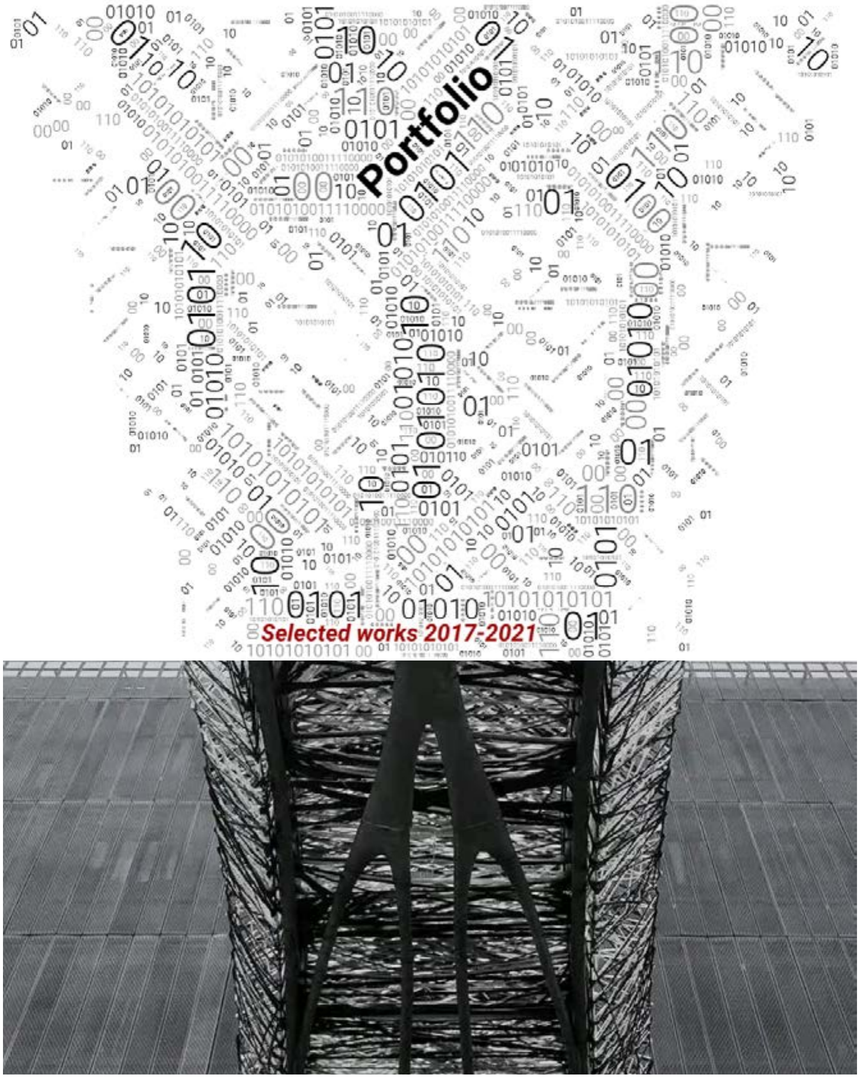
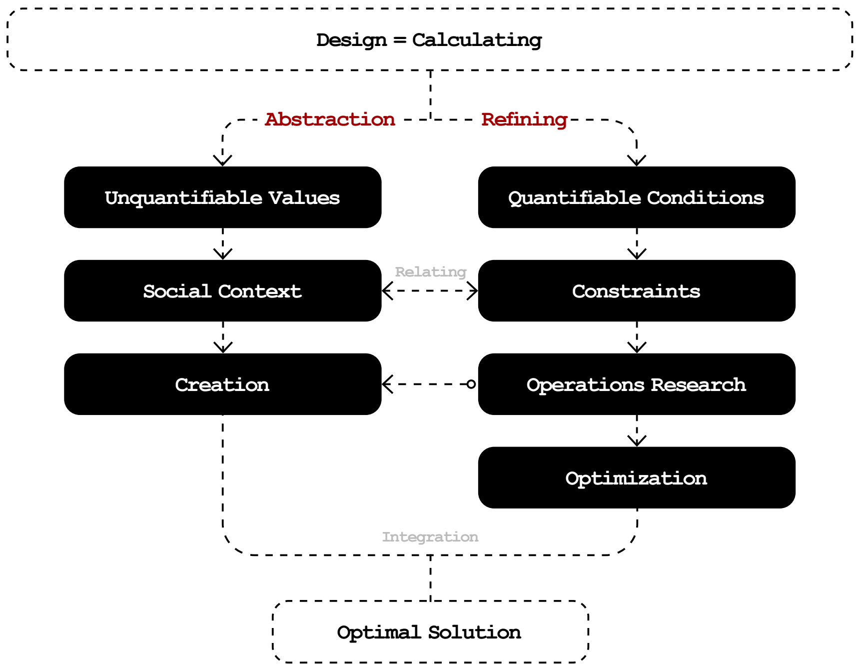
Design is calculating.



Xing HAO

Email: Siegfried0825@outlook.com



Design Operations Research

[Intrinsic Logic]

PORTFOLIO OF XING HAO

portfolio ***selected works;***

timeSpan ***time = 2017-2021;***

{

01 robotic fabrication **HYBRIDE CRAFTS BRIDGE**

{

teamwork;

A Bridge With Two Robotic Fabrication Methods;

}

02 application **FU BRICKS**

{

individual work;

An APP based on Flexpendant of ABB Robots;

}

03 augment reality design **AR MAGIC CUBE**

{

teamwork;

An Intercative Game to Popularize History of Water System of Beijing;

}

04 robotic fabrication **MIX**

{

individual work;

3D Printing Chair with Two Paths;

}

05 parametric design **MULTI-RESOLUTION**

{

individual work;

A Digital Libraty in Copenhagen;

}

06 other design **OTHER WORKS**

{

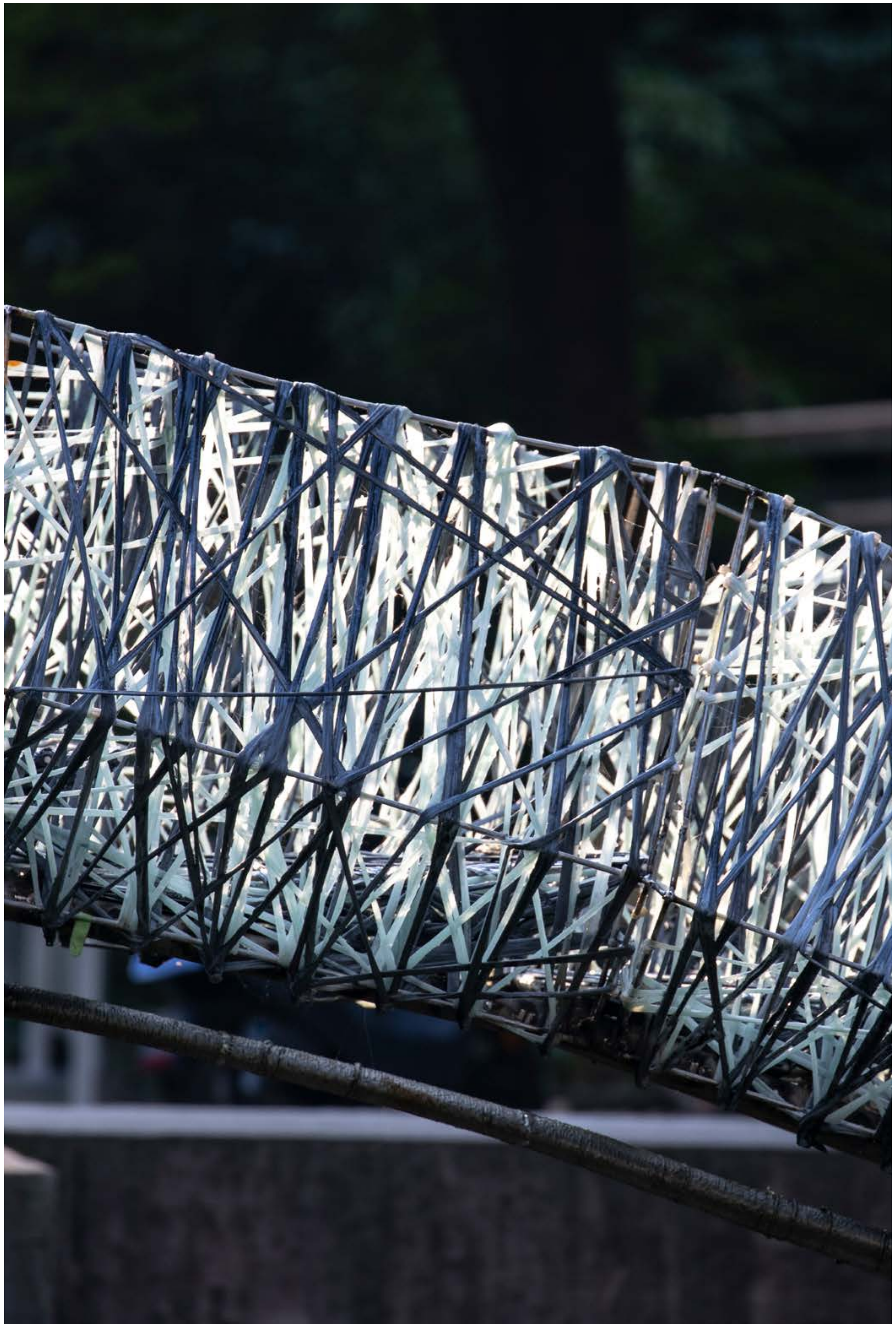
06 individual work | Architecture Design;

07 team work | Manual Fabrication;

08 team work | Robotic Fabrication;

}

} *//CONTENTS*



01

HYBRIDE CRAFTS BRIDGE

A Bridge with Two Kinds of Robotic Crafsmanship

{

DigitalFUTURES 2019 Summer Workshop
Team work; Individual Redraw
Partner: Xingtai HUANG/Xiaofei HONG/Zhongsheng YU
Instructor: Philip F.YUAN
Durition: 9 Weeks
Published in dezeen:
https://www.dezeen.com/2019/11/29/robotic-fabricated-hybrid-bridge-technology/#/
Summer 2019

[RESPONSIBLE PART] 30%Concept design/Stairs design/ 80%Robotic winding path design/Physical model/50%Fiber Fabrication

What is focused in this project is **how digital tools integrate fabrication into design**. our task is to build a light, strong and durable bridge which can hold 20 people. Compared to traditional building methods, robotic fabrication and addictive manufacturing have a great potential in material and energy saving in the architecture field. This project is an exploration of two relatively recent construction methods : large scale metal 3D printing and filament winding, as well as how these two techniques work in synergy.

The methodology of **operations research** and has been adapted into the design strategy of this project. By abstracting the calculation parts such as digital modeling and kinematics and combing them with the form finding process, this methodolgy allows us elaborate our design's personality instead of the universality.

In this project, combing two advanced methods and bring the function of all materials into full play, the clean, accurate, strong structure presents both structural and aesthetic consideration. "*As a result, designer's capabilities can considerably be expanded through the 'operatinality' of the robot.*"

}

DESIGN STRATEGY | Conditions & Design Research

Robotic Craftsmanship

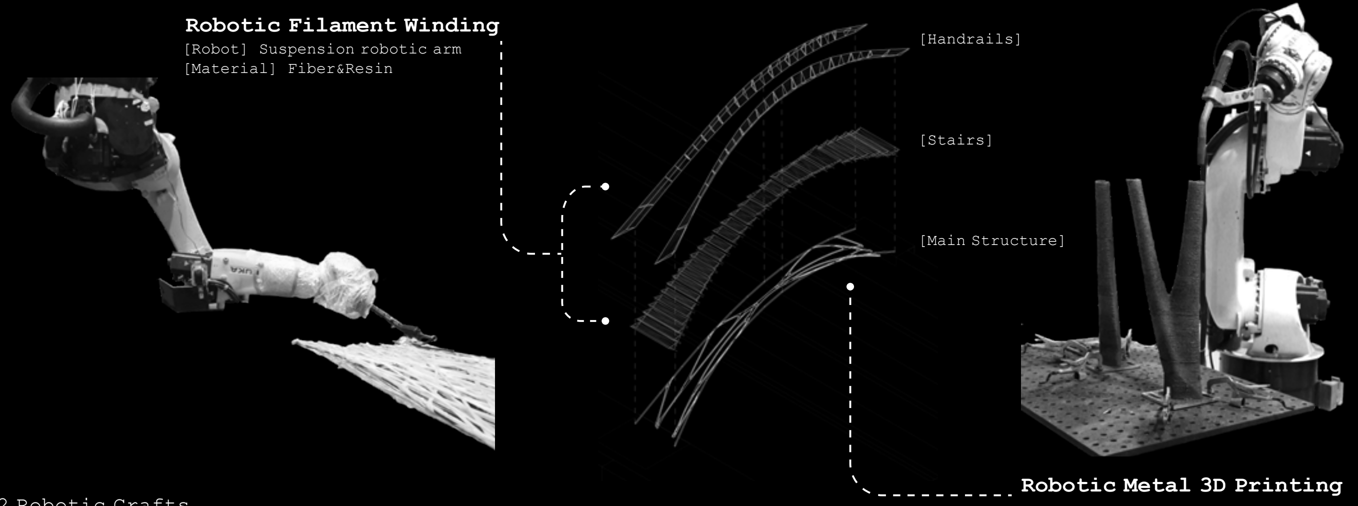
What is focused in this project is how digital tools integrate fabrication into design. our task is **to build a light, strong and durable bridge which can hold 20 people.** Compared to traditional building methods, robotic fabrication and addictive manufacturing have a great potential in material and energy saving in the architecture field. This project is an exploration of two relatively recent construction methods : large scale metal 3D printing and filament winding, as well as how these two techniques work in synergy.

Operations Research

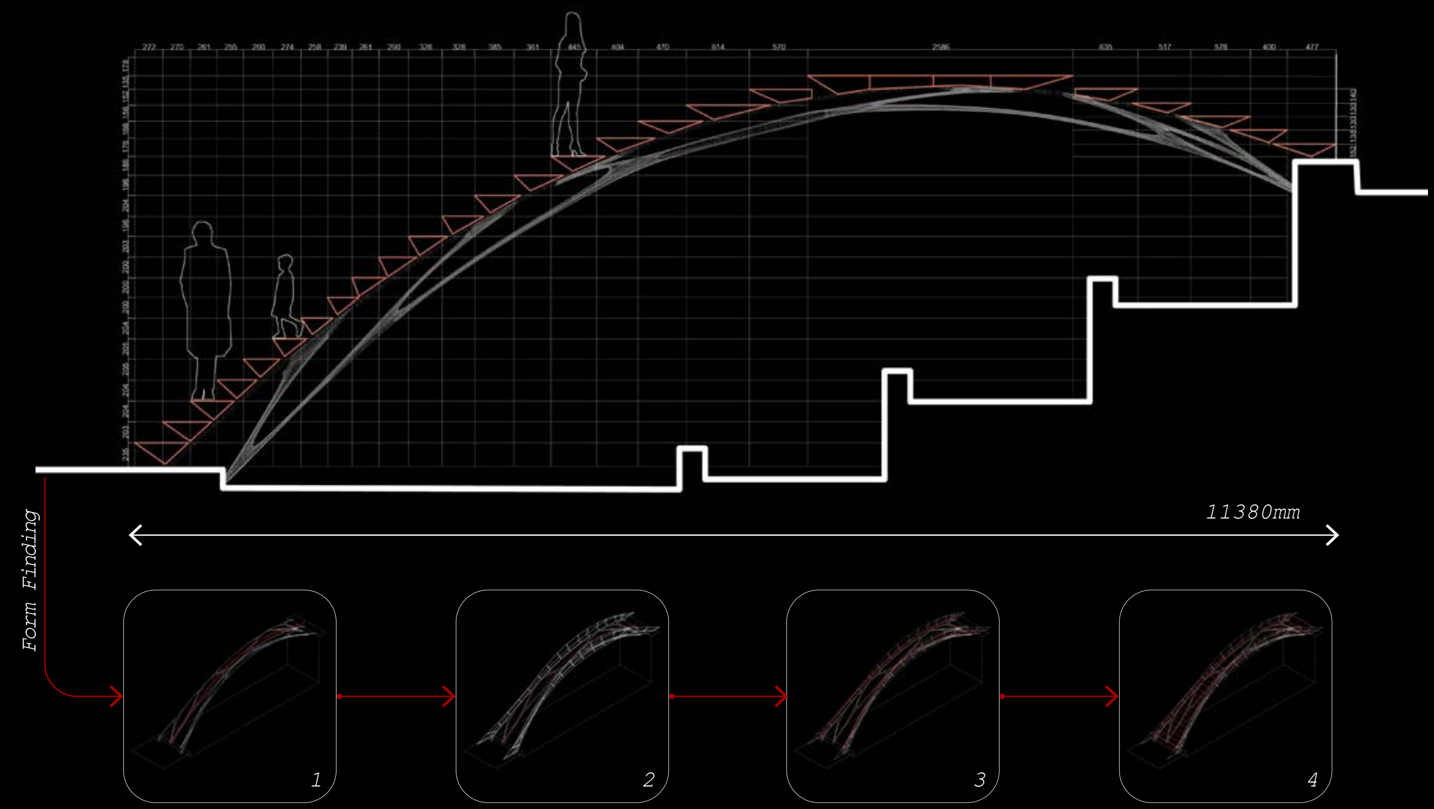
The methodology of operations research and has been adapted into the design strategy of this project: identifying goals,confirming constraints, modeling, finding feasible solutions, optimizing, getting optimal solution. By abstracting the calculation parts such as digital modeling and kinematics and combing them with the form finding process, this methodology allows us elaborate our design's personality instead of the universality -- the clean, accurate, strong structure presents both structural and aesthetic consideration.

Ergonomics Research

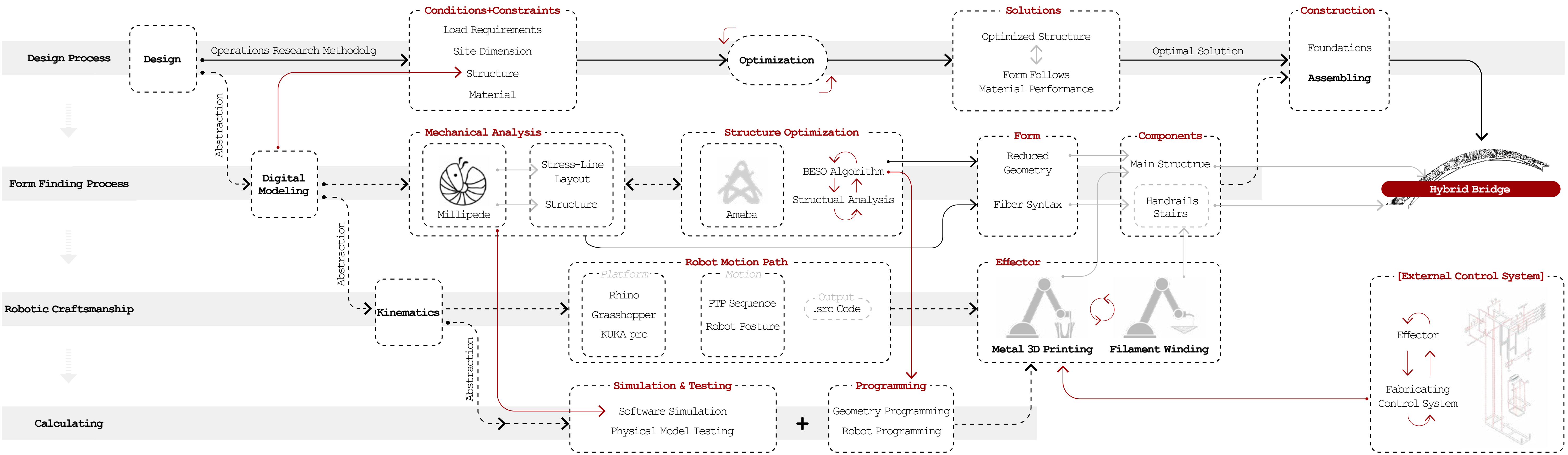
The geometric shapes of the steps hinge on the human body demension and the shape of main structure.



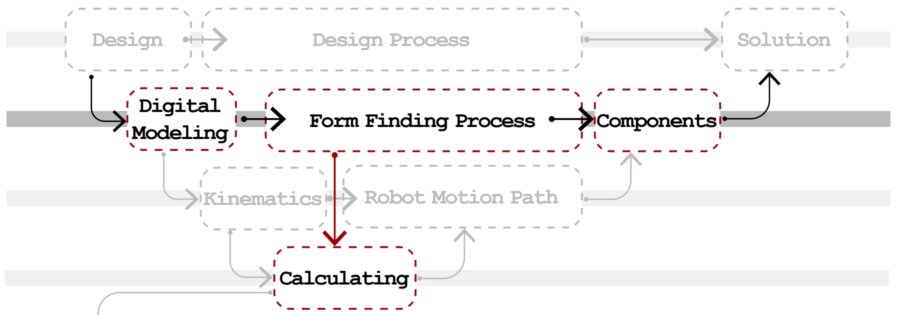
2 Robotic Crafts



Research Framework | *How Operations Research Abstracted And Refined the Process of Design*



OPTIMIZATION & ITERATION | Form Design & Simulation

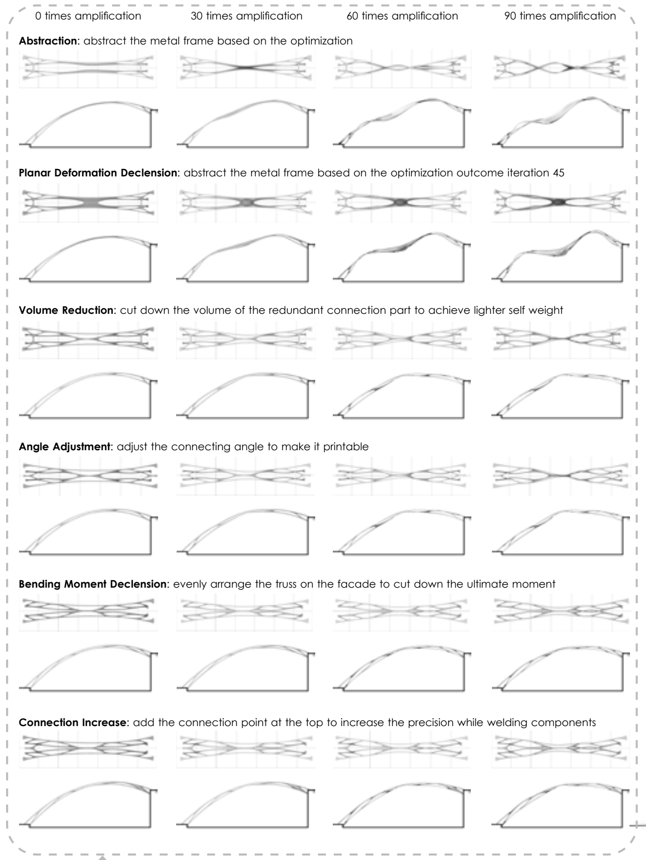


Millipede is a structural analysis and optimization component for grasshopper. It allows for very fast linear elastic analysis of frame and shell elements in 3d,2d plate elements for in plane forces, and 3d volumetric elements. All systems can be optimized using built in topology optimization methods and have their results extracted and visualized in different ways.

Based on the **Bi- directional Evolutionary Structural Optimization (BESO)**, Ameba allows user , according to design requirements, apply different loading and boundary conditions to the initial design domain. During the computational process by the software, the design domain will evolve, similar to an ameba, into various shapes, and eventually reach an organic form that is structurally efficient.

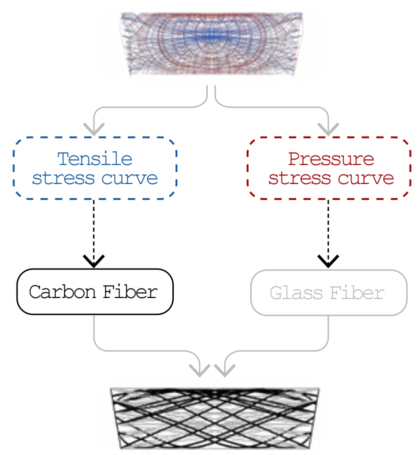
Main Structure Design

To reduce the dead weight of structure and bring the function of all materia ls into full play, The form of main structure has been optimized through the calculation and **volume reduction** of Ameba.



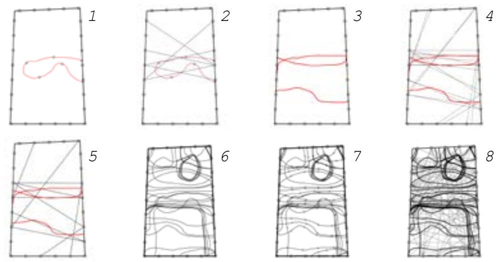
Stairs Design

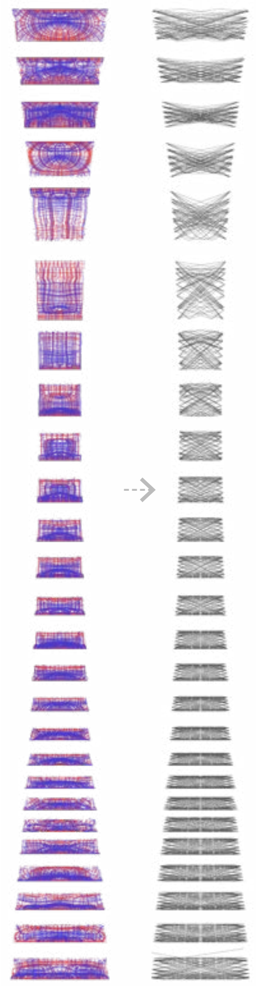
The winding path of stairs comes from the layout of stress lines calculated by Millipede, which stimulates 150kg (weight of two adults). Then accoding to the **material performance**, carbon fiber fits the layout of tensile stress curve while glass fiber fits that of pressure stress curve.



Wind Form Simulation

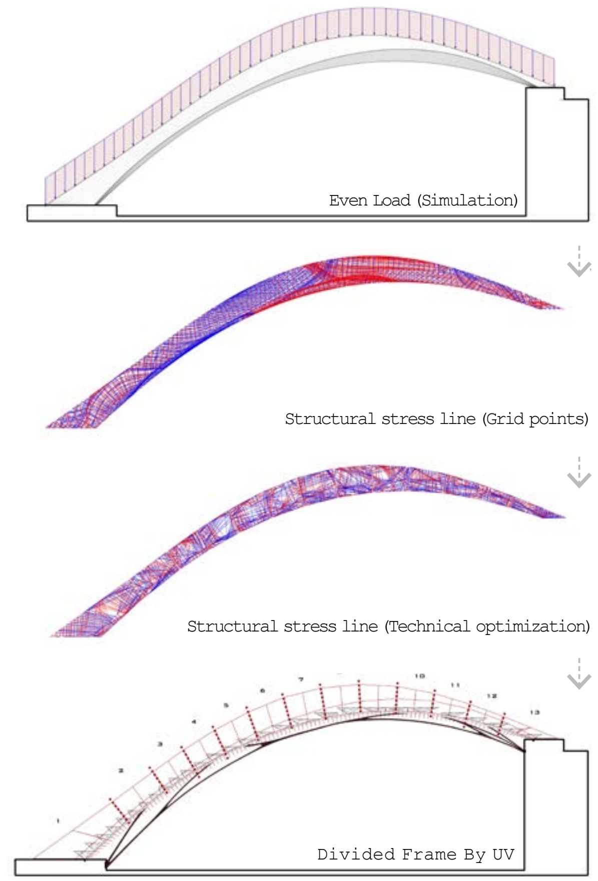
How staight lines fit the curve stress lines

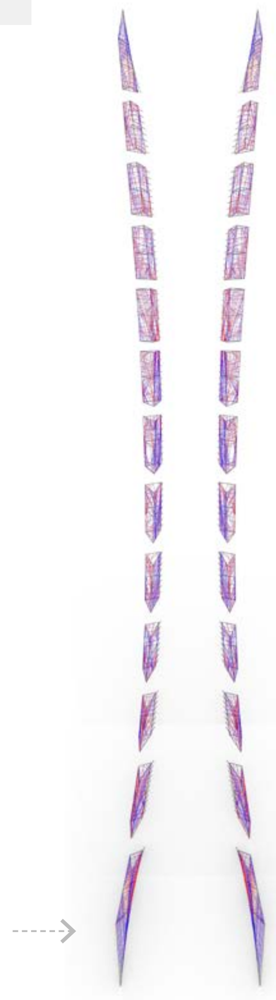


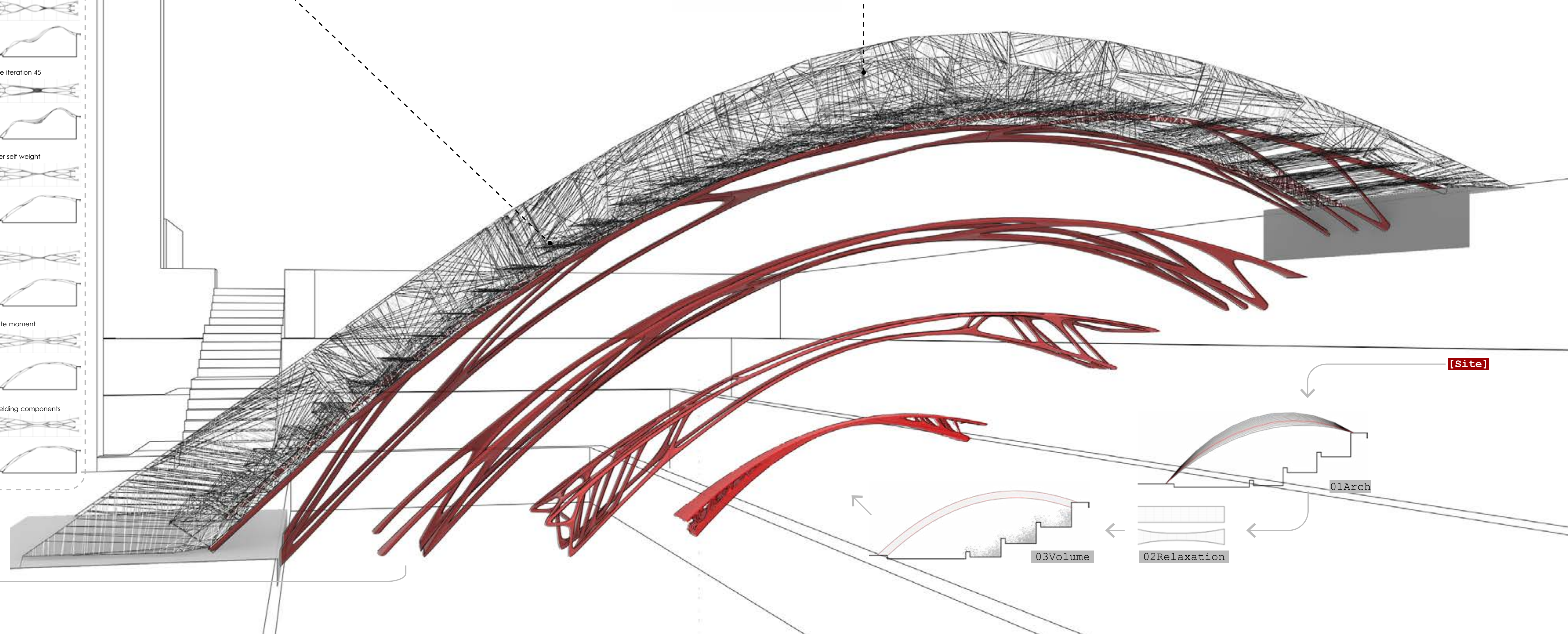


Handrails Design

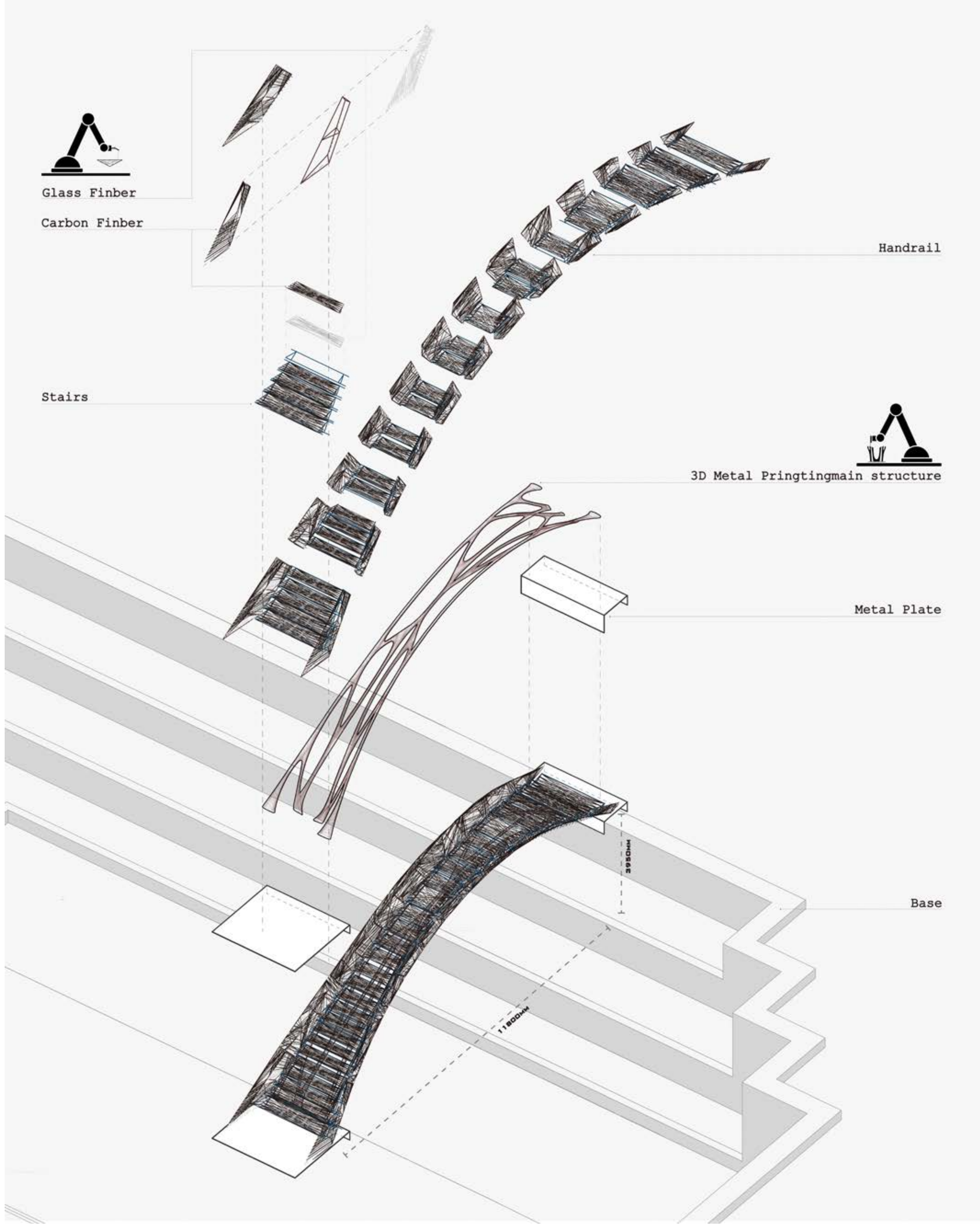
The form of handrails arises from the fiber syntax, which follows the layout of stress-lines calculated by Millipede.







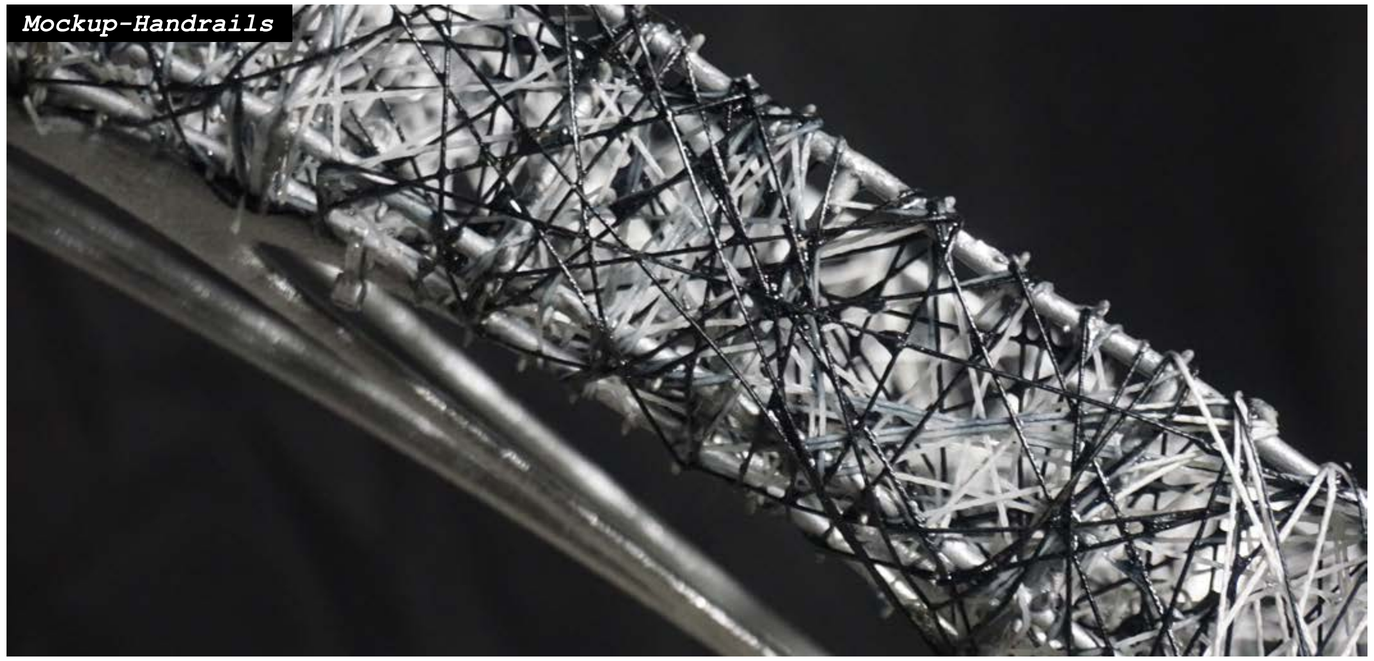
ASSEMBLING PROPOSAL|Analysis & Physical Model



Component Overview Axonometric

The main structure is divided into **13** segments based both on structure optimization and technical requirements from robotic 3d metal printing. **26** handrails and **28** steps are pre-fabricated through robotic filament winding. In total, **3889** meters of glass fiber and **4072** meters of carbon fiber were used to form the steps and the handrails.

Mockup-Stairs

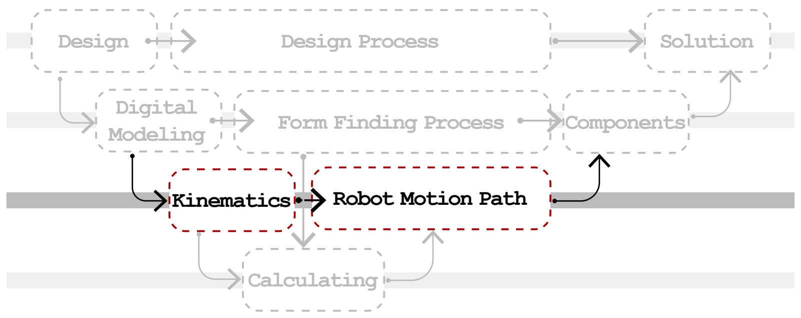


Mockup-Handrails

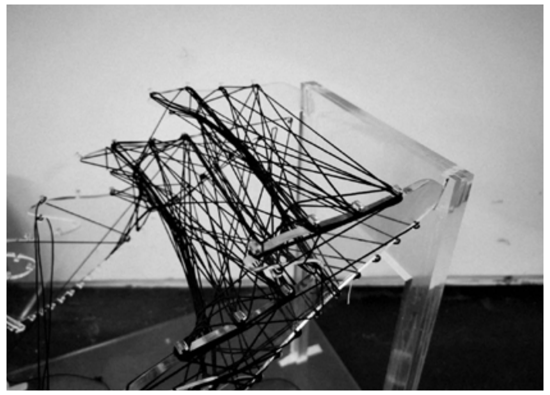
Mockup-Main Structure

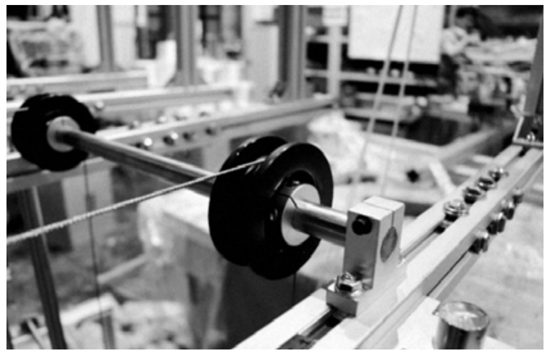
KINEMATICS RESEARCH | Robotic Winding Path Design

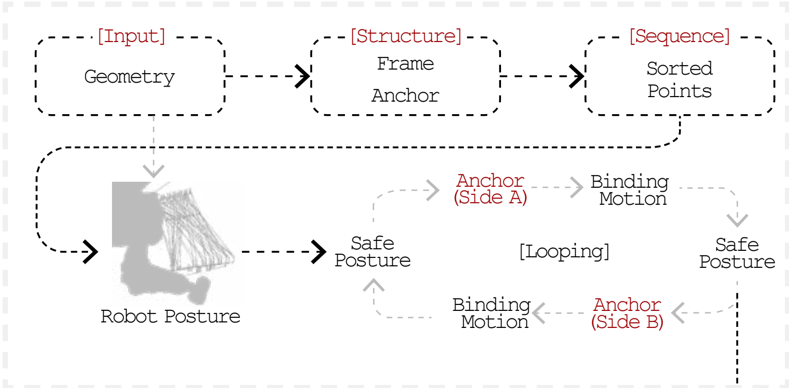
Kinematics research is conducted to use 6-axis robotic arm to fabricate the components of stairs and handrails as designed. The position of **anchors** and the **winding order** are the keys to realize the scientifically rational form. We did a simulation experiment by both 3D model and physical mockup. Eventually the mode of "anchor-safe posture" was decided. The safe posture allow the robotic arm pull the fibers tight without tangling them together. Eventually, the mix-woven with carbon and glass fiber was cured by the resin.



Winding Simulation





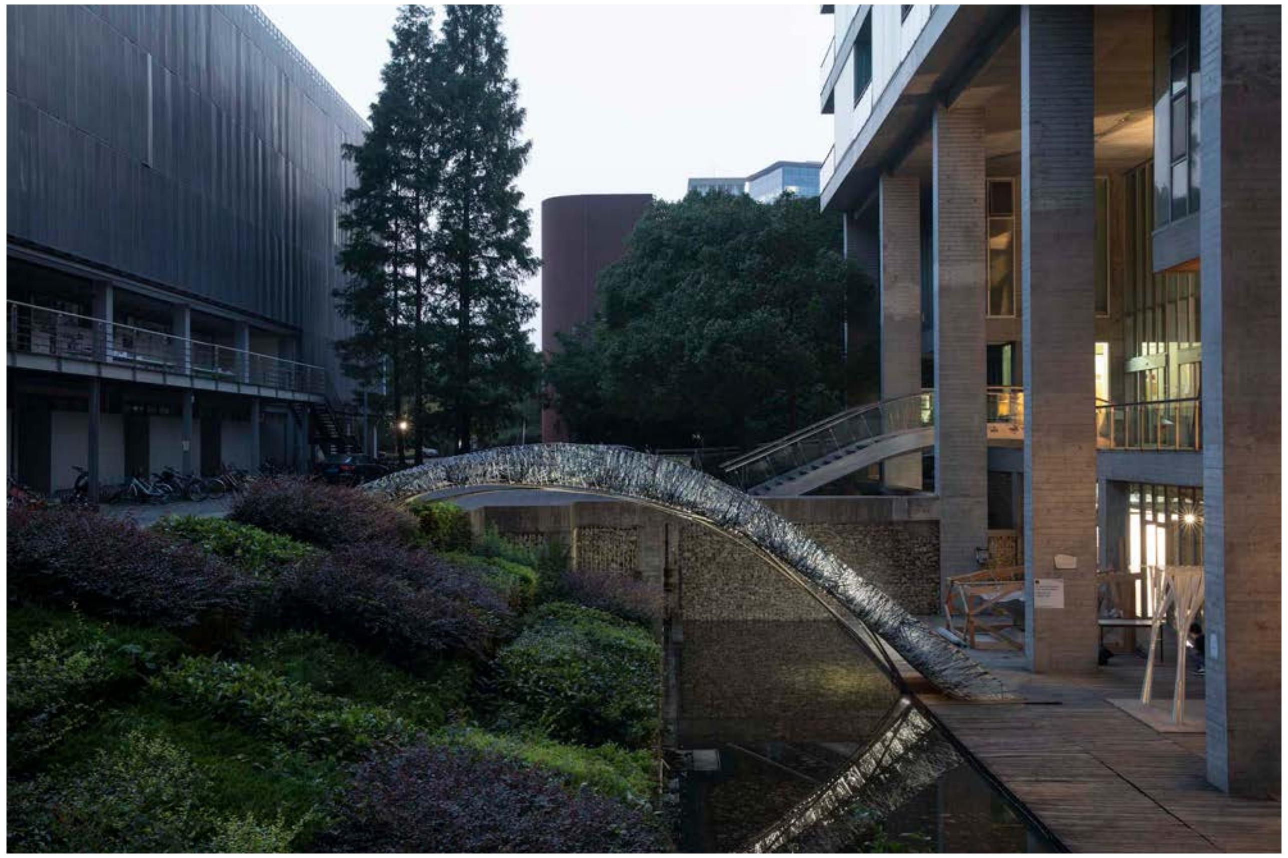



```
;FOLD LIN SPEED IS 0.25 m/sec, INTERPOLATION SETTINGS
IN FOLD
$VEL.CP=0.25
$APO.CVEL=100
$ADVANCE=3
;ENDFOLD
;FOLD COMMANDS IN FOLD. SELECT EDIT/FOLDS/OPEN ALL
FOLDS TO DISPLAY
PTP {E6POS: X 1574.564, Y 1100.886, Z 889.543, A 0, B
90, C 15.009, E1 0, E2 0, E3 0, E4 0, S 'B 110'} C_PTP
LIN {E6POS: X 1574.564, Y 1100.886, Z 889.543, A 0, B
90, C 15.009, E1 0, E2 0, E3 0, E4 0} C_DIS
LIN {E6POS: X 1574.564, Y 1100.886, Z 879.543, A 0, B
90, C 15.009, E1 0, E2 0, E3 0, E4 0} C_DIS
ArcOn()
LIN {E6POS: X 1574.564, Y 1100.886, Z 879.543, A 0, B
90, C 15.009, E1 0, E2 0, E3 0, E4 0} C_DIS
LIN {E6POS: X 1573.566, Y 1102.617, Z 879.543, A 0, B
90, C 15.009, E1 0, E2 0, E3 0, E4 0} C_DIS
ArcOff()
LIN {E6POS: X 1573.566, Y 1102.617, Z 889.543, A 0, B
90, C 15.009, E1 0, E2 0, E3 0, E4 0} C_DIS
LIN {E6POS: X 1574.564, Y 1100.886, Z 889.543, A 0, B
90, C 15.009, E1 0, E2 0, E3 0, E4 0} C_DIS
LIN {E6POS: X 1574.564, Y 1100.886, Z 890.543, A 0, B
90, C 15.009, E1 0, E2 0, E3 0, E4 0} C_DIS
LIN {E6POS: X 1574.564, Y 1100.886, Z 880.543, A 0, B
90, C 15.009, E1 0, E2 0, E3 0, E4 0} C_DIS
ArcOn()
PTP {E6POS: X 1574.564, Y 1100.886, Z 889.543, A 0, B
90, C 15.009, E1 0, E2 0, E3 0, E4 0, S 'B 110'} C_PTP
LIN {E6POS: X 1574.564, Y 1100.886, Z 880.543, A 0, B
90, C 15.009, E1 0, E2 0, E3 0, E4 0} C_DIS
LIN {E6POS: X 1571.82, Y 1107.894, Z 880.543, A 0, B
90, C 15.009, E1 0, E2 0, E3 0, E4 0} C_DIS
LIN {E6POS: X 1571.621, Y 1115.436, Z 880.543, A 0, B
90, C 15.009, E1 0, E2 0, E3 0, E4 0} C_DIS
LIN {E6POS: X 1573.757, Y 1122.667, Z 880.543, A 0, B
90, C 15.009, E1 0, E2 0, E3 0, E4 0} C_DIS
LIN {E6POS: X 1578.464, Y 1128.512, Z 880.543, A 0, B
90, C 15.009, E1 0, E2 0, E3 0, E4 0} C_DIS
LIN {E6POS: X 1584.993, Y 1131.165, Z 880.543, A 0, B
90, C 15.009, E1 0, E2 0, E3 0, E4 0} C_DIS
```

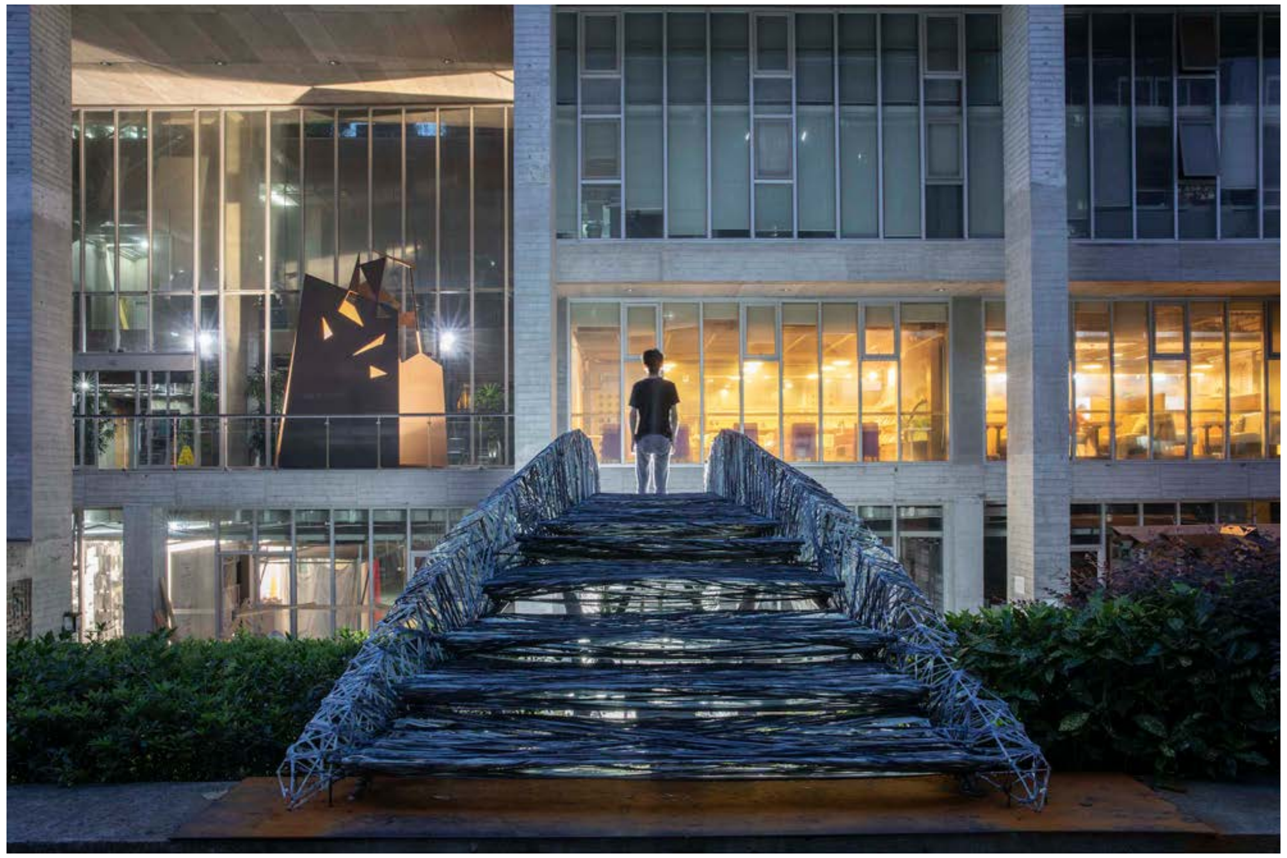
Safe Posture
Anchor (Side A)
Binding Motion
Safe Posture
Anchor (Side B)
Binding Motion

Digital Fabrication Process

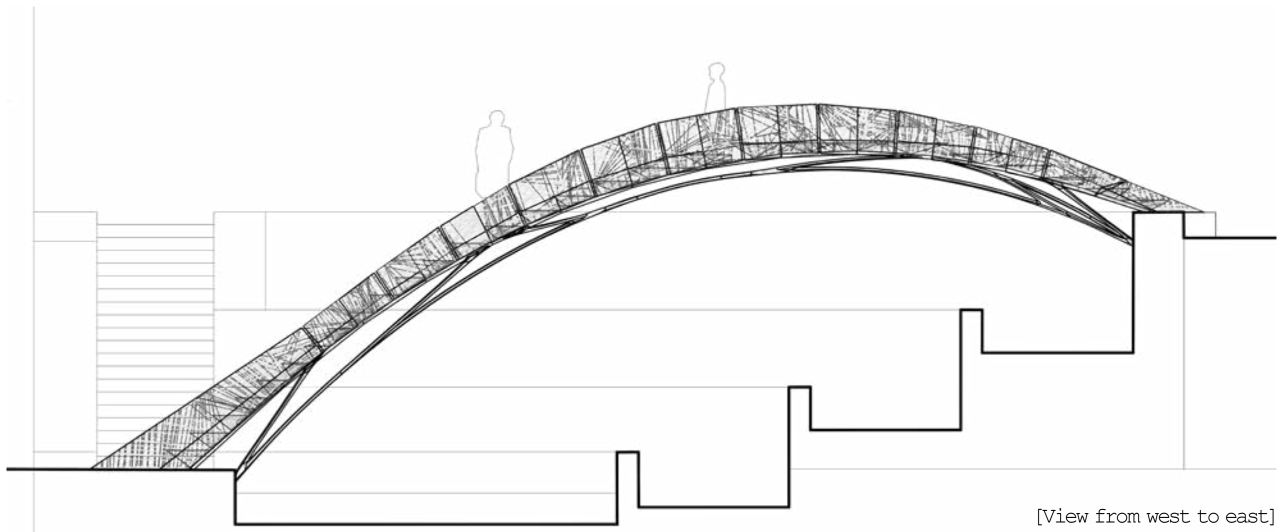
BRIDGE ON THE SITE|Comparison of Object & Model



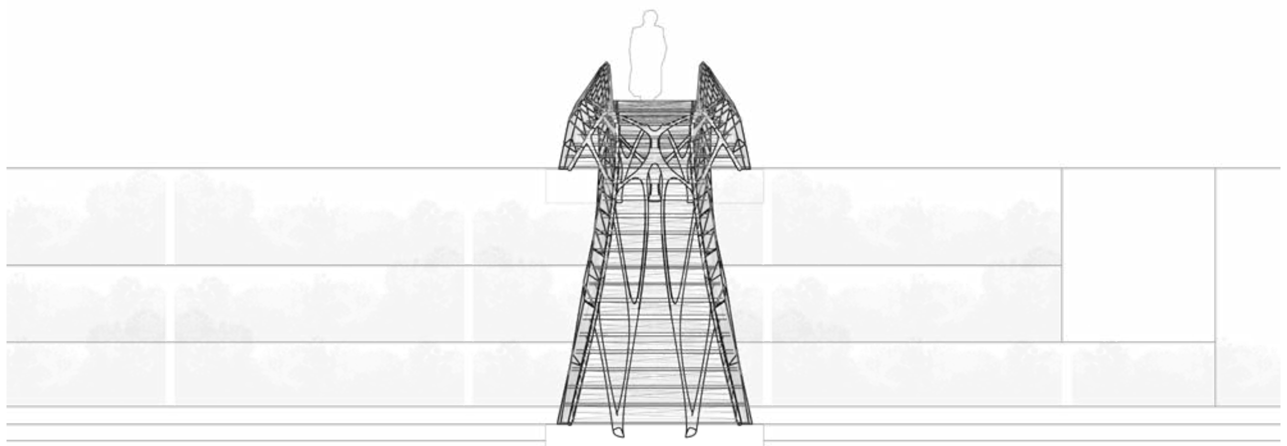
Photographed By Fangfang TIAN [View from east to west]



Photographed By Fangfang TIAN [View from south to north]



[View from west to east]



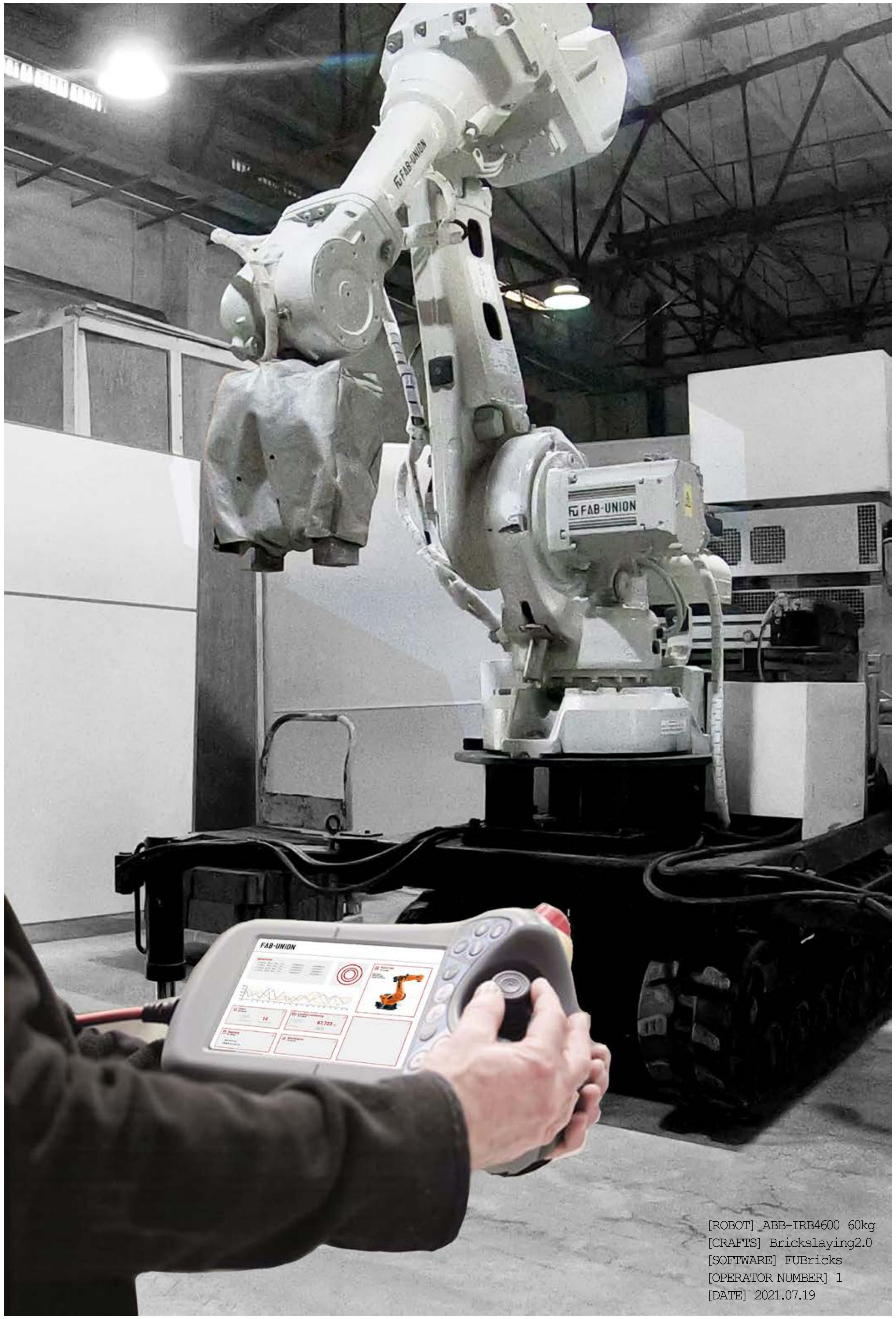
[View from north to south]

Echoing To The Entrance

New bridge is echoing to the existing bridge on the site, which serves as the entrance of C building. The light from the sunshine travels through the glass fibre, creates a soft soothing glow.

High Performance Structure

Only 260.2 kg of stainless steel was used for the main structure, and it could hold up more than 20 people.



02

FU BRICKS

An Application for Robot Operator Based on ABB FlexPendant

{

Design for Fab-Union
Individual Work
Instructor: Yifan ZHOU
Durition: 3 Months
Summer 2021
[This project does not involve commercial intellectual property rights]

Based on my work results in Fab-Union, the **optimization and improvement of workflow of robotic bricks-laying process** and related design, this project integrate the user and the developer of robotic craftsmanship. FUBricks is an interactive software for Flexpendant, a robot teaching-programming pendant of ABB.

In the production process of bricks wall, the rigid workflow is the main painpoint -- everytime new pattern is designed, the engineer need to build a new workflow, which will waste a lot of time. To promote the coordination of all links and improve the operator experience, the program system was divided into four parts: calibration data, robot motion code about crafts, production setting adn geometry information, which are relatively defined by machanical engineer, R&D engineer, robot operator and designer.

There are two main functional modules in FUBricks including operator mode and developer mode, which makes their work process flexible and independent.

}

"SYSTEM UPGRADE" | Optimization of Workflow of Robotic Crafts

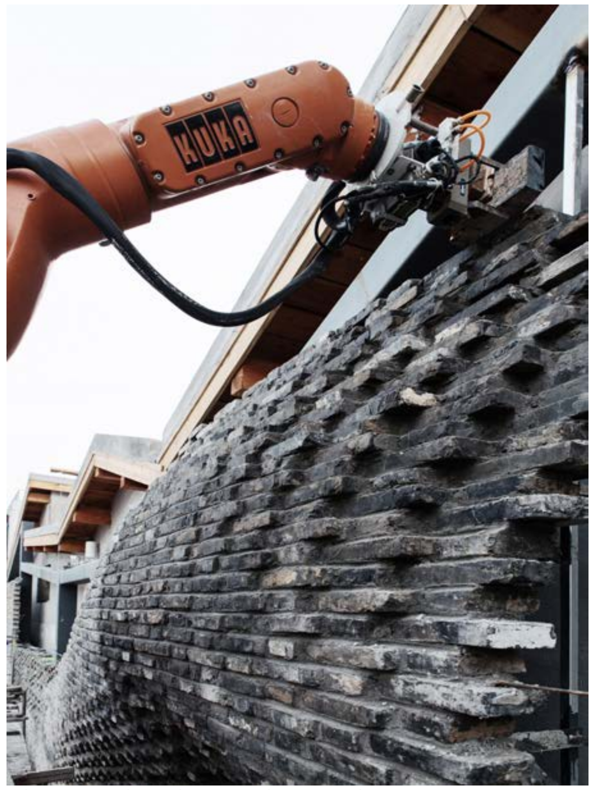


Fig1. Robotic Bricks-laying at ChiShe

As the oldest building material of mankind, **bricks** are widely used in all kinds of buildings. With the help of design tools and construction machines, the horizontal and vertical types of brick bond In traditional brick masonry, such as stretcher bond, header bond, English bond and Flemish bond, have been expanded into new construction form such as **break-joint**, **dislocation** and **gradient rotation**. With the improvement of structural performance simulation technology, the design of mortar and reinforcement can make parametric masonry logic more accurate, surpassing the traditional parallel and vertical logic systems.

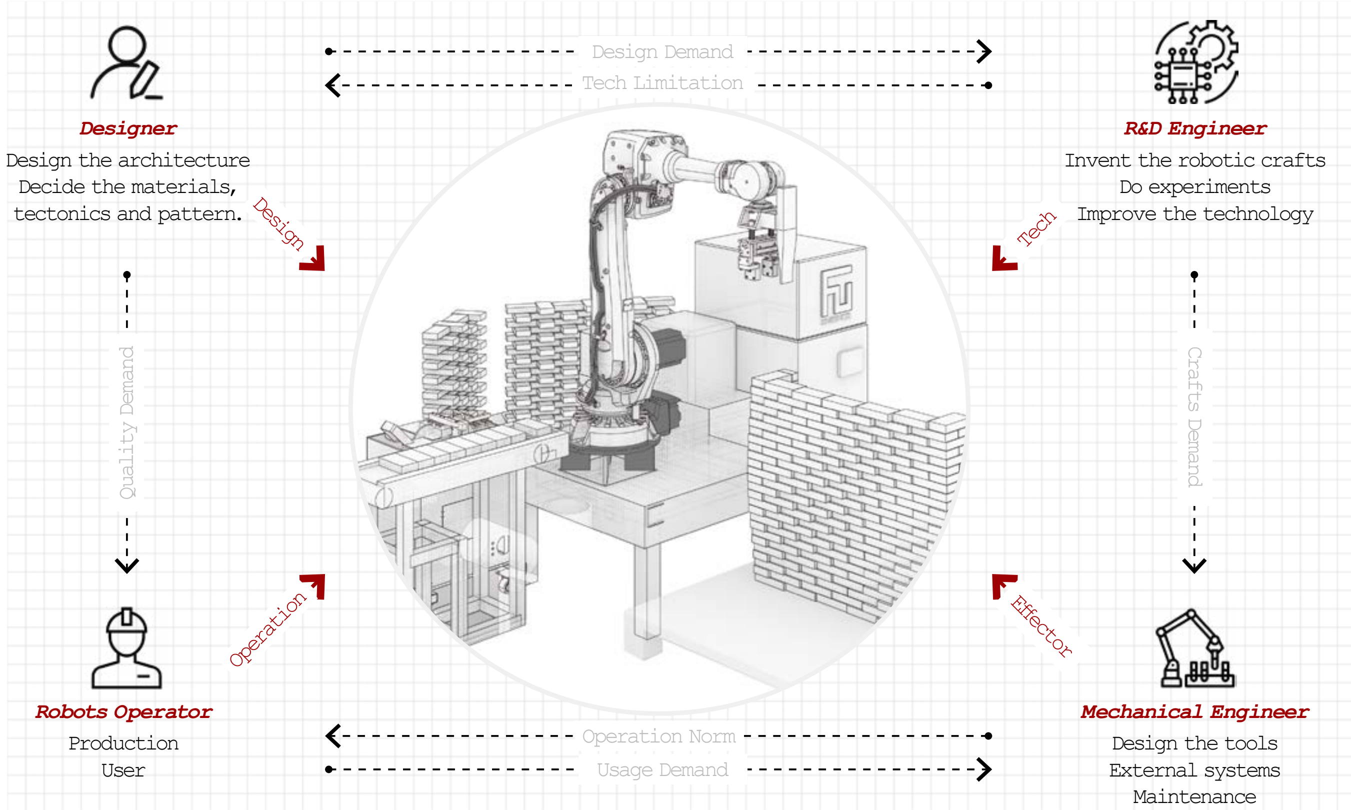
Combined with the digital design, the **six-axis robotic arm masonry technology** can greatly improve the traditional bricklaying technology. The masonry process is **a repetitive cycle** -- taking bricks, cutting bricks (if required), mortaring, putting bricks. Compared to manual, the robotic arm can carry out high-speed continuous work. And the accuracy of the robot creates the conditions for the realization of subtle changes in parametric design. The robot arm's ability to precisely construct complex forms thus expands the possibilities of masonry structural design.

The development of robotic arm masonry technology is the process of turning design into products, during which many works, such as the mechanical design of the robotic tool, the coordination of auxiliary equipment and robotic arms and the arrangement of production modes, all need to be taken into account.

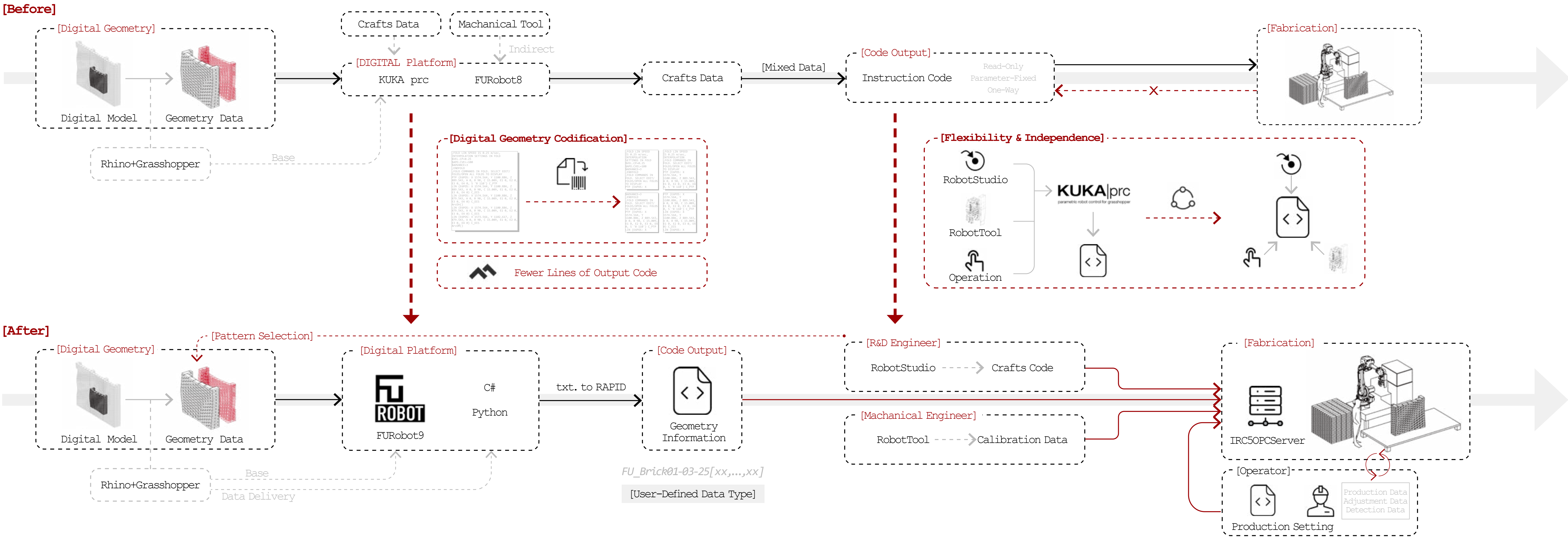
References:

[1]Philip F.YUAN, Archim Menges. Building Robotics: Technology, Craft and Methodology[M]. Architecture & Building Press. 2019.

R&D System of Robotic Craftsmanship

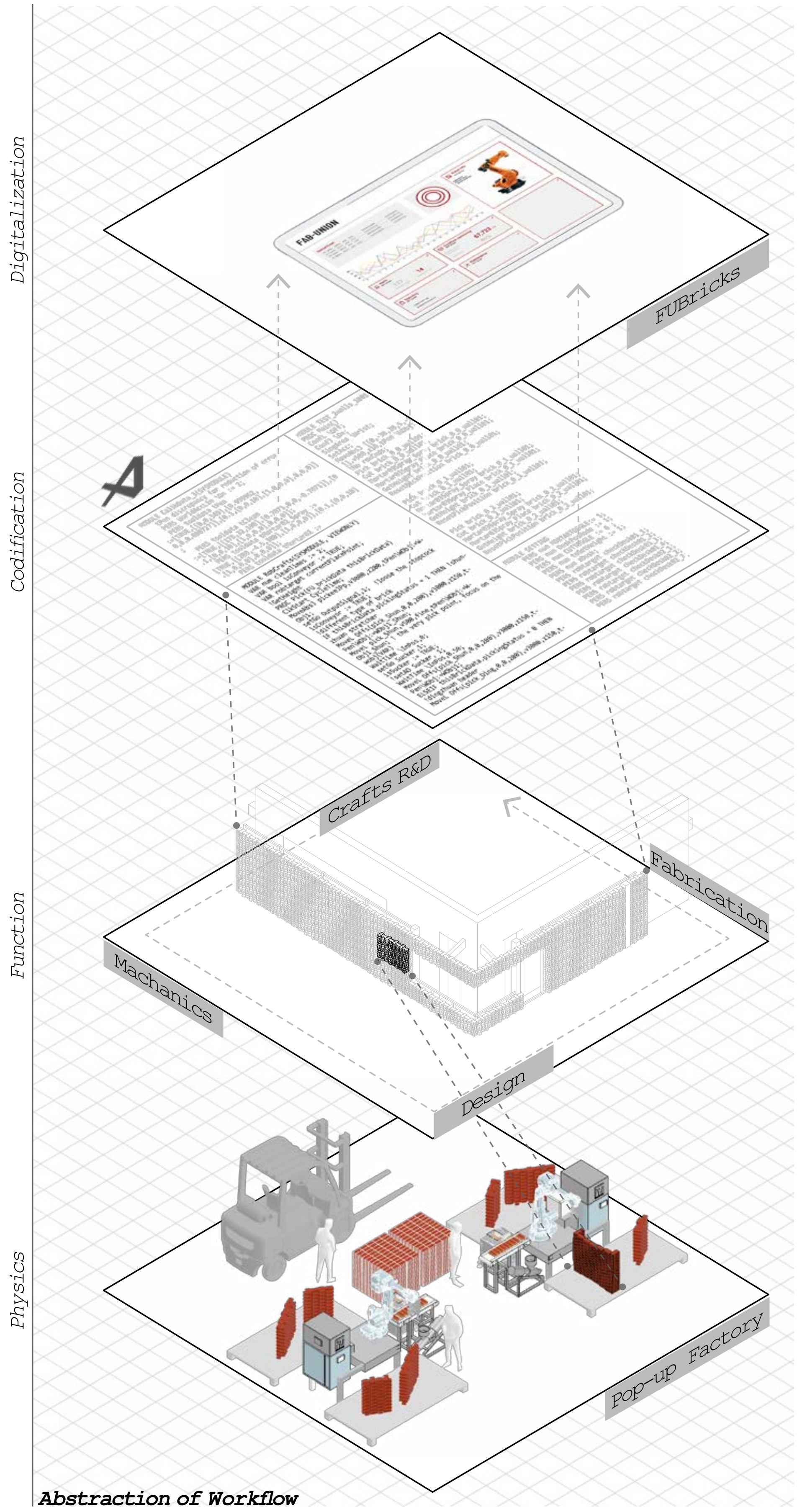


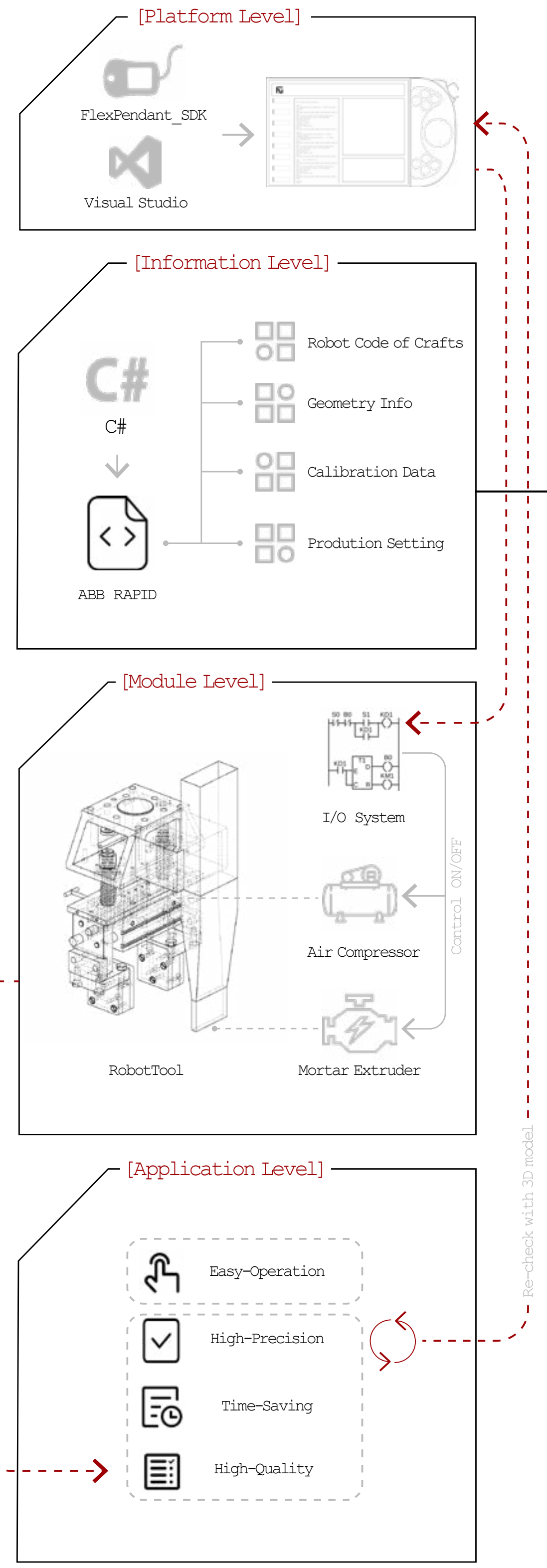
Optimization of Workflow



FUBRICKS | Optimization of Code Architecture

Based on **ABB RAPID**, the program of robotic bricks - laying is divided into four inter- related parts. After defining the name of **variable, subroutine and function**, the person who manages one of these parts is able to iterate his own program and no additional parts need to be modified. This architecture is the basis of subsequent design.





[Calibration Data]

```
MODULE CalibData_3(SYSMODULE)
   tPen discrepancy for reduction of error
   PERS WorldAccLim \On := 2;
   PERS tooldata tPen :=[TRUE,[[0,0,349],[0.999962,
0,0,0.008727]],[0.1,[0,0,10],[1,0,0,0],0,0,0]];
   PERS tooldata tClean
:=[TRUE,[[178,32,190],[0.7071,0,0,-
0.7071]],[0.1,[0,0,10],[1,0,0,0],0,0,0]];
   PERS tooldata tMortar02_Spray := [TRUE,[[200,-
4.5,380],[1,0,0,0]],[0.1,[0,0,10],[1,0,0,0],0,0,0]];
    PERS tooldata tMortar02 := [TRUE,[[245,-
3,355],[1,0,0,0]],[0.1,[0,0,10],[1,0,0,0],0,0,0]];
!    PERS tooldata t_shun_center:=[TR
UE,[[0,0,392],[1,0,0,0]],[1,[0,0,1],[1,0,0,0],0,0,0]];
```

[Robot Code of Crafts]

```
MODULE RobCrafts(SYSMODULE, VIEWONLY)
VAR num cleanTimes := 2;
VAR bool isConveyor := TRUE;
VAR robtarget currentPlacePoint;
!GetHeight
PROC Pick(FU_brickData thisBrickData)
ClkStart CycleTime;
MoveAbsJ pickeeJPp,v3000,z200,tPen\WObj:=WObj1;
setGo OutputSignal,1;  !loose the stopcock
isConveyor := TRUE;
!different type of brick
IF thisBrickData.pickingStatus = 1 THEN !shunzhuan
stretcher
MoveL Offs(pick_Shun,0,0,200),v3000,z150,tPen\
WObj:=WObj1_Shun;
MoveL pick_Shun,v500,fine,tPen\WObj:=WObj1_Shun; !
the very pick point, focus on the wobj(VAR)
WaitTime \InPos,0;
setGo Sucker,1;
isSucker := TRUE;
!setAO Sucker, 1;
WaitTime \InPos,0.50;
MoveL Offs(pick_Shun,0,0,200),v3000,z150,tPen\
WObj:=WObj1;
ELSEIF thisBrickData.pickingStatus = 0 THEN
!dingzhuan header
MoveL Offs(pick_Ding,0,0,200),v3000,z150,tPen\
WObj:=WObj1_Ding;
MoveL pick_Ding,v500,fine,tPen\WObj:=WObj1_Ding; !
the very pick point, focus on the wobj(VAR)
```

[Geometry Information]

```
MODULE TEST_2walls_1001
PROC Main()
ConfL \Off;
ConfJ \On;
SingArea \Wrist;
SetAcc;
MoveAbsJ [[0,-30,20,5,-10,180],[9E9,9E9,9E9,9E9,9E9
,9E9]],v500,z10,tPen \WObj:=wobj1;
!No rowCmds;
Pick brick_0_0_wall01;
Cut brick_0_0_wall01;
Mortar03Spray_Spray brick_0_0_wall01;
Mortar03Spray_Place brick_0_0_wall01;
GetHeight brick_0_0_wall01;
ResetPickPosition brick_0_0_wall01;

Pick brick_0_1_wall01;
Cut brick_0_1_wall01;
Mortar03Spray_Spray brick_0_1_wall01;
Mortar03Spray_Place brick_0_1_wall01;
GetHeight brick_0_1_wall01;
ResetPickPosition brick_0_1_wall01;

Pick brick_0_2_wall01;
Cut brick_0_2_wall01;
Mortar03Spray_Spray brick_0_2_wall01;
Mortar03Spray_Place brick_0_2_wall01;
GetHeight brick_0_2_wall01;
ResetPickPosition brick_0_2_wall01;
```

[Prodution Setting]

```
MODULE SETTING
    PERS num MORTARTOGGLE:= 1;
    PERS num DeskPosMode := 1;
    PERS num CUTTOGGLE := 0 ;
    PERS num toGetHeight := 1;
    PERS num pickingStatus := 1;
    PERS num zDesk;
    PERS robtarget checkDesk01_1;
    PERS robtarget checkDesk01_2;
    PERS robtarget checkDesk01_3;
    PERS robtarget checkDesk01_4;
    PERS robtarget checkDesk02_1;
    PERS robtarget checkDesk02_2;
    PERS robtarget checkDesk02_3;
```

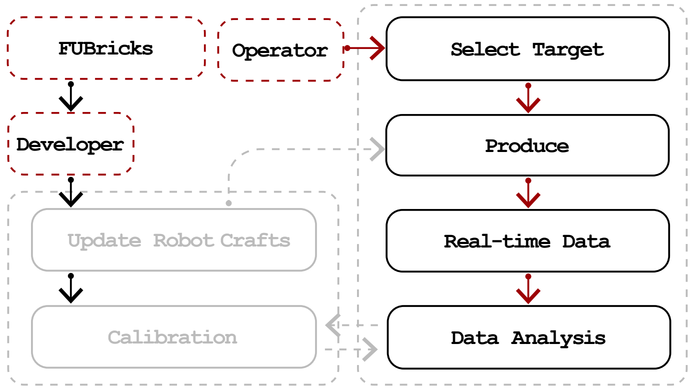
Define PERS/CONST

Choose Module ON/OFF

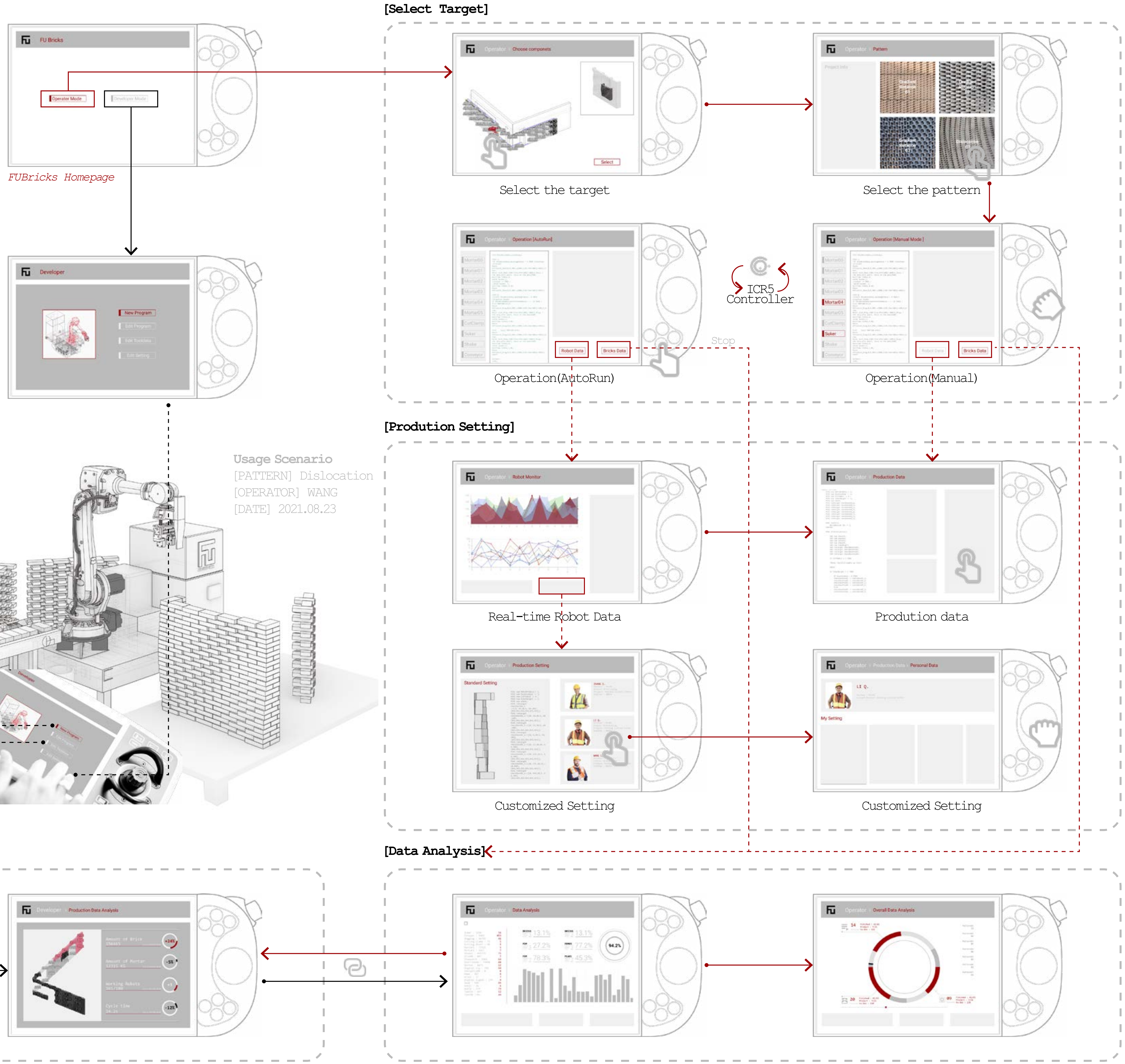
Check Value

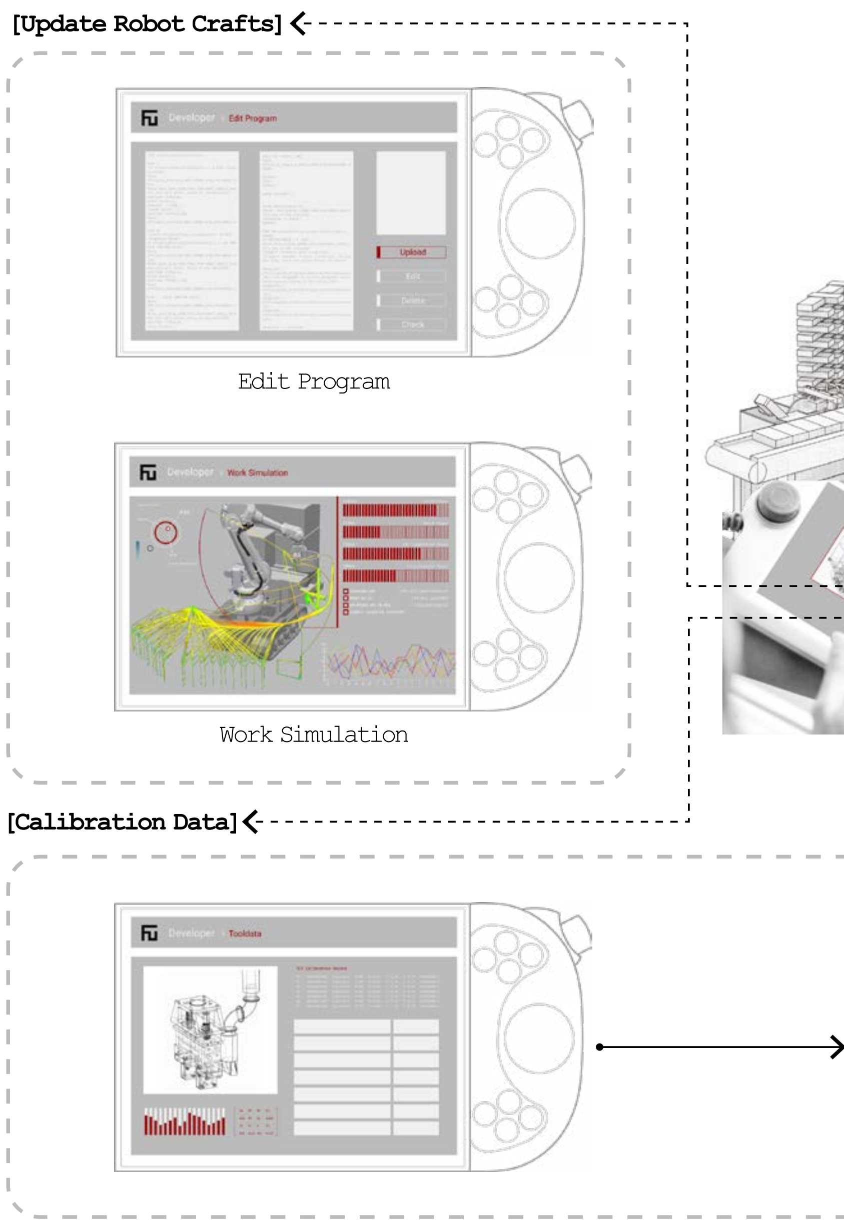
Define PERS/CONST

WIREFRAME | Manual of FUBricks



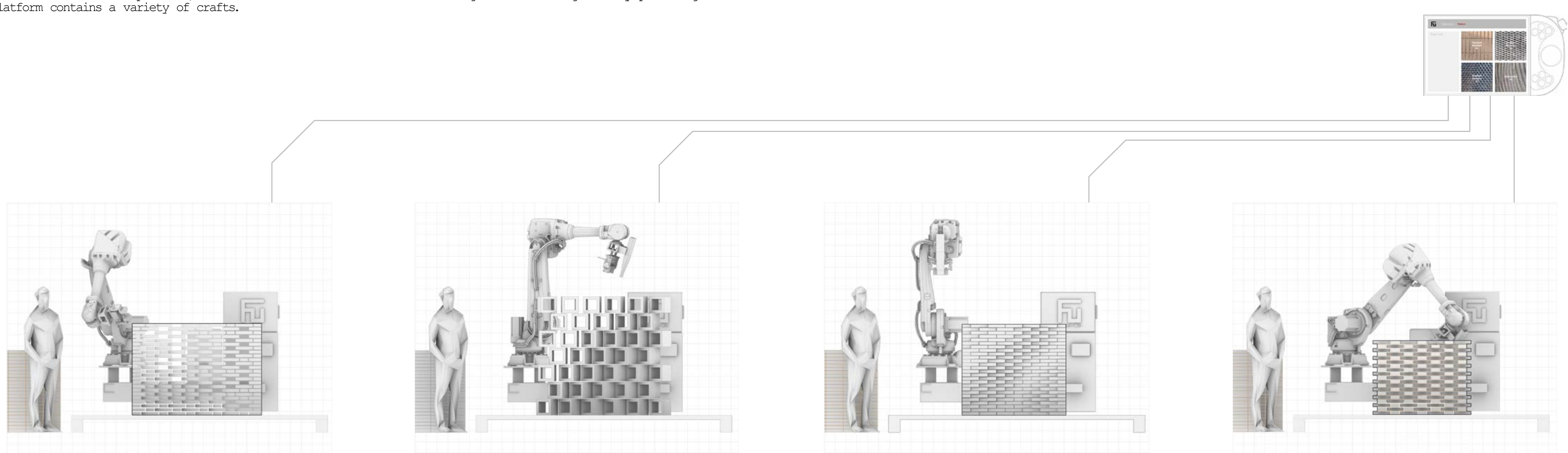
FUBricks has two basic module - ***Operator Mode*** and ***Developer Mode***. Operators are able to use this app to finish the whole production procedure including selecting targets, choose patterns, operating the robots and check the real-time data. The production data, such as **masonry accuracy** and **cycle time**, will be collected as the reference for R&D engineer to improve the robot crafts.

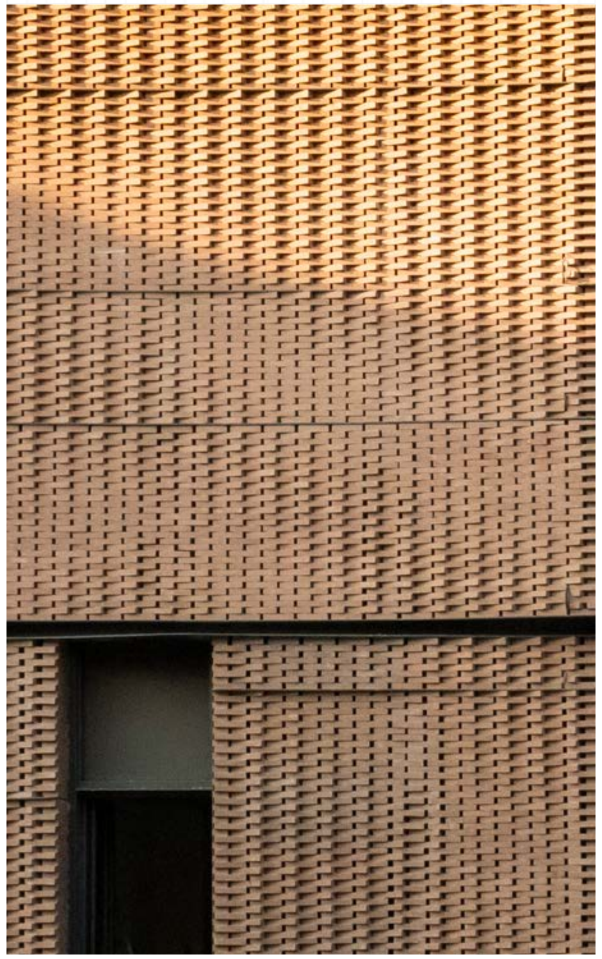




PATTERN FREE | A Platform Contains A Variety of Bricks-laying Crafts

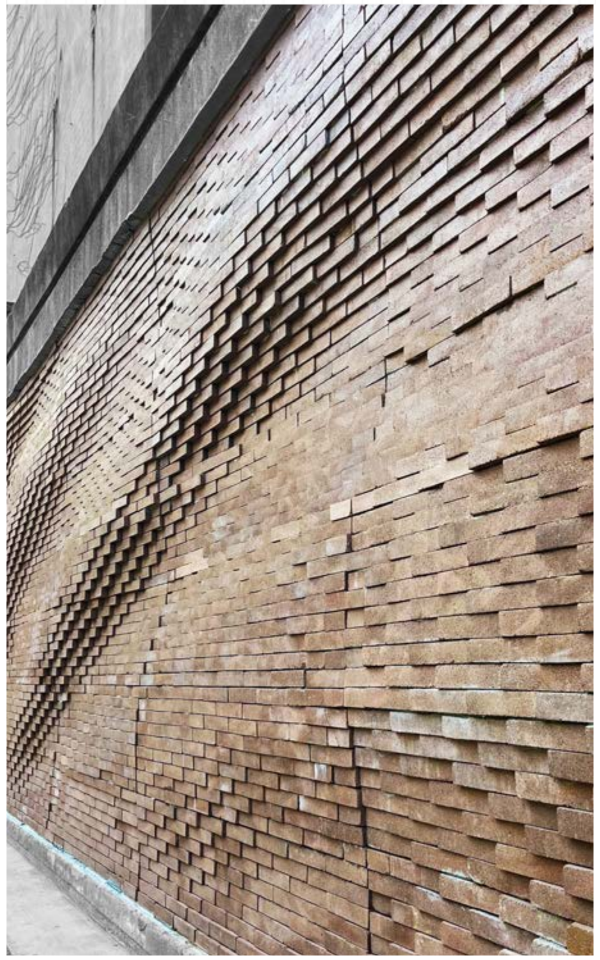
Similar to E-commerce platform, FUBricks can make the 'deal' between designer and R&D engineer by providing a platform contains a variety of crafts.





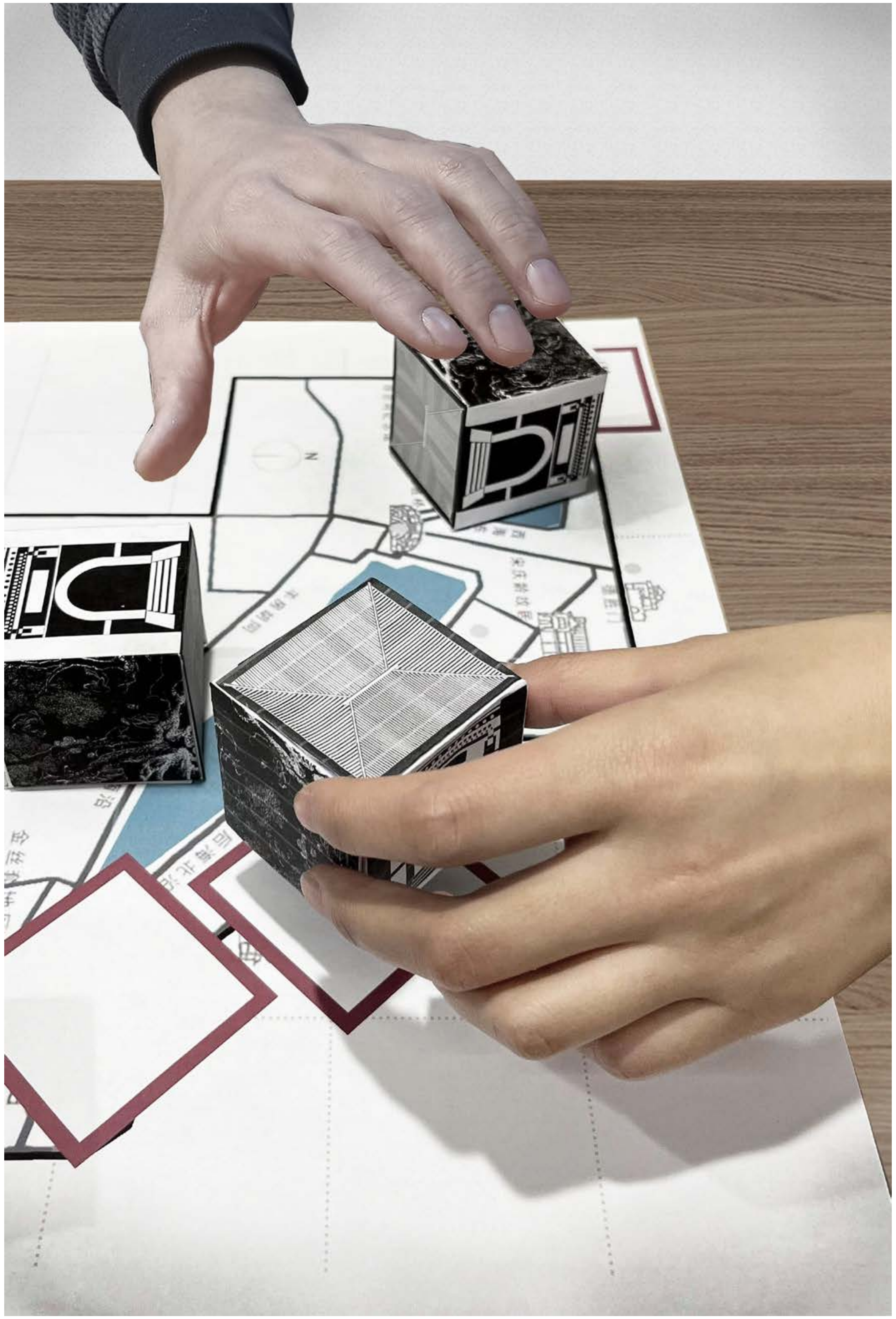
Sample wall 2020 Fab-Union

J-Office 2016 Fab-Union



No.81 Gongqing Rd. 2021 Fab-Union

Visitors' Center at Kunming Expo Garden 2021



03

AR MAGIC CUBE

An Augmented Reality Design on Water System of Beijing

{

Workshop
Team work; Individual Redraw
Partner: Xinyi ZHOU
Instructor: Xu ZHANG
Fall 2021

[RESPONSIBLE PART] 50%Context research/100%Cube design/ 80%AR technology/100%Physical model

As one of the oldest city in China, Beijing has the most complicated city water system, which has witnessed the development process of this historic city. Many culture meme, such as Hutong(name of traditional streets) and Obon(a traditional a traditional Buddhist and Taoist festival), are related to the water system. However, many people do not know these knowledge and cultural significance. This project aims to popularize the knowledge and history of water system of Beijing.

Media technology can build multiple virtual worlds in parallel for different groups of interest, encouraging creation and recreation without the constraints of time, space, and social class. This project abstracted the characteristics of **Shichaha**, a manmade lake lies in the center of Beijing, and combined augmented reality with paper box in order to allow people experience the ancient activities related to water and arouse people's awareness of protecting the water environment.

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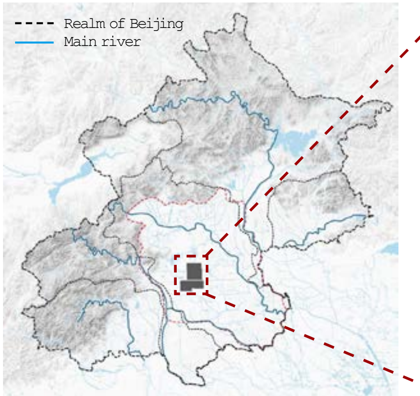
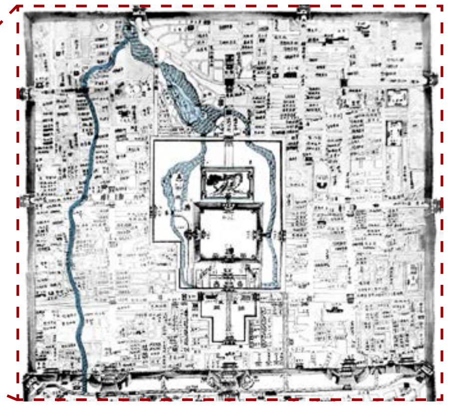
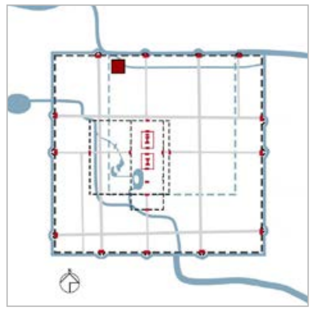
BIOPOLITICS|Research on Context

Beijing | Histroy | Watersystem





Lying in the north of the North China Plain, **Beijing** has abundant water resources brought by five river systems. Since 1153(Jin Dynasty), Beijing has always served as the political and cultural center of the northern regime and even the whole country. Thus culture about the water system is also thriving.
The water system in the city of Beijing mainly **provided water and landscape for the imperial city**. At the same time, the flourishing of Buddhism led to the development of the water landscape into royal palaces, temples and suburban landscapes.



Jin Dynasty [AD 1153]

The governors of Jin Dynasty first made Beijing the political center, and the construction of palace gardens and the use of water became their first considerations.

Yuan Dynasty [AD 1215]

The city was rebuilt around the Bailiantan lake so that it is convenient for grains and materials from all over the country to the capital through water transportation.

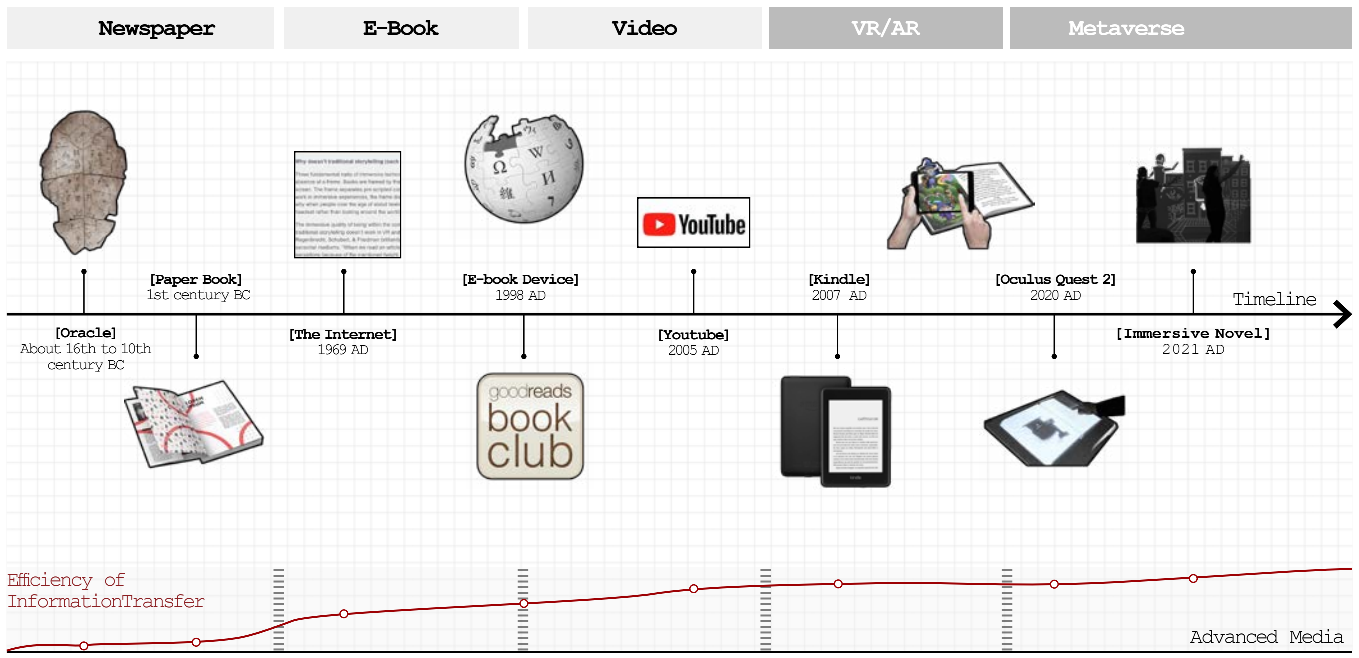
Ming Dynasty [AD 1420]

In order to defend against enemies in the north, the Ming Dynasty moved the city walls south and rebuilt the moat on the original city.

Qing Dynasty [AD 1658]

During the Qing Dynasty, the city of Beijing followed the pattern of the Ming Dynasty and began to build gardens when the river was being treated.

Evolution of Reading Media



[Reading by AR]

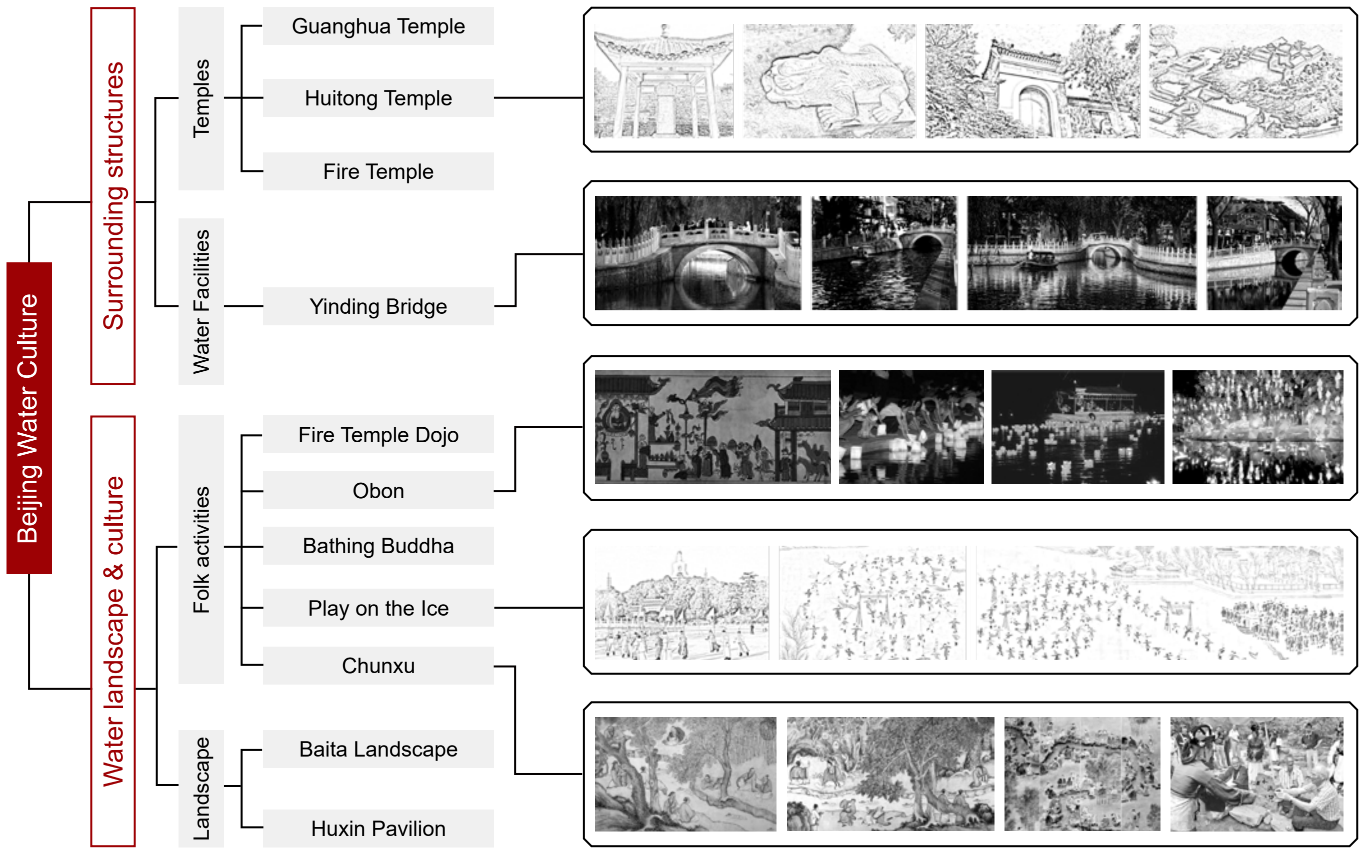
Physical Target → **Interaction** →

[Content in AR]

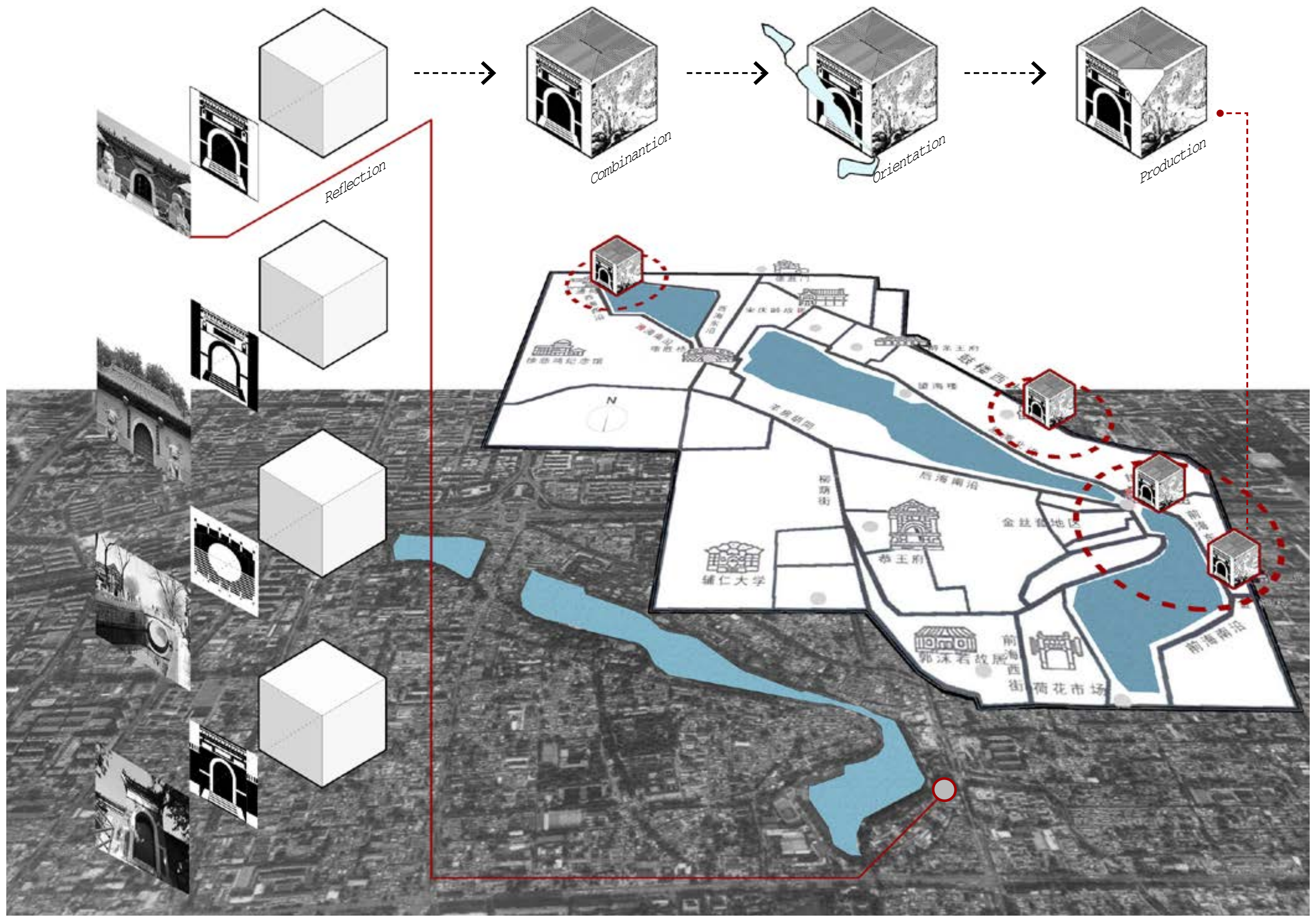
[Text] [Image] [Video] [3DModel] [3DAnimation]

In many cases, augmented reality can effectively replace human imagination and place objects or devices in front of the learner's eyes at the right moment in the training.

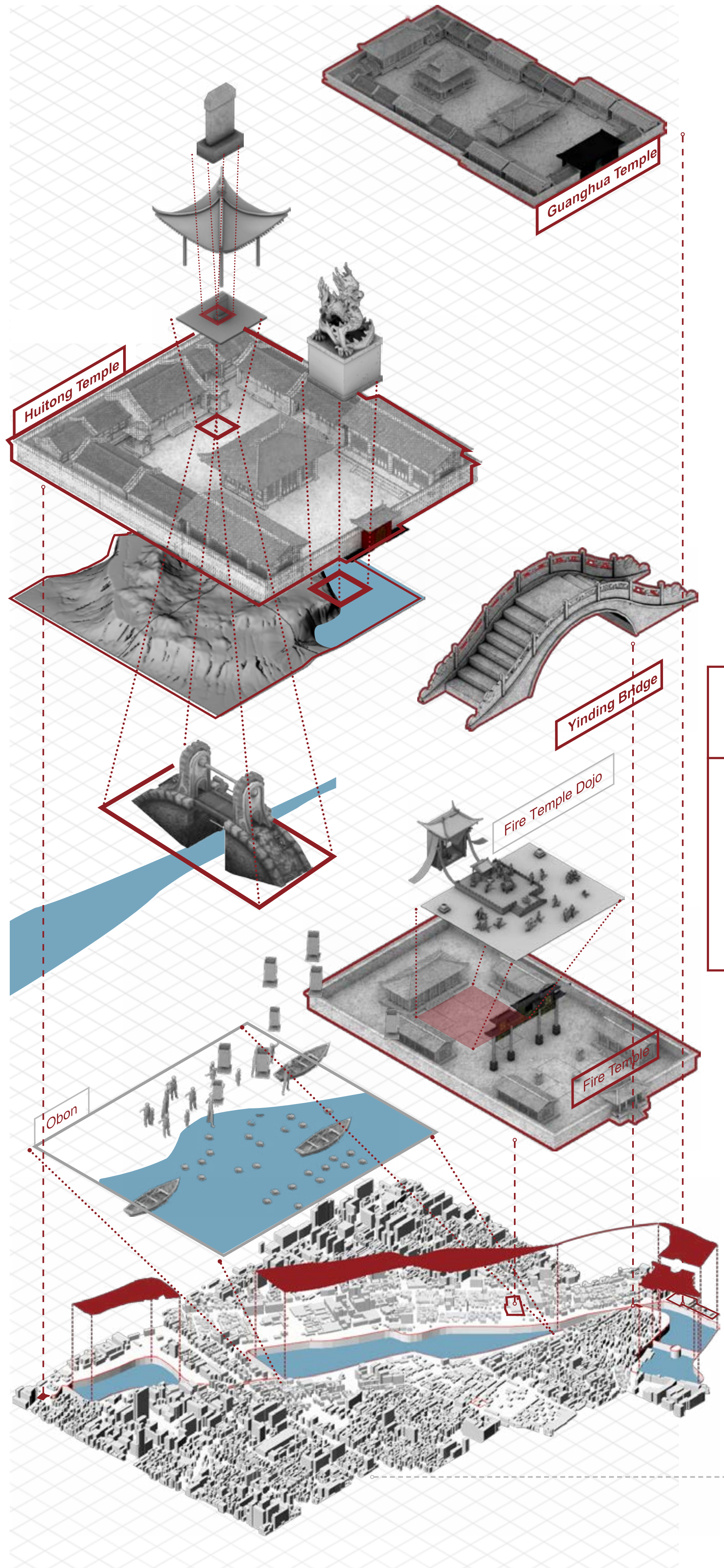
Content Structure

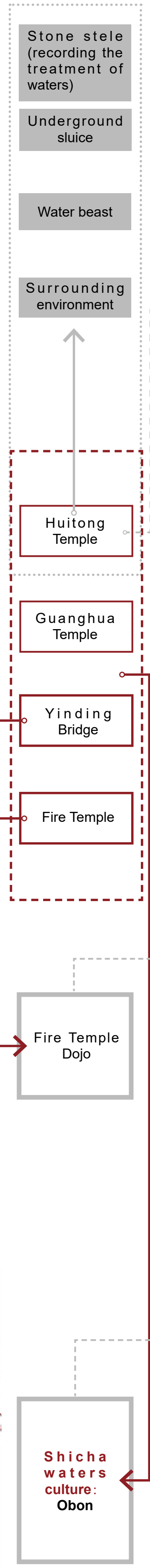


Making Process of Object Tracking and Cude Mode



AR TO HISTORY|Intersection Method





Huitong Temple

There is a large water gate under Huitong Temple with movable wooden gates embedded in the stone troughs on both sides. The water level and flow rate of the entire Beijing waters are controlled. Therefore, it is called the throat of the capital waters.

Underground Water Gate

Fire Temple Dojo

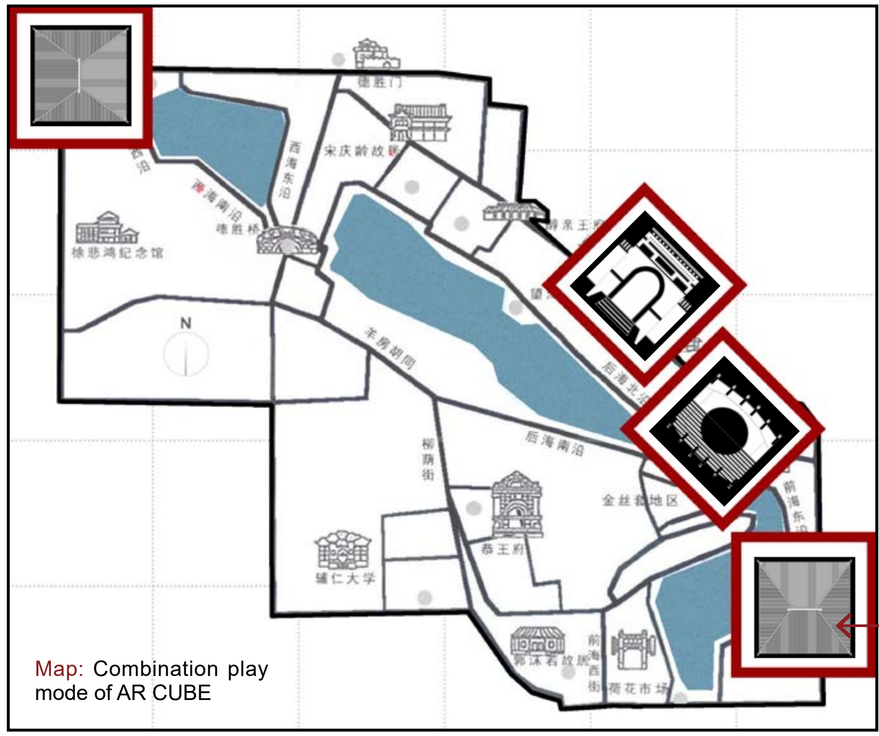
On June 23rd, all fire temples in the capital will hold grand avenues. Di'anmen Fire Temple is the largest of the fire temples in Beijing. The Taoist priests wore robes and vestments and held law enforcement instruments or musical instruments when doing the dojo.

Obon

The Buddhist community held a grand Obon Festival on the Lunar New Year's Day on the 15th day of the lunar calendar. There were mass activities such as the lighting of river lanterns and burning of boats.

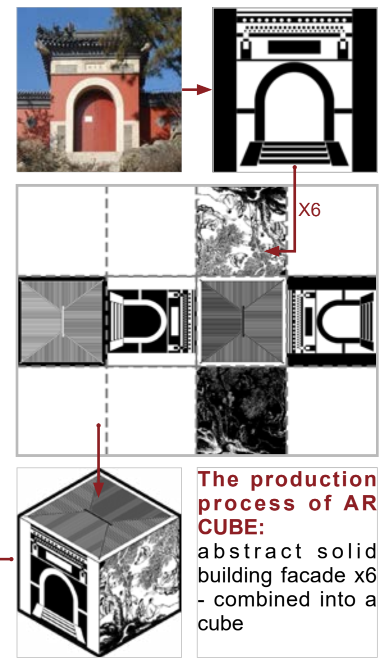
Shicha Waters Culture

The Shicha sea area was the terminal of the Beijing-Hangzhou Grand Canal in the Yuan Dynasty. It was the basis for the planning of the capital city of the Yuan Dynasty.

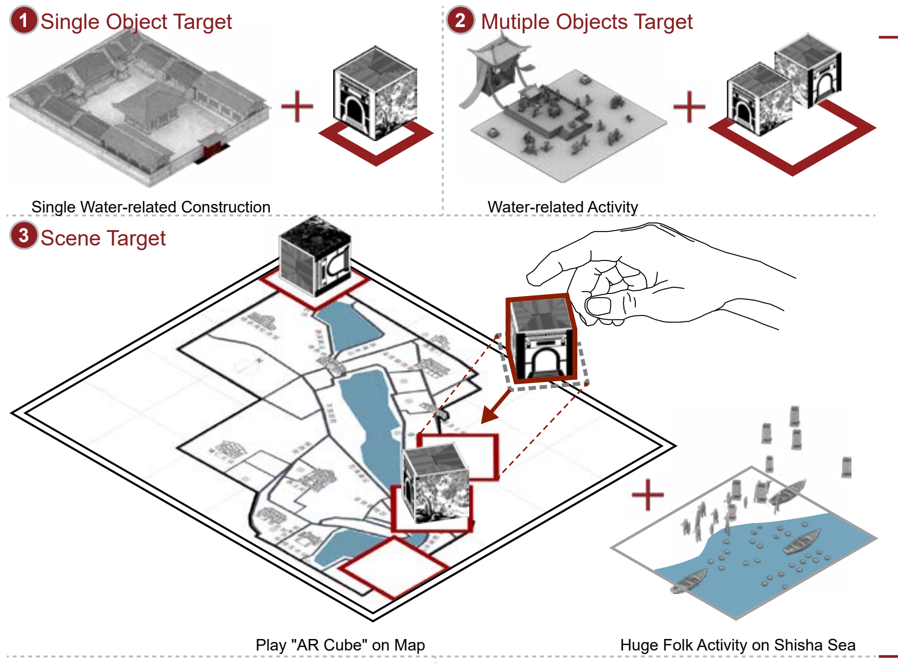


Map: Combination play mode of AR CUBE

STEP1: MAKING



The production process of AR CUBE: abstract solid building facade x6 - combined into a cube

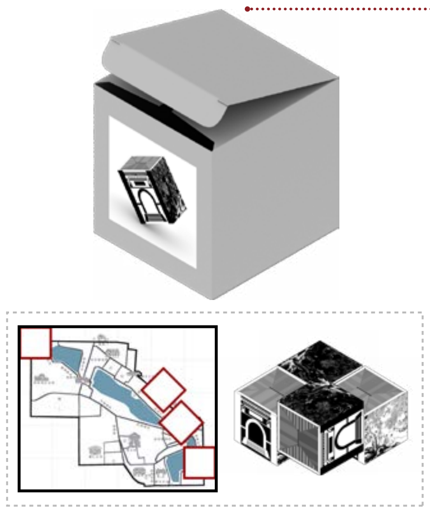


STEP2: LINKING

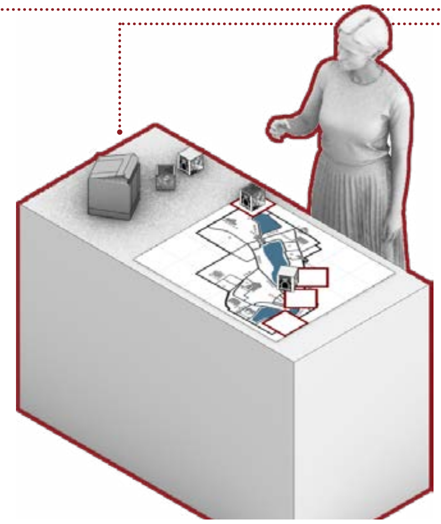
vuforia + unity

Use the Vuforia platform in Unity to link virtual assets and physical objects and divide them into three levels of content for presentation: 1. Single object target 2. Multiple objects target 3. Scene target. To produce a better product experience for consumers and further understand the rich Shichahai water cultural content.

Product

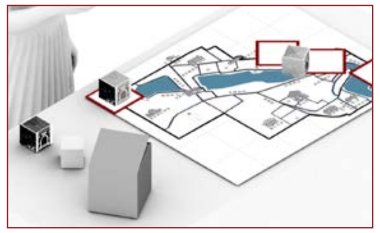


Dissemination



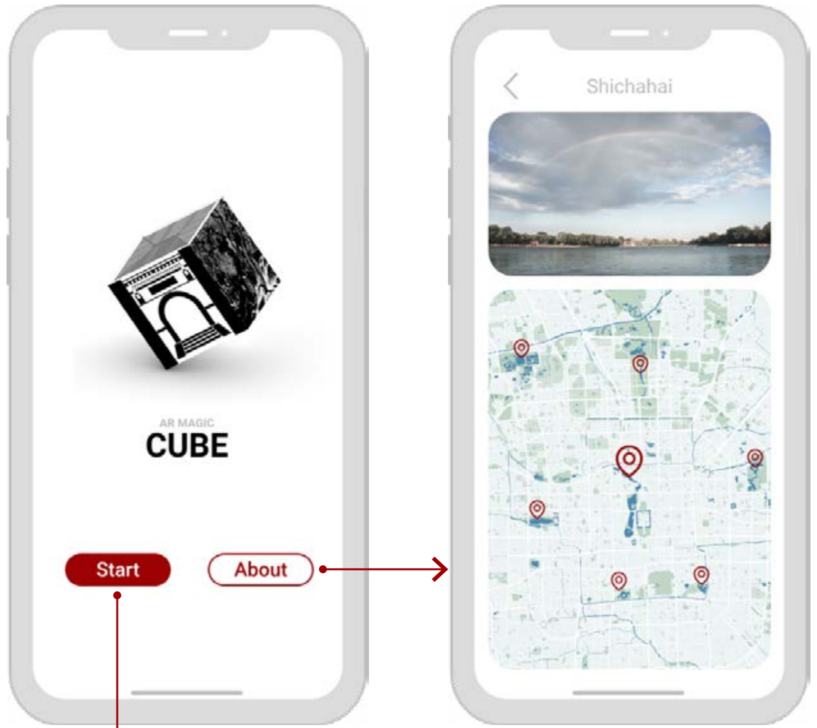
STEP3: DISSEMINATION

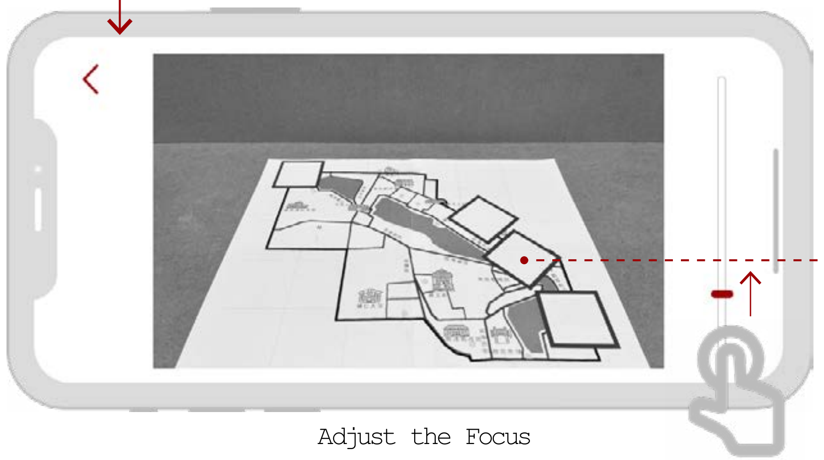
Package the designed AR Cube and Map into "AR CUBE" products for sale and dissemination. To publicize and promote the disappearing water culture of Beijing and let more people learn about and protect Beijing water culture through this exciting product.



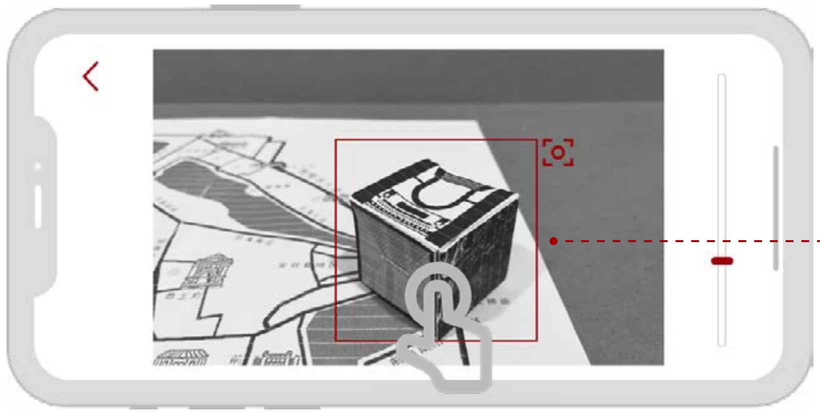
AR APP | UI Design & Cube Play Mode

This app has two main functions: **'Start'** and **'About'**. 'Start' is a camera mode UI, through which users could scan the cubes and the map. Then the 3D model of the sites including Huoshen Temple, Guanghua Temple, Yindian Bridge and Huitong Temple will be displayed. 'About' allows users to get the details of the sites directly.
The combination of the cubes and the map will show different **folk activities** related to Shichahai.

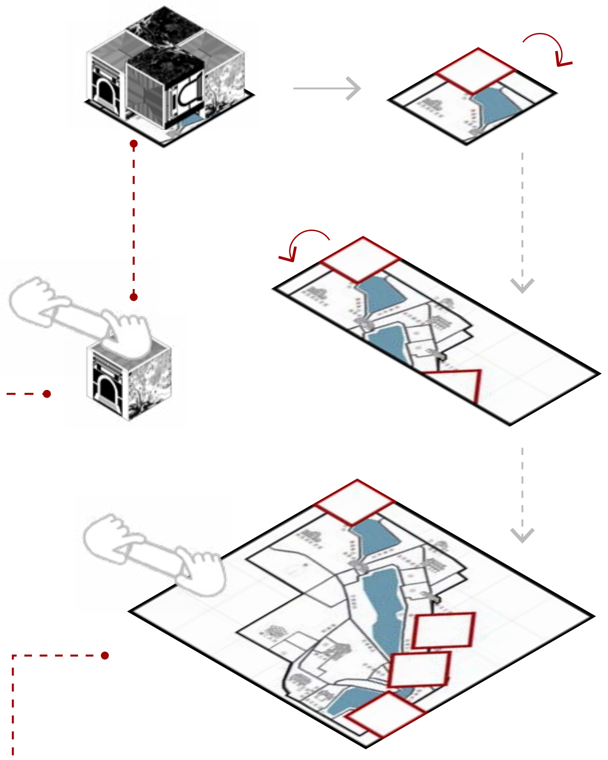




Adjust the Focus

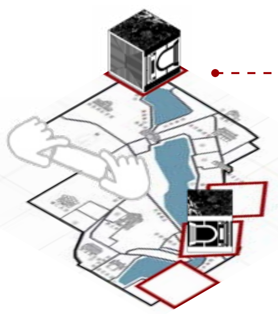


Manual Focus



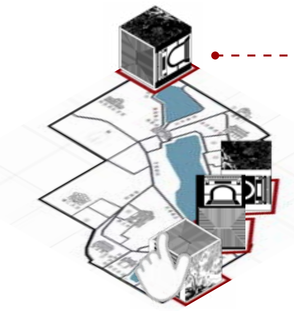
1 Cube + Map

By scaning individual cube on the map, users can get detailed knowledge of the architecture and its components related to shichahai and water culture.



2 Cubes + Map

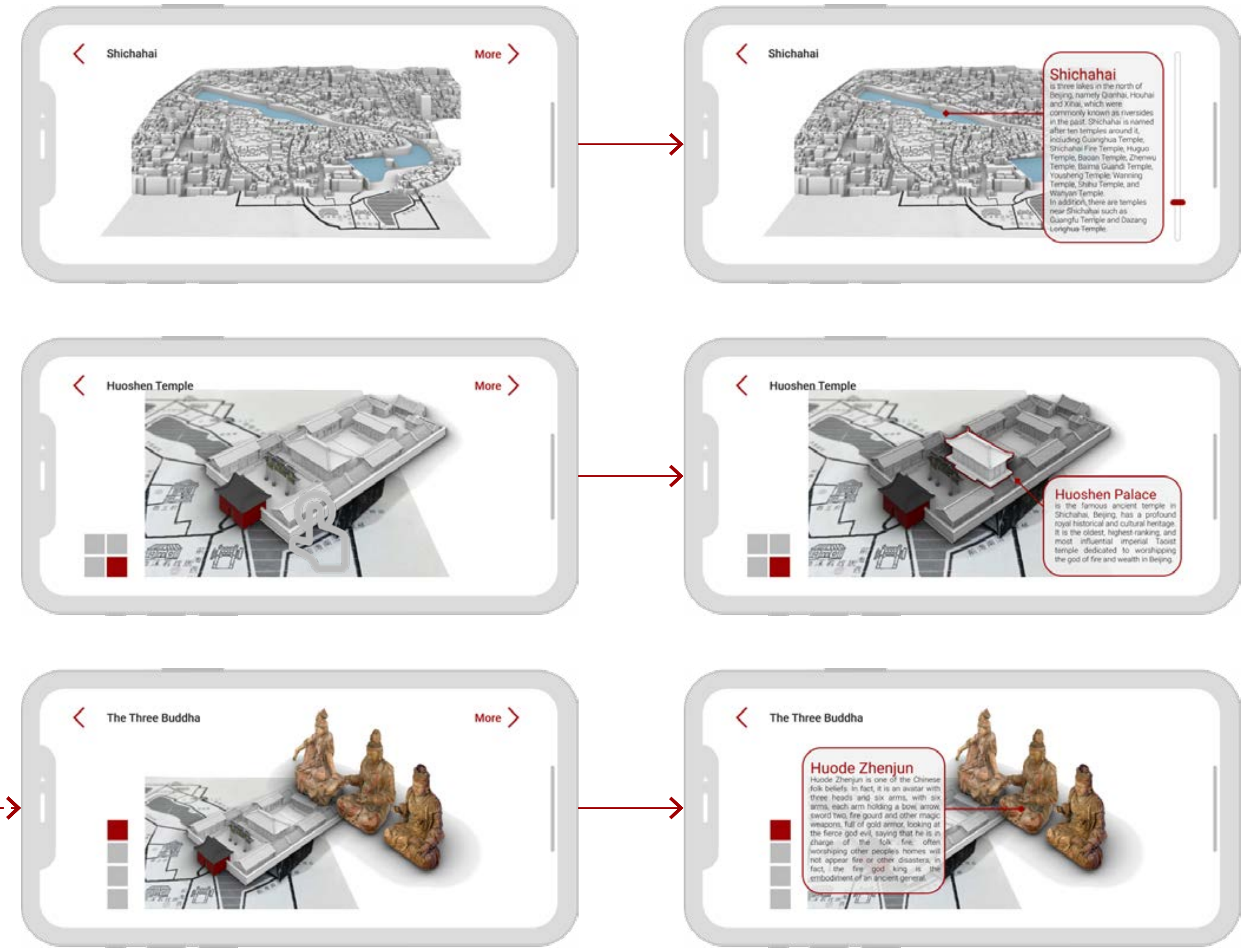
The combination of two cubes and the map will show the users the relevant cultural activities about this two buildings as well as the landscape around Shichahai.



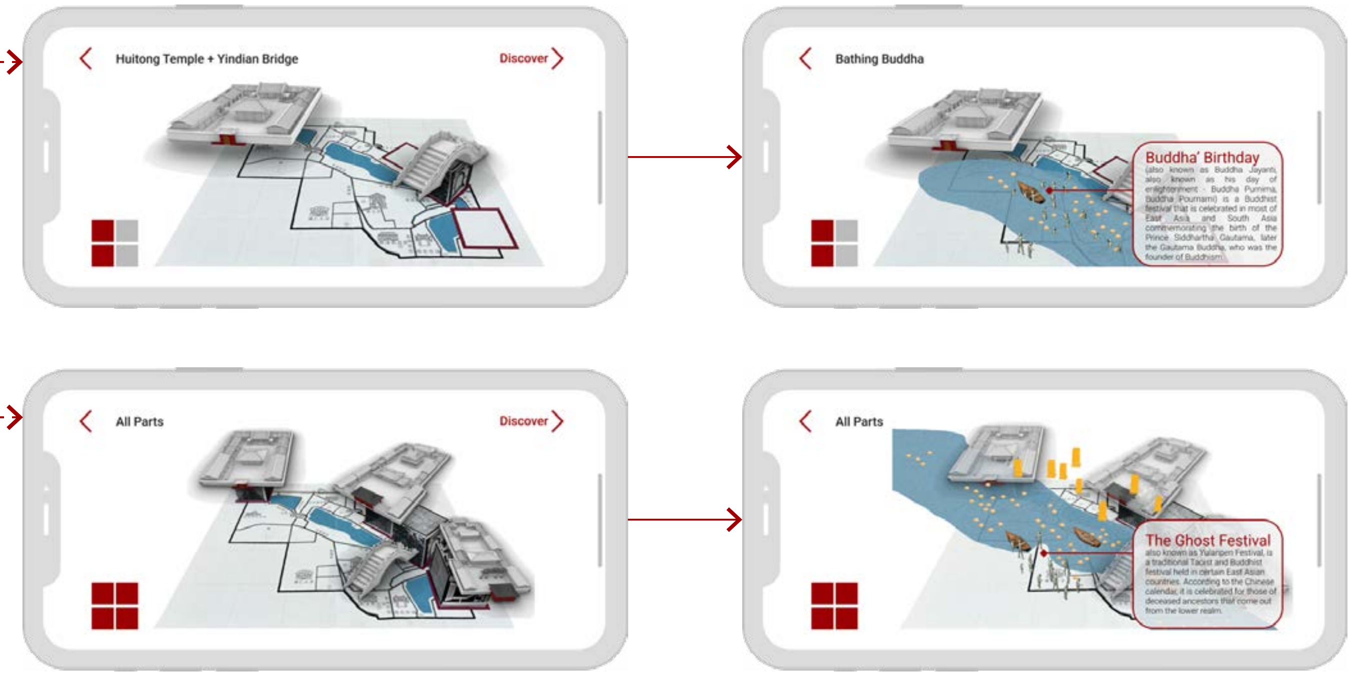
4 Cubes + Map

If all of the four cubes and the map are scanned, the Obon Festival, the most celebrated festival during the history of Shichahai, will be displayed.

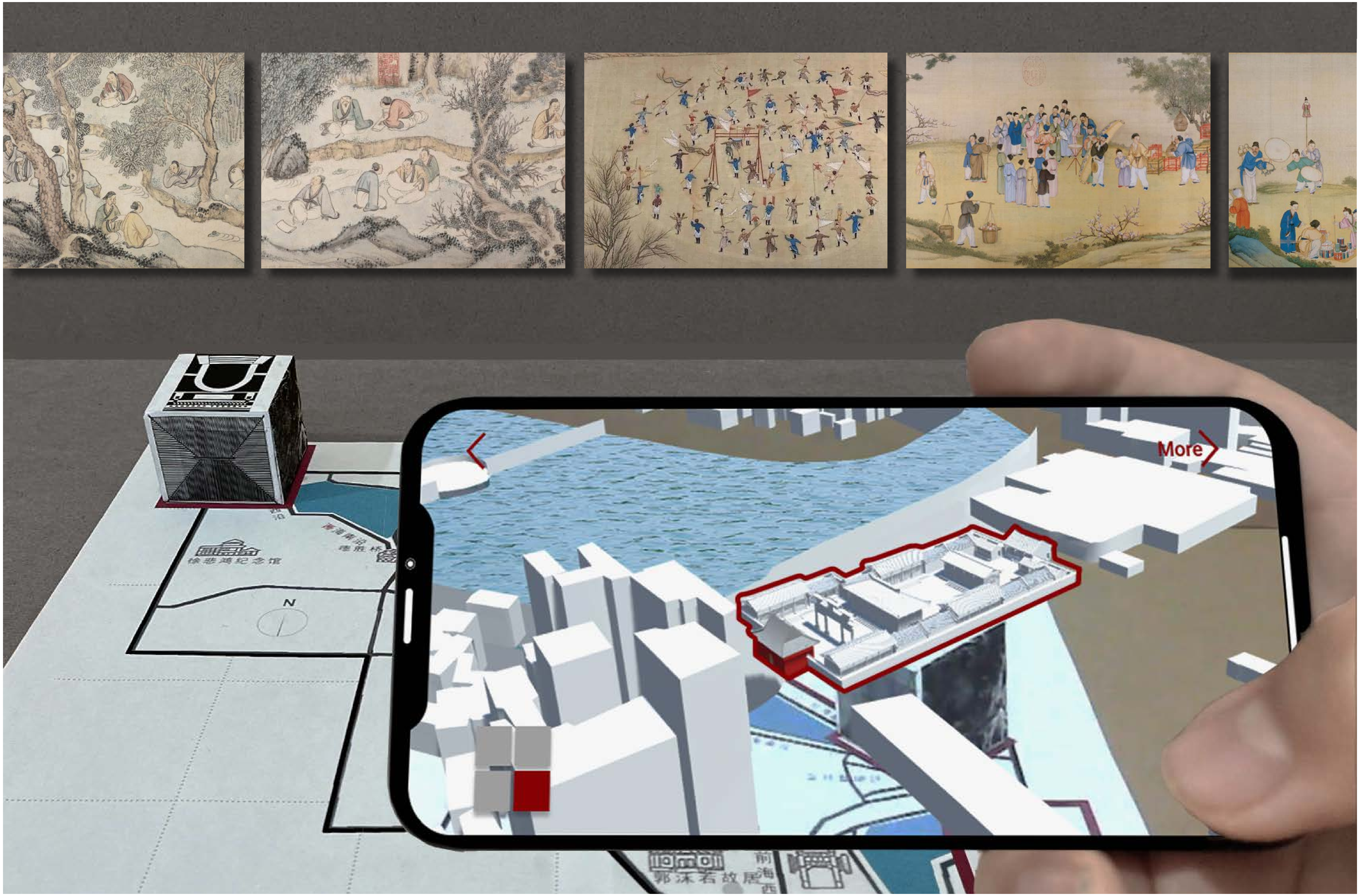
[Sanning Individual AR Cube]



[Sanning Multiple AR Cubes]



PROTOTYPE | **Usage Scenario**



04

MIX

3D Printing Chair With Two Printing Paths

{

Tongji CAUP Academic Studio
Individual Work
Instructor: Philip F.YUAN/Lim ZHANG
Durition: 6 Weeks
Spring 2019

Mix is a high performance chair which attempts to make full use of two robotics addictive manufacture methods -- **Fused Deposition Modeling(FDM)** and **spatial 3D printing** (Another kind of fused modeling method that can achieve partly self-supporting). Both of them use PLA objects, a widely used degradable plastic, as material and the same printing effector whose operating temperature reaches 500 degrees Celsius. By designing a mix printing path , a specific fabrication strategy has been added into this process.

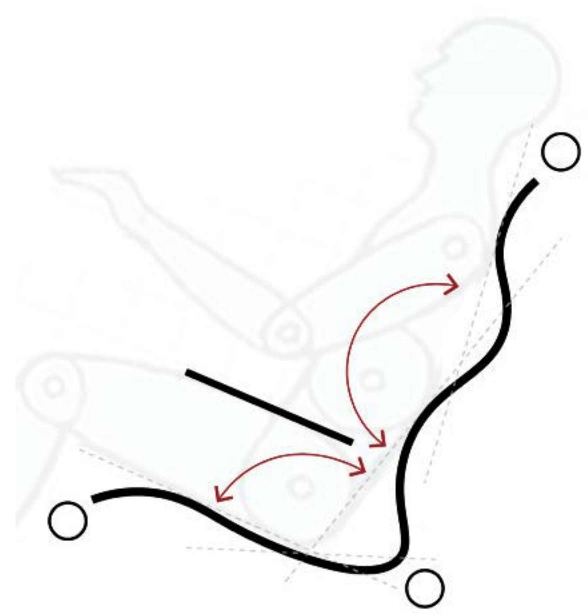
Starting with the research on the structure of elytra , an organ of insect to fly, this project tries to explore the structural potential of 3D printing and the materiality of PLA. The challenge of making this chair is that these two printing methods share robot and material while their fabrication demands varies widely. Therefore, it is the core of this project how to a design printable, ergonomic and energy saving printing path.

}

FORM STRATEGY | Biomimetic Structure Design & Simulation

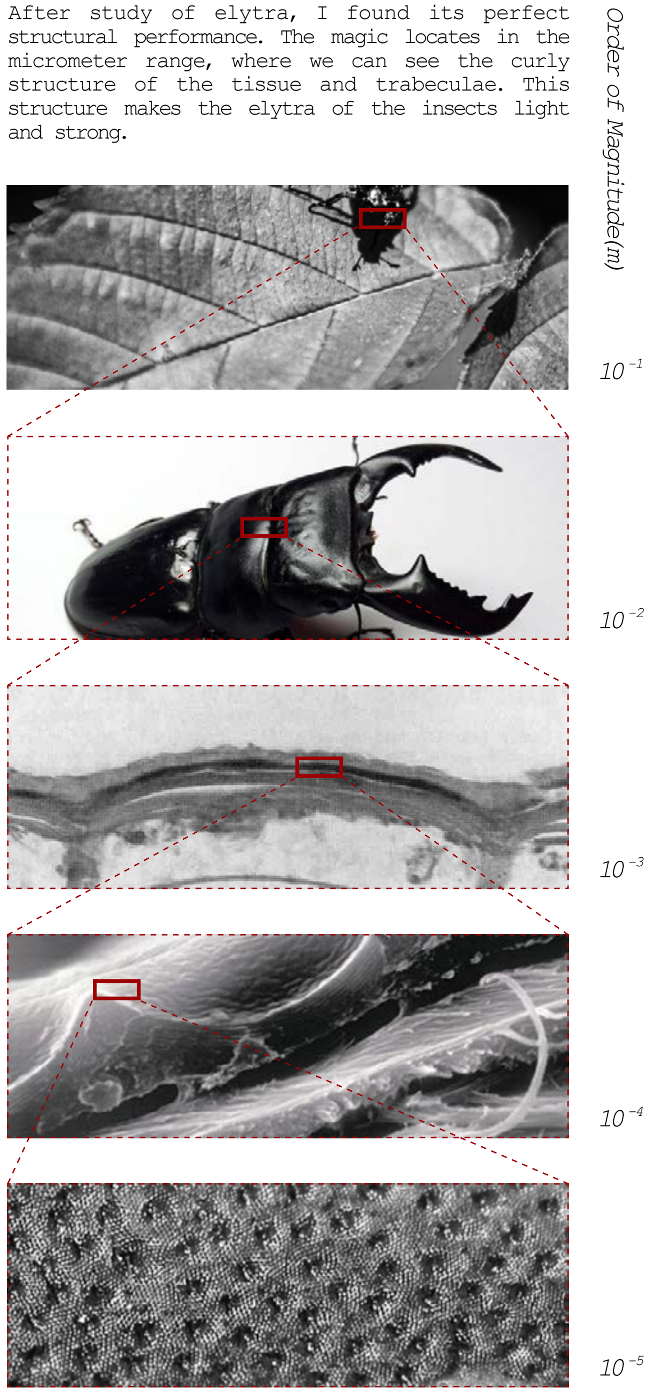
3D printing technology is suitable for making chairs due to its **flexibility** and **material property** – the surface of the chair can be maximally conformed to the human body, thus it bring good experience to users. However, traditional 3D printing technology such as FDM mostly relies on the superimposition of thermoplastic PLA/ABS material along direction of gravity, which limits the form of fabrication target. Although the spatial 3D printing technology can achieve partly self-supporting, there exists many limitations. This project tries to **avoid this defect** and expand **the potential of form finding**.

Starting with the research on Ergonomics, this project is going to exploit the advantages of 3D printing and offer users great experience through the curve fitting the back.



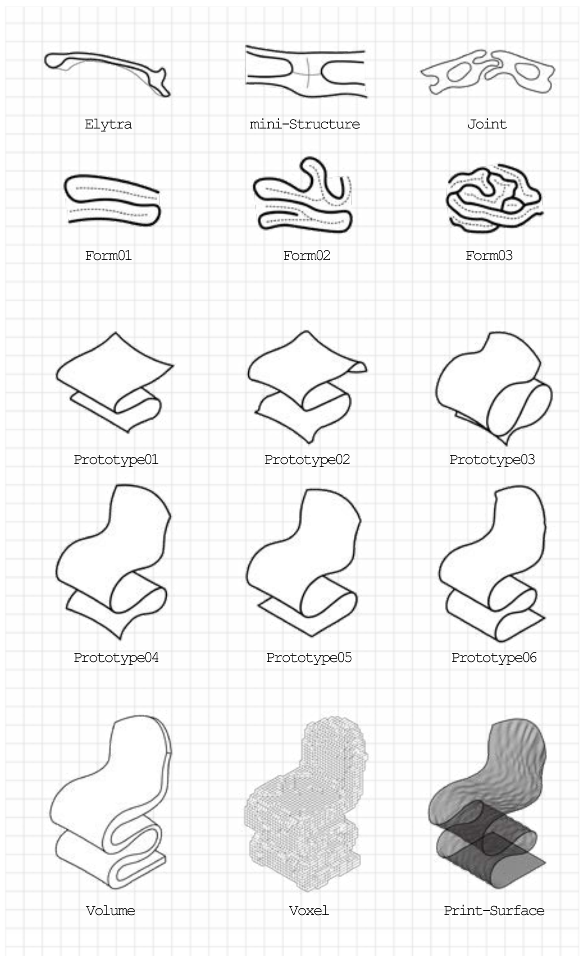
Structure Inspiration from Elytra

After study of elytra, I found its perfect structural performance. The magic locates in the micrometer range, where we can see the curly structure of the tissue and trabeculae. This structure makes the elytra of the insects light and strong.



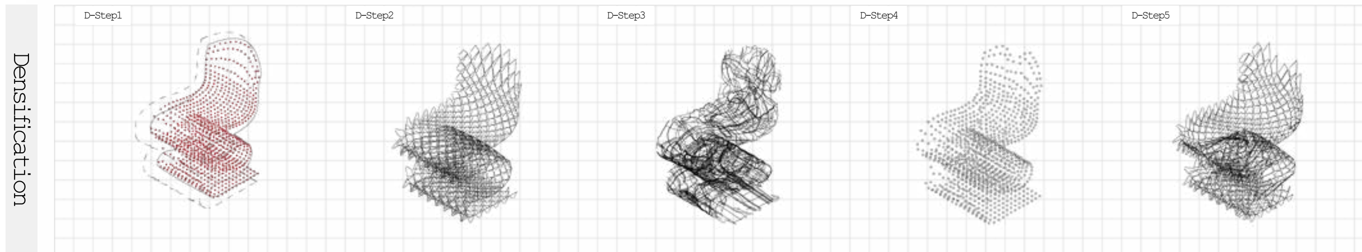
Form Finding Process

After deliberating on three kinds of micro structure of elytra including curly crust, trabeculae and joints, I found that the curly pattern can be applied in the supporting of the chair. Two parts of the elytrum – surface and trabeculae beneath relatively serve as covering and supporting. Besides, this difference inspires the subsequent fabrication strategy.

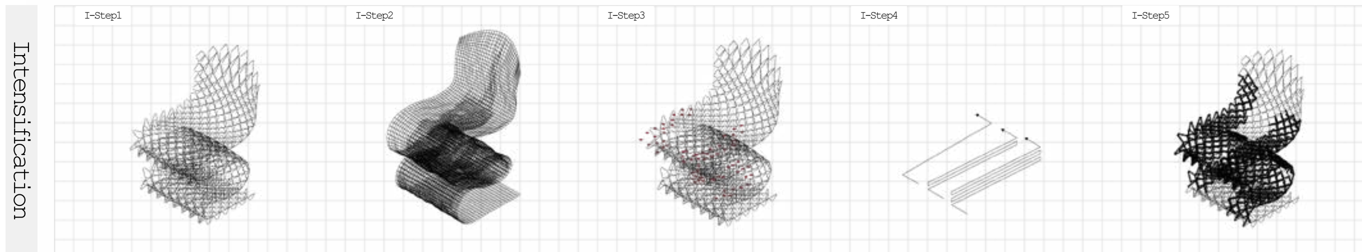


Load Simulation and Enforcement of Printing Path

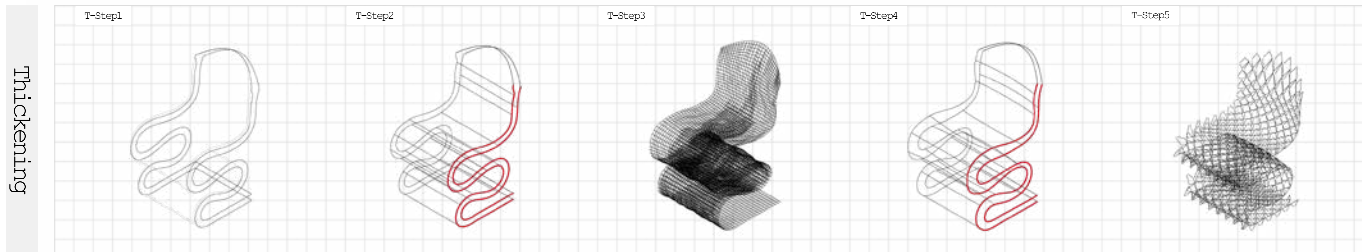
[Deformation Simulation with External Force | F=1200N]



[Structural Reinforcement Method1: Densification]

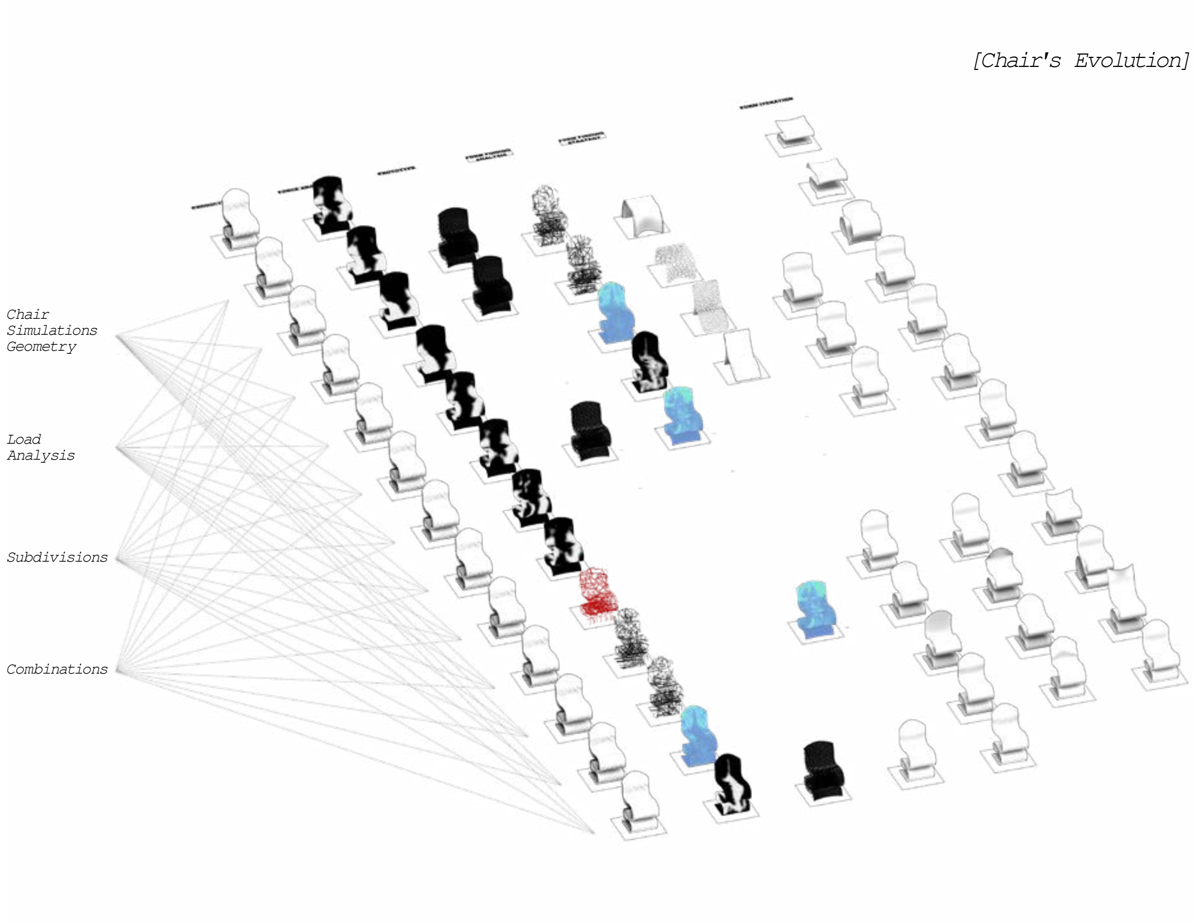


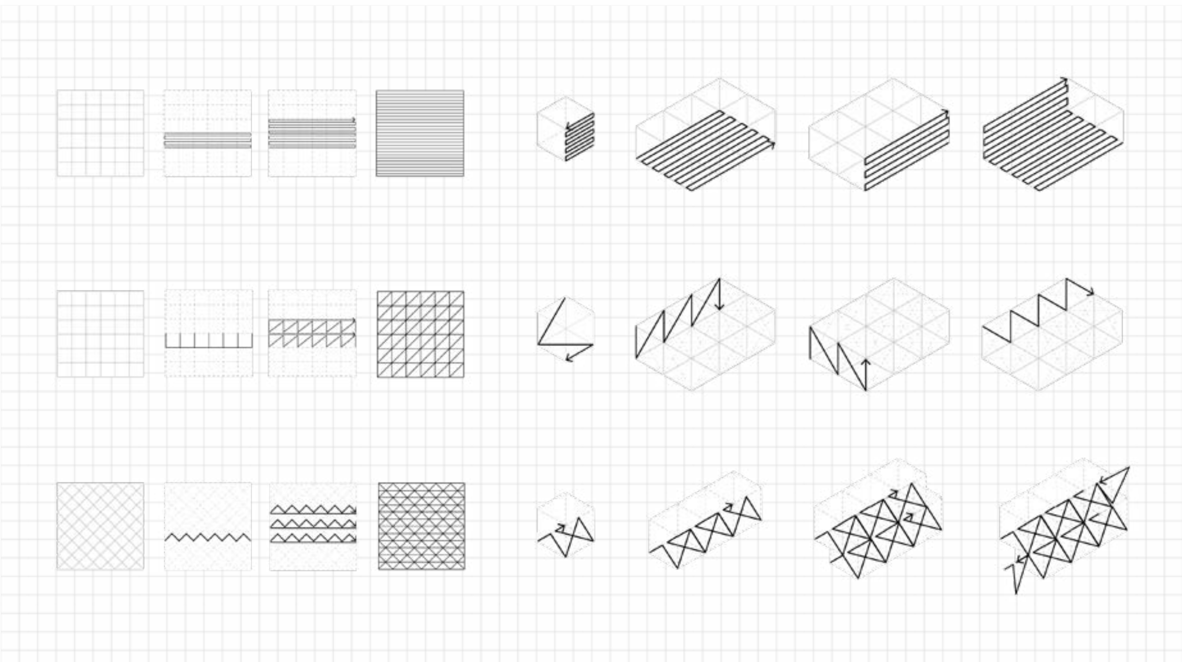
[Structural Reinforcement Method2: Intensification]



[Structural Reinforcement Method3: Thicking]

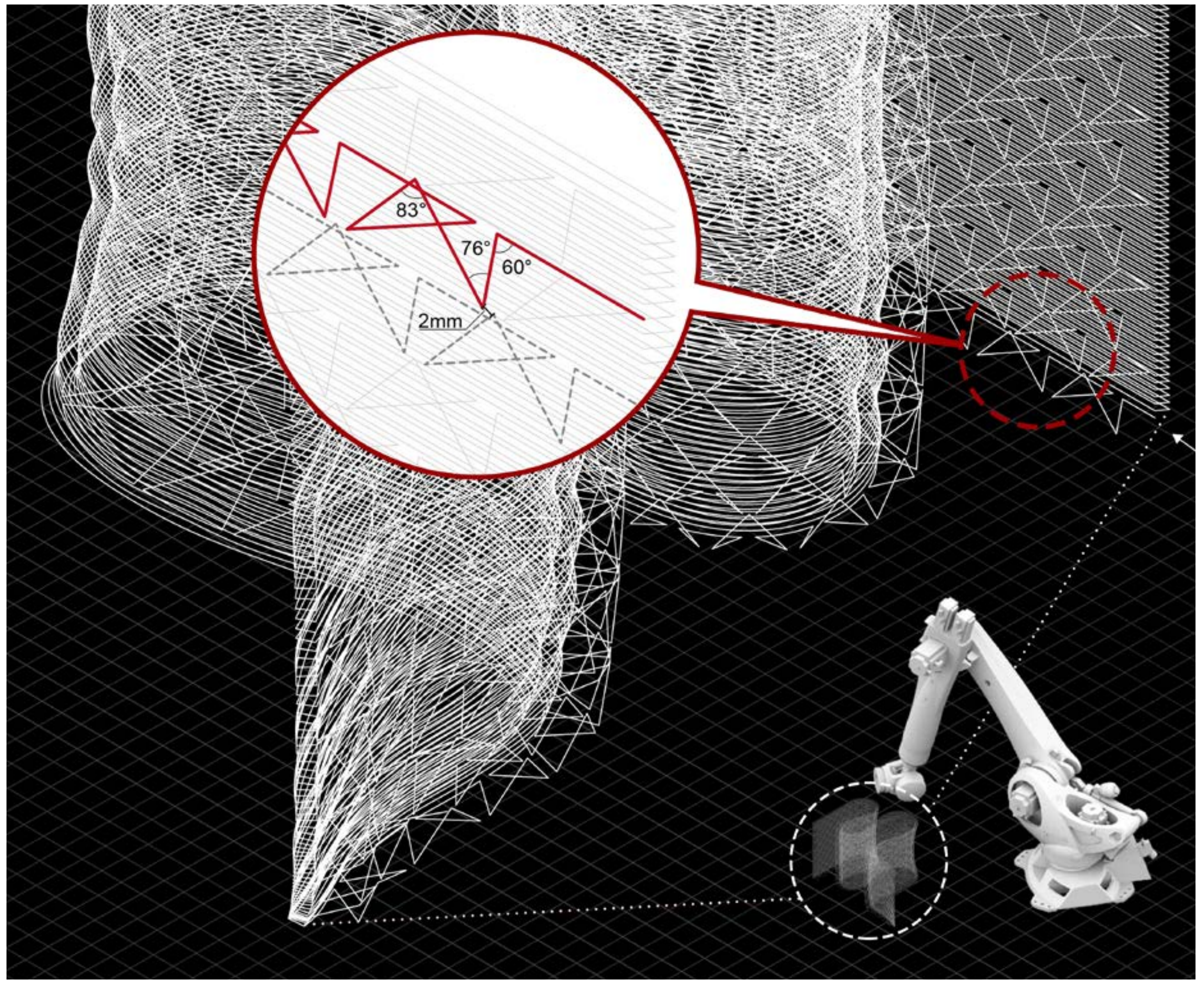
FABRICATION STRATEGY | Printing Path Design & Robotic Fabrication

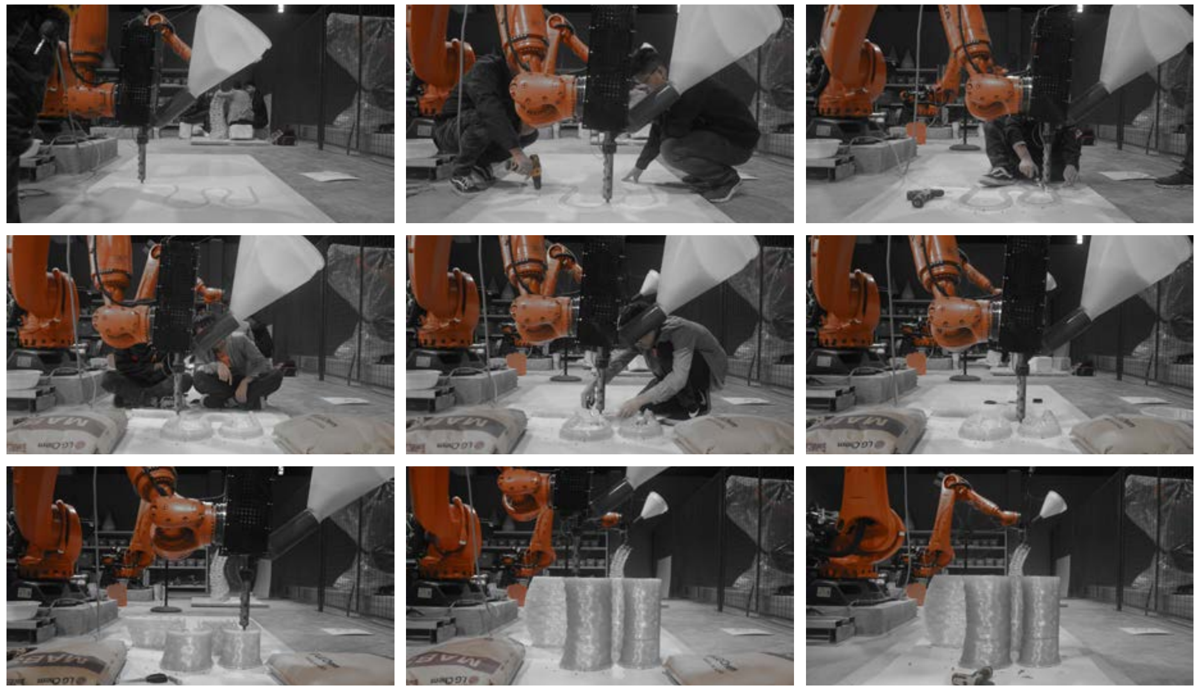




Form Evolution and Combination of Printing Path

Taking the spatial quadrileral as unit, the spatial printing path distributes and transforms according to the structure strength demand

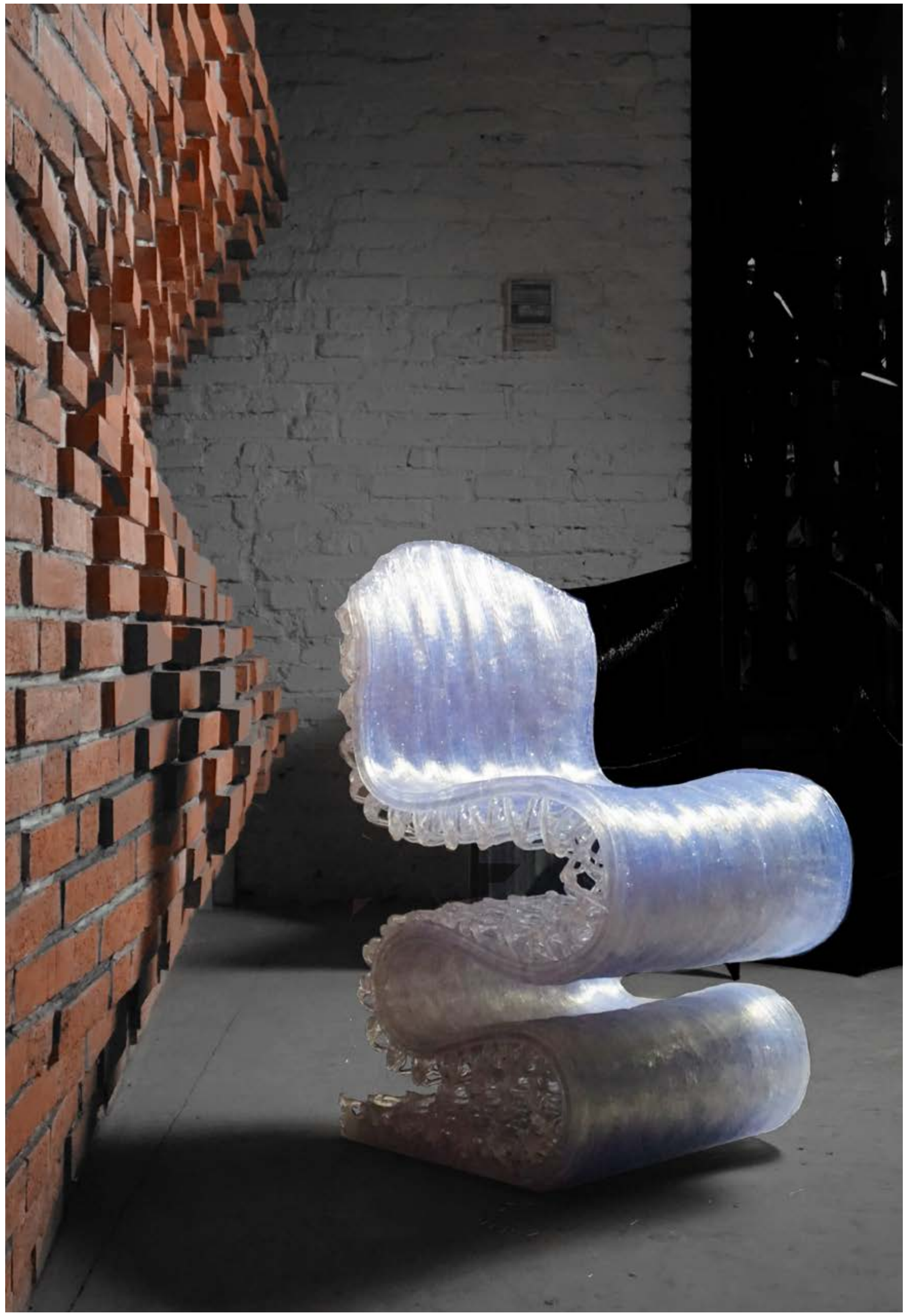




Whole Printing Process

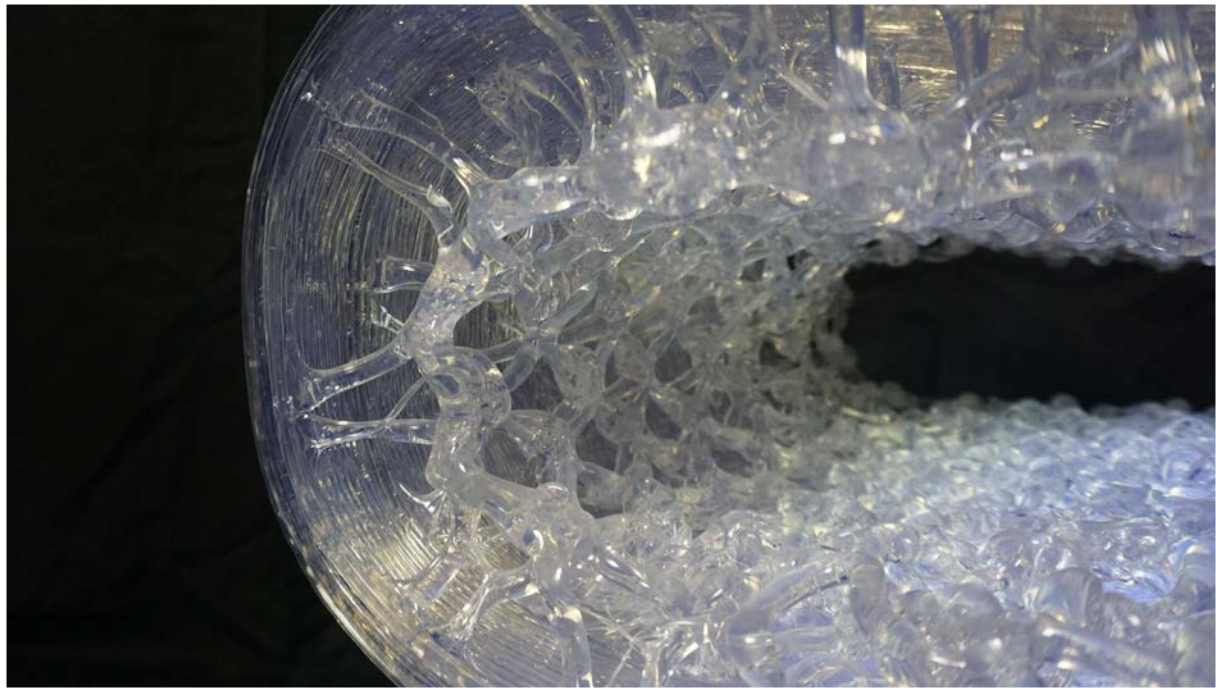
The combination of FDM printing path and the spatial printing path realized the exceptional ideas that continuously curved form and a slightly undulating surface.

MIX|One Path, Two Structures



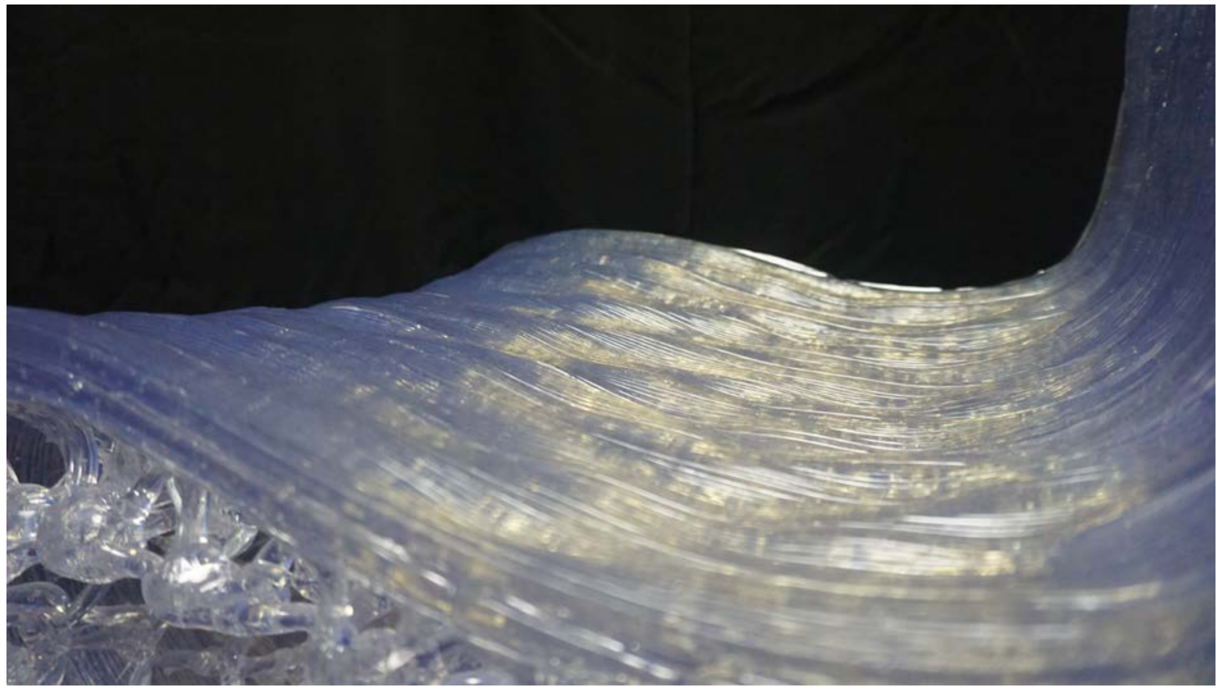
Continuously Curved Form and Floating Structure

The combination of FDM printing path and the spatial printing path realized the exceptional ideas that continuously curved form and a slightly undulating surface.



Supporting Structure

The supporting structure beneath the surface applied the spatial printing path and made full use of material performance.

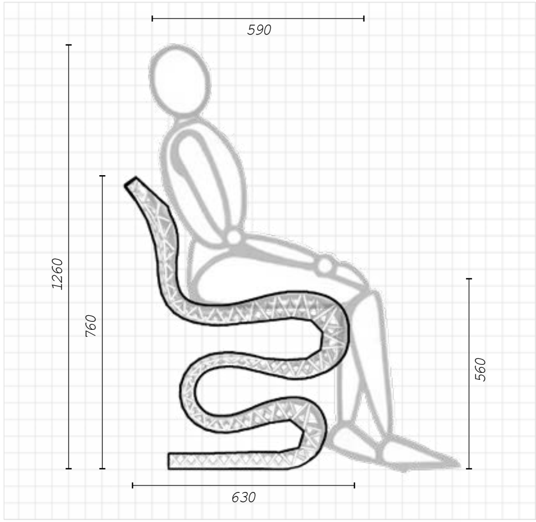


Parametric Interference Chair Surface

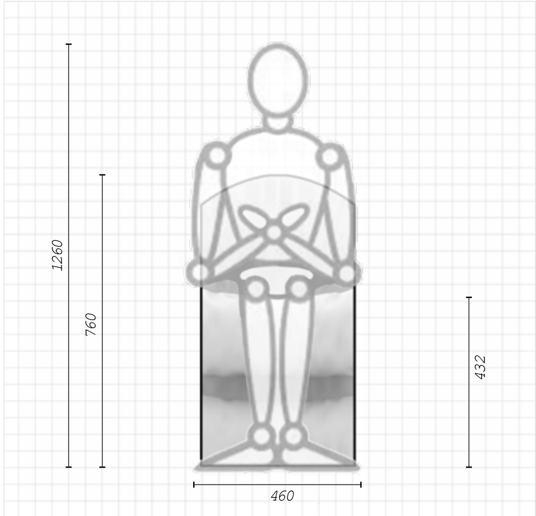
FDM printing path made the back of chair fit human body curve as closely as possible. Besides, the subtle bumps have the effect of massage.

ERGONOMICS | User Experience

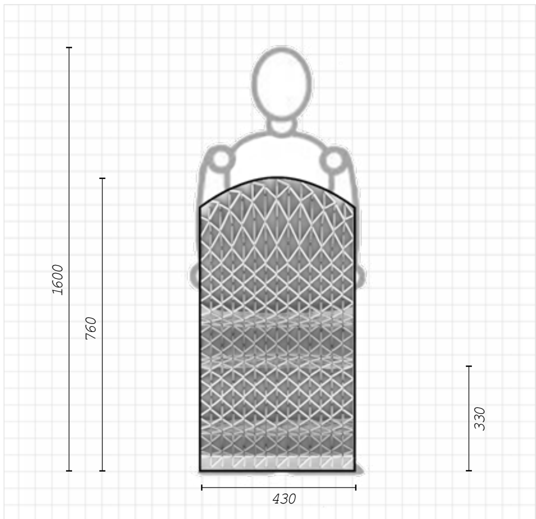
Right



Front



Back



05

MULTI RESOLUTION

Digital Libraty in Copenhagen

{

Canopy Open Studio
Individual Work
Instructor: Xiaonan YANG
Durition: 4 Weeks
Fall 2019

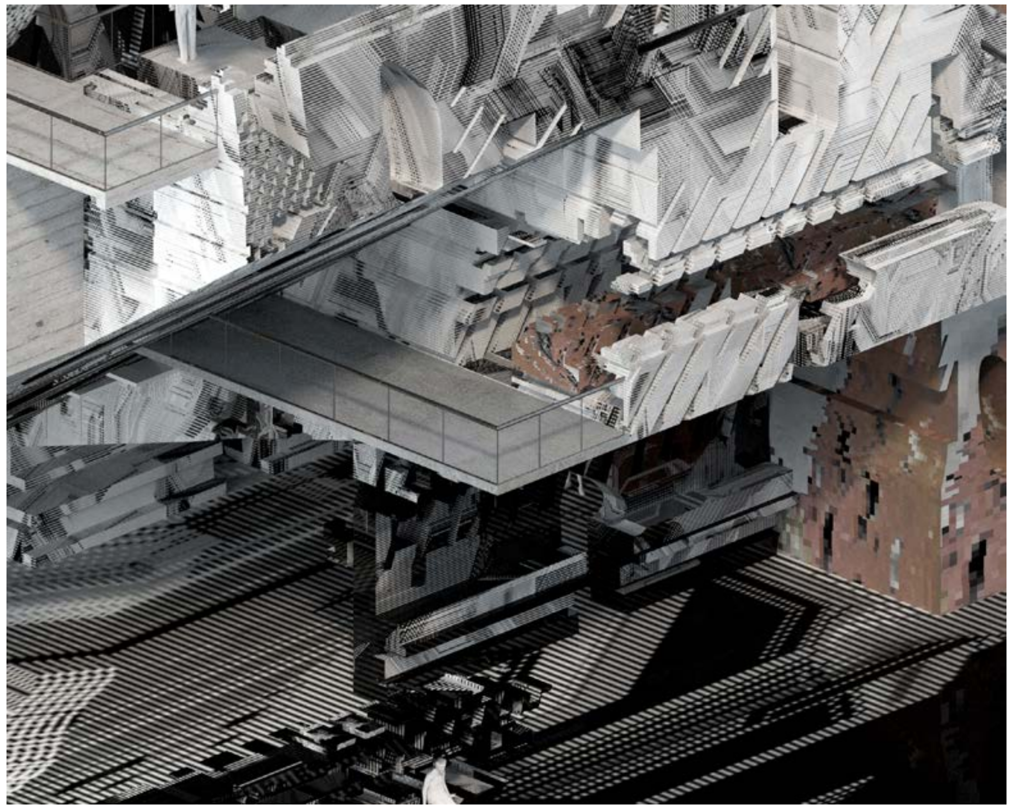
Contextualized through a digital library in Copenhagen, Denmark, this project delves deeply into issues of form and graphic both in two-dimensional(2D) and three-dimensional(3D), as well as the transformation process of graphics to spaces.

Image resolution, which applies to 2D graphics, is the detail an image holds. To be specific, higher resolution means more image detail and more information it contains. Through careful selection and interception of 2D images such as street view photos or aerial pictures of the city that reflect the urban environment and existing architectural characteristics of the base, the 3D objects containing specific image information are obtained through projections in three different directions of the XYZ axis.

The research goal of this project is to explore the possibility of different image resolutions in shaping space. Taking advantage of the difference in resolution brought about by the different degrees of pixelation that occur during image processing, the architectural shape and space are deconstructed and restructured.

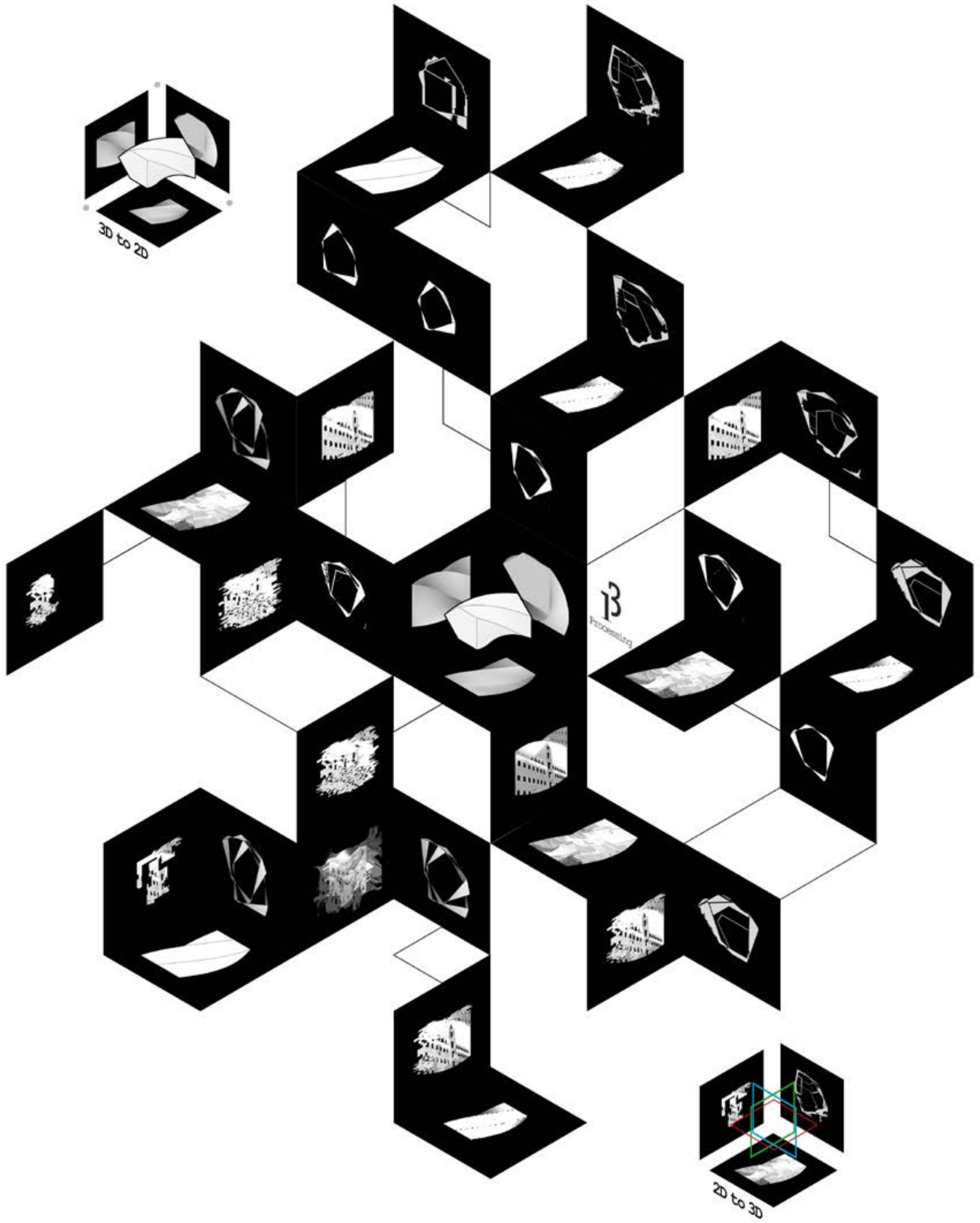
}

PROCESSING IMAGES|From 2D To 3D



Generation Of Mapping

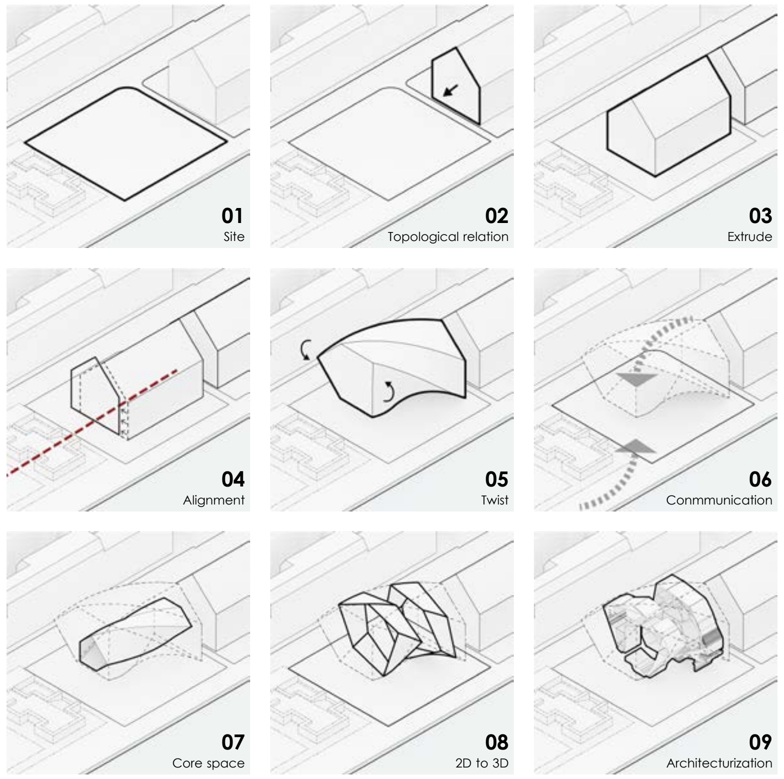
In this project, the mapping is considered as an factor to make the form(3D) and graphics(2D) engaged. The mapping implies where the space derived from.



Graphic Form

The central problem of this studio is: how to generate forms or spaces by processing a graphic image? These matched images describe how to process the initial three views of the conceptual volume.

FORM FINDING | From 2D To 3D



SW Isometric View

Derived from the old building near the site, the topological shape of the pentagonal wall was extracted to shape the volume.

```
import toxi.geom.*;

PImage img;
PImage img2;
a
PGraphics pg;
PGraphics pg2;
float noiseScale = .005;
int noiseCount;
int step = 50;


void setup(){
 size(1024,1024);
 noiseCount = int(random(100));
 img = loadImage("111.jpg");
 img2 = loadImage("111.jpg");
 pg = createGraphics(width,height);
 pg2 = createGraphics(width,height);
 initGraphics();
}

void draw(){
 background(255);
 image(pg,0,0);
 image(pg2,0,0);
 if(frameCount%step == 0){
  noiseCount++;
  noiseSeed(noiseCount);
 }
 model();
 if(frameCount%2== 0){
  saveFrame();
  if(frameCount > 1000){
   exit();
  }
 }
}

void initGraphics(){
 pg.loadPixels();
 pg2.loadPixels();
 for(int i = 0; i < img.width; i++){
  for(int j = 0; j < img.height; j++){
   int index = i + j*img.width;
   if(j%2 == 0){
    pg.pixels[index] = img.pixels[index];
   }else{
     pg2.pixels[index] = img2.pixels[index];
   }
  }
 }
 pg2.updatePixels();
 pg.updatePixels();
}
```

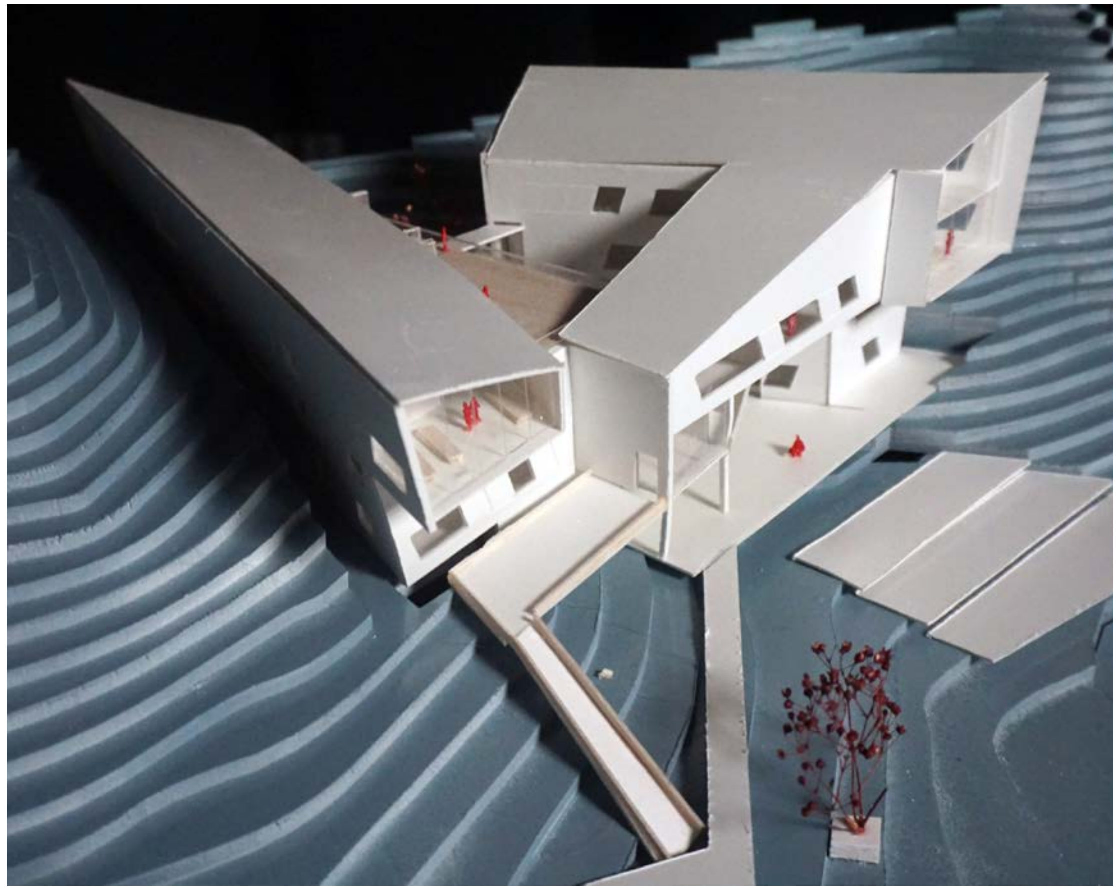
Exterior Texture

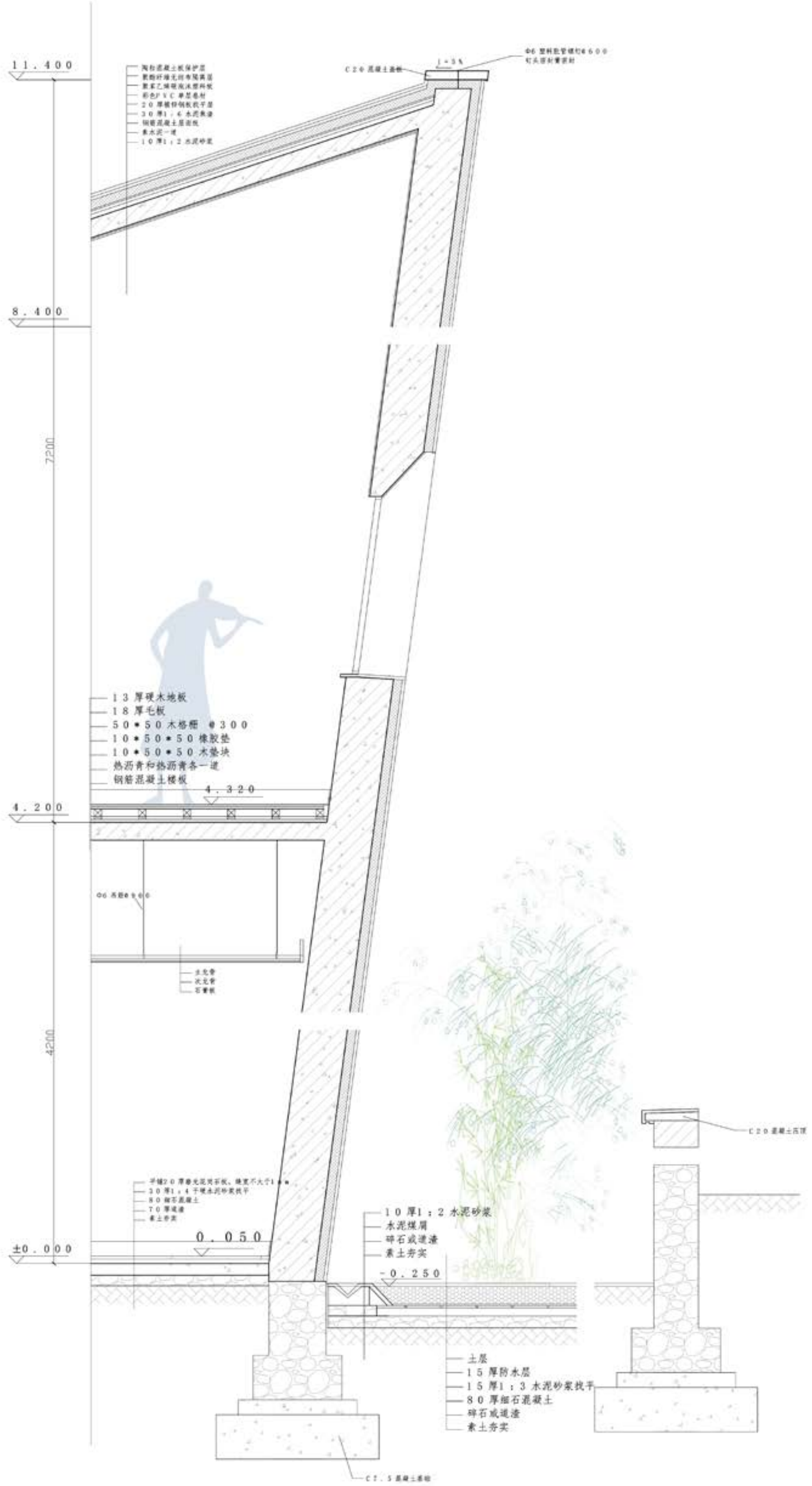
After extracting the graphic information of the image to obtain the form of the building, the color information contained in the original picture is restored, and the color map is processed with multiple levels of resolution.

The map serves as the texture of exterior building envelope to imply different size of interior architectural spaces.

06 " 川 "|Architecture Design|Mountain Shooting Club

[Individual Work]





Form

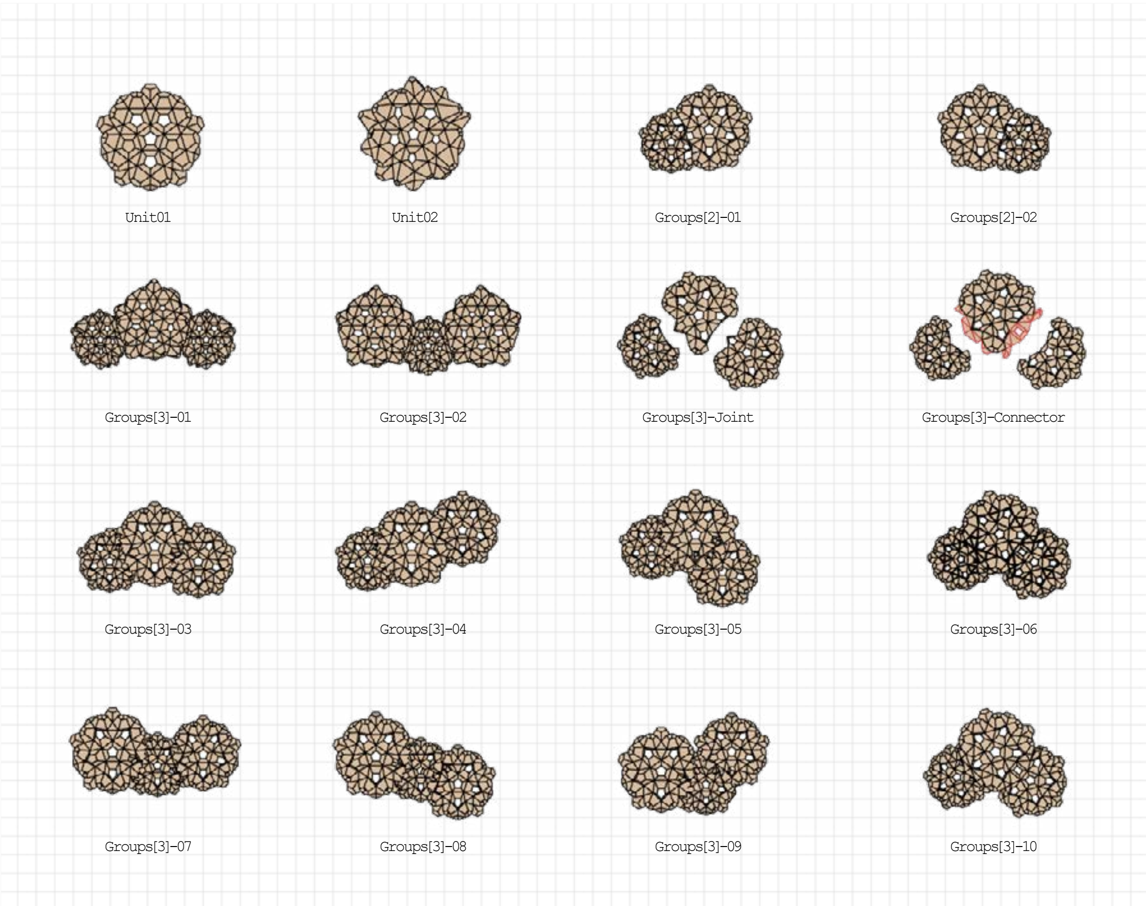
Like a Chinese character "川" from the aerial view, which means stream in the moutain, the final building form and massing is the direct result of the combination of the natura l environment and shooting demand.

Wall Structural Section

The sloping concrete strengthens the building's volume and enhances its orientation.

07 CARBOARD PAVILION|Manual Fabrication

[Role] 40%Concept Design/ 50%Organization/ 20%Fabrication



Combination of Construction Unit

Inspired by the football, the Construction unit consists of pentagons and triangles. This form also adapts to the processing of cardboard.

08 GLASS FIBER CHRISTMAS TREE|Robotic Fabrication

[Role] 50%Winding Path Design/ 30%Fabrication

Lightweight Structure

To celebrate Chirstmas 2019, my team operated two 6-axis robotic arm and fabricate a Christmas tree made of glass fiber and resin in the courtyard of Fab-Union.

Human | Robots | Architecture

Selected Works 2017-2021