the connections.

On the Inner Mongolia Prairie, the grass is unbounded and the altitude are more than 1000m on average. Few trees, which help creating a clear line between sky and prairie. Futher more, in Inner Mongolia, they name sky as Long live sky, and prairie as Mother earth. They believe that after the death, the souls will fly back to the sky and body will reborn on the prairie.



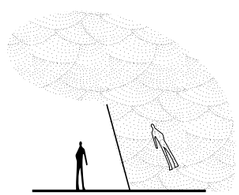
Reflection

see the illusion of reader in the illusion of sky



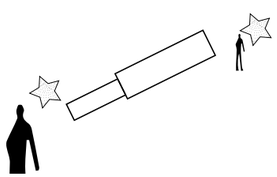
Mirror Hill

blur the edge between sky and earth, make reader sink into the surrounding of reality and illusion of sky



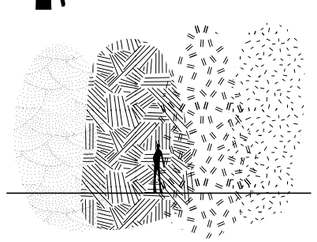
Glass Labyrinth

overlap the illusion of reader onto the sence of sky.



Observatory

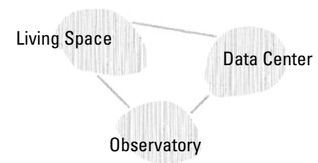
narrow the distance between sky and reader, make details of sky more vivid



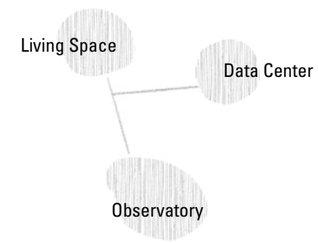
Living Space

see the changing of sky

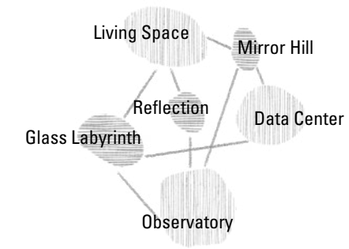
Programme Formation



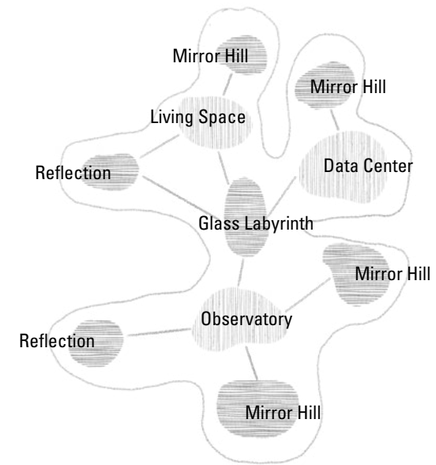
1. Three prgrammes have connections with each other



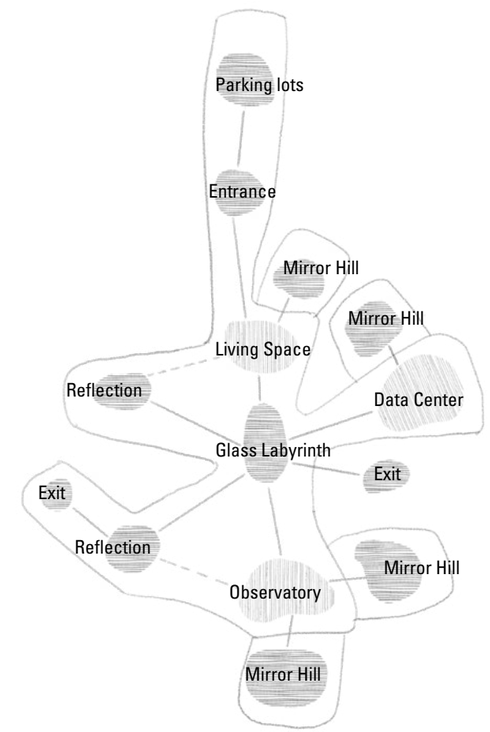
2. Simplify the connection



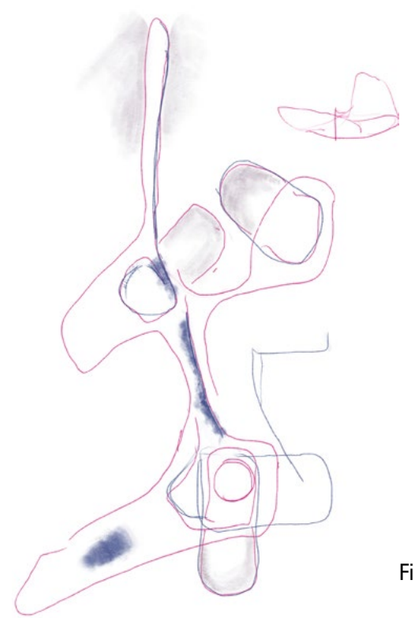
3. Introduce other three non-building programme into the system



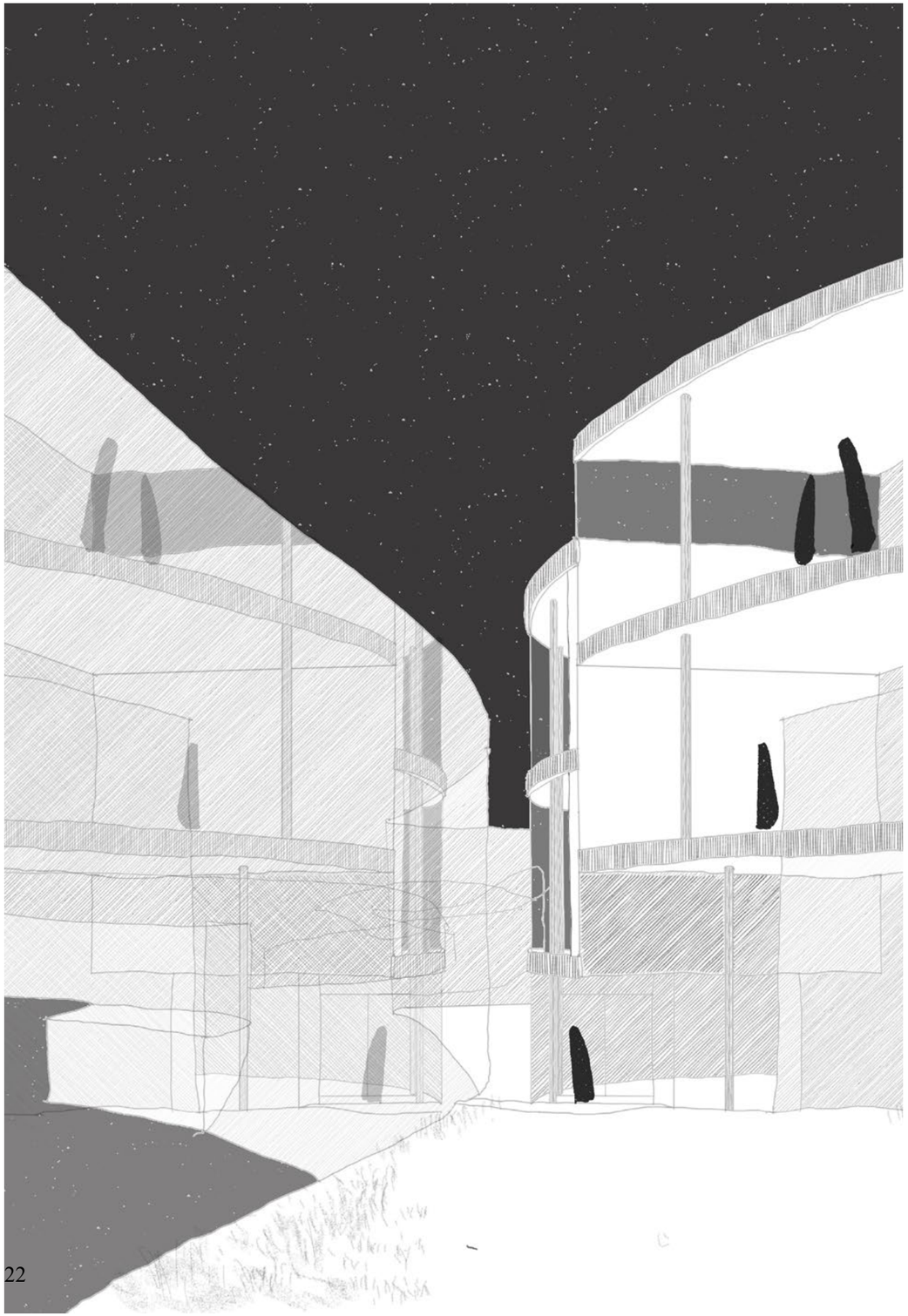
4. Expend the connections onto a plane



5. Connect the system to the outside

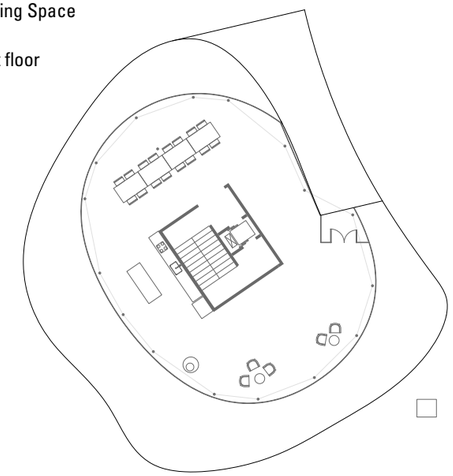


Final sketch

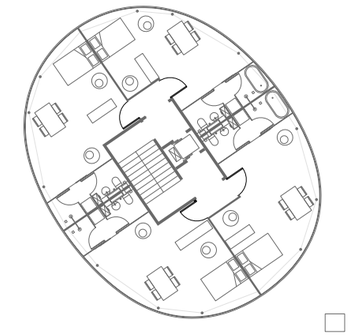


Living Space

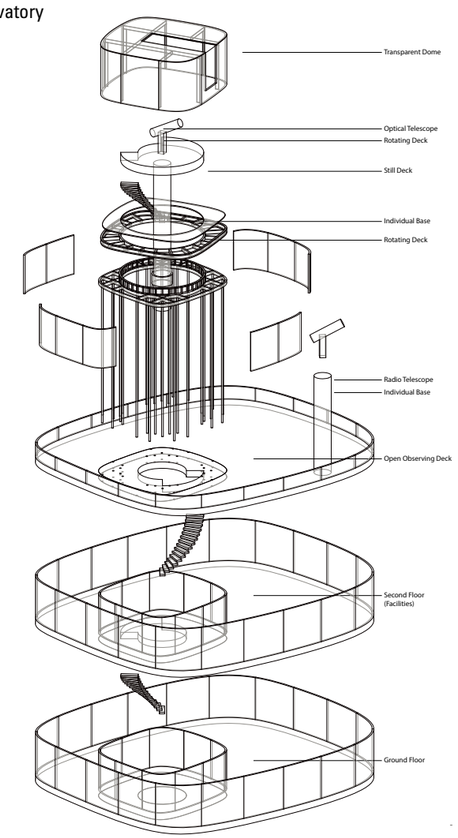
1st floor



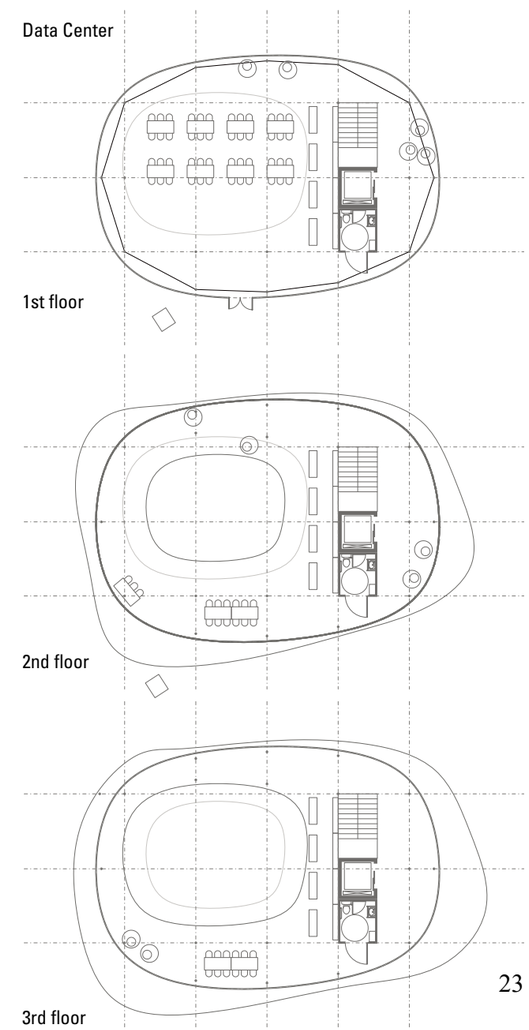
other floors

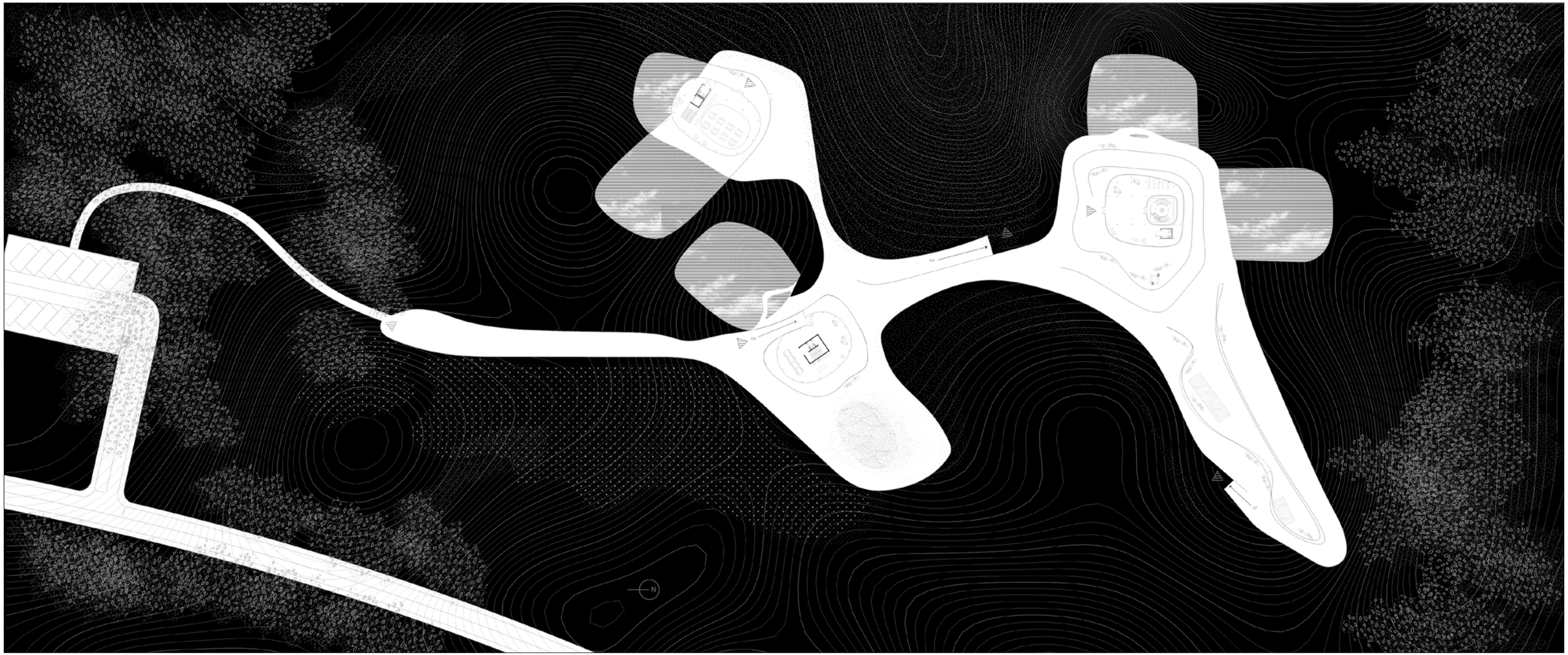


Observatory



Data Center





Site Plan

In the projects **Bone Structure** and **Darwin's Bark Spider** (Both are taught by Jenny Sabin), my teams were doing researches of either bone structure or Darwin's bark spider first, and then extract an algorithm from each case. Finally, use these algorithms as tools to design architectural elements. This shows virtual object can disassemble the properties of a certain matter and reorganize them by discourses.

In Bone Structure, firstly, we analyzed bones from several animals. From the morphological aspect, these bones share some similarities but entirely different in size, composition, density, etc. These properties shift from part to part and from species to species. However, logic is behind the form. If they share some similarities in shape, there must be the same logic behind. The logic is immaterial, is virtual. For finding the

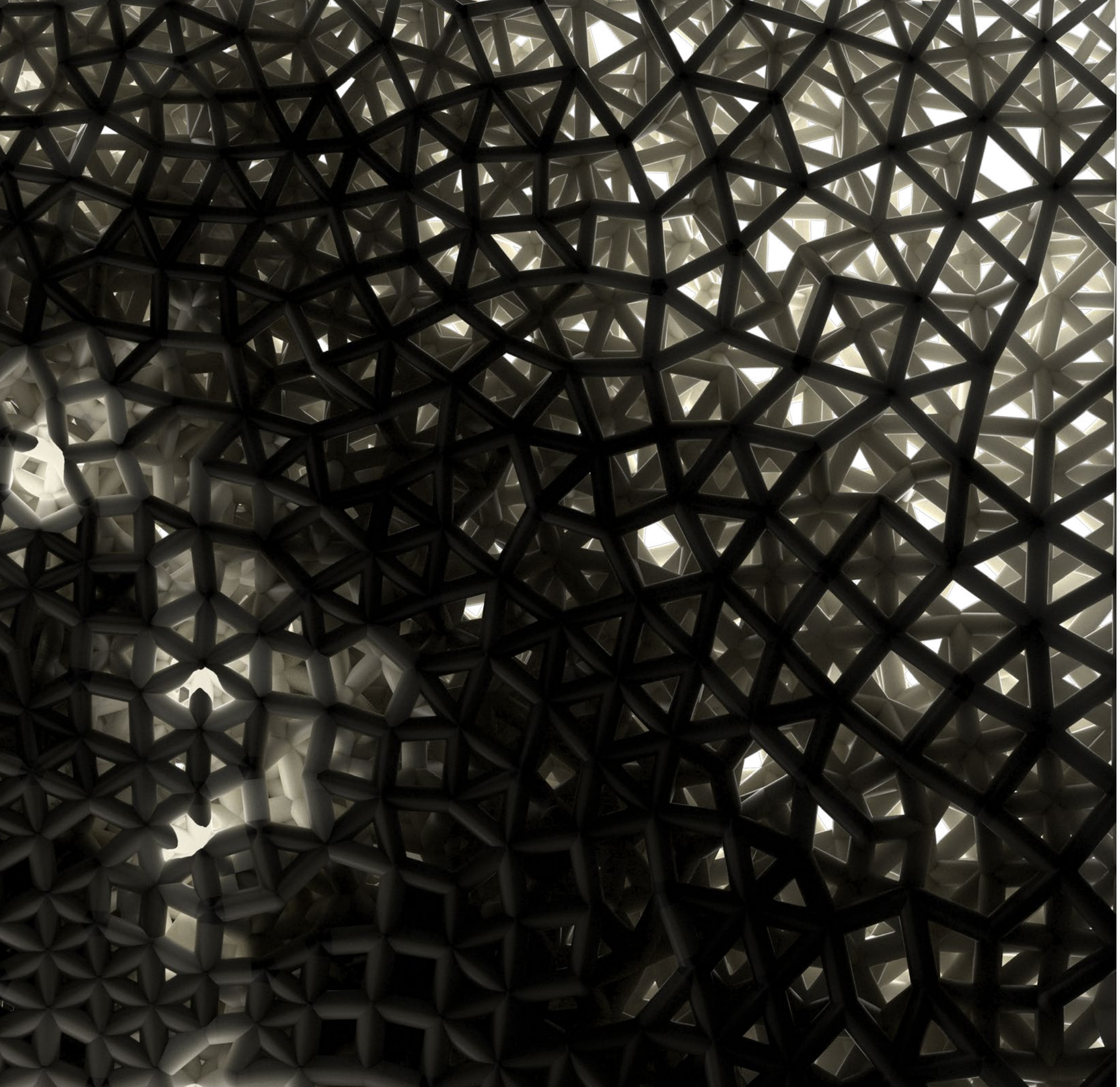
logic, we assumed the possible theory and algorithm first, and compare the results of the algorithm with the real bone structure, then modify the algorithm. With the help of engineering school, we had 3D scanned model of the trabecular system for making the comparison in different scales.

The first version of the algorithm was named as Sphere packing, and we assumed the trabecular system equal to a bunch of spheres with different radius stacked in a bucket. The links between central points of the spheres are equal to the axis lines of a trabecular system. For the radius varies, the length of the link varies. In later updates, we add more function in this algorithm. One is called Kissing Sphere Packing, which means the link will only be established if the two spheres have a direct contact. In this practice, we didn't directly copy or mimic the form of a matter. Instead, we abstract the logic from the matter, create an immaterial proxy for the material under the instruction of the logic, then use the proxy to produce matrixes of meshes. After 3D printing, the meshes had good mechanical performances as the distribution of forces were similar to the trabecular system. The virtual object here helped in rebuilding the matter by decomposing and recombining it.

In Darwin's Bark Spider, we did research of a certain spider which can weave the largest spider orb web in the world. At first, we broadly research al the information related to the weaving, such as properties of the material, the comparison between Darwin's bark spider and other species. And then, we carefully examined the processing of weaving spider web and concluded the hierarchy of the web structure. Later we rouse a question in our mind, what could it be if there were many webs works together for forming a much bigger area of capture. Then we tried to find a logical answer based on the researches. Eventually, two methods were invented. The first one was from top to bottom, which shows the logic of developing. It assumed that the side-bridge line of the former web would become the bridge line of the later web. In this hierarchy, web aggregation will become bigger and bigger. In the other approach,

based on NASA's drugged spider weaving behavior experiment, we believed the web is the result of the spider's behavior. For each web matches to one spider, the web aggregation is the product of a spider aggregation. In this method, we designed an algorithm in processing to demonstrate the moving points will cast lines along their paths, and we the moving point have contacts with their path lines, they will either pass through or bounce back to another direction. In some cases, they will make a knot to the path lines when they have contact. Then their movement will drag the existed line a little bit. This agent base 3D model successfully represented some patterns in the drugged spider weaving experiment.

In this case, similar to Bone Structure, we abstract the logic from the research object and use the logic to simulate a result, a digital mesh, for making comparison with the research object. The virtual object here is the digital model and algorithm. But in Darwin's bark spider, we did one step forward, which is using the mesh to make toolpath for a robotic arm, then the robotic arm will build a new web by hot glue instead of spider silk. The hot glue made web became a prototype of further constructing a project. Here, in this case, the virtual object helped to rebuild a material. It took the essential of a certain matter, the spider web, and rebuild a new matter on a larger scale and with different material. The virtual object is the key tool to make the translation happen.



Brick of Bone Structure

Polybrick2.0-ceramic brick
research based on Wolff's law

Brick is a basic unit of a building. It is usually made by clay and fired in kilns.
Perforated brick reduce the mass of structure, the clay we use, the fuel we fire in kilns, and of course the price of the brick. Also, the effects of sound and thermal insulation become much better.

But could a brick be even lighter?

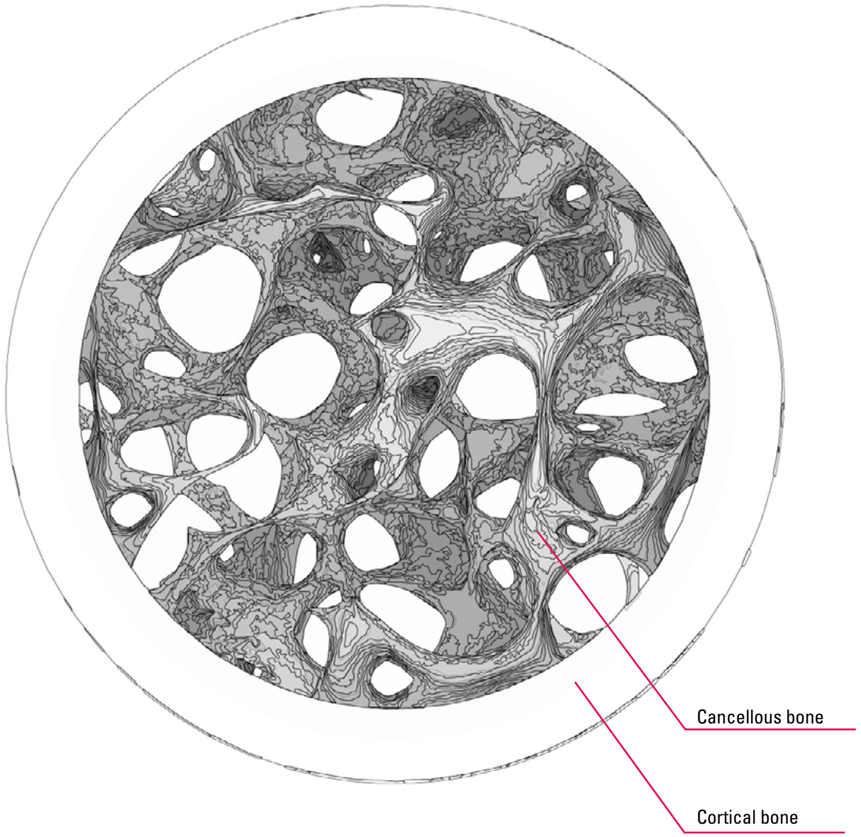
We research the bone structure of animals, to find the possibility of redeucing the weight of brick to another level while making sure its efficiency in loading bearing.

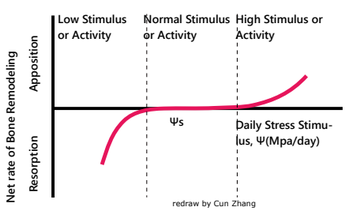
Instructor: Jenny Sabin
Team member: Yao Lu, Cun Zhang, Ege Sekkin, Eda Birol

The background research of Bone

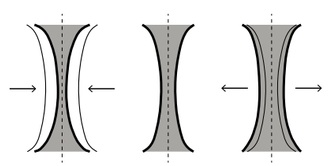
A bone has two parts, Cortical part and Cancellous part. Cortcal part, also known as compact bone, has a hard and high-density composition and has high resistance to bending and torsion. And cancellous bone, as known as Spongy bone, reduce the weight of the skeleton and gives skeleton strength by absorbing shocks.

Patition of bone





Stimulus setpoint:
When the net activity is near a physiological level called Ψs.
Mechanbiologic response drives bone to Ψs.
Net apposition when Ψs<Ψ
Net resorption when Ψs>Ψ
hazy phase when Ψs=Ψ
Apposition and resorption are a function of mechanical loading



Wolff's Law

redraw by Cun Zhang

Wolff's Law states that bone in a healthy person or animal will adapt to the loads under which it is placed. If loading on a particular bone increases, the bone will remodel itself over time to become stronger to resist that sort of loading. The internal architecture of the trabeculae undergoes adaptive changes, followed by secondary changes to the external cortical portion of the bone.

Specific physical properties associated with specific mechanical properties
Trabecular Number
Trabecular Thickness
Trabecular Separation
Trabecular Connectivity
Adaptability and possibility of change within these properties
Emphasis on specialization and light weight
Emphasis on regeneration

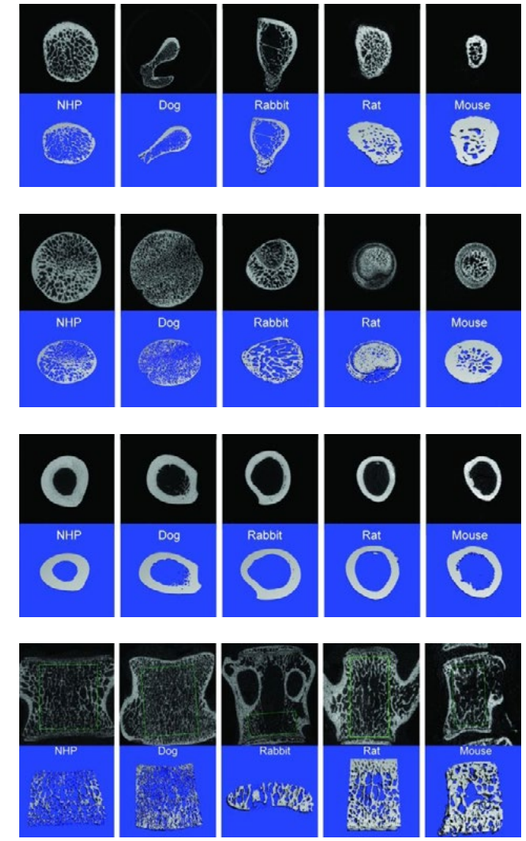
Cortical and cancellous bone parameters obtained from animals by using CT

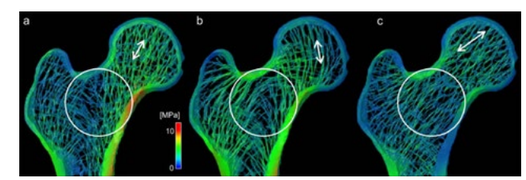
Mice	Femoral head	Femoral neck	Proximal diaphysis	Lumbar vertebrae	Mandible
Tissue volume (mm^3)	0.25 ± 0.06	0.08 ± 0.02	0.56 ± 0.07	0.77 ± 0.15	0.11 ± 0.00
Bone volume (mm^3)	0.19 ± 0.06	0.05 ± 0.01	0.22 ± 0.04	0.17 ± 0.03	0.08 ± 0.01
Bone volume : Tissue volume (ratio)	0.77 ± 0.12	0.62 ± 0.05	0.38 ± 0.03	0.22 ± 0.03	0.69 ± 0.11
No. of trabeculae (per mm)	6.16 ± 1.55	8.53 ± 0.76	not done	5.98 ± 0.49	5.44 ± 0.47
Trabecular thickness(μm)	0.13 ± 0.05	0.13 ± 0.05	not done	0.04 ± 0.003	0.13 ± 0.02
Trabecular separation(μm)	0.04 ± 0.01	0.04 ± 0.003	not done	0.13 ± 0.02	0.06 ± 0.02
Trabecular connectivity(per mm^3)	247.5 ± 127.5	482.5 ± 127.5	not done	541.5± 91.0	62.76 ± 33.36
Bone mineral density(g/cm^3)	898.5 ± 85.4	937.7 ± 36.9	1206.4 ± 24.5	845.3 ± 10.7	1286.9 ± 62.6
Cortical thickness (mm)	not done	not done	0.23 ± 0.03	not done	not done
Marrow volume (mm^3)	not done	not done	0.35 ± 0.3	not done	not done

Rabbits	Femoral head	Femoral neck	Proximal diaphysis	Lumbar vertebrae	Mandible
Tissue volume (mm^3)	5.60± 1.19	11.79 ± 1.56	156.8 ± 9.8	6.96 ± 0.46	1.00 ± 0.03
Bone volume (mm^3)	3.22 ± 0.58	3.44 ± 1.02	59.7 ± 2.9	0.67 ± 0.26	0.46 ± 0.17
Bone volume : Tissue volume (ratio)	0.58 ± 0.04	0.29 ± 0.07	0.38 ± 0.02	0.24 ± 0.04	0.46 ± 0.17
No. of trabeculae (per mm)	3.83 ± 0.65	2.28 ± 0.85	not done	6.68 ± 0.21	2.15 ± 0.53
Trabecular thickness(μm)	0.15 ± 0.02	0.15 ± 0.02	not done	0.09 ± 0.01	0.21 ± 0.04
Trabecular separation(μm)	0.11 ± 0.02	0.32 ± 0.07	not done	0.29 ± 0.09	0.30 ± 0.22
Trabecular connectivity(per mm^3)	138.2 ± 48.1	39.2 ± 10.3	not done	68.9± 22.2	6.74 ± 5.48
Bone mineral density(g/cm^3)	718.9 ± 27.1	785.1 ± 12.5	1167.5 ± 17.5	718.9 ± 10.4	973.6 ± 44.7
Cortical thickness (mm)	not done	not done	9.5 ± 0.4	not done	not done
Marrow volume (mm^3)	not done	not done	97.2 ± 8.6	not done	not done

Dogs	Femoral head	Femoral neck	Proximal diaphysis	Lumbar vertebrae	Mandible
Tissue volume (mm^3)	160.14± 12.23	39.68 ± 2.20	422.4 ± 54.0	72.65 ± 22.9	8.83 ± 0.34
Bone volume (mm^3)	59.72 ± 10.87	8.83 ± 1.50	201.1 ± 17.0	9.65 ± 1.95	3.13 ± 1.16
Bone volume : Tissue volume (ratio)	0.37 ± 0.05	0.22 ± 0.04	0.48 ± 0.02	0.14 ± 0.02	0.35 ± 0.12
No. of trabeculae (per mm)	3.58 ± 0.14	2.44 ± 0.21	not done	2.54 ± 0.08	1.93 ± 0.27
Trabecular thickness(μm)	0.10 ± 0.02	0.09 ± 0.01	not done	0.05 ± 0.01	0.18 ± 0.05
Trabecular separation(μm)	0.18 ± 0.01	0.32 ± 0.04	not done	0.34 ± 0.003	0.35 ± 0.10
Trabecular connectivity(per mm^3)	92.30 ± 14.42	52.2 ± 11.2	not done	112.7± 20.0	31.94 ± 7.71
Bone mineral density(g/cm^3)	850.3 ± 7.0	871.2 ± 9.5	1058.5 ± 9.5	855.9 ± 12.8	904.39 ± 14.2
Cortical thickness (mm)	not done	not done	14.3 ± 2.7	not done	not done
Marrow volume (mm^3)	not done	not done	221.3 ± 37.0	not done	not done

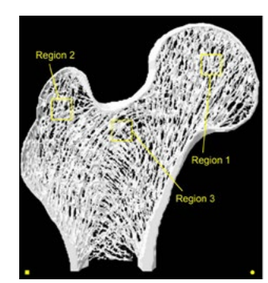
Rats	Femoral head	Femoral neck	Proximal diaphysis	Lumbar vertebrae	Mandible
Tissue volume (mm^3)	3.51± 1.17	1.49 ± 0.20	2.66 ± 0.12	3.35 ± 0.20	0.97 ± 0.06
Bone volume (mm^3)	2.59 ± 0.90	0.99 ± 0.15	1.01 ± 0.03	1.10 ± 0.11	0.60 ± 0.14
Bone volume : Tissue volume (ratio)	0.74 ± 0.06	0.66 ± 0.07	0.38 ± 0.02	0.33 ± 0.03	0.61 ± 0.15
No. of trabeculae (per mm)	5.58 ± 0.54	5.32 ± 0.18	not done	4.77 ± 0.31	3.33 ± 0.29
Trabecular thickness(μm)	0.13 ± 0.02	0.13 ± 0.02	not done	0.07 ± 0.003	0.19 ± 0.06
Trabecular separation(μm)	0.05 ± 0.01	0.06 ± 0.01	not done	0.14 ± 0.01	0.11 ± 0.04
Trabecular connectivity(per mm^3)	227.6 ± 39.1	171.7 ± 33.7	not done	178.6± 29.2	23.65 ± 8.33
Bone mineral density(g/cm^3)	788.1 ± 11.6	928.1 ± 15.9	1117.6 ± 9.5	760.4± 8.0	1024.4 ± 42.5
Cortical thickness (mm)	not done	not done	0.44 ± 0.03	not done	not done
Marrow volume (mm^3)	not done	not done	1.64 ± 0.12	not done	not done





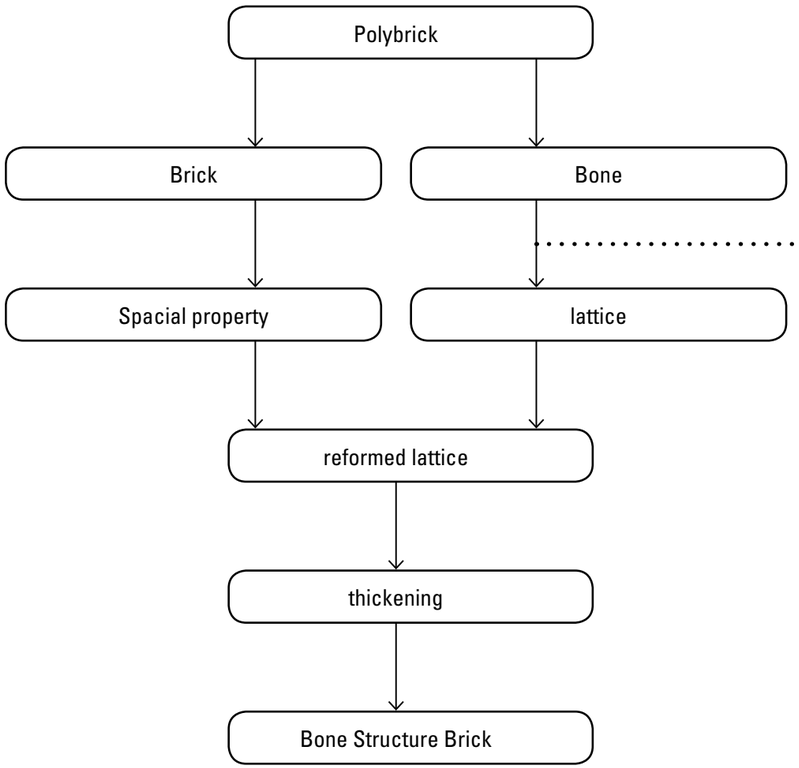
pics are from internet and research paper

pictures show how different bones from different animals which have different usages have different patition and structure of bones.



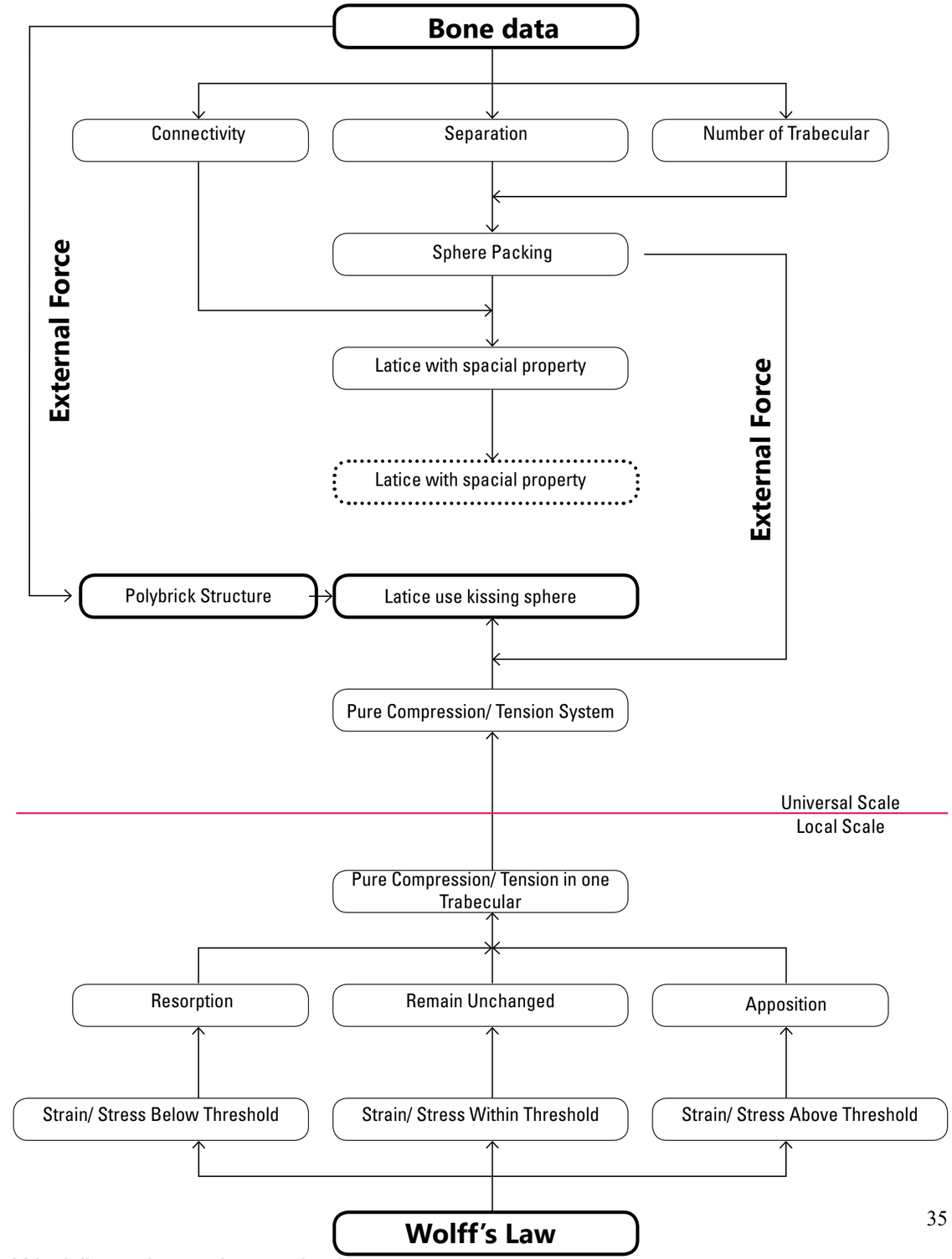
pics are from internet and research paper

Overall workflow



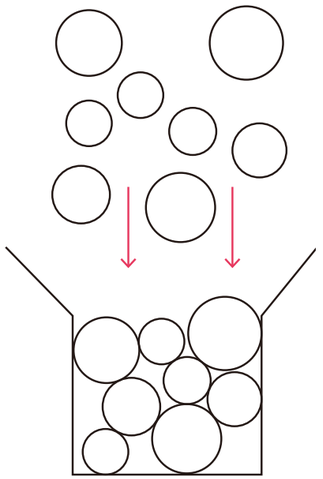
Goal: Specialization of building blocks through implementation of lessons from the bone

We set the general work flow and the key process is how to generate the LATTICE from information from bone.



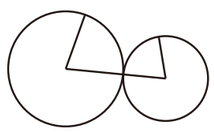
Workflow : bone data to lattice

Bone to lattice



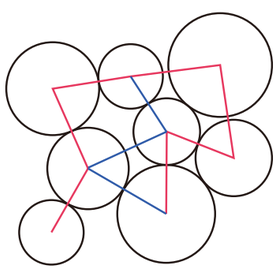
Random falling

We generate random born sphere with different radius in the half air. Then they will start falling and bump in to each other and finally fall into a box. This box is the shape of a brick. The connections between central points merge to the lattice.



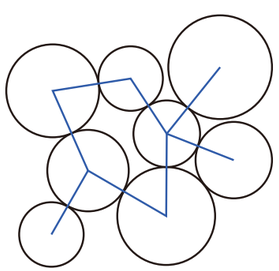
Radius and lattice density

These sphere have a radius from a range. Then the density of lattice can be manipulated by controlling the range of radius.



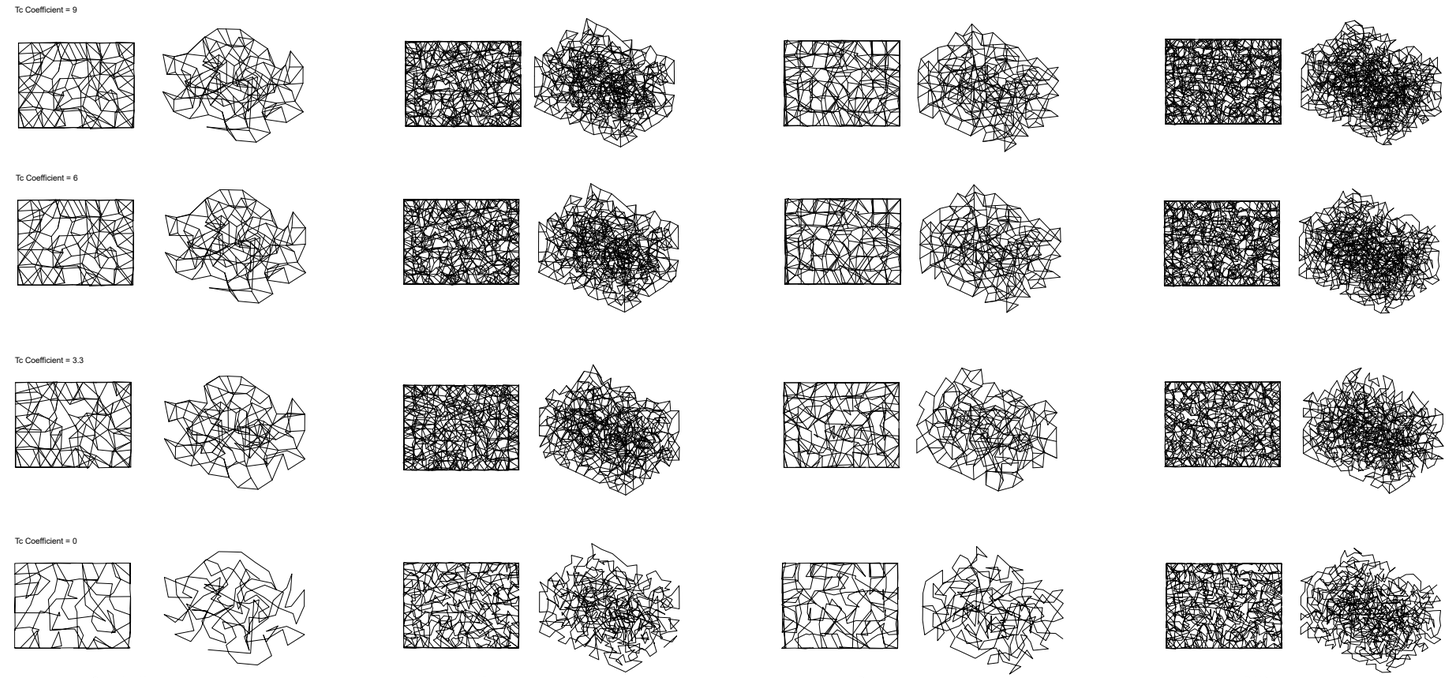
Sphere Packing by connectibity control

Our first algorithm is sphere packing by connectivity control. It means the start point will link the closed unlinked central point. Then step by step, a lattice is made by giving more connectivity number which is larger than the number of spheres.



Kissing Sphere Packing

But in the first algorithm, some connections will be too long to be a efficient structure. Then we change it to a rule that, all the spheres have touch with others, their central points will connect to those central points of the others. Finally another type of lattice is made.



Cynomolgus Macaques

Total number of sphere in set region:
133

Tt(um): 0.14 ±0.02

Ts(um): 0.24 ±0.04

Tc(per mm^3): 63.44 ±19.05 (80*3.3)

Mice

Total number of sphere in set region:
630

Mice Lumbar

Tt(um): 0.04 ±0.003

Ts(um): 0.13 ±0.02

Tc(per mm^3): 541.5 ±91(600*3.3)

Dogs

Total number of sphere in set region:
265

Tt(um): 0.10 ±0.02

Ts(um): 0.18 ±0.01

Tc(per mm^3): 92.3±14.42 (110*3.3)

Rabbits

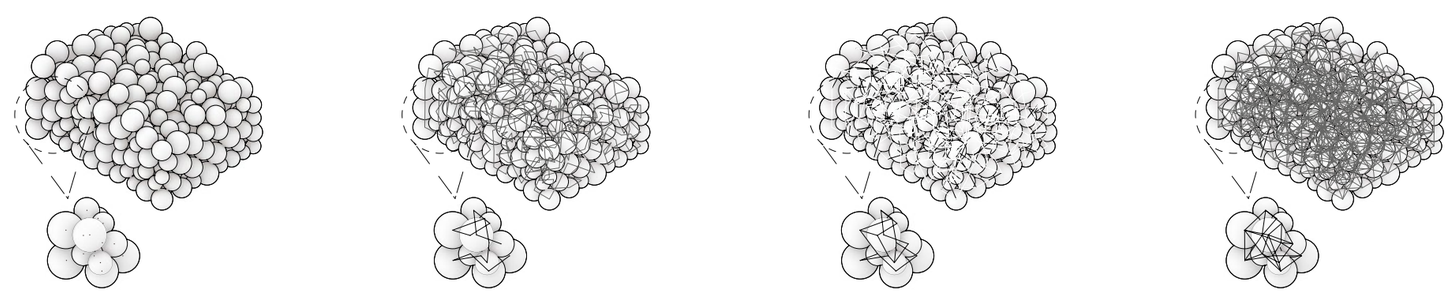
Total number of sphere in set region:
594

Tt(um): 0.15 ±0.02

Ts(um): 0.11 ±0.02

Tc(per mm^3): 138.2 ±48.1(160*3.3)

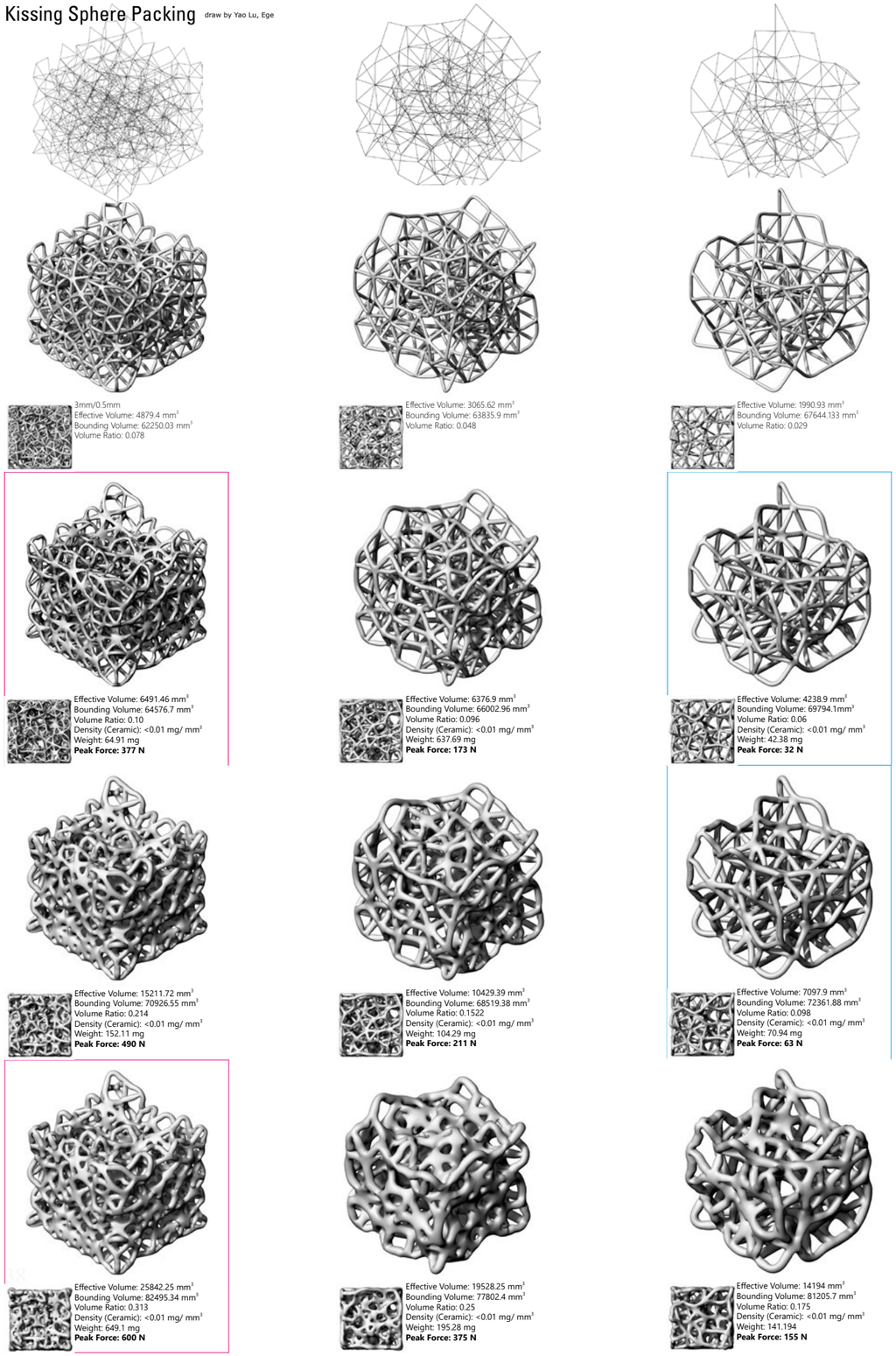
Using the data of four animal to generate lattice



Sphere Packing

Kissing Sphere Packing

draw by Yao Lu, Ege



3mm/0.5mm
Effective Volume: 4879.4 mm³
Bounding Volume: 62250.03 mm³
Volume Ratio: 0.078

Effective Volume: 3065.62 mm³
Bounding Volume: 63835.9 mm³
Volume Ratio: 0.048

Effective Volume: 1990.93 mm³
Bounding Volume: 67644.133 mm³
Volume Ratio: 0.029

Effective Volume: 6491.46 mm³
Bounding Volume: 64576.7 mm³
Volume Ratio: 0.10
Density (Ceramic): <0.01 mg/ mm³
Weight: 64.91 mg
Peak Force: 377 N

Effective Volume: 6376.9 mm³
Bounding Volume: 66002.96 mm³
Volume Ratio: 0.096
Density (Ceramic): <0.01 mg/ mm³
Weight: 637.69 mg
Peak Force: 173 N

Effective Volume: 4238.9 mm³
Bounding Volume: 69794.1mm³
Volume Ratio: 0.06
Density (Ceramic): <0.01 mg/ mm³
Weight: 42.38 mg
Peak Force: 32 N

Effective Volume: 15211.72 mm³
Bounding Volume: 70926.55 mm³
Volume Ratio: 0.214
Density (Ceramic): <0.01 mg/ mm³
Weight: 152.11 mg
Peak Force: 490 N

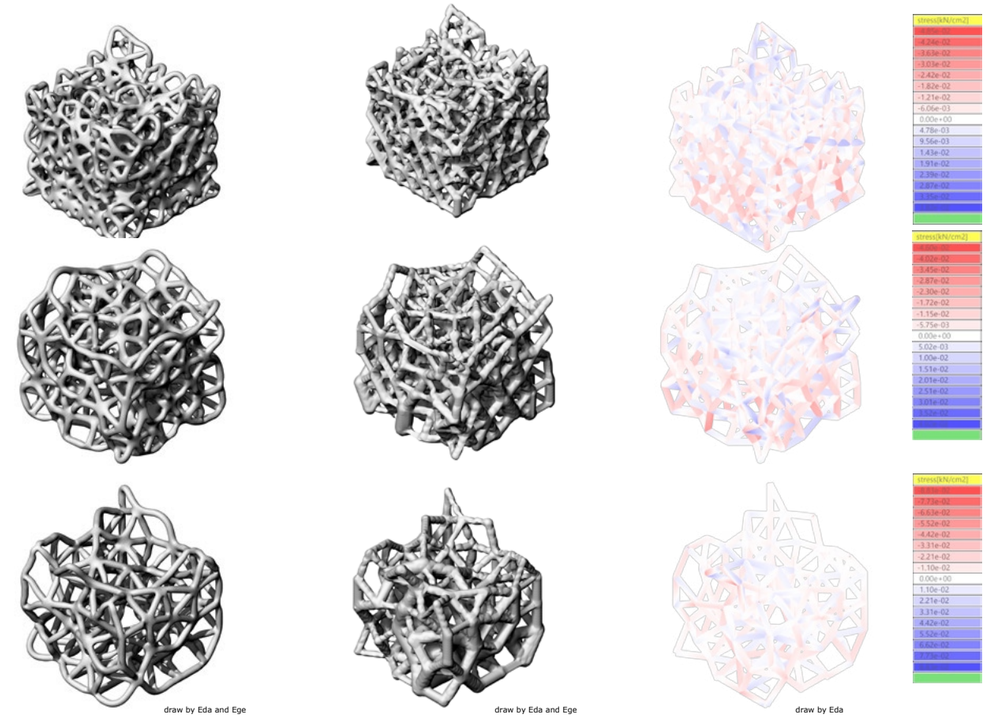
Effective Volume: 10429.39 mm³
Bounding Volume: 68519.38 mm³
Volume Ratio: 0.1522
Density (Ceramic): <0.01 mg/ mm³
Weight: 104.29 mg
Peak Force: 211 N

Effective Volume: 7097.9 mm³
Bounding Volume: 72361.88 mm³
Volume Ratio: 0.098
Density (Ceramic): <0.01 mg/ mm³
Weight: 70.94 mg
Peak Force: 63 N

Effective Volume: 25842.25 mm³
Bounding Volume: 82495.34 mm³
Volume Ratio: 0.313
Density (Ceramic): <0.01 mg/ mm³
Weight: 649.1 mg
Peak Force: 600 N

Effective Volume: 19528.25 mm³
Bounding Volume: 77802.4 mm³
Volume Ratio: 0.25
Density (Ceramic): <0.01 mg/ mm³
Weight: 195.28 mg
Peak Force: 375 N

Effective Volume: 14194 mm³
Bounding Volume: 81205.7 mm³
Volume Ratio: 0.175
Density (Ceramic): <0.01 mg/ mm³
Weight: 141.194
Peak Force: 155 N



draw by Eda and Ege

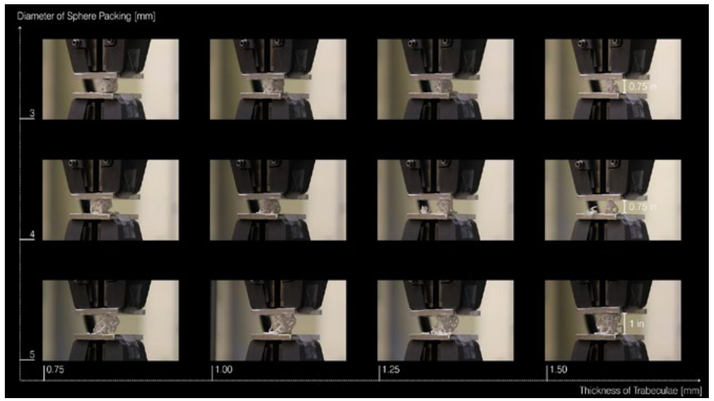
draw by Eda and Ege

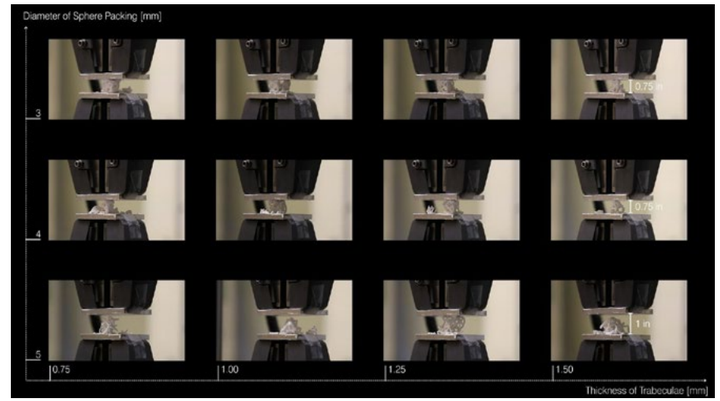
draw by Eda

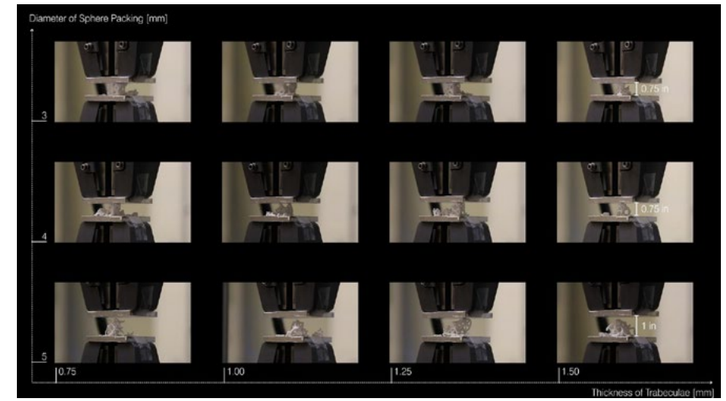
Kissing Sphere Packing

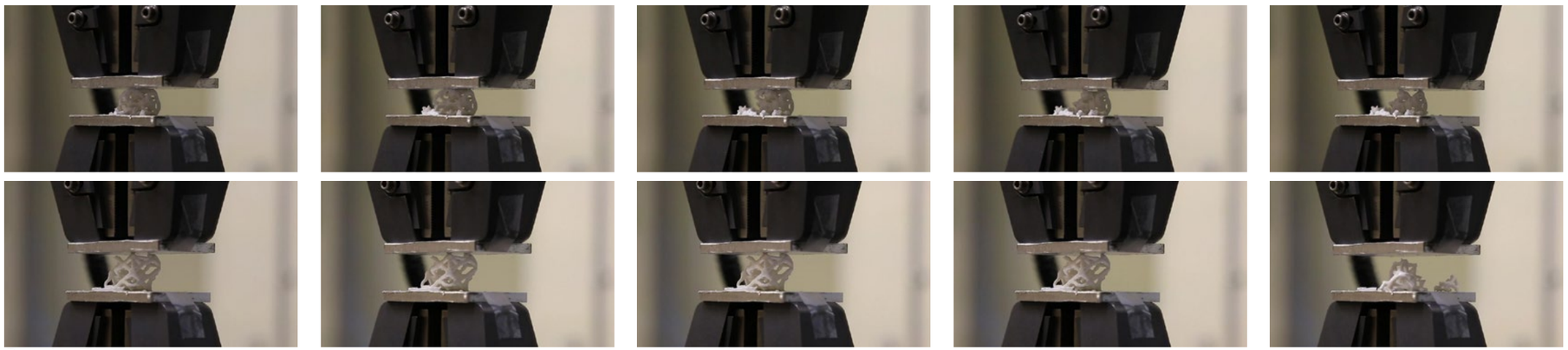
we make and test different bone structure unit with different lattice and thickness. print them in Jenny Sabin Lab and then fire them in the kiln with 1800C. The resin will disappear for the high temperature but the ceramic mud will be light and strong after the fir, fragile also.

Models, made by 3D-print, material: resin with Ceramic mud, then fired in kiln





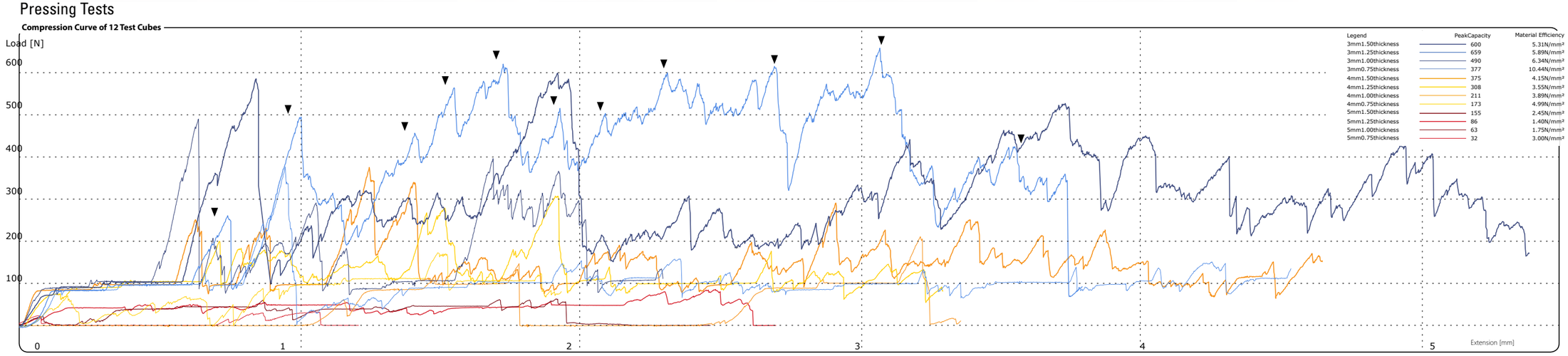




With the help of Professor Christopher Hernandez, the expert in bone structure from Cornell College of Engineering, we had tutorial and access to use the compressing strength testing platform in College of Engineering to test the strength of of poly brick unit. And we made comparison with the a solid cube which has same material with the others.

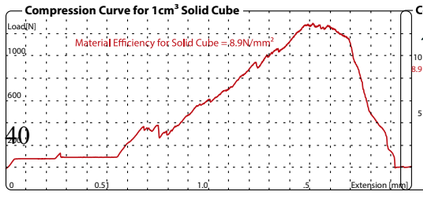
Pressing Tests

Compression Curve of 12 Test Cubes

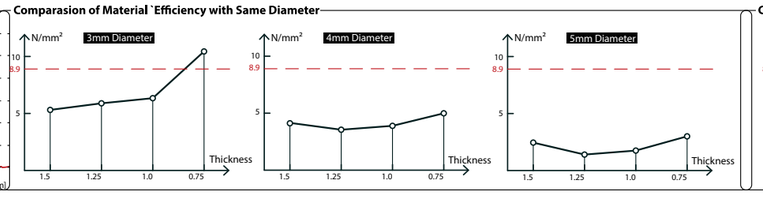


Legend		PeakCapacity	Material Efficiency
3mm1.50thickness	—	600	5.31N/mm²
3mm1.25thickness	—	659	5.89N/mm²
3mm1.00thickness	—	490	6.34N/mm²
3mm0.75thickness	—	377	10.44N/mm²
4mm1.50thickness	—	375	4.15N/mm²
4mm1.25thickness	—	308	3.55N/mm²
4mm1.00thickness	—	211	3.89N/mm²
4mm0.75thickness	—	173	4.99N/mm²
5mm1.50thickness	—	155	2.45N/mm²
5mm1.25thickness	—	86	1.40N/mm²
5mm1.00thickness	—	63	1.75N/mm²
5mm0.75thickness	—	32	3.00N/mm²

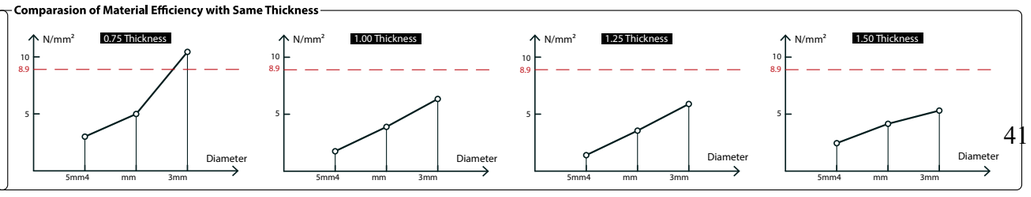
Compression Curve for 1cm³ Solid Cube



Comparasion of Material `Efficiency with Same Diameter



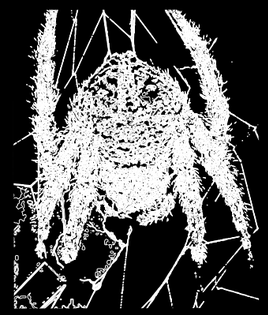
Comparasion of Material Efficiency with Same Thickness



draw by Yao Lu

Darwin’s Bark Spider

Study of Darwin's Bark Spider

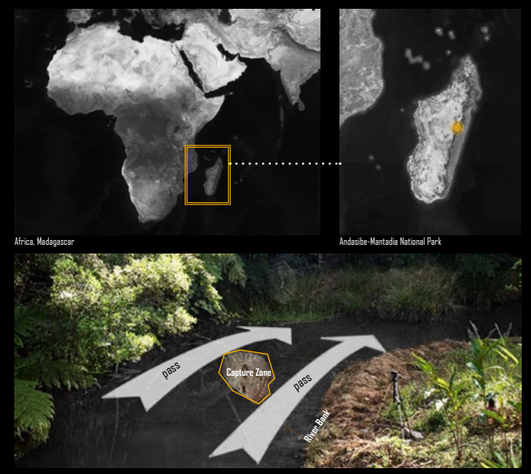


Basic Infos

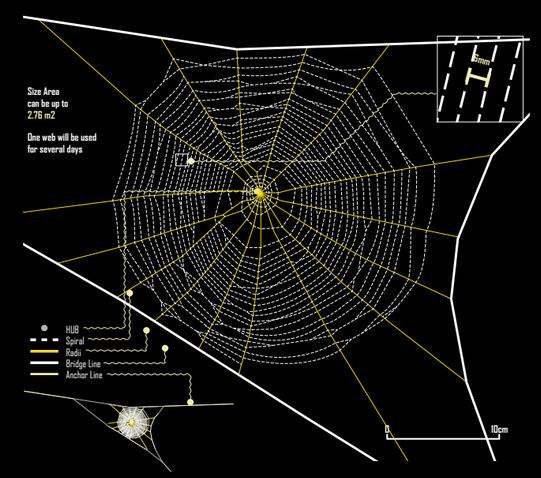
Scientific Name	**Caerostris Darwini**
Type of Web-weaving	**Orb-weaver Spider**
Family	**Araneidae**
Found date	**2009**
Found area	**Madagascar**

Sexual Dimorphism and Real Size

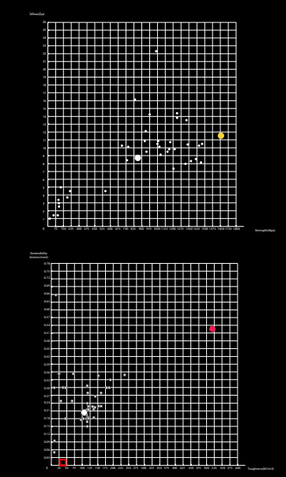
Habitat



Web Structure



Web Toughness Comparation



Stiffness (GPa)

Darwin's Bark Spider — Average of other Spider

11.5 = 8.8

Strength (MPa)

Darwin's Bark Spider — Average of other Spider

1652 = 878

Exstensibility (ln(mm/mm))

Darwin's Bark Spider — Average of other Spider

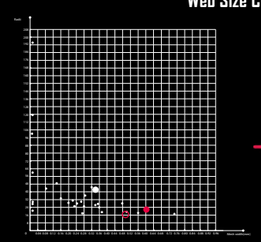
0.52 = 0.2

Toughness(MJ/m3)

Darwin's Bark Spider — Average of other Spider

520 = 107

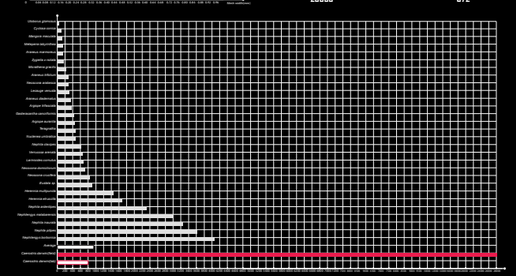
Web Size Comparation



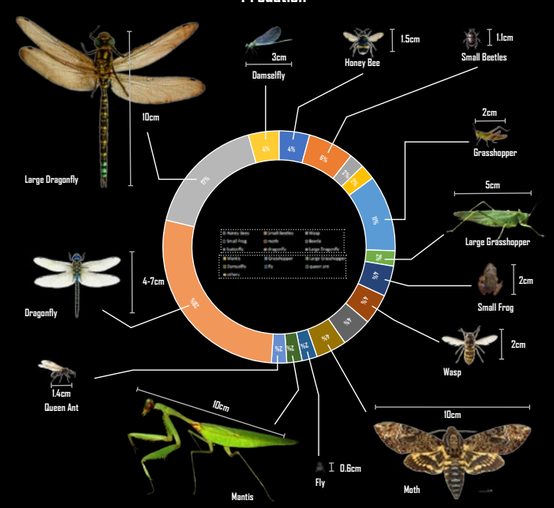
Area (cm2)

Darwin's Bark Spider — Average of other Spider

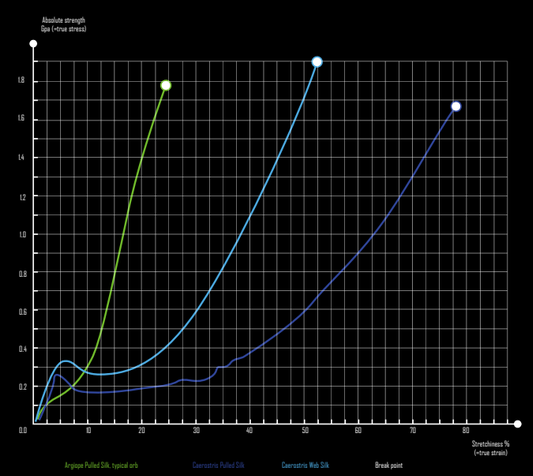
28000 = 972



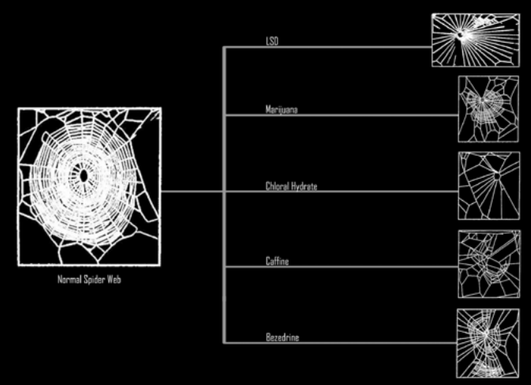
Predation



Web Size Comparation

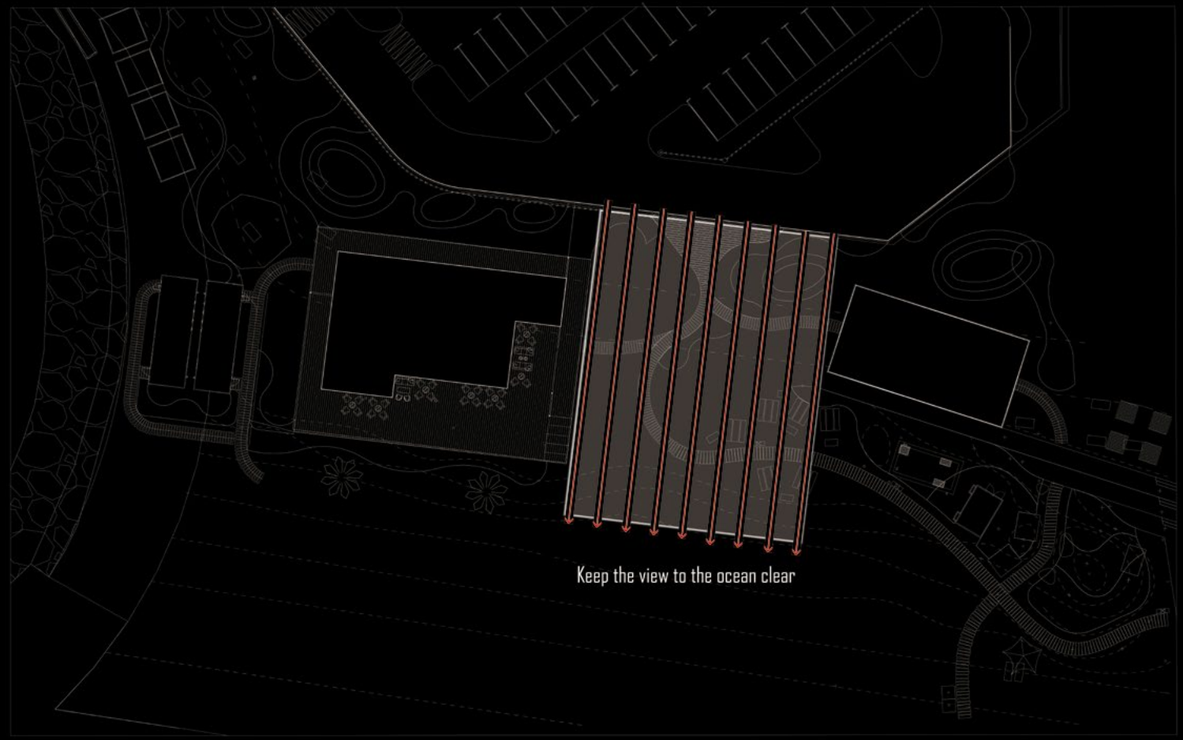


Drug intervened Webbing behavior

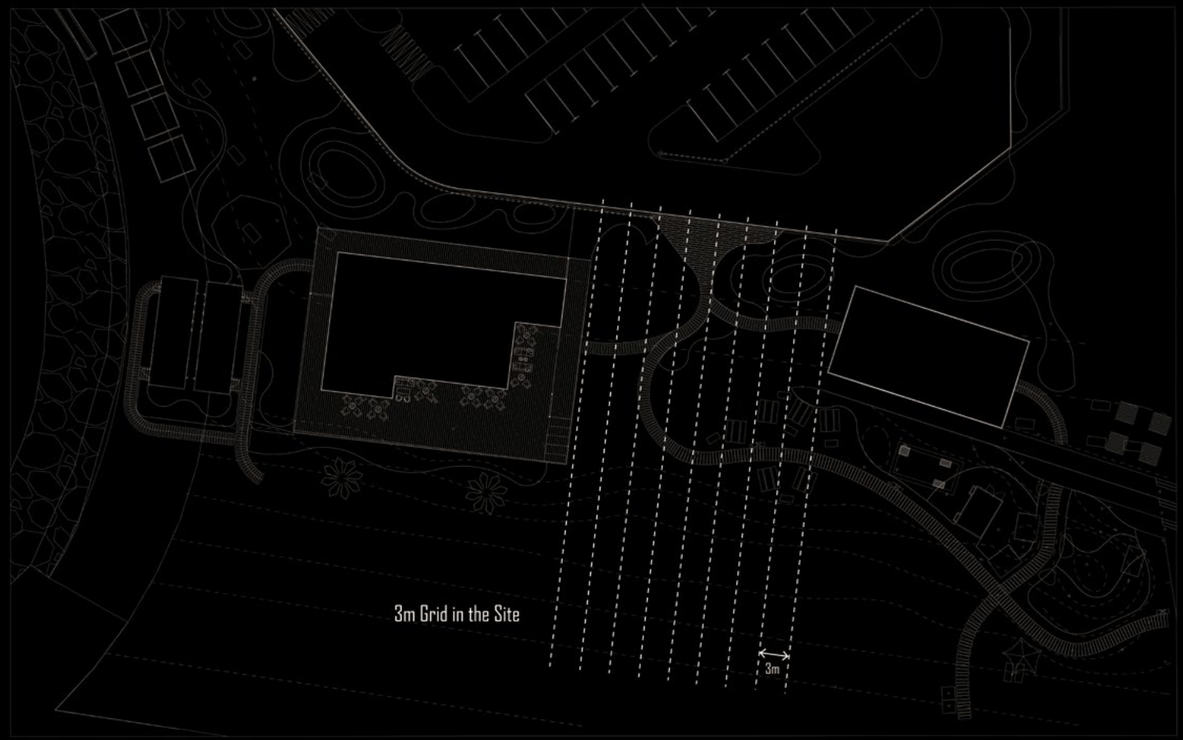


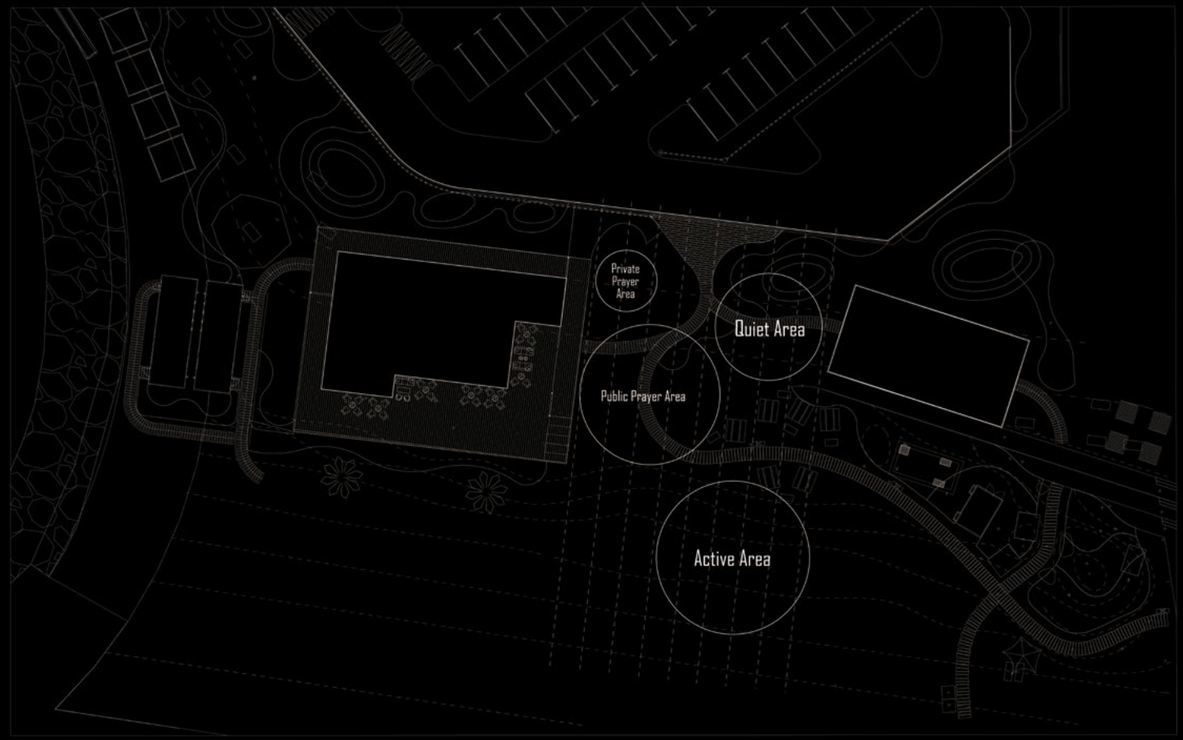
* This experiment was not made on Darwin's bark spider, but typical orb-web garden spiders.

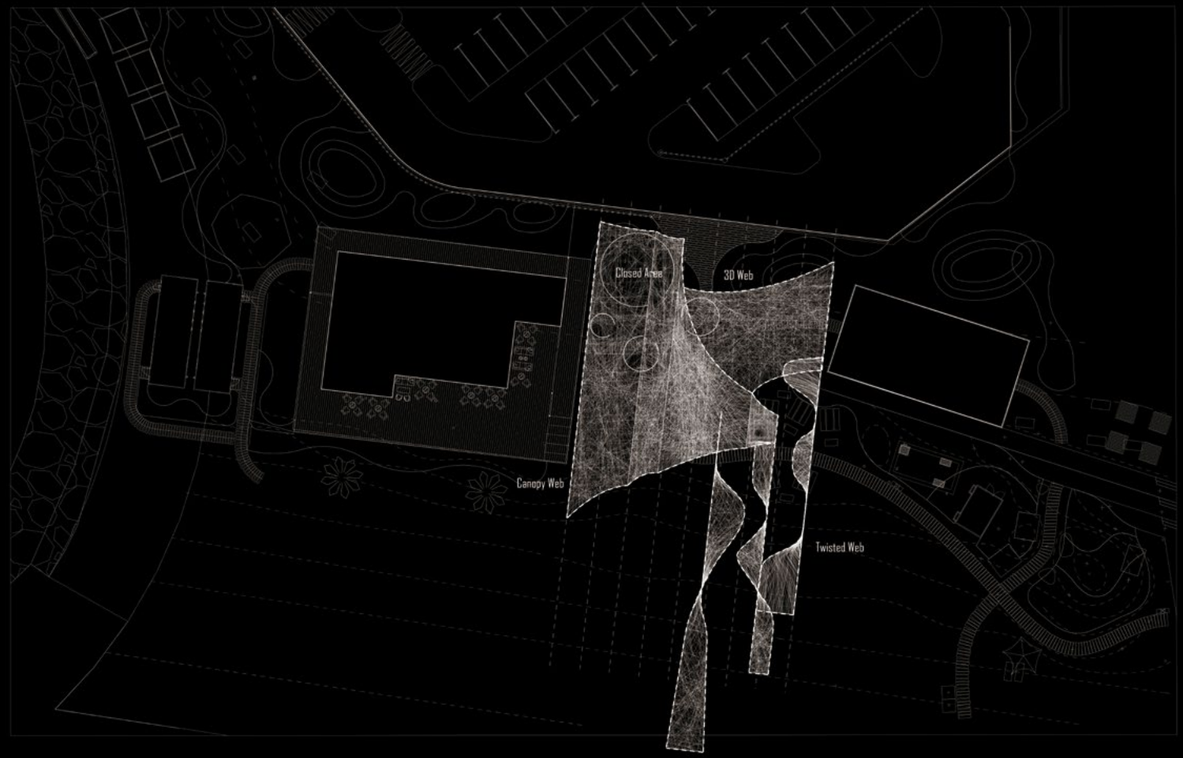

Parking Lots
Cafe
Lumen
Beach

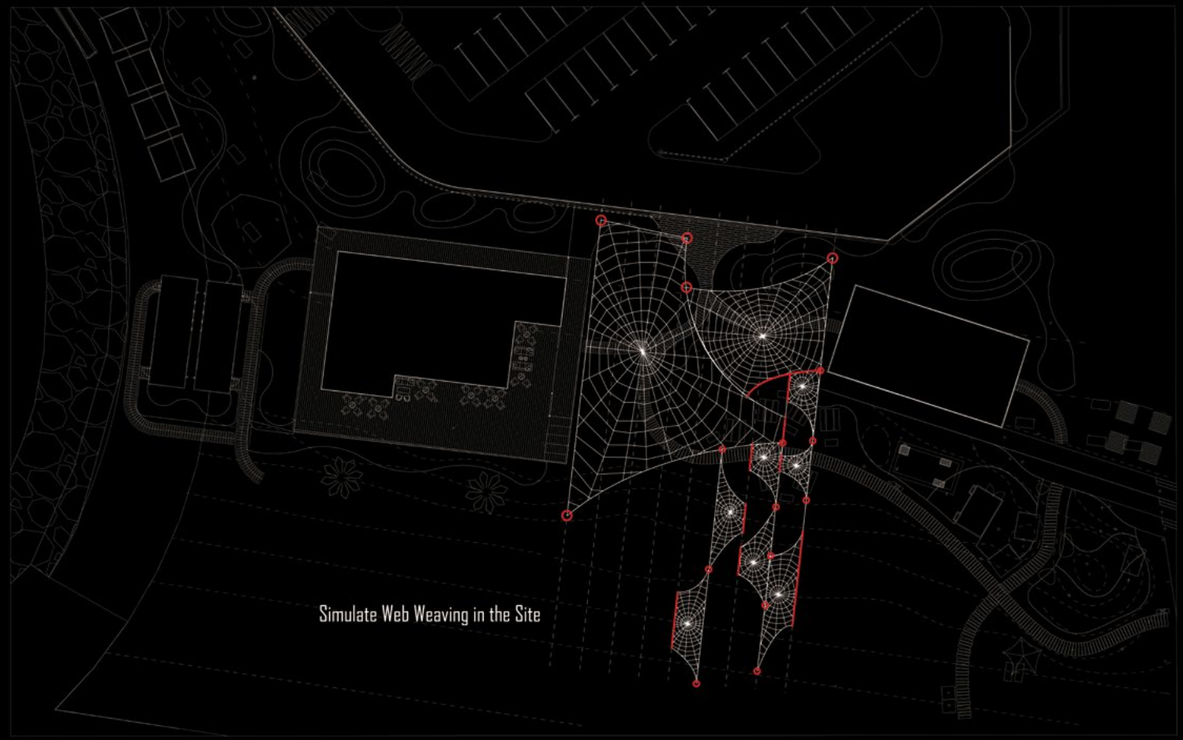

Keep the view to the ocean clear


Web in the Site

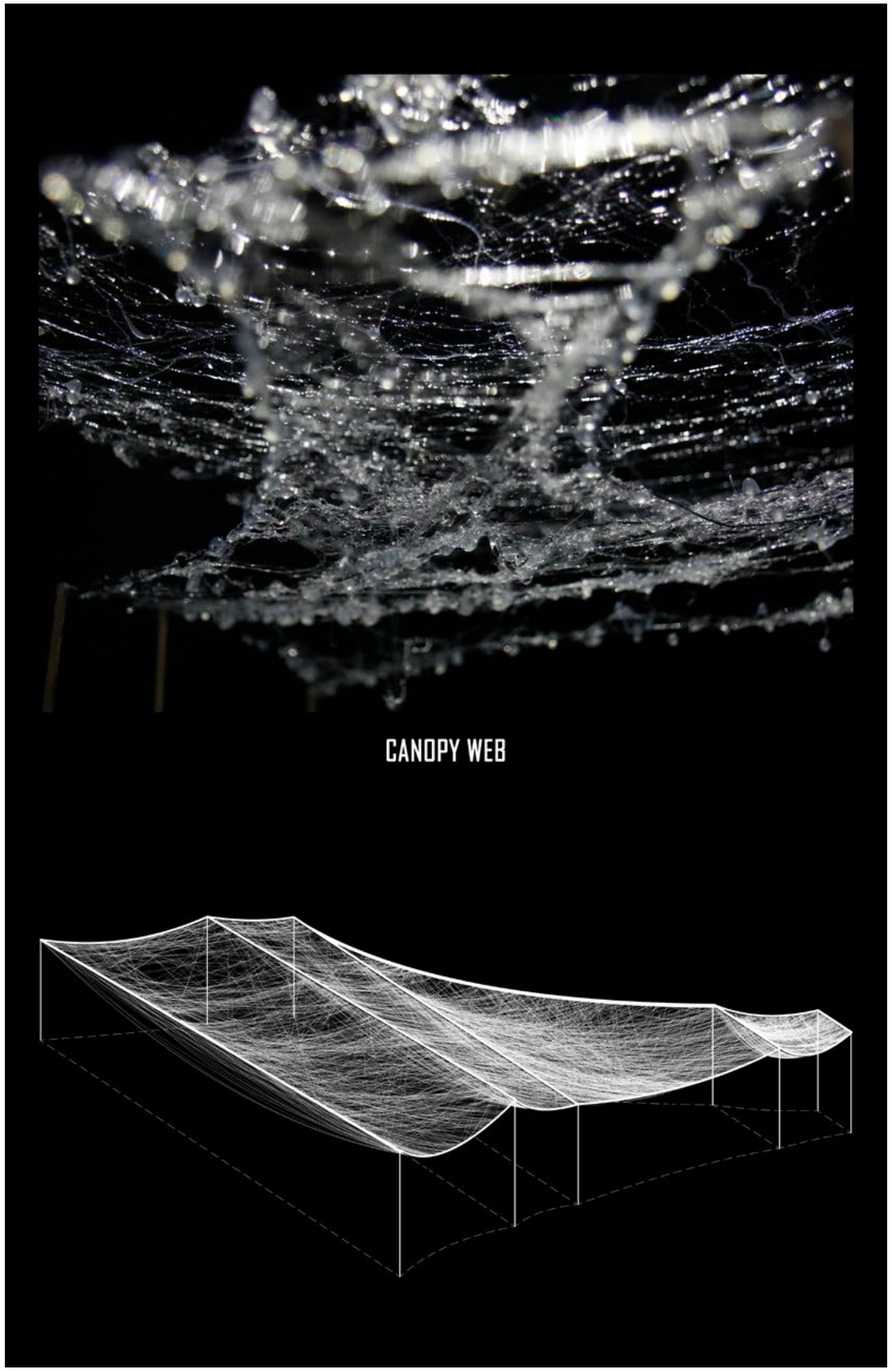

3m Grid in the Site
3m

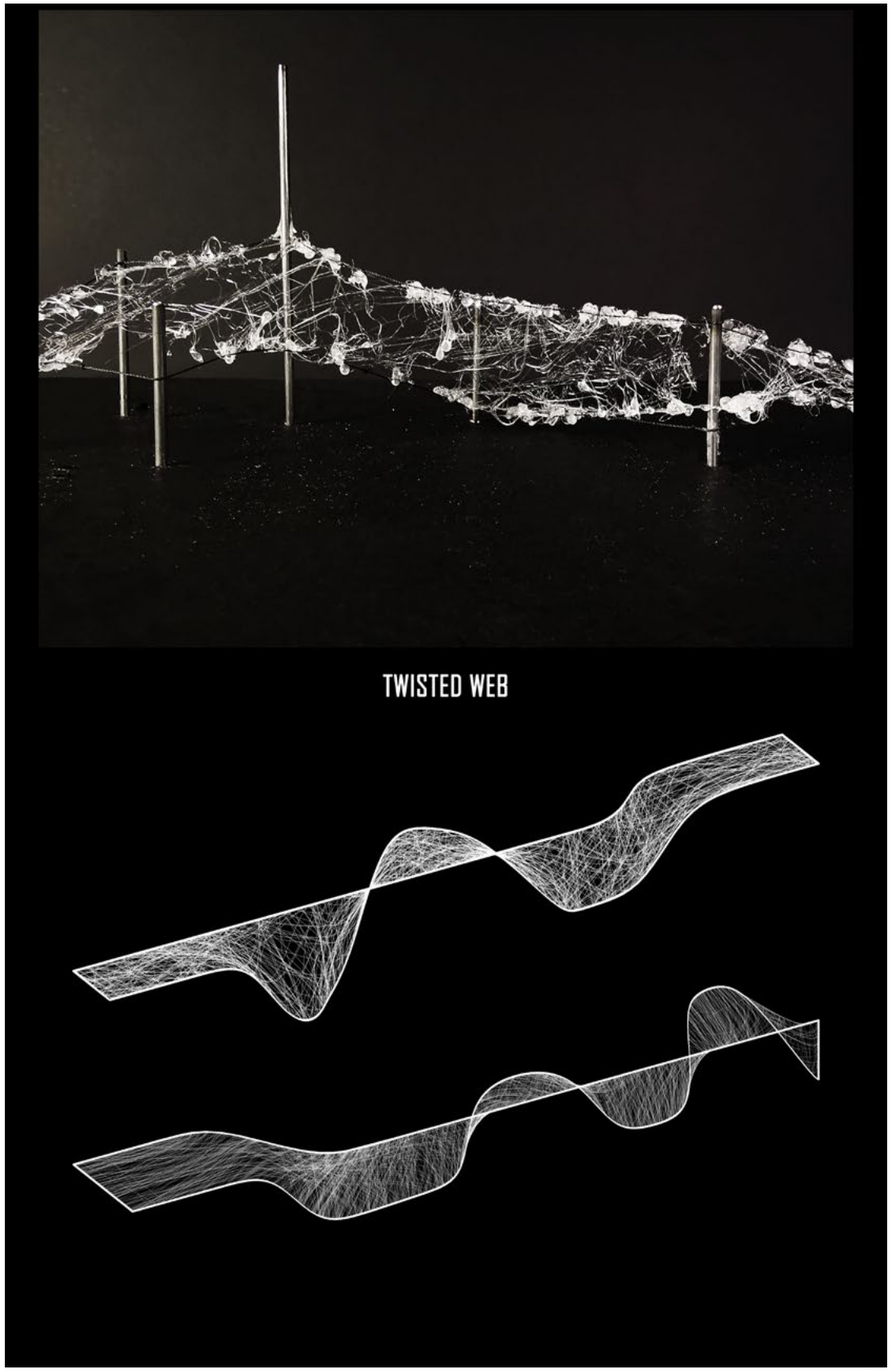

Private Prayer Area
Quiet Area
Public Prayer Area
Active Area


Closed Area
3D Web
Canopy Web
Twisted Web

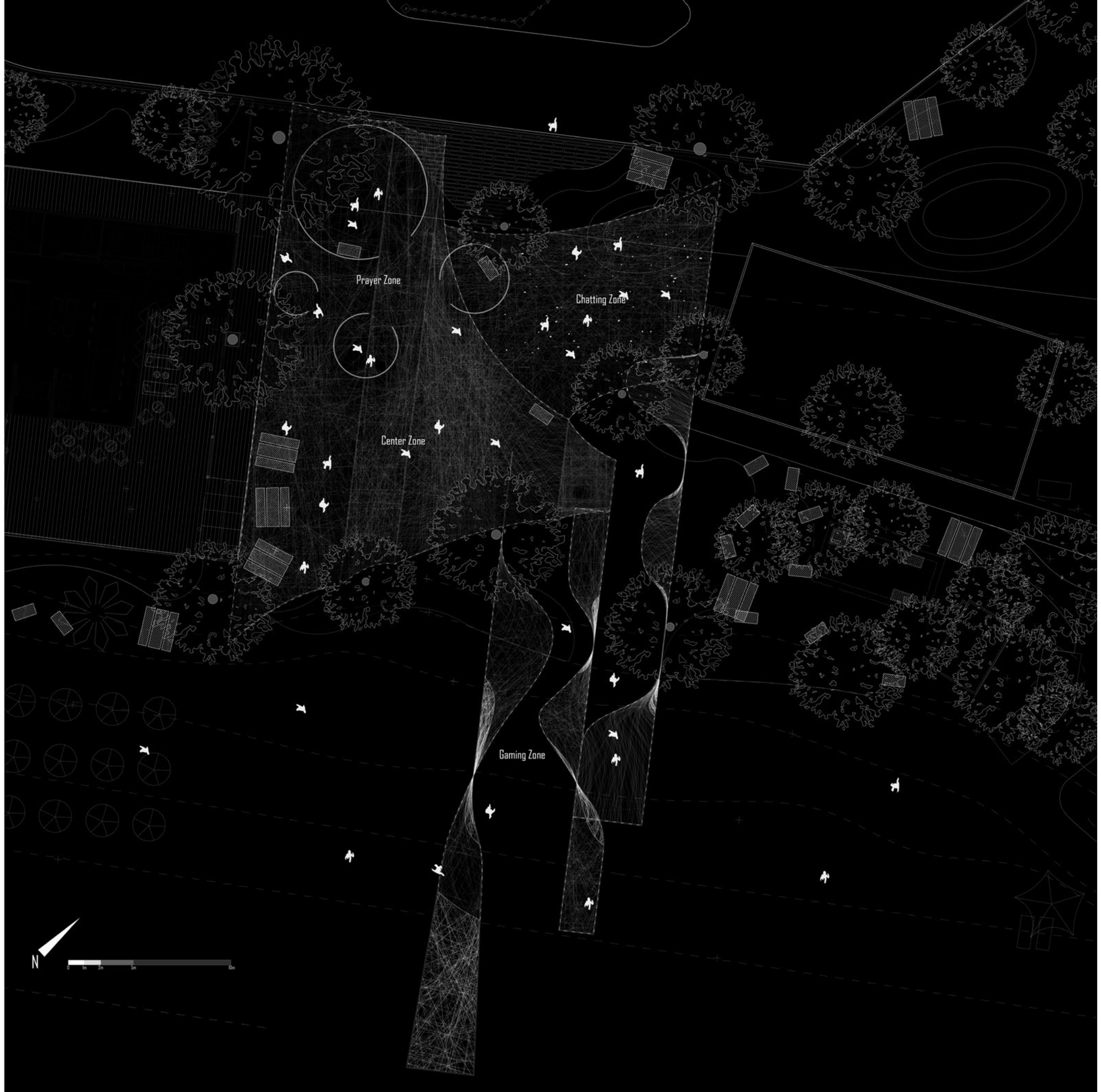

Simulate Web Weaving in the Site

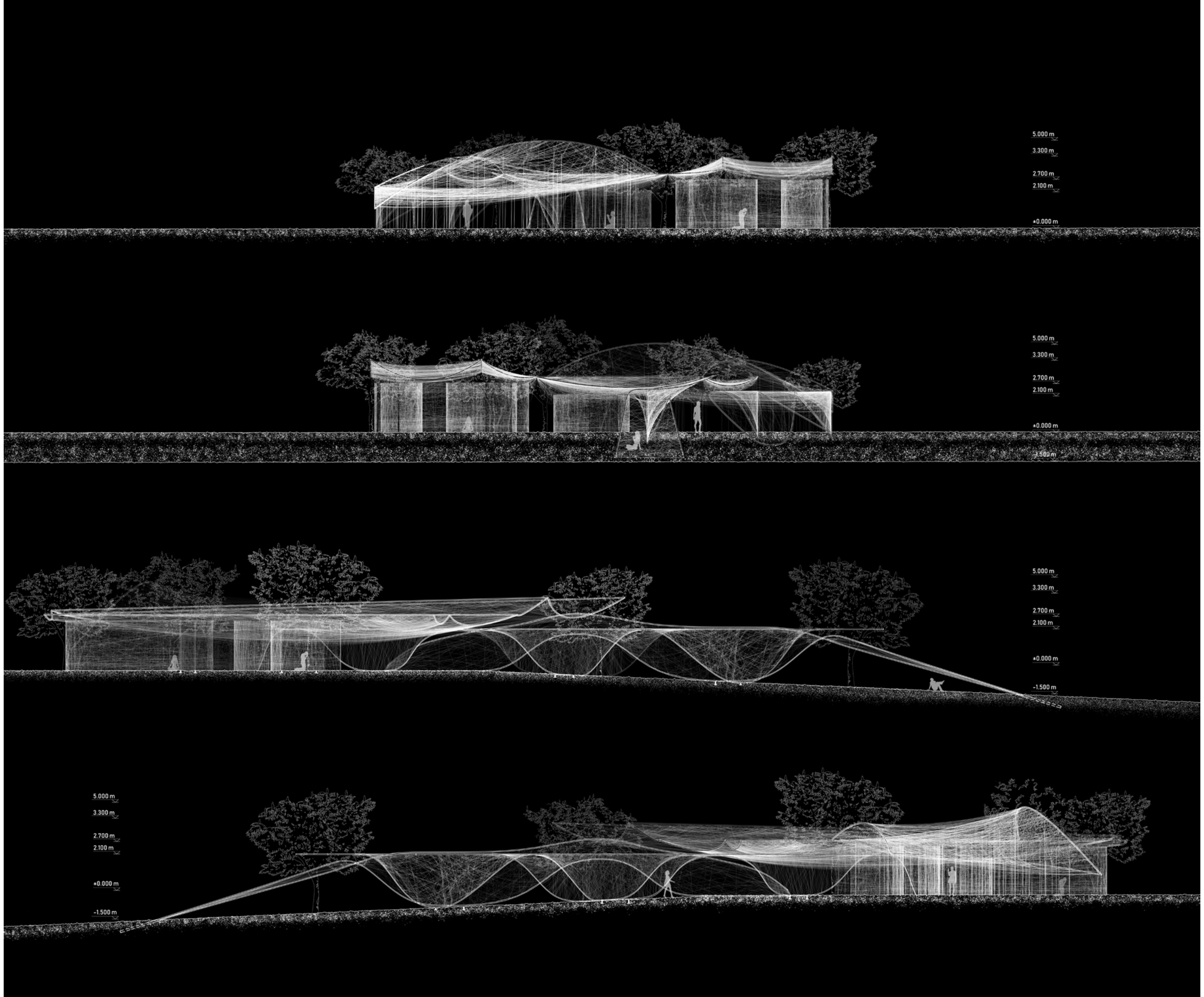

Planting trees as column to support the structure

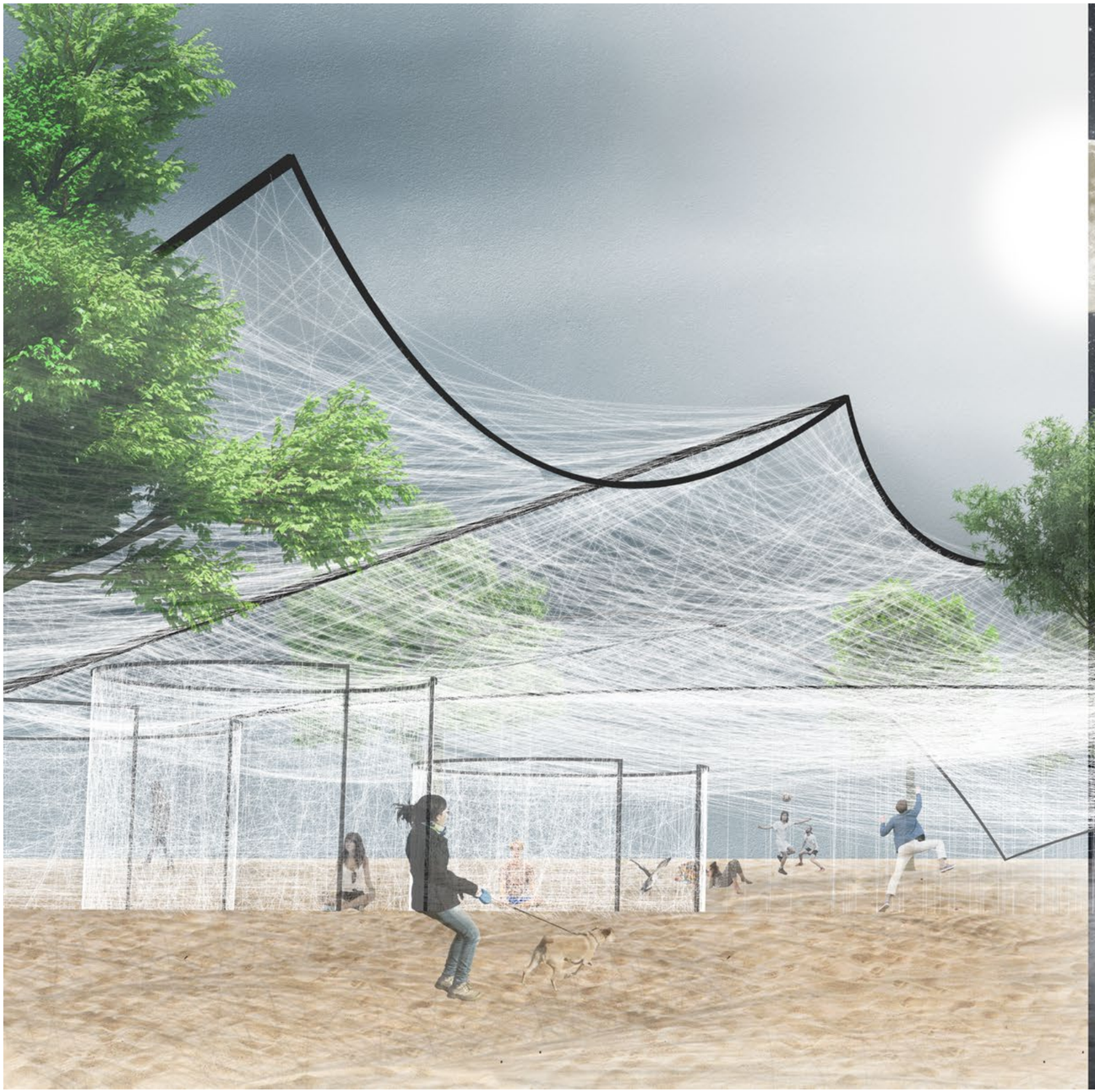

CANOPY WEB

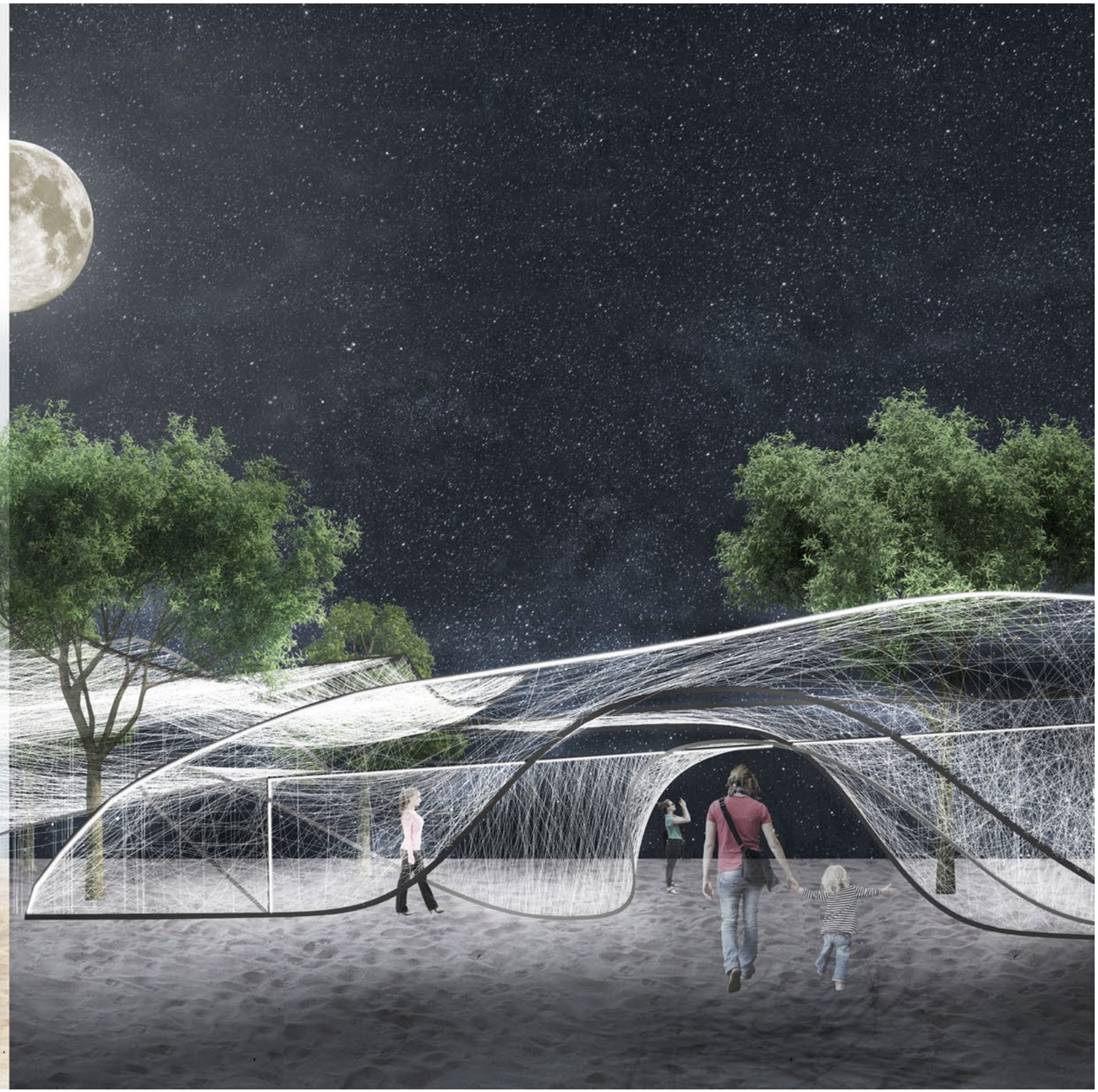

TWISTED WEB


N


Prayer Zone
Chatting Zone
Center Zone
Gaming Zone
N


5.000 m
3.300 m
2.700 m
2.100 m
±0.000 m
5.000 m
3.300 m
2.700 m
2.100 m
±0.000 m
-1.500 m
5.000 m
3.300 m
2.700 m
2.100 m
±0.000 m
-1.500 m
5.000 m
3.300 m
2.700 m
2.100 m
±0.000 m
-1.500 m

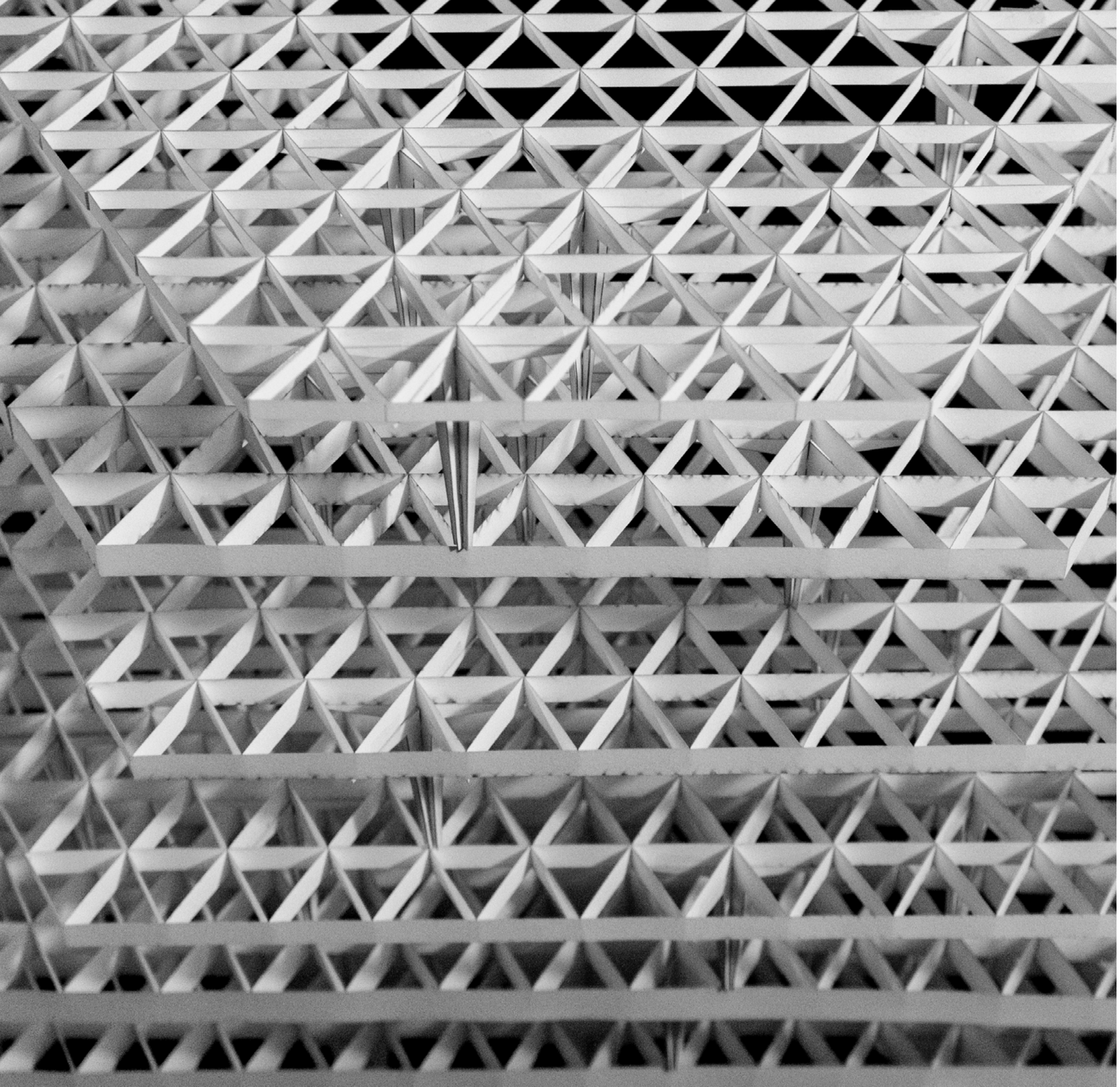




In **rethinking timber system** (taught by Katharina Kral), my team was trying to design a wood structure high-rise based on the research of a wood pavilion. Similar workflow to the Bone Structure and Darwin's Bark Spider, but the differences are: firstly, we are translating a building to another by discourse; secondly, the evaluation or assessment of the digital result are not done by us the researchers, but the software. We used Grasshopper and Kramba3D to assist the design, generating the possible plans, potential optimization method of the structure, and specific requirement for the building material. The virtual object here did most volume of the jobs in designing. Thousands of plans generated by the algorithm; we only need to select the best one as our needs. Virtual objects saved us time in finding the best solution. There was no possibility to do such an amount of work in four months without the help of virtual objects. Virtual objects speed up the time and bring the result to reality from the future.

In the class **Gaming Architecture**(taught by Henry Richardson), I used Unreal Engine to represent a project of mine in Virtual Reality way. Architectural design is never truly in reality before it finishes constructing. The physical models, 3D models, drawings are always virtual in one way or the other. In traditional training and workflow, the physical model is crucial because it is the only way you can perceive the real light diffusion and reflection with the sense of space. Then you will understand where to modify and update your design. However, it is hard to view the physical model with real material and with 1:1 scale. Virtual Reality technology creates an immersive experience for the audience. Dynamic reactive water will never exist on paper, so does the tree. Before the application of this technology, the importance of water and tree cannot be discussed. If we cannot discuss or see the materials or details in person, we cannot fully in charge of the qualities of a design, unless we have enough experience. In this way, virtual objects accelerate the accumulation of experience.

The virtual objects actually have significant impacts on architectural spaces and design, and in some cases it elaborate architectural meaning functions in spaces.



Rethinking Timber System

Bamboo made Parallel strand
lumber high-rise

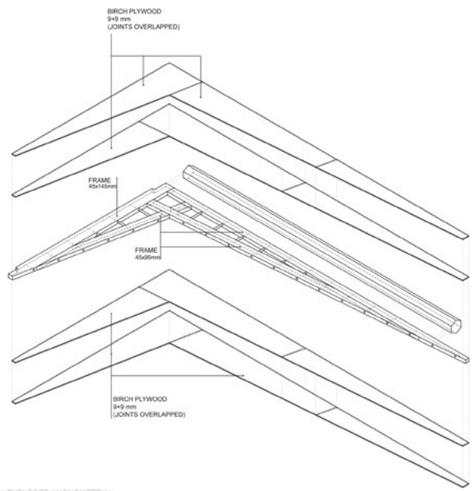
Tapered tree-like columns support a triangulated wooden canopy in Helsinki designed by Aalto University student Pyry-Pekka Kantonen and constructed by a team from the university's wood studio.

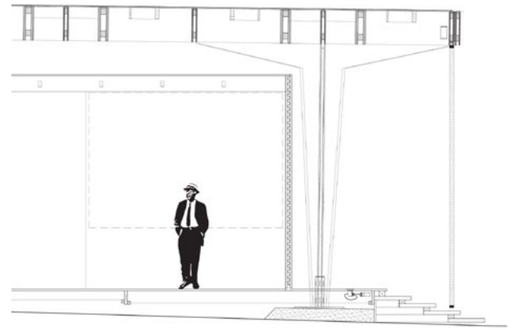
Our design in Seminar: Rethinking Timber System is based on the research of Helsinki Pavilion. And aimed to build a high rise wooden structure building in the final.

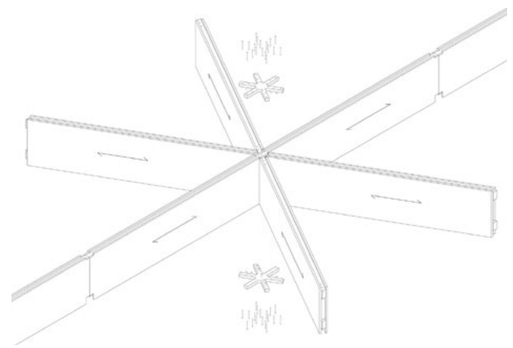
Instructor: Katharina M. Kral
Team member: Cun Zhang, Haoming Wu

Case study: Helsinki Pavilion

First, we tried to find infomation about Helsinki Pavilion, the backgrounds, the drawings, everything may help us better understand this building.







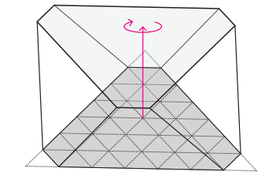
Joinery Detail redraw by Haoming Wu

Research Model

Conceptual Sketches

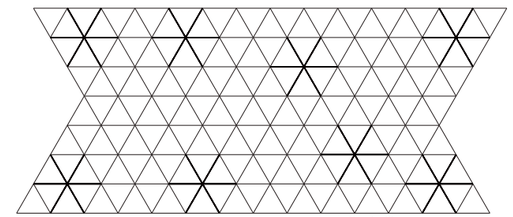
From the research in Phase1, we concluded the Helsinki Pavilion as Triangular grid and random located columns. These two features then became our discourse in designing the high-rise in Phase3.

we rise and rotate the grid to make a concise volume which has significant setbacks and advances in each side.



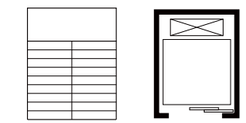
volume formation

Feature1: Triangular Grid

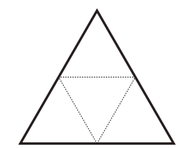


draw by Haoming Wu

the darker lines mean the beams licked to the columns

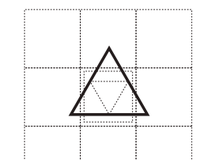


For triangular grid feature, not matter what is the shape of outline, the outline must be analysised by equilateral triangle. The columns in the grid will form a hexgon by its six branches. Six branches increase the contact area between columns and beams.



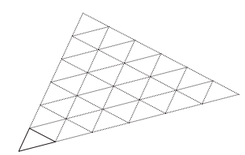
one unit include 3 beams(thick line) and 3 trabecular which enhace the stablity and mounting the roof glass

However in the high-rise, the staircases and elevators are inevitably retangular. The transformation from triangular grid to retangular grid is necessary.



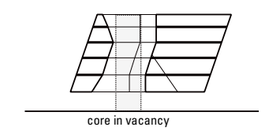
conflict between triangular and retangular grid

In the Helsinki Pavilion, there is a hierachy among beams. Long thick high beams are for load bearing structure, which create the overal loading structure. The smaller beams aimed to create suitble size of holes for installing glasses on the roof purpose.



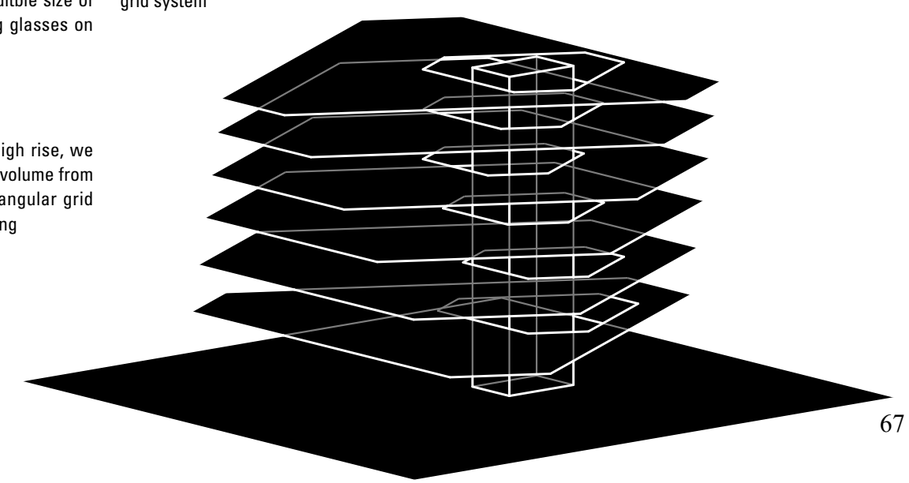
grid system

For solving this delimma, a vacancy across slabs is created. The vacancy not only followes the shape of triangular grid, but also creates spaces for retangular verticle transporting.

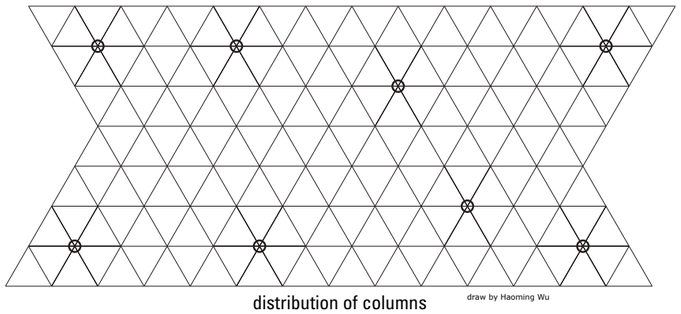


core in vacancy

In designing the high rise, we start to create the volume from generating the triangular grid at the very beginning

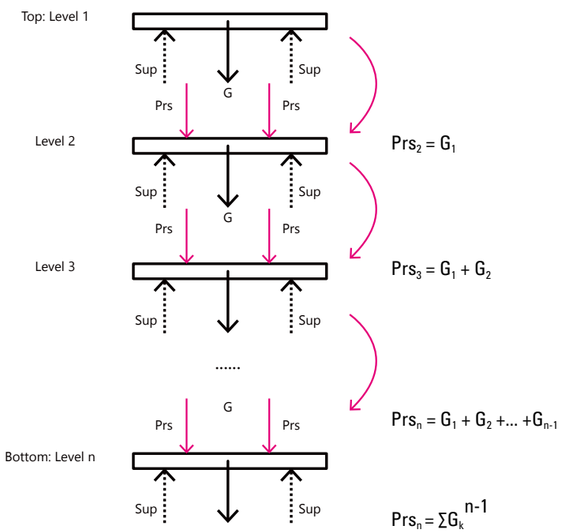


Feature2: Random Located Columns



distribution of columns

The random located columns breake the potential symmetric of the plan. However the utilization and displacement of beams limit the possible locations for the columns.



$Prs_2 = G_1$

$Prs_3 = G_1 + G_2$

$Prs_n = G_1 + G_2 + ... + G_{n-1}$

$Prs_n = \sum_{k=1}^{n-1} G_k$

sequence of force conducting

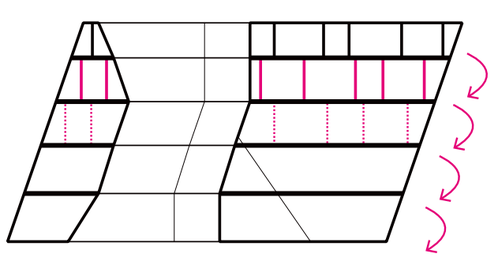
As the main force(Gravity) in the system points towards the down direction,

In a set numbers of columns, we use Karamba3d to calculate the total displacement of the whole level(both beams and columns included). Then we use Gene pool and Galapagos to find he most efficient set of columns for the certain level. In the view of Greedy algorithm, this situation can be convergent, and local optimization will lead to overall optimization.

we calculate and form the random located columns from the top level to the bottom level. In this case, the upper level, as the parent level, will conduct the gravity to the lower level(sub level).
And the sub level will have no influnce on the parent level.

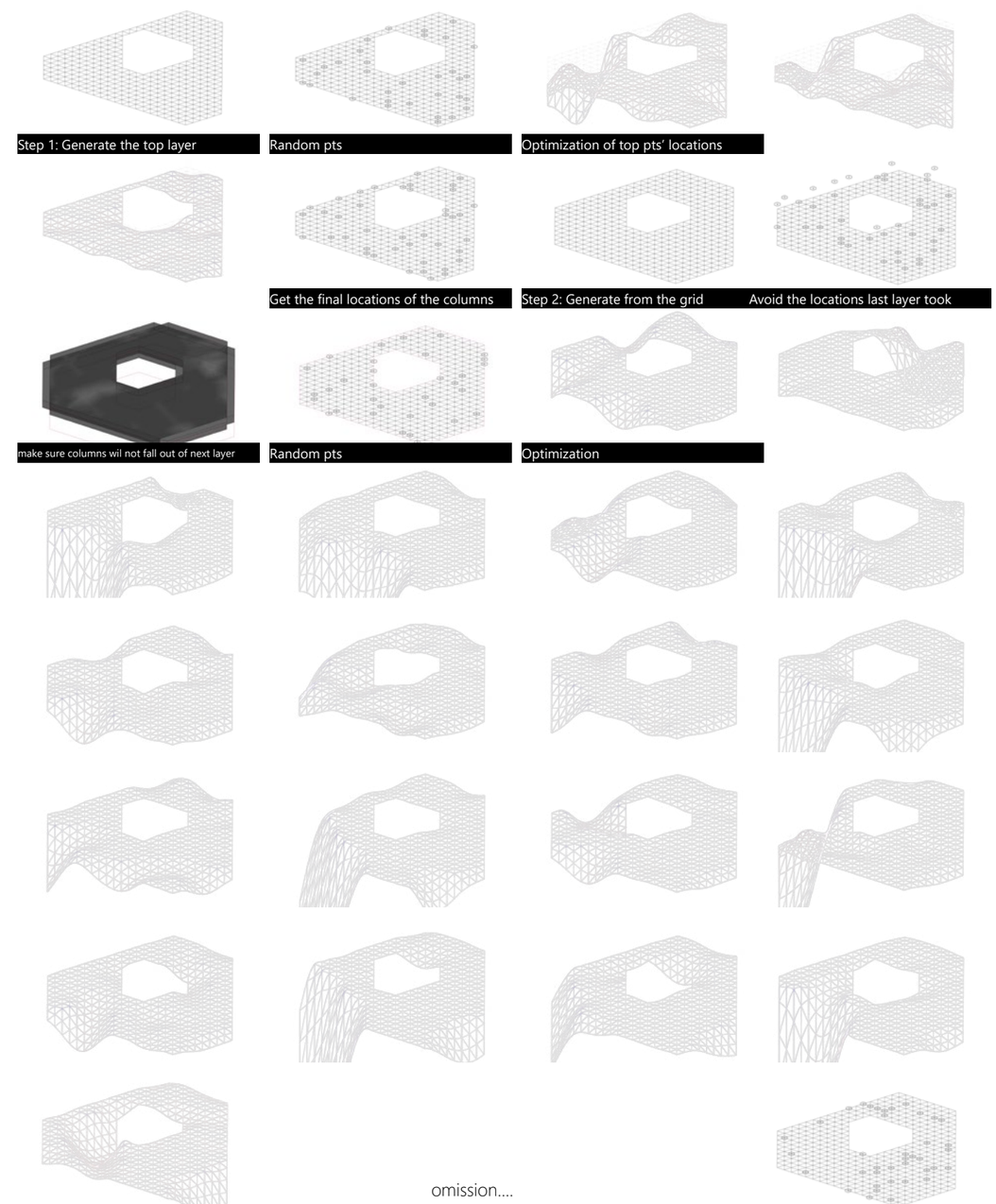
If we calculate from bottom to top, the sub level(upper) will affect the parent level(lower), then all the levels need to be recalculate.

In another words,the utilization is not gonna easily converge to a minimized number.

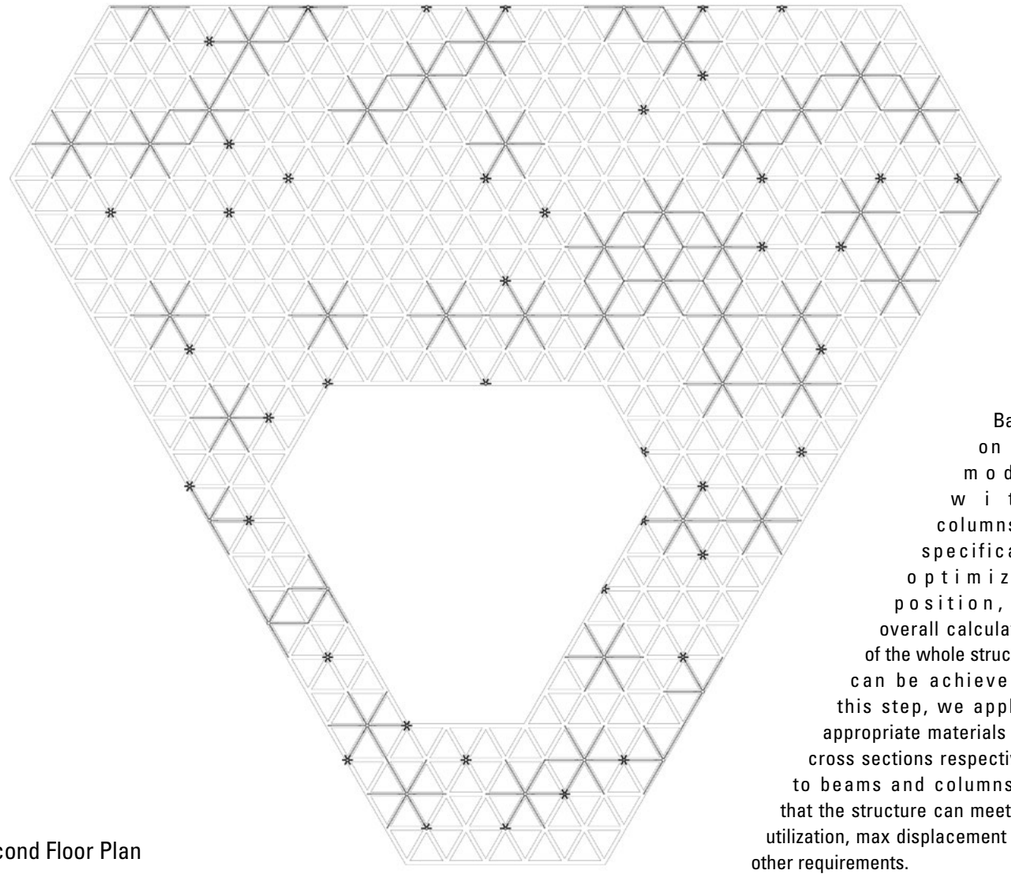


sequnce of generating

Generative Design Process

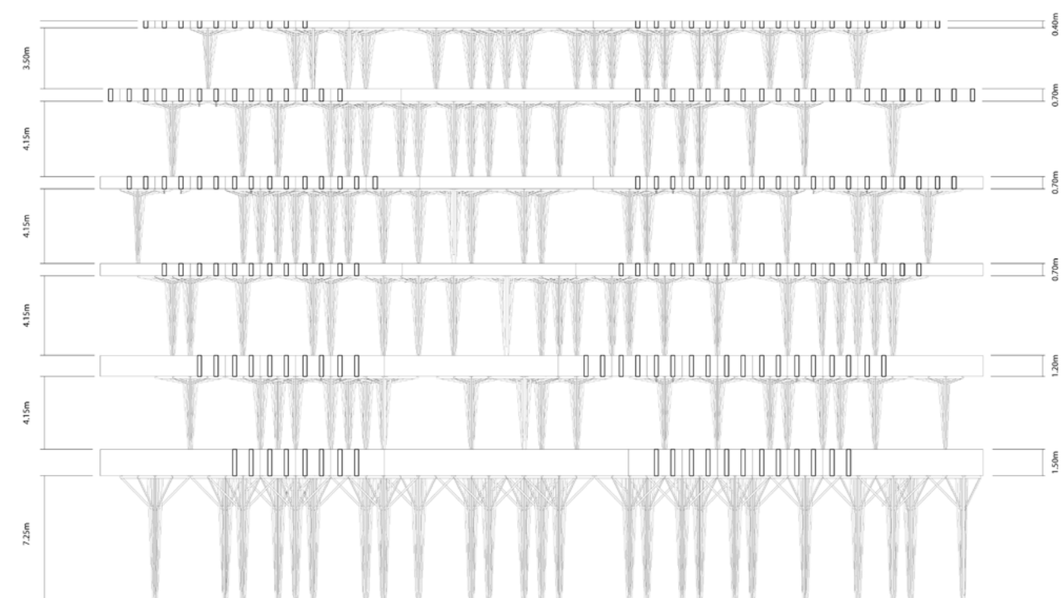


process of generating columns' locations in one layer

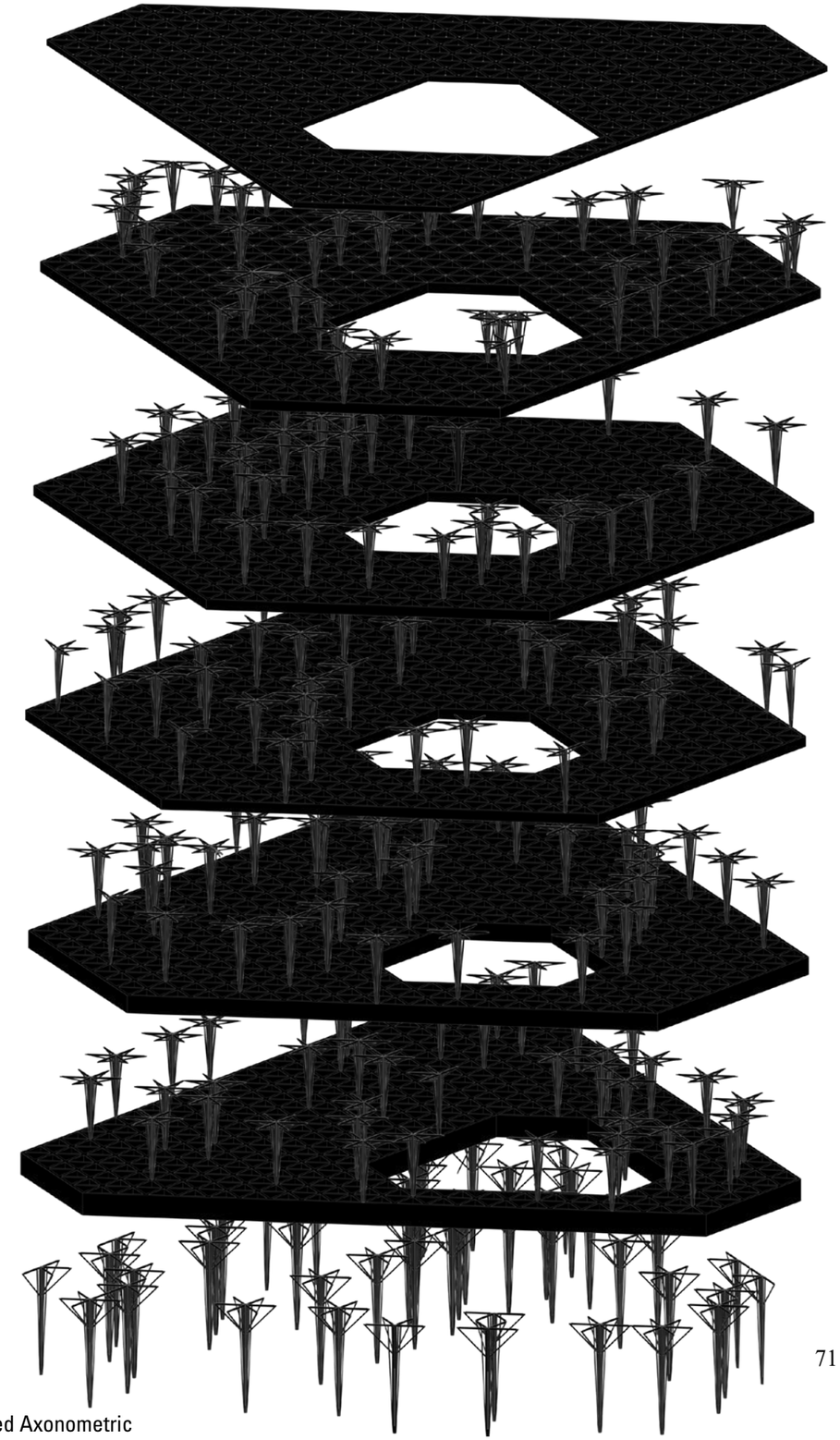


Second Floor Plan

Based on the model with columns in specifically optimized position, an overall calculation of the whole structure can be achieve. In this step, we applied appropriate materials and cross sections respectively to beams and columns so that the structure can meet the utilization, max displacement and other requirements.

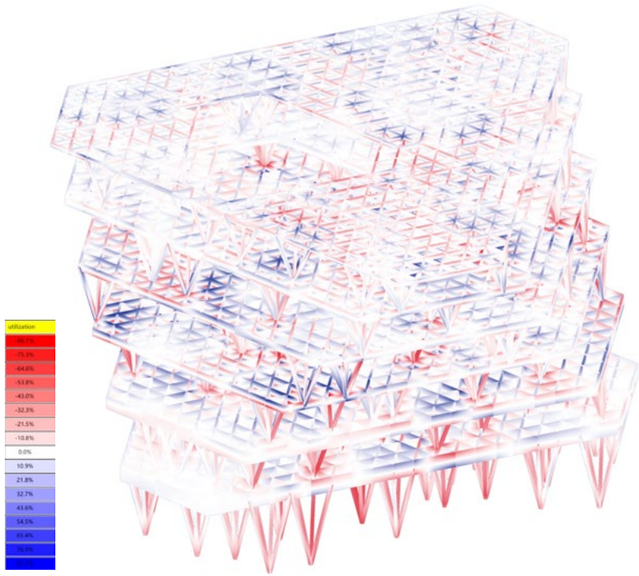


Section



Exploded Axonometric

Load Bearing Evaluation



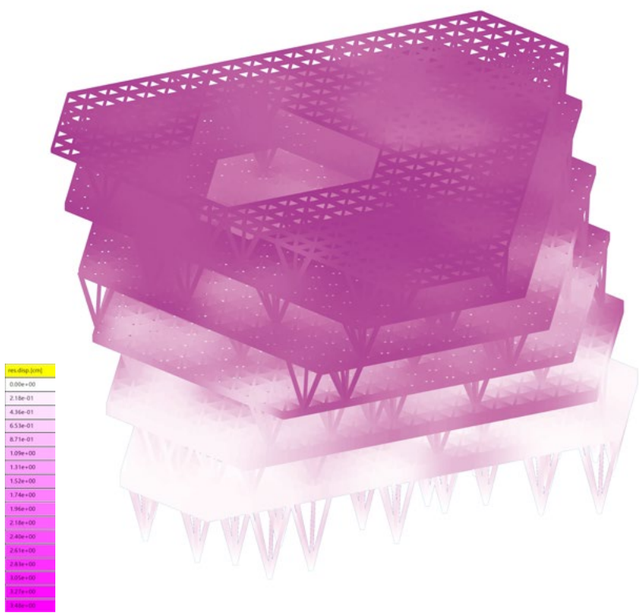
Global utilization

We use Karamba3d to evaluate the overall strength of the whole system.

In the assignment requirements we need to building a high-rise building prototype with requirements below:

6 stories
-10,000 m^2 ± 10% useable area incl. core
-primary program: office
-different articulation of ground floor, i.e. lobby space, entrance

dead-load: weight of main structure
-uniform floor live-load: 2.5 kN/m2
-embodied carbon [kg CO2] based on building mass
[see Inventory of Carbon & Energy ICE database]
-sequestered carbon [kg CO2] based on building mass
-utilization 70% - 90%



Global displacement

Beam Cross section top to bottom:

1: 200mm*400mm
2: 200mm*750mm
3: 200mm*750mm
4: 200mm*750mm
5: 200mm*1200mm
6: 200mm*1500mm

Material	Timber General
Building Mass	1.464e+6 kg
Embodied Carbon	4.32e+5 kg CO_2 (fos)+6.0024e+5(bio) kg CO_2
Sequested Carbon	1.992e+6kg CO_2
Totall Carbon emmision	-6e+5kg CO_2

Material setting:

Name: Bamboo

E: 2000
G:1000
gamma:6
fy:2.5

Comparison With Steel Structure And Concrete Structure

when material change into steel

Material	Steel:Bar & rod - UK (EU) Average Recycled Content
Building Mass	1.9154e+7 kg
Embodied Carbon	2.509173e+7 kg CO_2

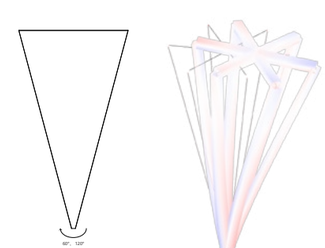
Steel structure performs much better than the bamboo-timber structure in load bearing. But embodied carbon in whole life term are much much more.

when material change into concrete

Material	Concrete General
Building Mass	6.1e+6 kg
Embodied Carbon	6.1e+5 kg CO_2

Concrete has lower performance compared with other two, their high weight make it need to re-optimised the crossection of the beams. But still has lots of carbon emmision

Optimization of Columns' shape



Loading Testing Condition:

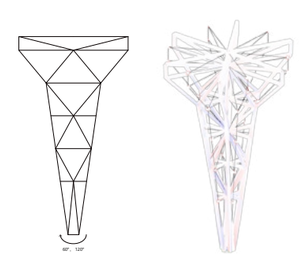
These two types of columns are calculated in same loading condition as below:
Algorithm: Eigen Modes
Uniform line: 1kN/m
Meshload Const
Deformation:1

This is the simplified columns modular we used in overall structure anaysis.

Crossection:

Trapezoid:

Upper width: 300mm
Lower width: 300mm
Height: 300mm



This is the actual columns modular, which has better structure performance than the simplified one.

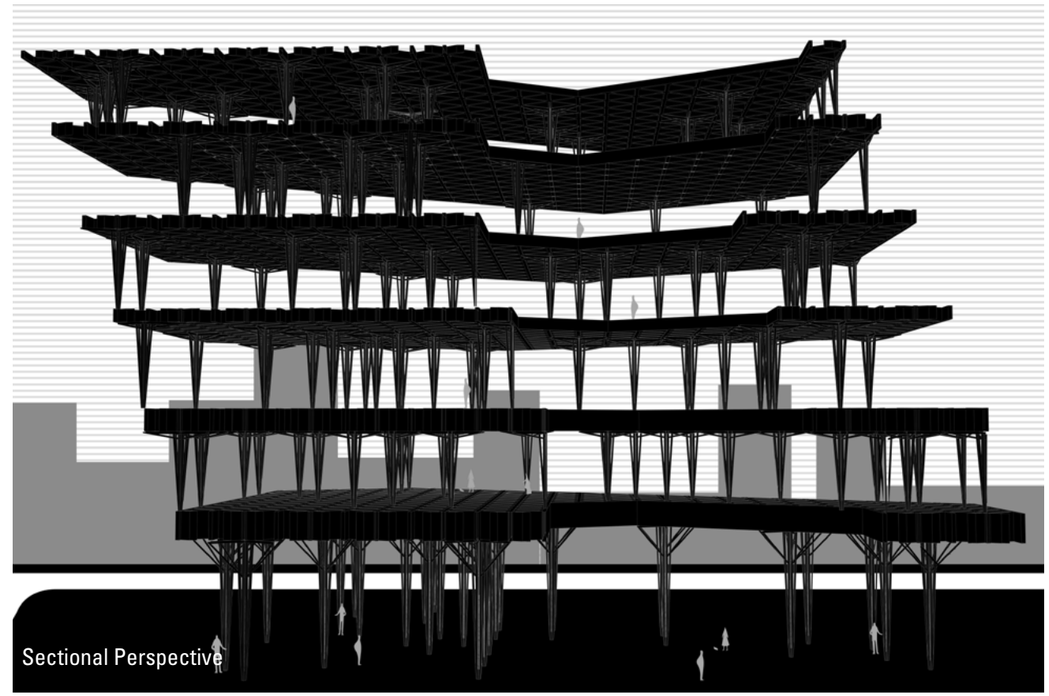
Crossection:

Trapezoid:

Upper width: 100mm
Lower width: 100mm
Height: 100mm

We used a simlified column shape to test in the global load bearing test.

Then we optimize it followed the idea of columns in Helsinki Pavilion. This comparison shows the optimized one has better performance than the simplified one.

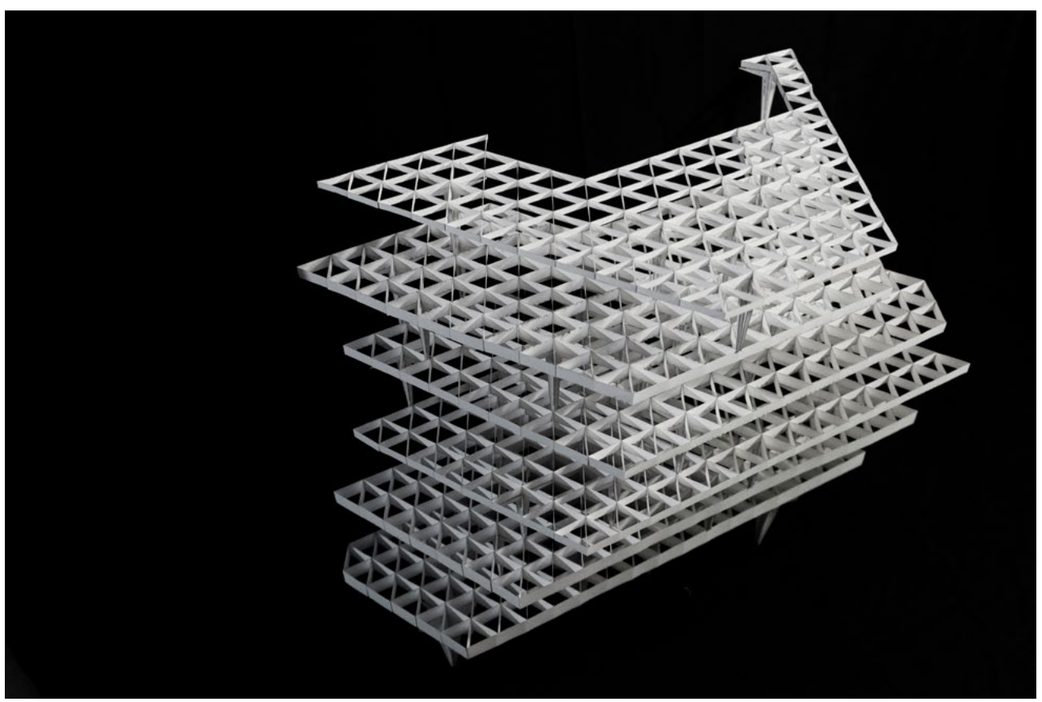


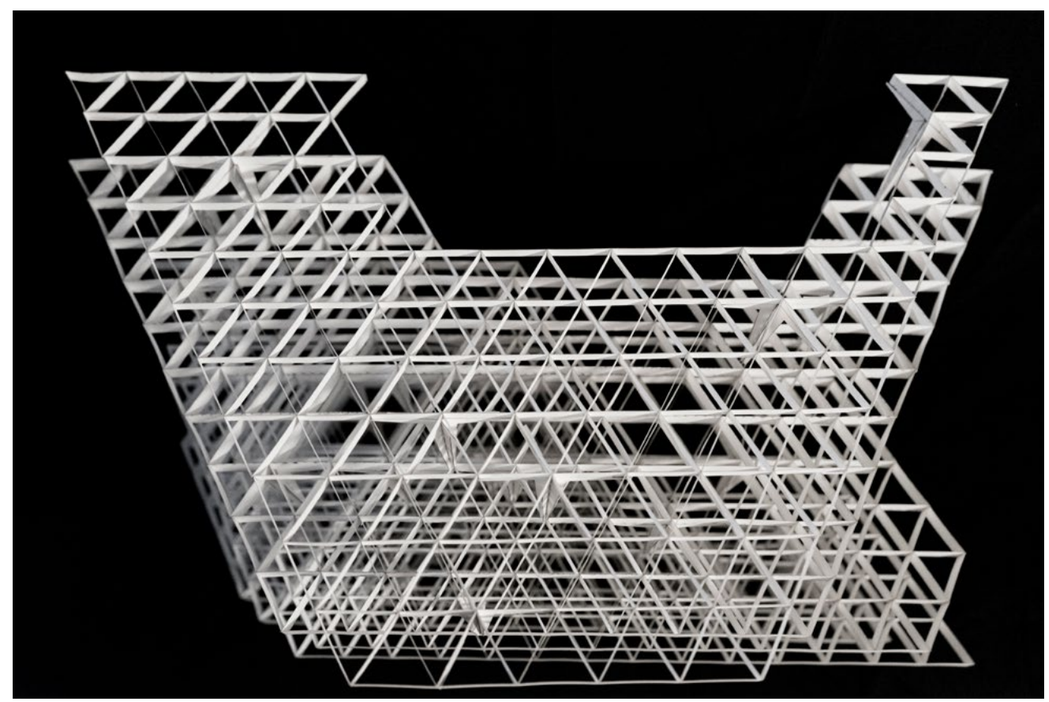
Model of Sectional perspective

made by Cun Zhang and Haoming Wu

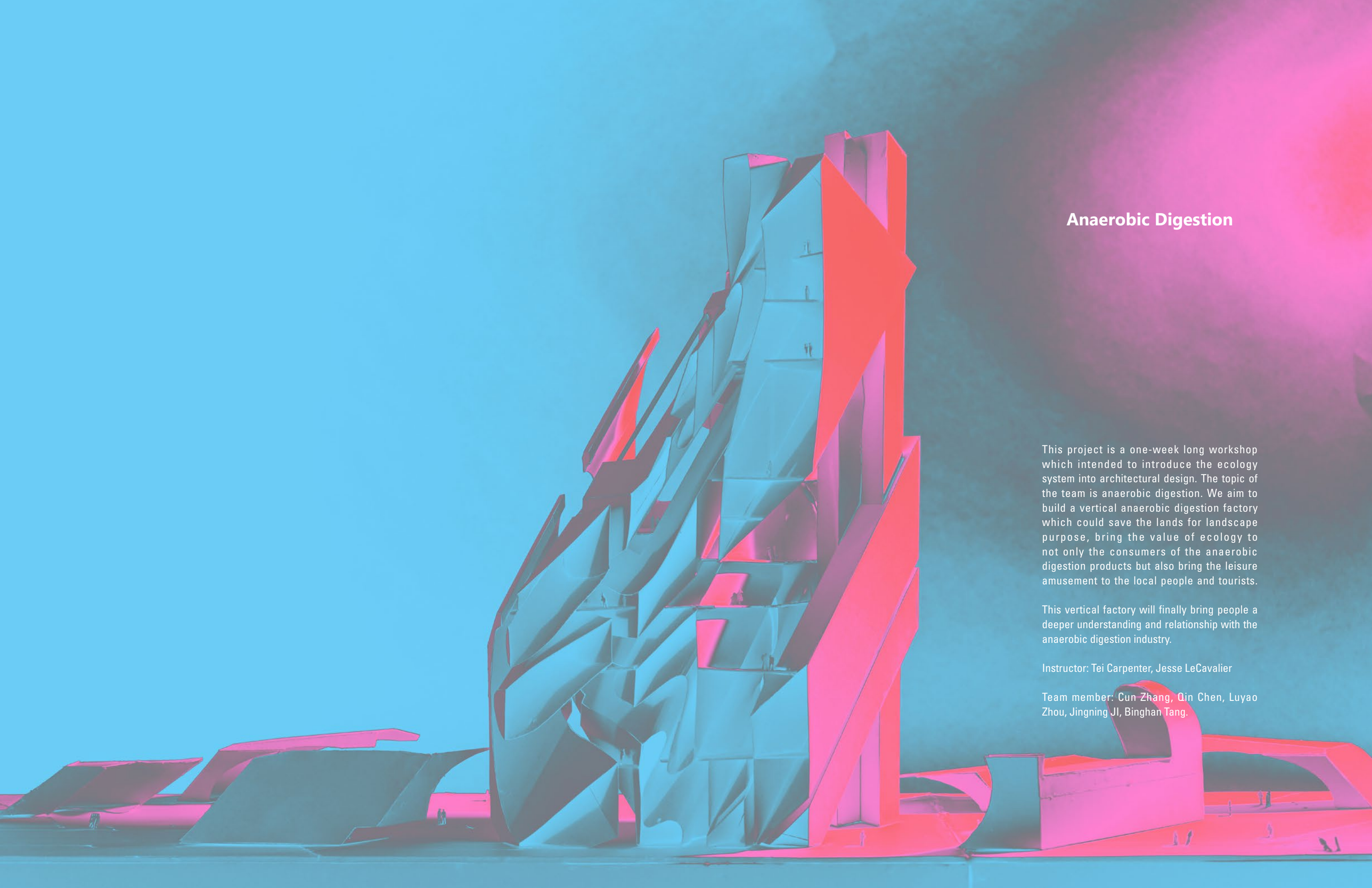
If we calculate from bottom to top, the sub level(upper) will affect the parent level(lower), then all the levels need to be recalculate.

In another words,the utilization is not gonna easily converge to a minimized number.





Also, I did researches out of my territory to expend my boundry.



Anaerobic Digestion

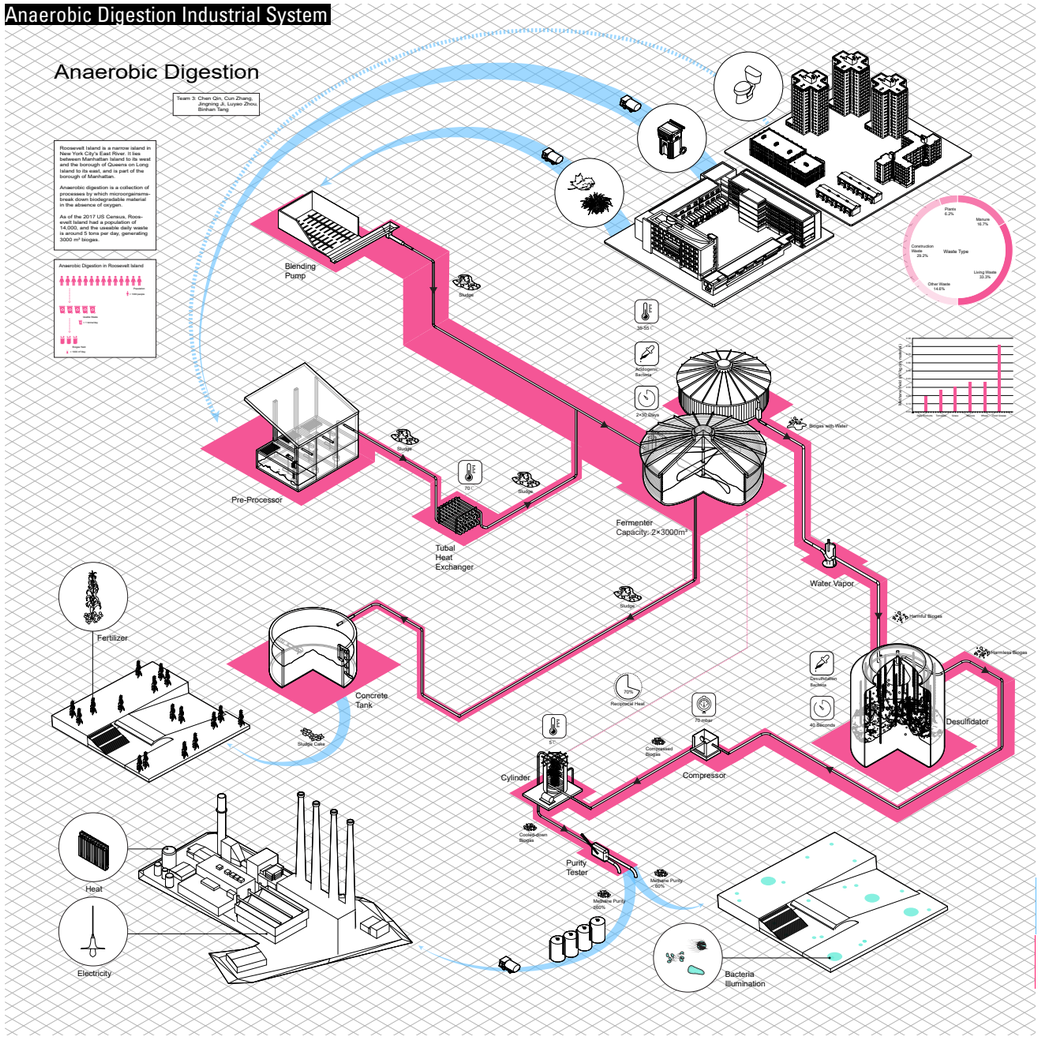
This project is a one-week long workshop which intended to introduce the ecology system into architectural design. The topic of the team is anaerobic digestion. We aim to build a vertical anaerobic digestion factory which could save the lands for landscape purpose, bring the value of ecology to not only the consumers of the anaerobic digestion products but also bring the leisure amusement to the local people and tourists.

This vertical factory will finally bring people a deeper understanding and relationship with the anaerobic digestion industry.

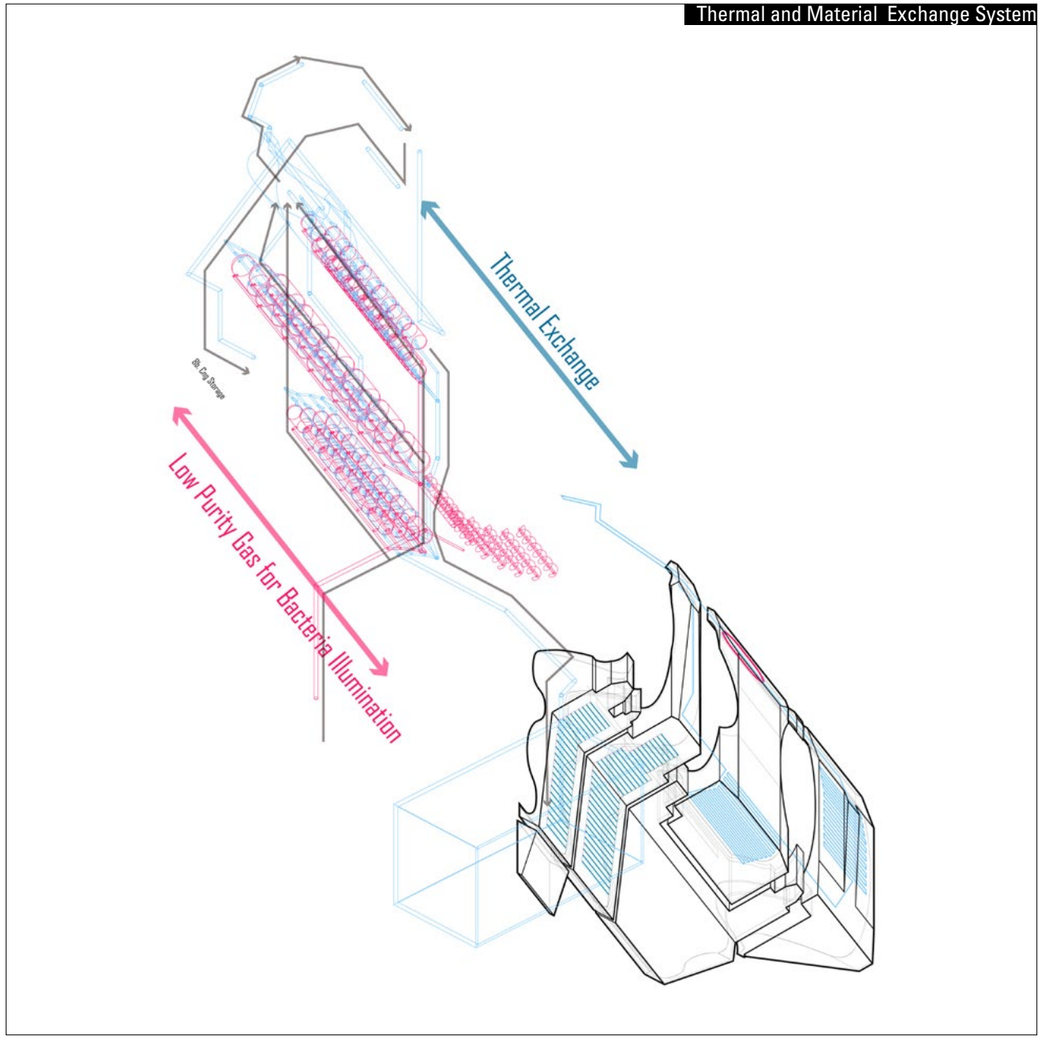
Instructor: Tei Carpenter, Jesse LeCavalier

Team member: Cun Zhang, Qin Chen, Luyao Zhou, Jingning JI, Binghan Tang.

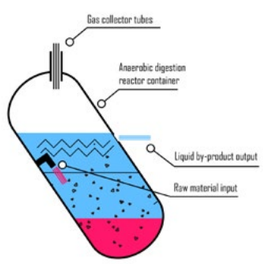
Anaerobic Digestion Industrial System

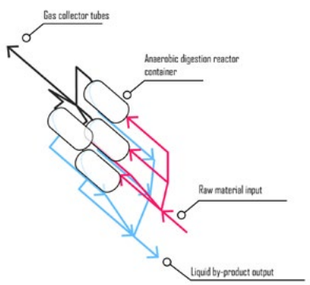


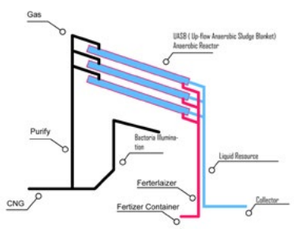
Thermal and Material Exchange System

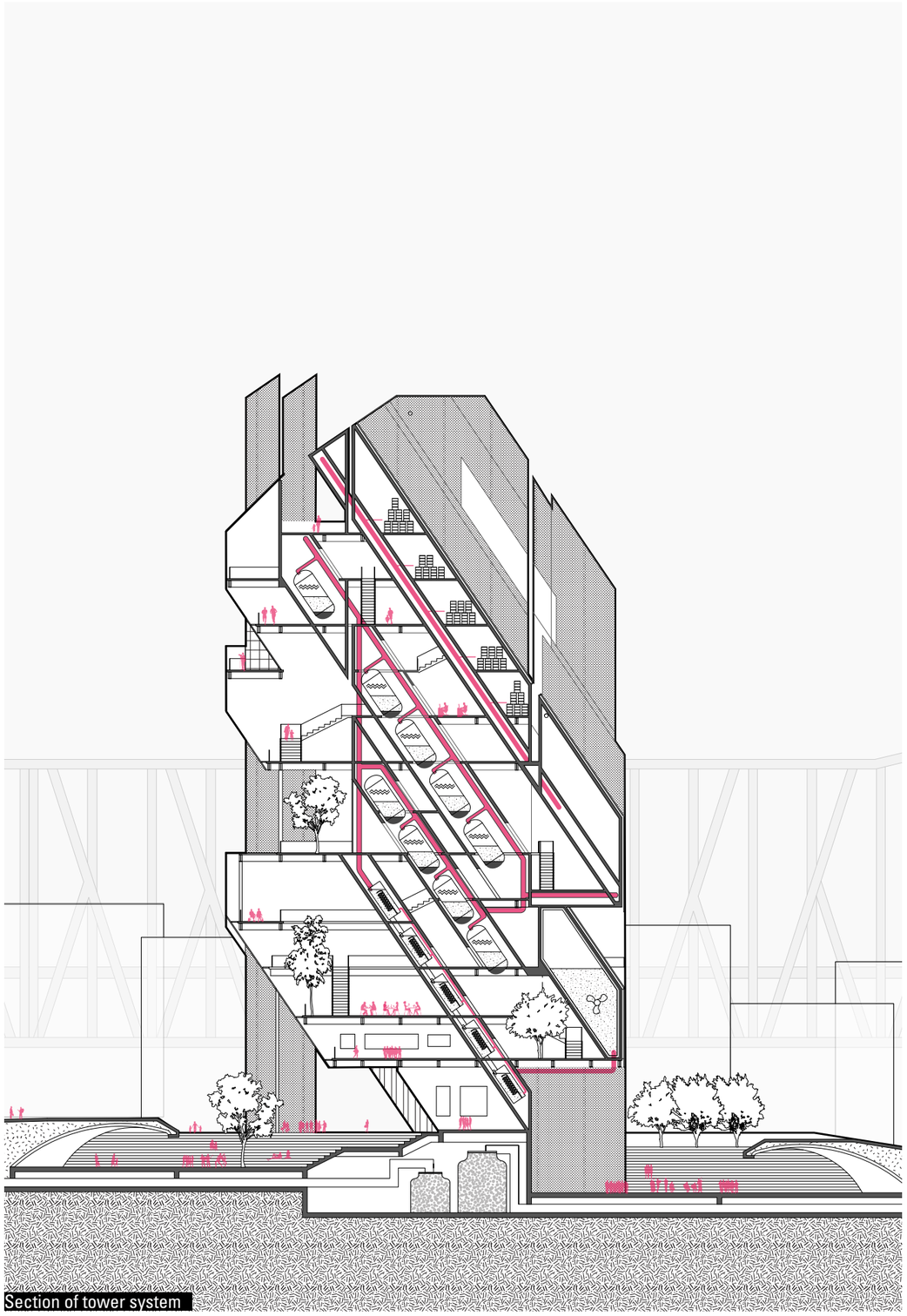


We diagram the whole system of anaerobic digestion industry and try to organize them into a compact volume. From the research of the whole system, we find out the methods to modify and assemble each part to a vertical tower system, which not only provides the same function but also saves the lands for entertainment purpose. When entertainment introduced into the site, there would be more people visit the anaerobic digestion tower and learn more about the environmental industry.



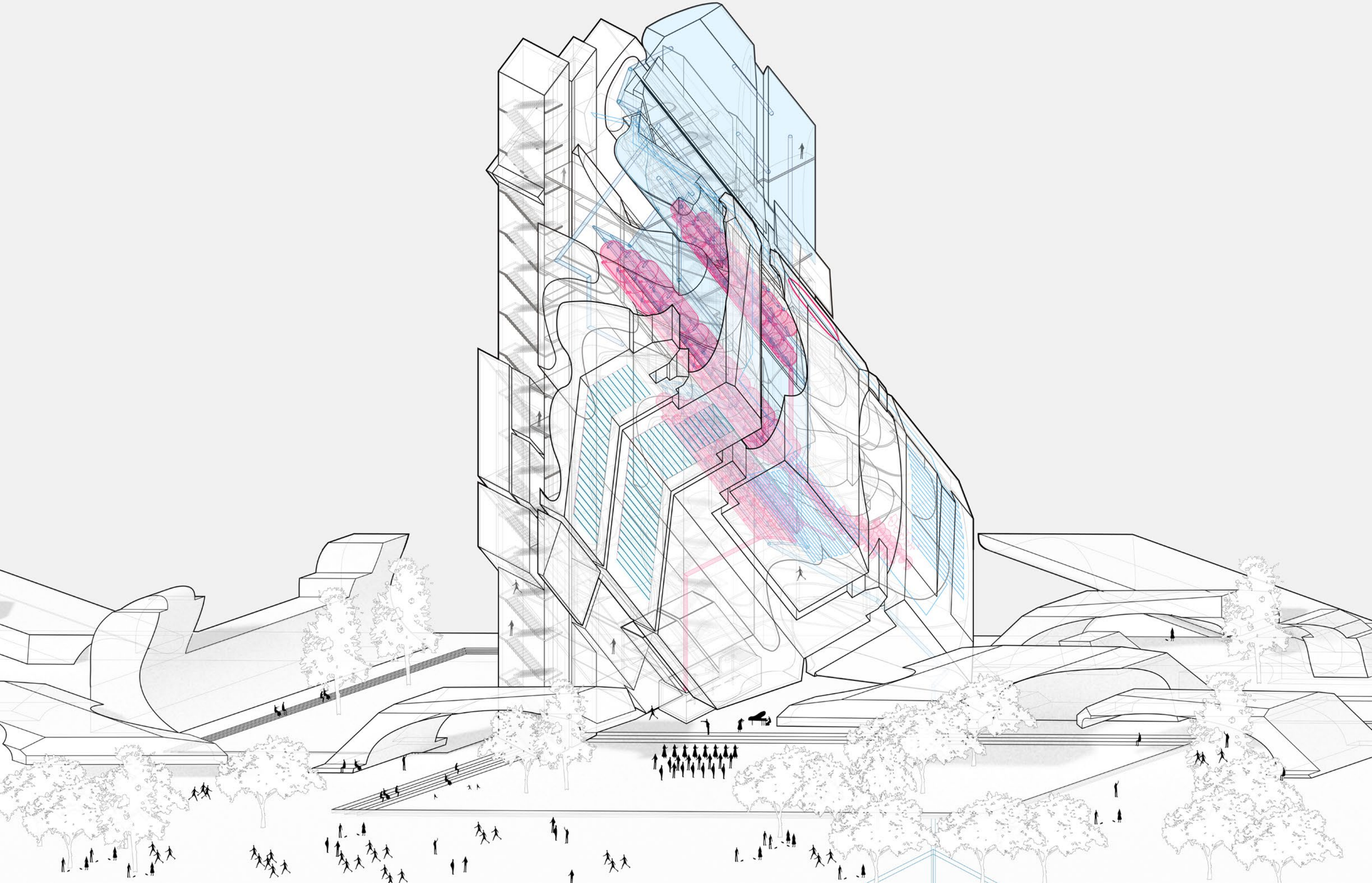


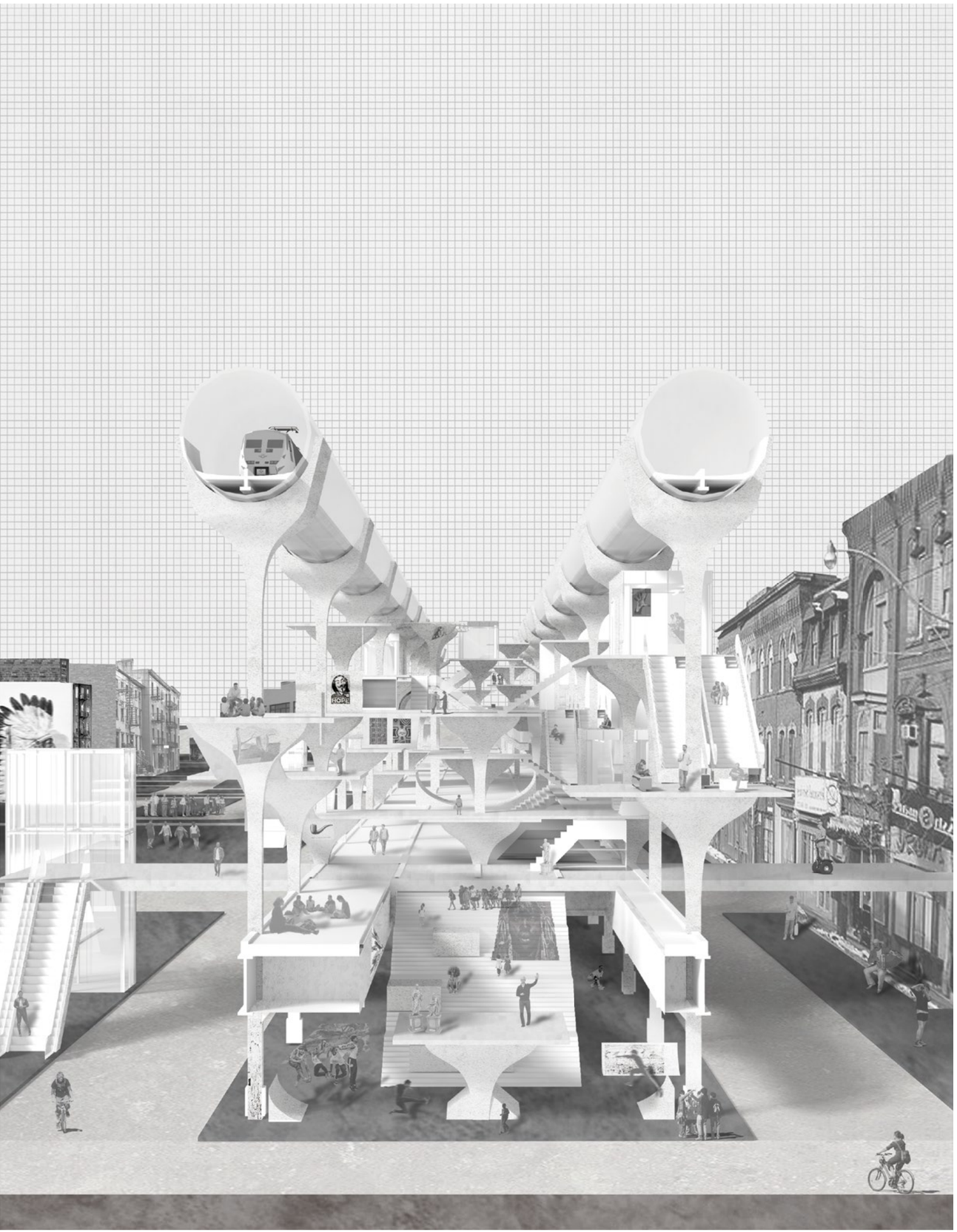




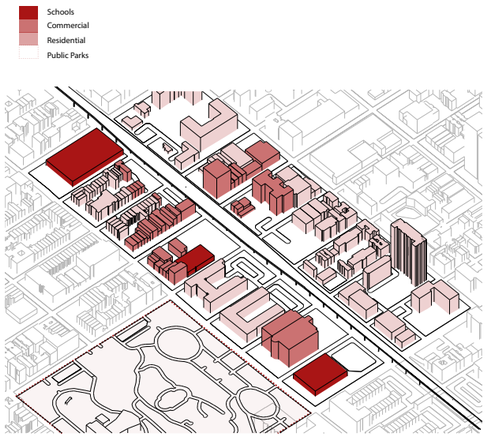
Section of tower system

Model of Tower and its landscape

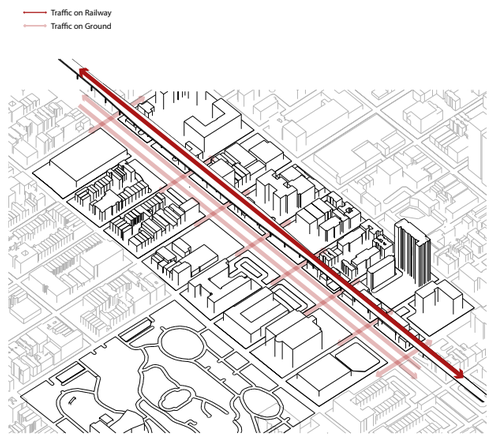




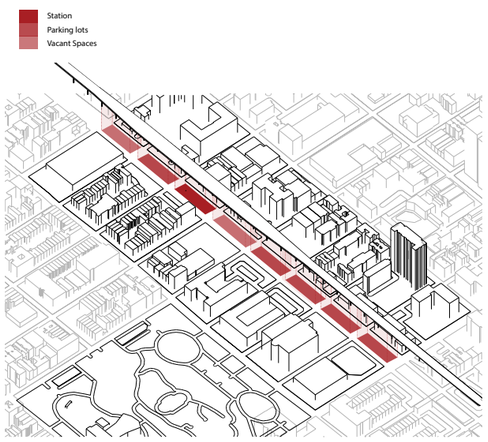
Manhattan 115th st.



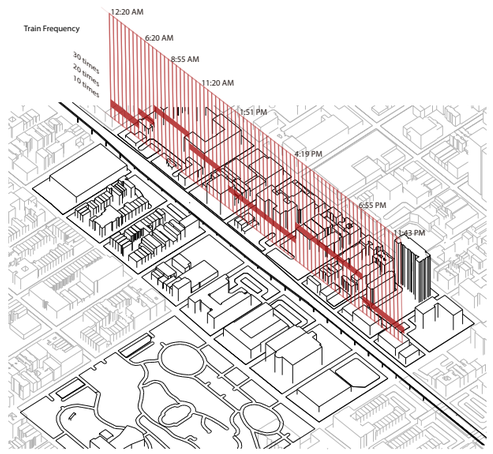
Neigborhood Zoning



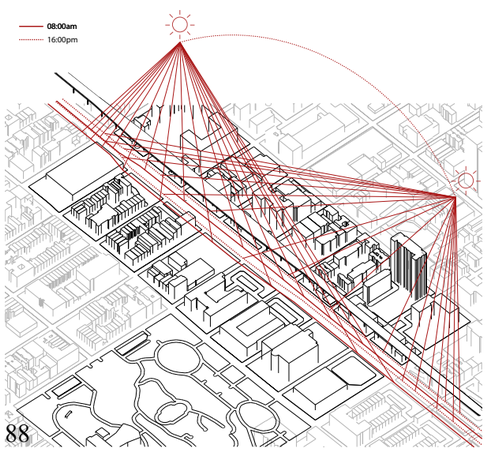
Traffic Research



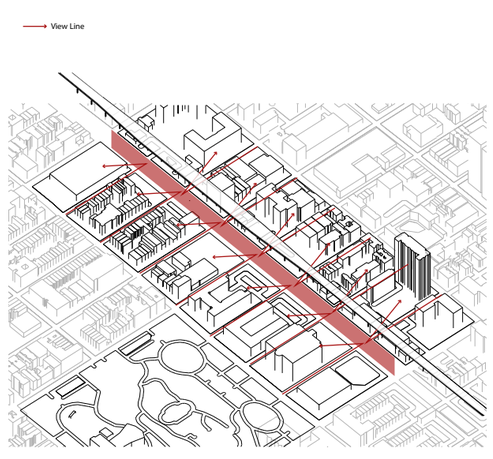
Spaces Underneath



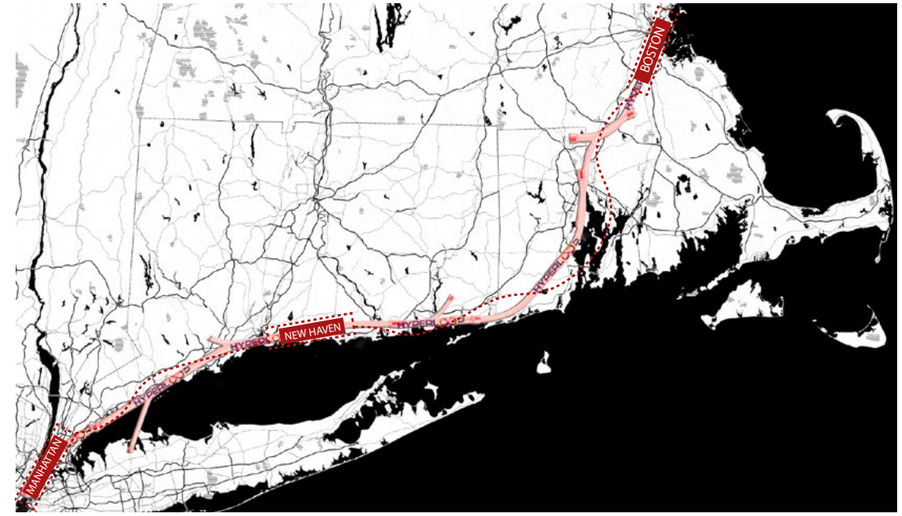
Noise Frequency

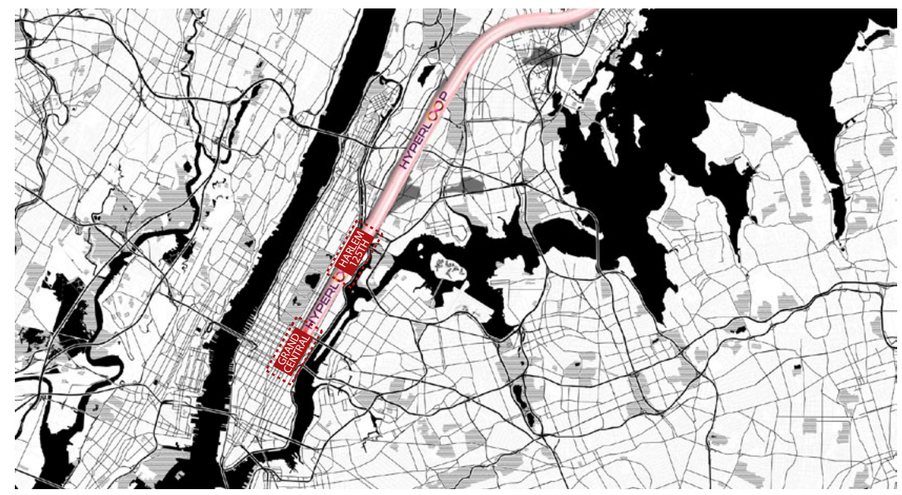


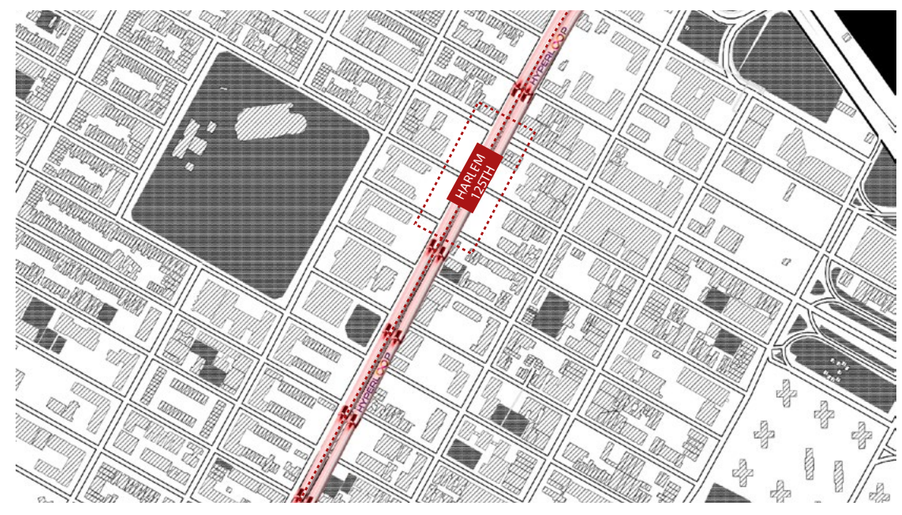
Solar Analysis

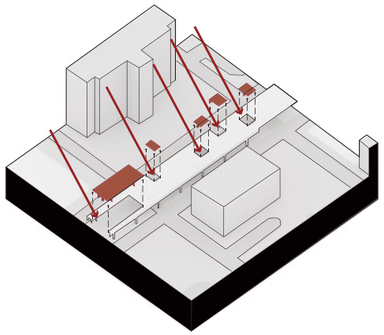


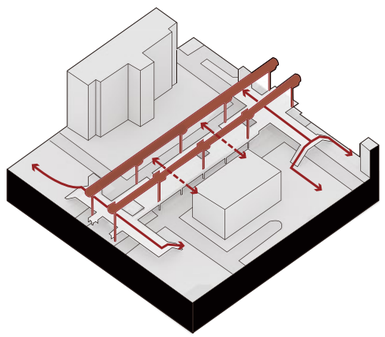
View Accessibility

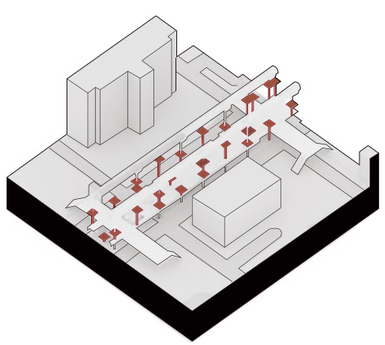


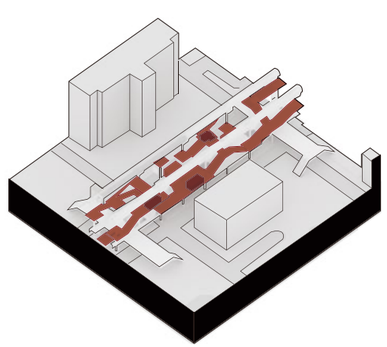


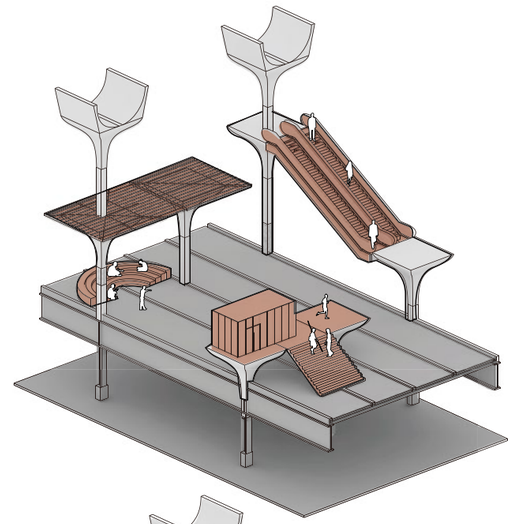


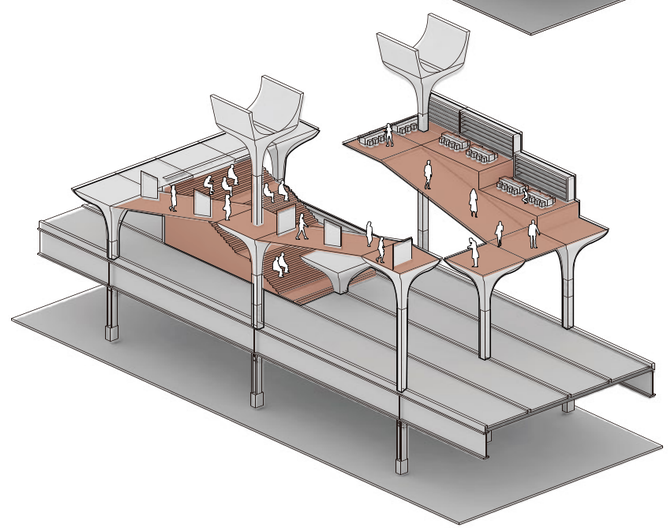


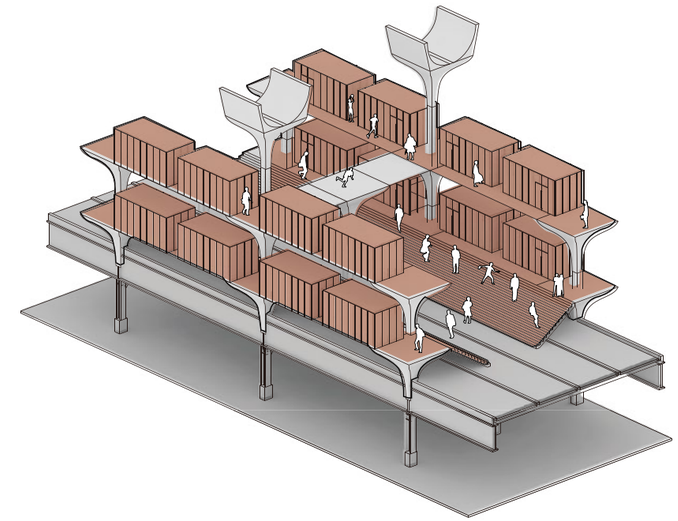


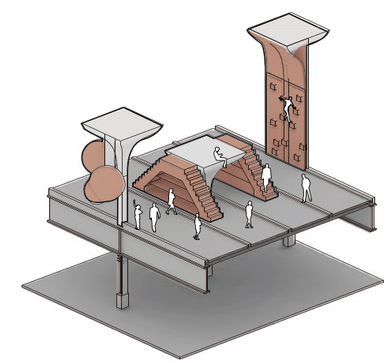












Single Column

Rock Climbing
Reading Stair

Hanging Art

Dual Columns

Vertical Circulation

Canopy & Sitting

Production

Triple Columns

Library

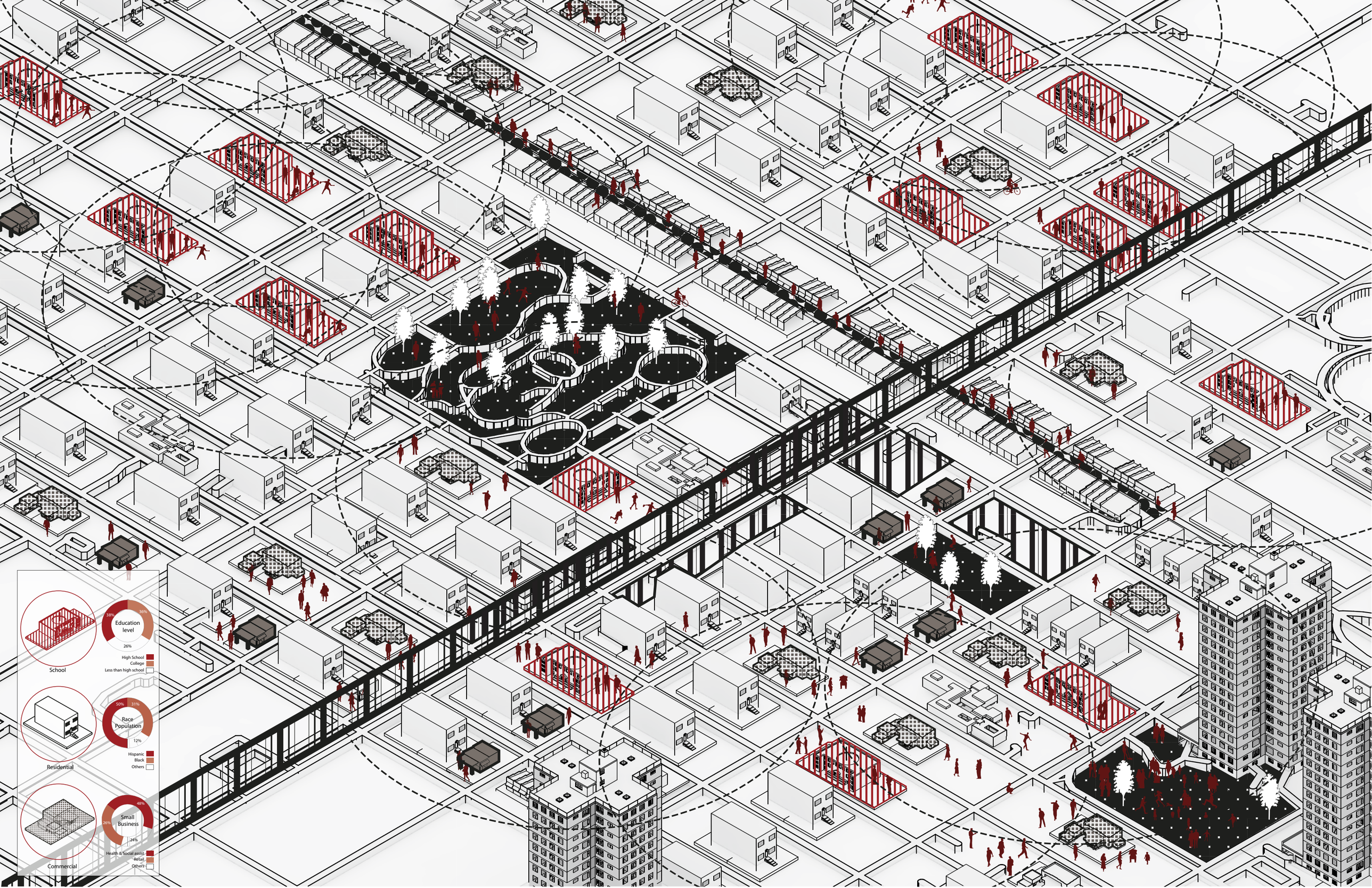
Exhibition

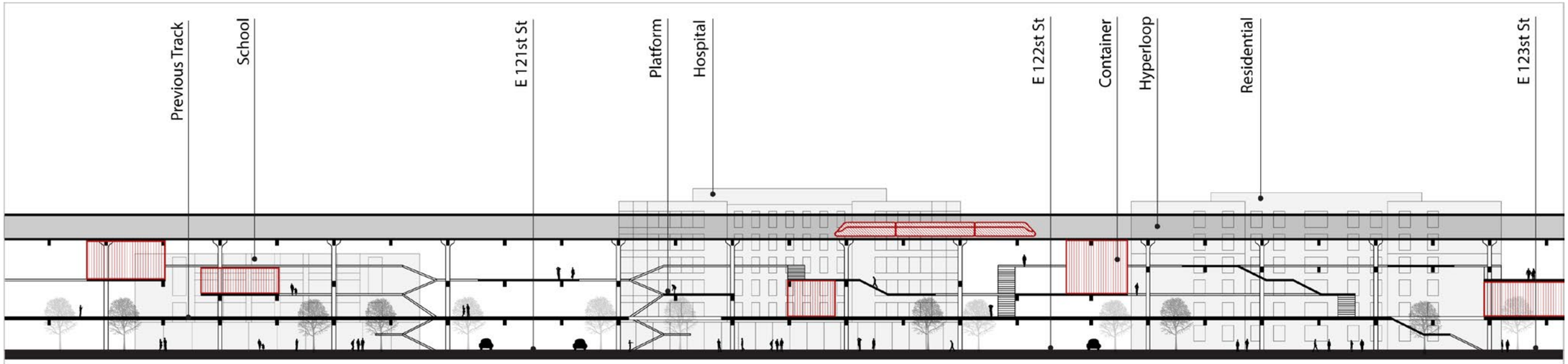
Auditorium

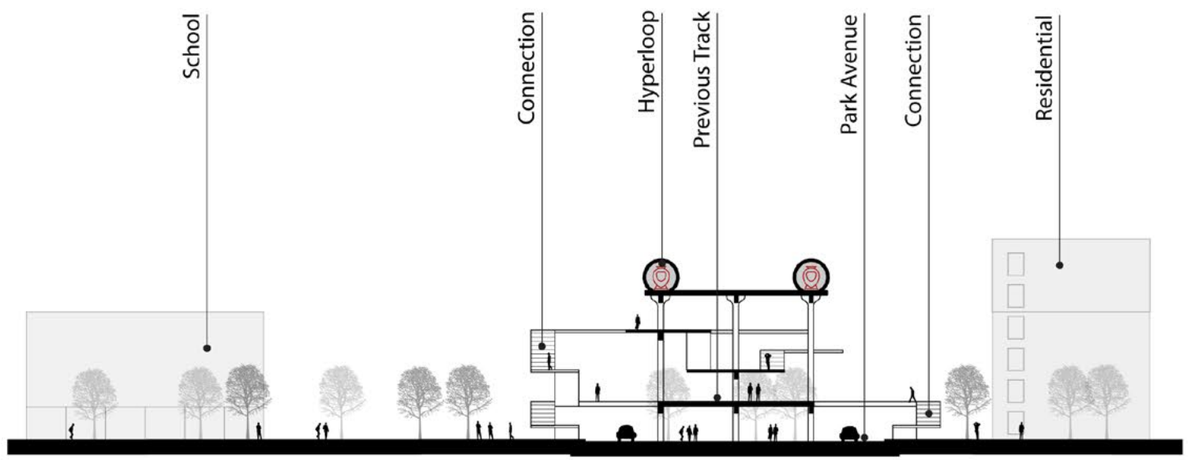
Zone

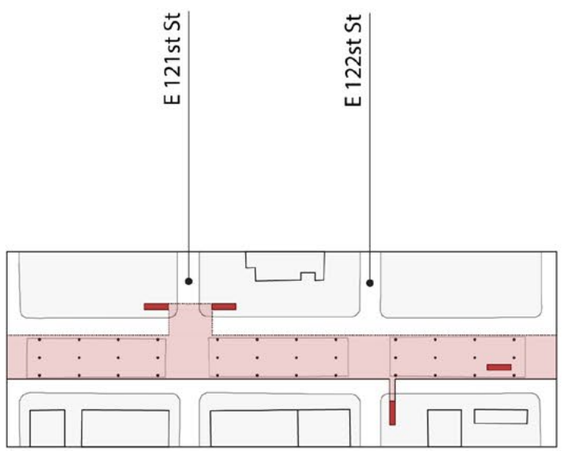
Atrium

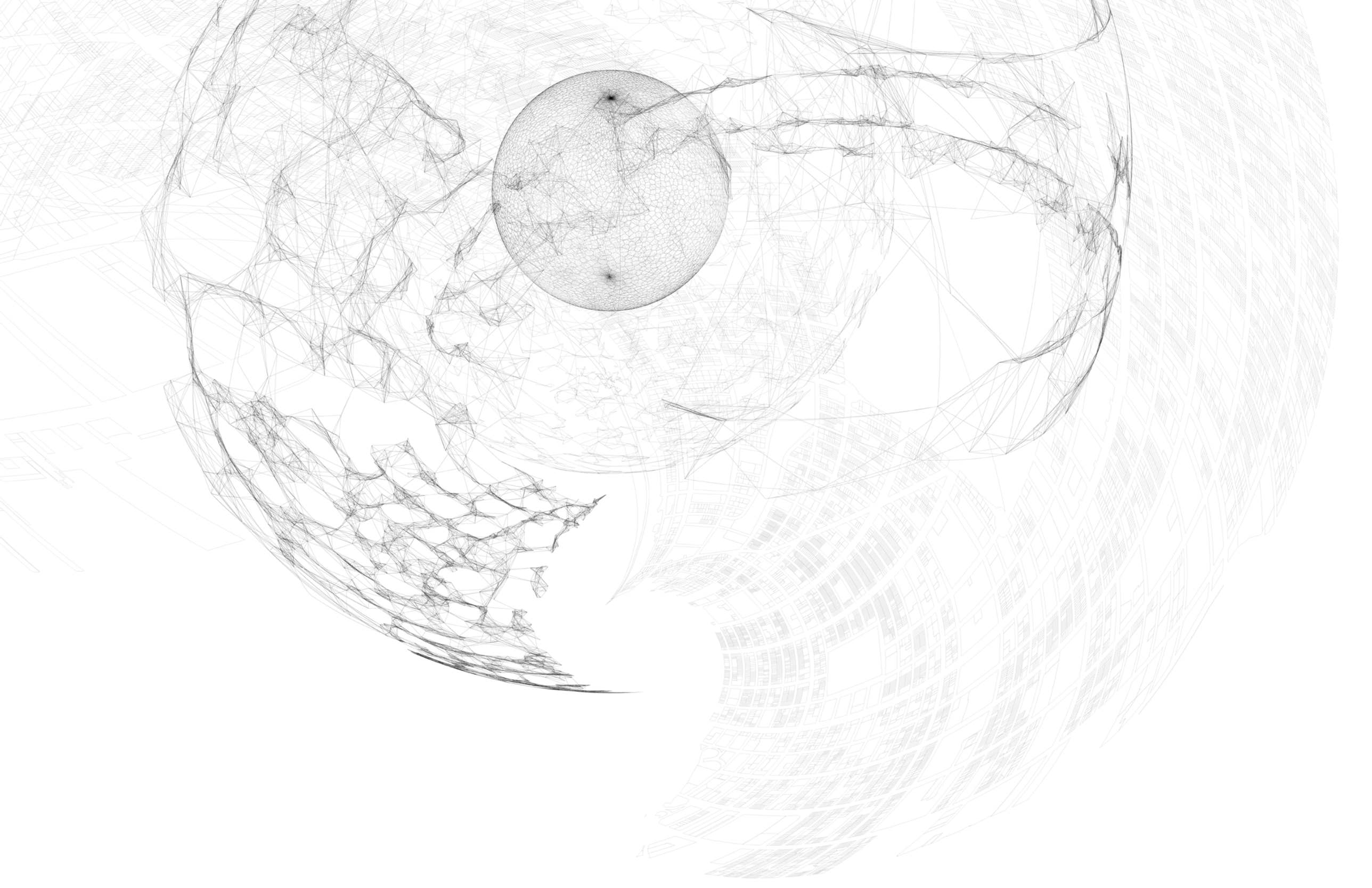
Arcade

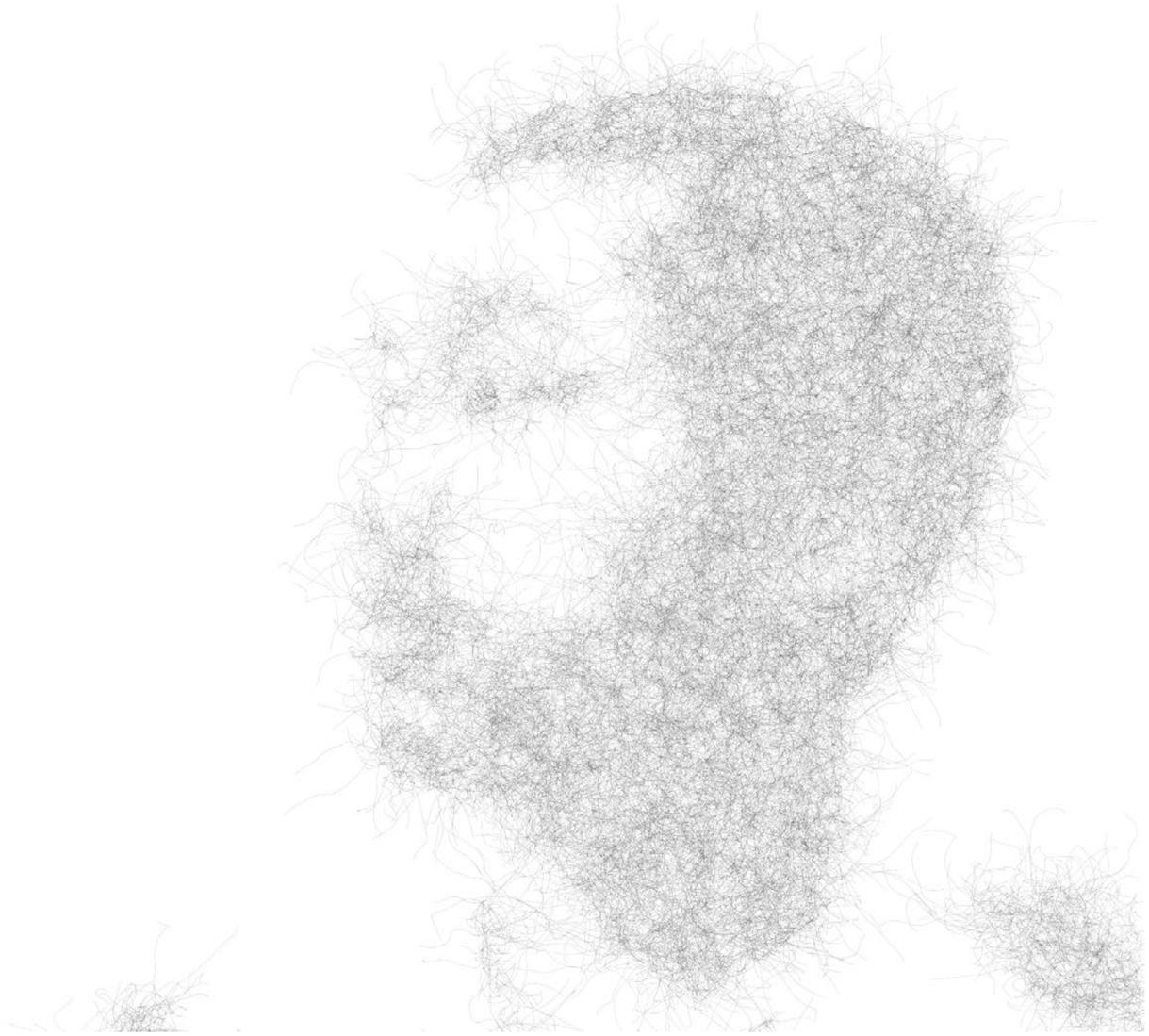

School
Education level
38%
36%
26%
High School
College
Less than high school
Residential
Race Population
50%
31%
12%
Hispanic
Black
Others
Commercial
Small Business
48%
36%
24%
Health & Social assist
Retail
Others

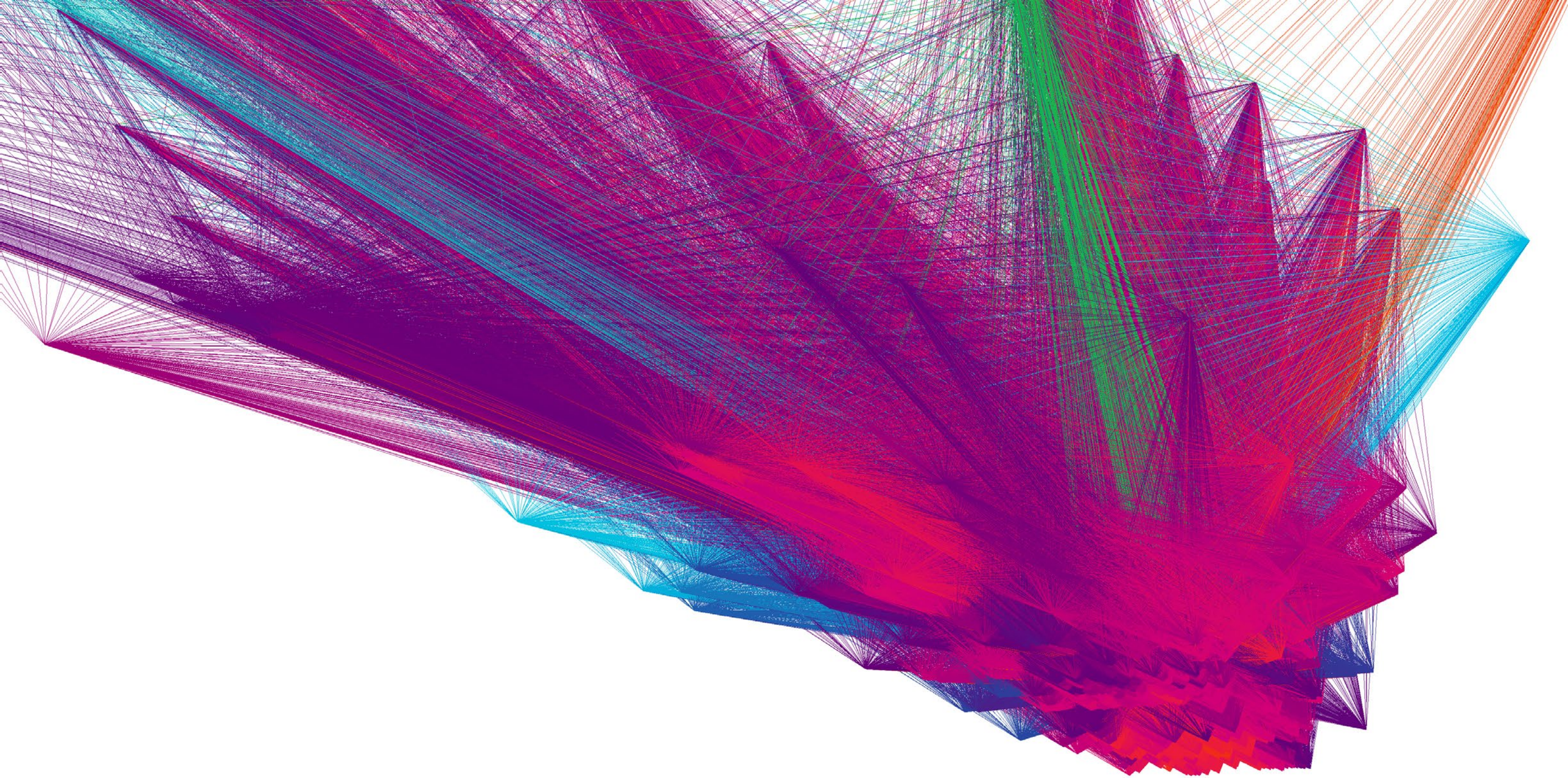

Previous Track
School
E 121st St
Platform
Hospital
E 122st St
Container
Hyperloop
Residential
E 123st St

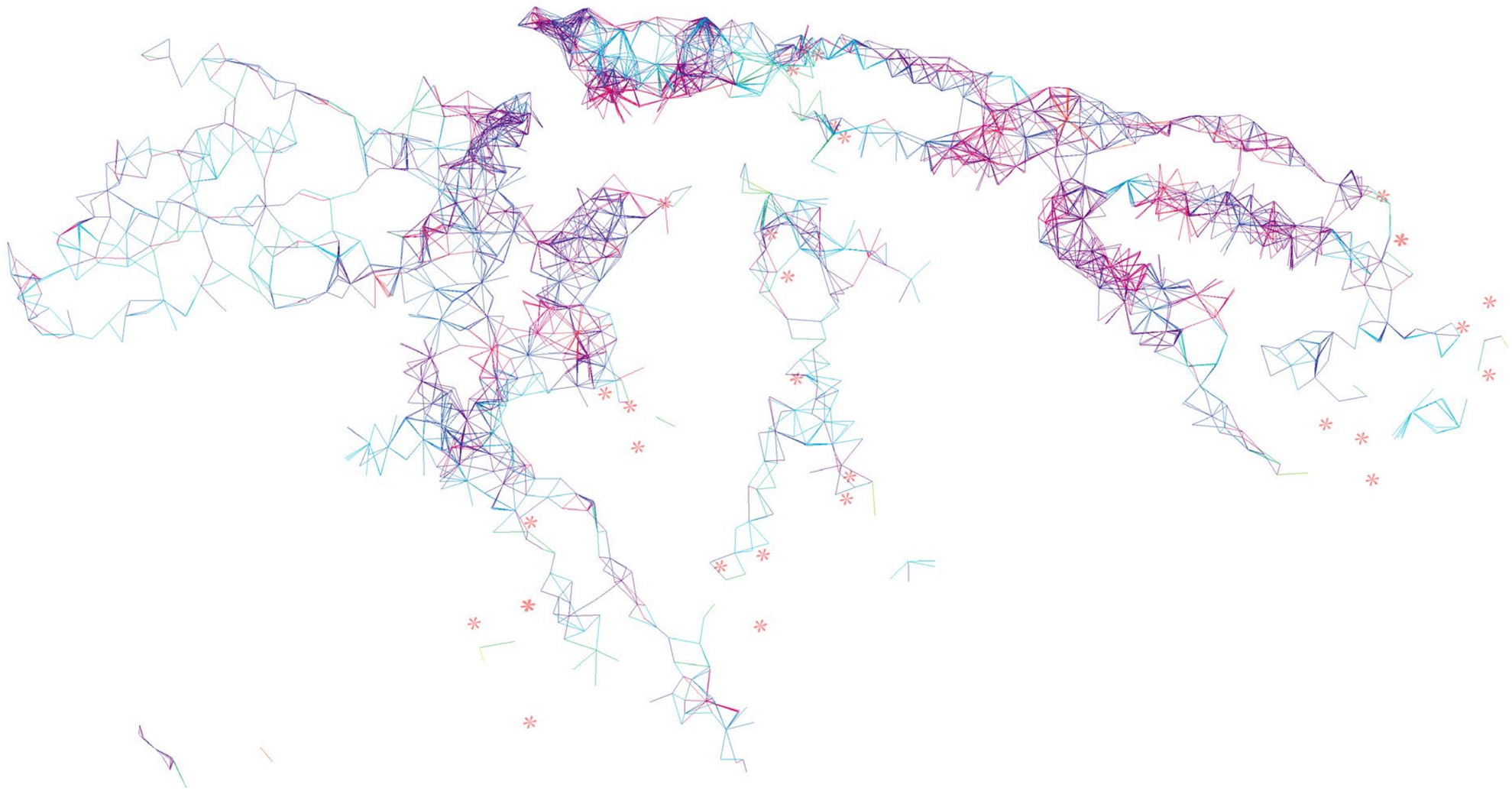

School
Connection
Hyperloop
Previous Track
Park Avenue
Connection
Residential


E 121st St
E 122st St









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