Hanning Liu

Selected Works 2023-2024

TONGJI UNIVERSITY ‘25
Master of Architecture

XI’AN UNIVERSITY OF ARCHITECTURE AND TECHNOLOGY ‘22
Bachelor of Architecture

(+86) 18729390225
hanning-liu.github.io
liuhanning@tongji.edu.cn

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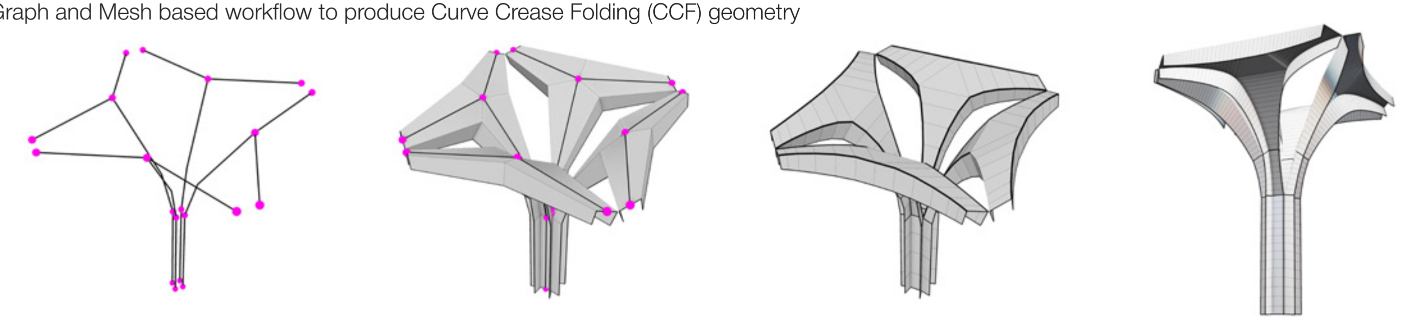
01

Composite Column

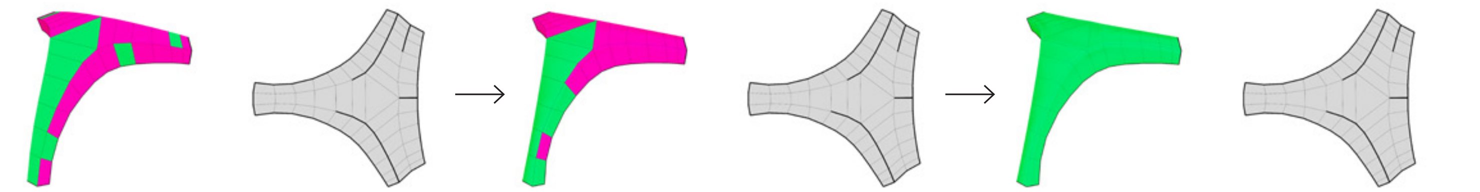
A Column Made with Foam Robotic Hot-Wire Cutting and Aluminum Panel Curve Crease Folding
DigitalFUTURES Workshop Tectonism ZHA CODE | 2023

Instructor: Shajay Bhooshan, Vishu Bhooshan, Jianfei Chu, Taizhong Chen
Teaching Assistant: Hanning Liu
(Team Work) Personal Contribution: Prototype Design, Robotic Fabrication, Pavilion Assembly

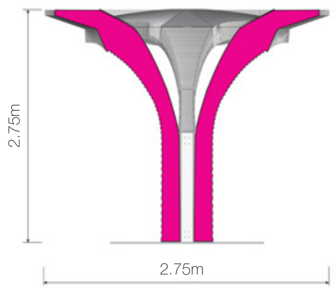
- Graph and Mesh based workflow to produce Curve Crease Folding (CCF) geometry



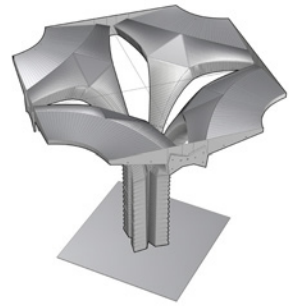
- Dynamic Relaxation of Y-Shape CCF component in both folded and unfolded states



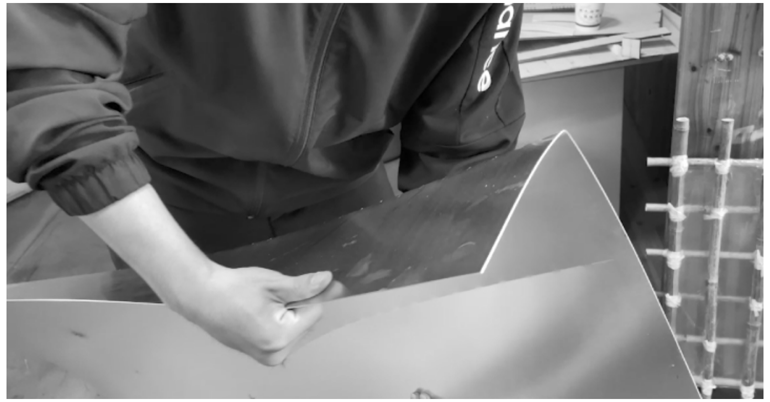
- Schematic Drawings

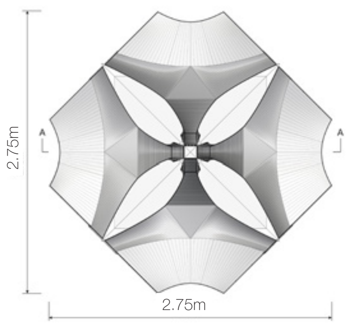


Section A-A

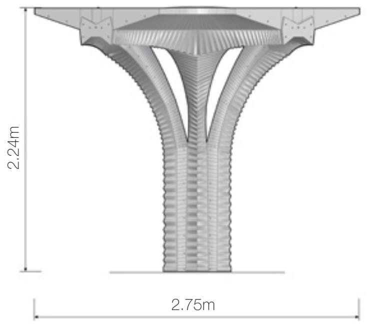


Perspective View

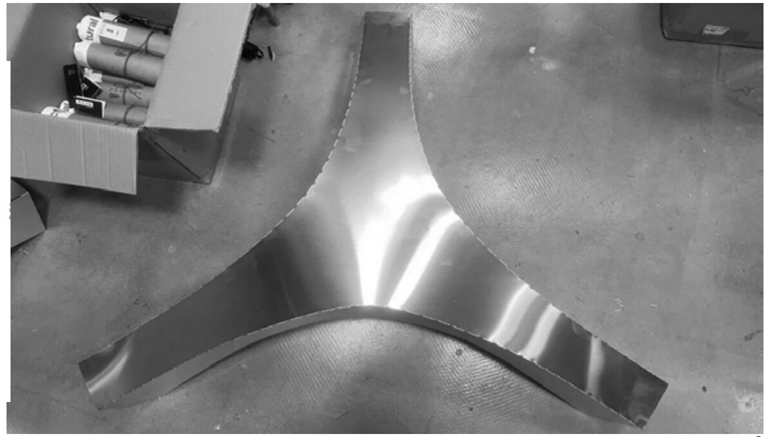




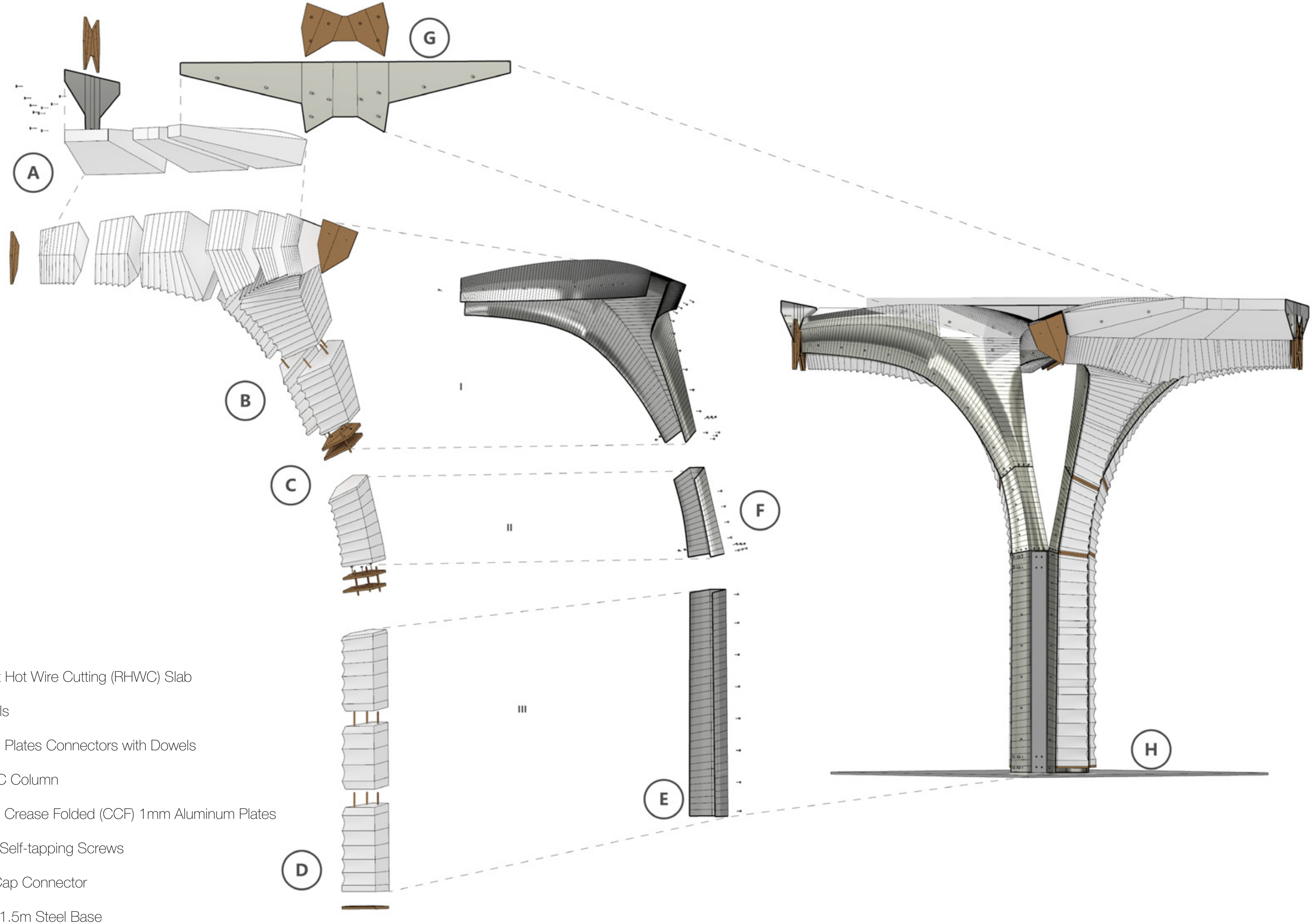
Plan



Front Elevation

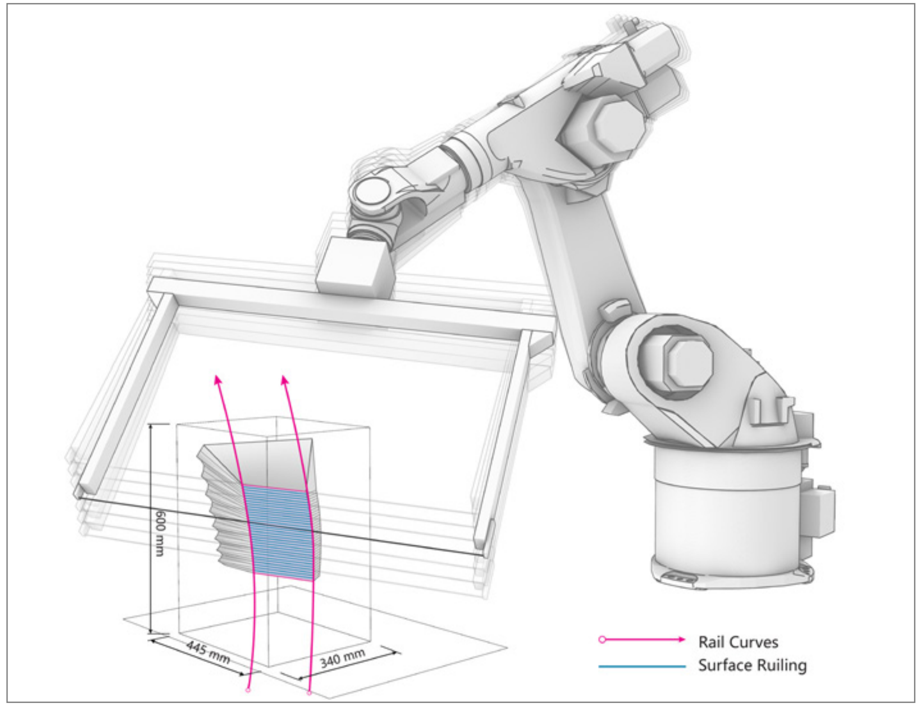


• Exploded View Showing the Assembly

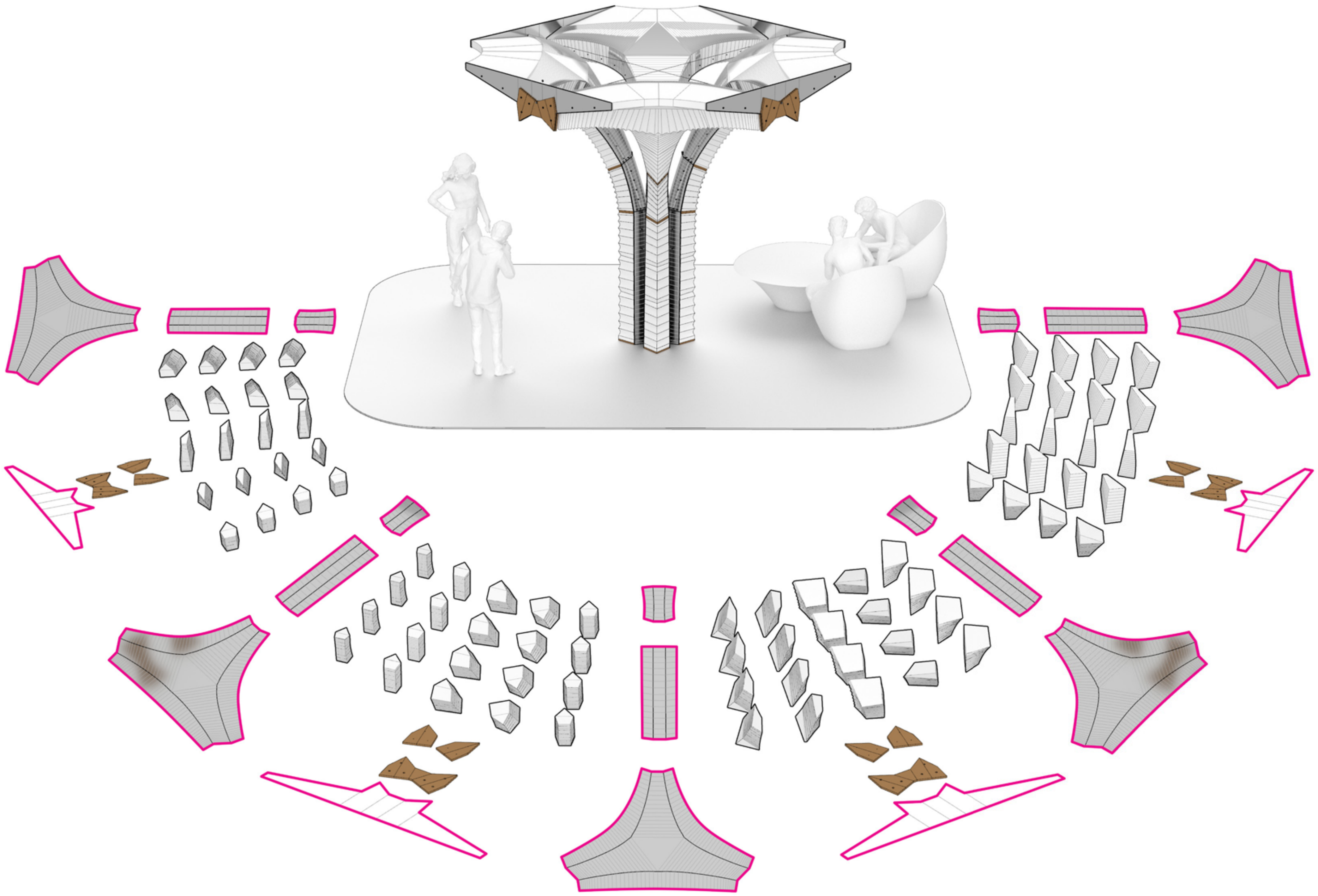


A	Robot Hot Wire Cutting (RHWC) Slab
B	Dowels
C	Wood Plates Connectors with Dowels
D	RHWC Column
E	Curve Crease Folded (CCF) 1mm Aluminum Plates
F	4mm Self-tapping Screws
G	End Cap Connector
H	1.5 x 1.5m Steel Base

• Robotic How Wire Cutting Path for One Block



• Aerial Perspective View with 12 unrolled CCF components and 80 individual foam blocks of the pavilion

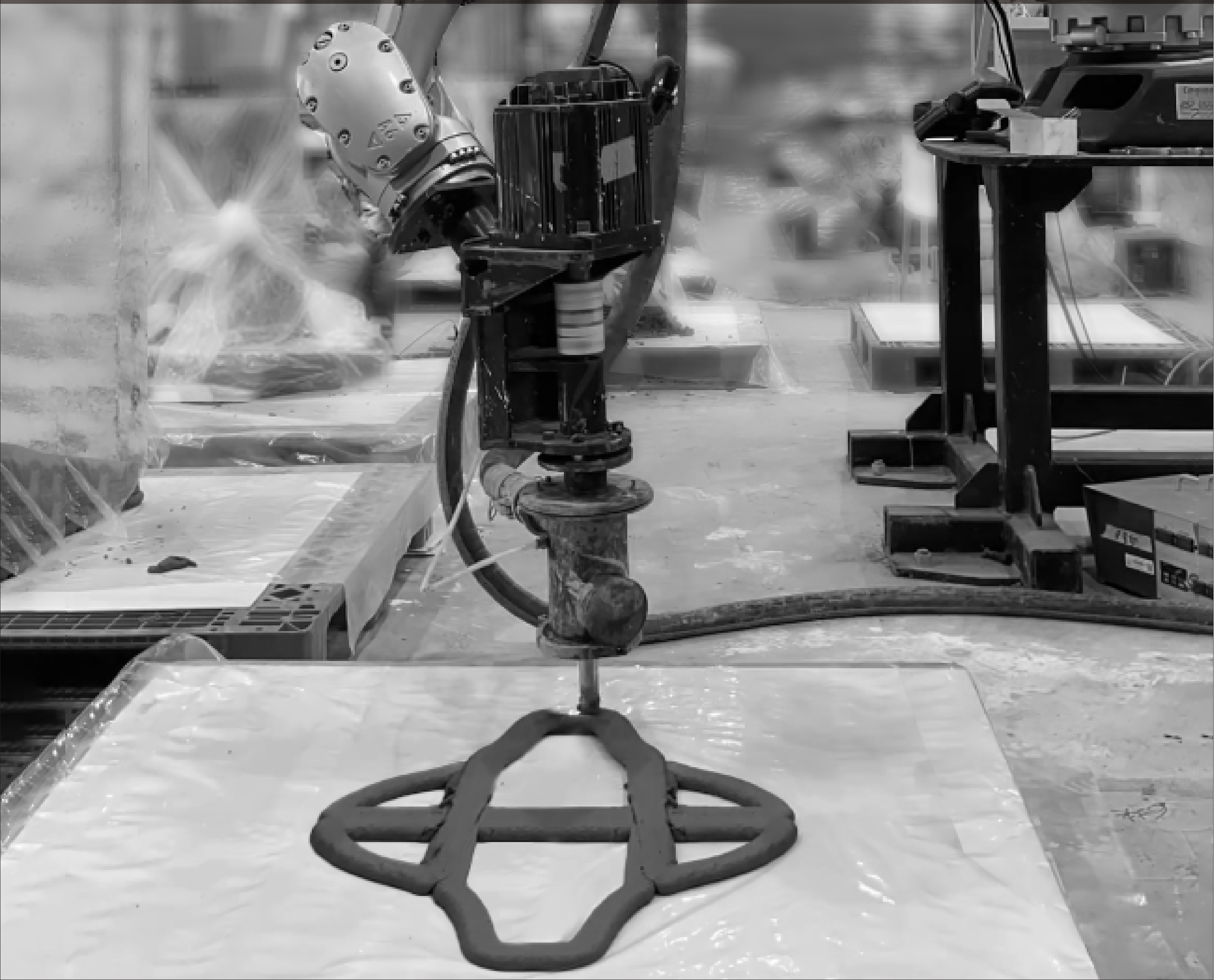


02

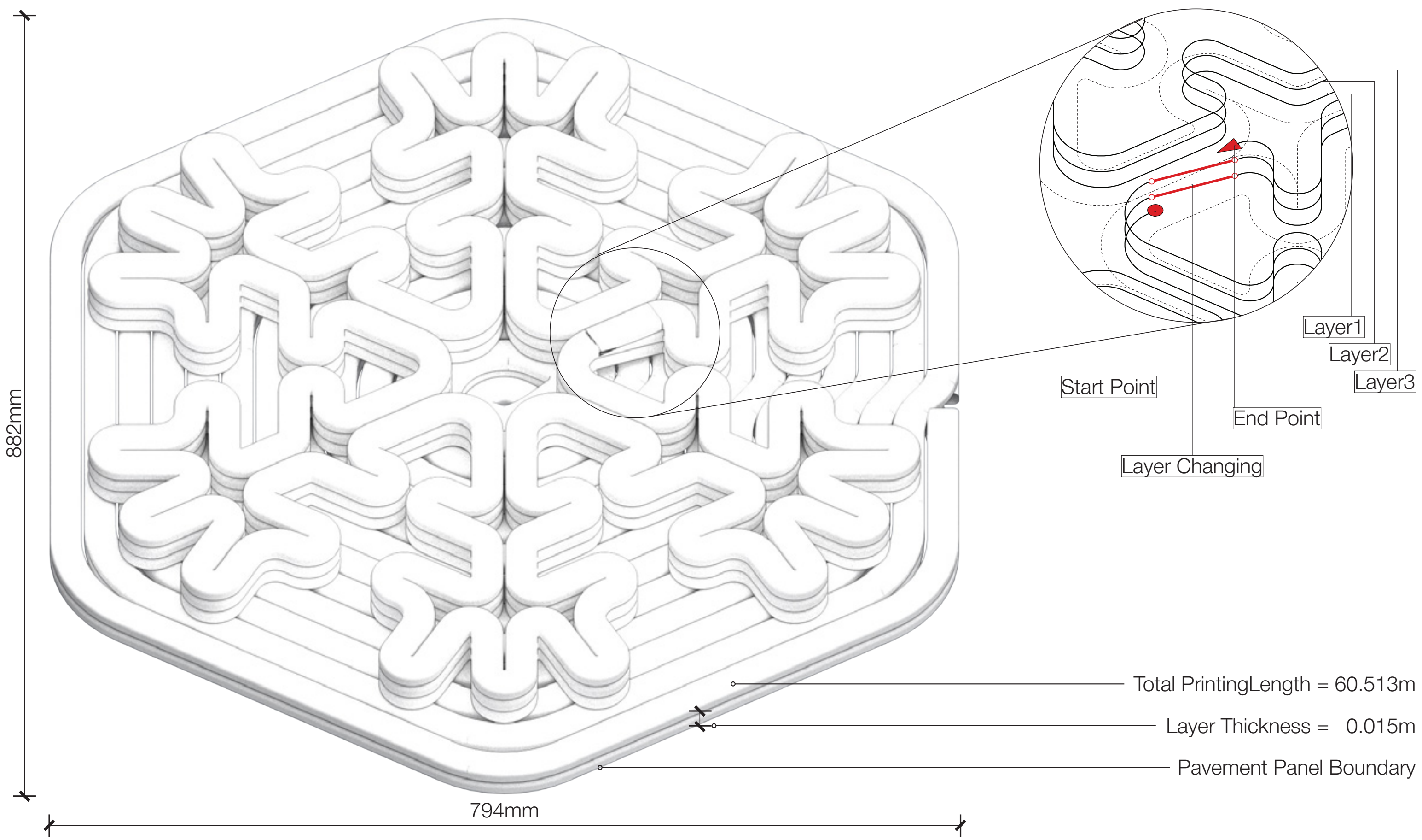
Snowflake Pavement

A Pavement Panel Deisgn and Fabrication with Concrete Robotic 3D Printing Technique
Landscape Project, ChangChun City, Jilin Province, China | 2023

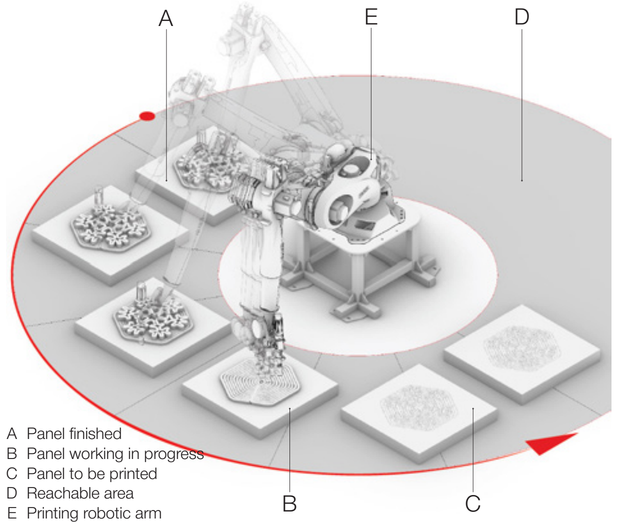
Designer: Hanning Liu
Solo Work: Prototype Design, Diagram Drawing, Prototype Robotic Fabrication



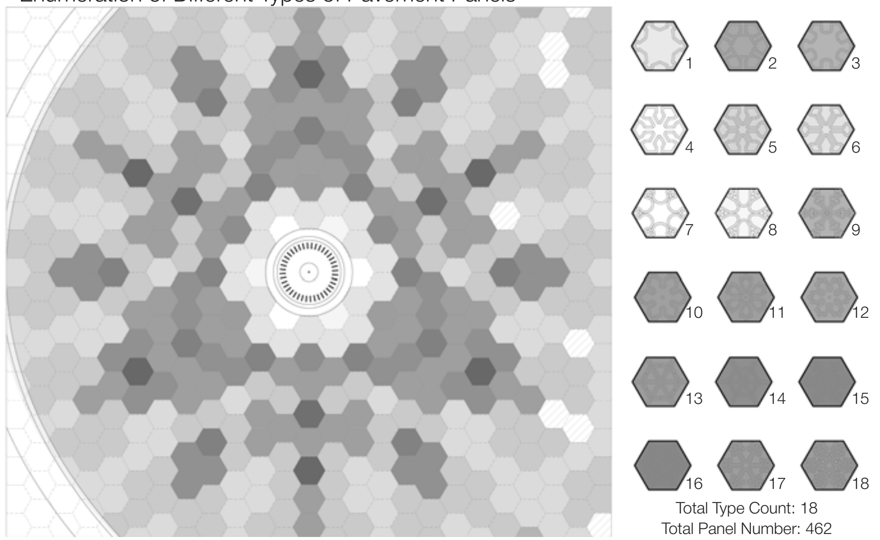
• Robotic 3D Printing Path for One Pavement Panel



• Work Space Overview



• Enumeration of Different Types of Pavement Panels

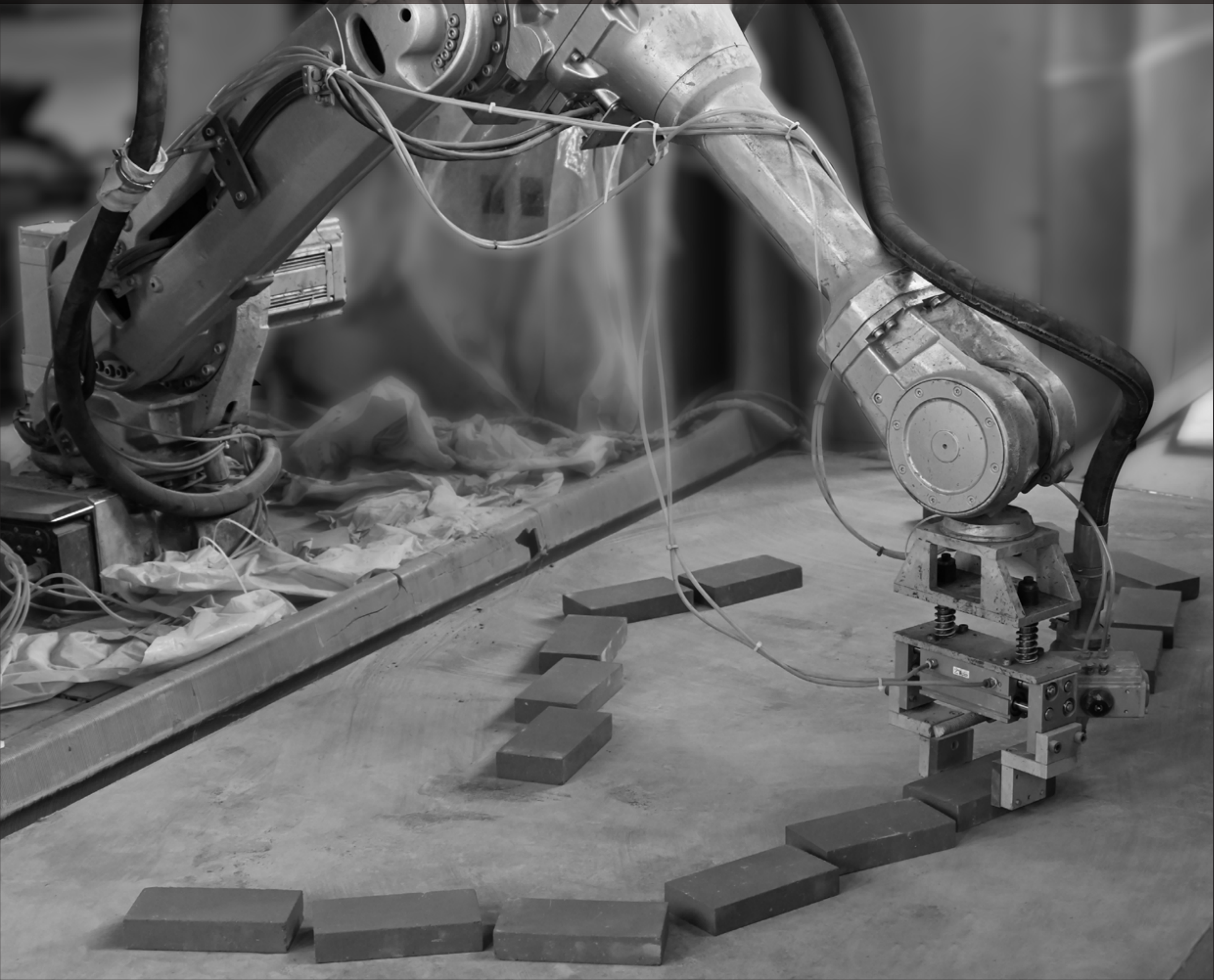


03

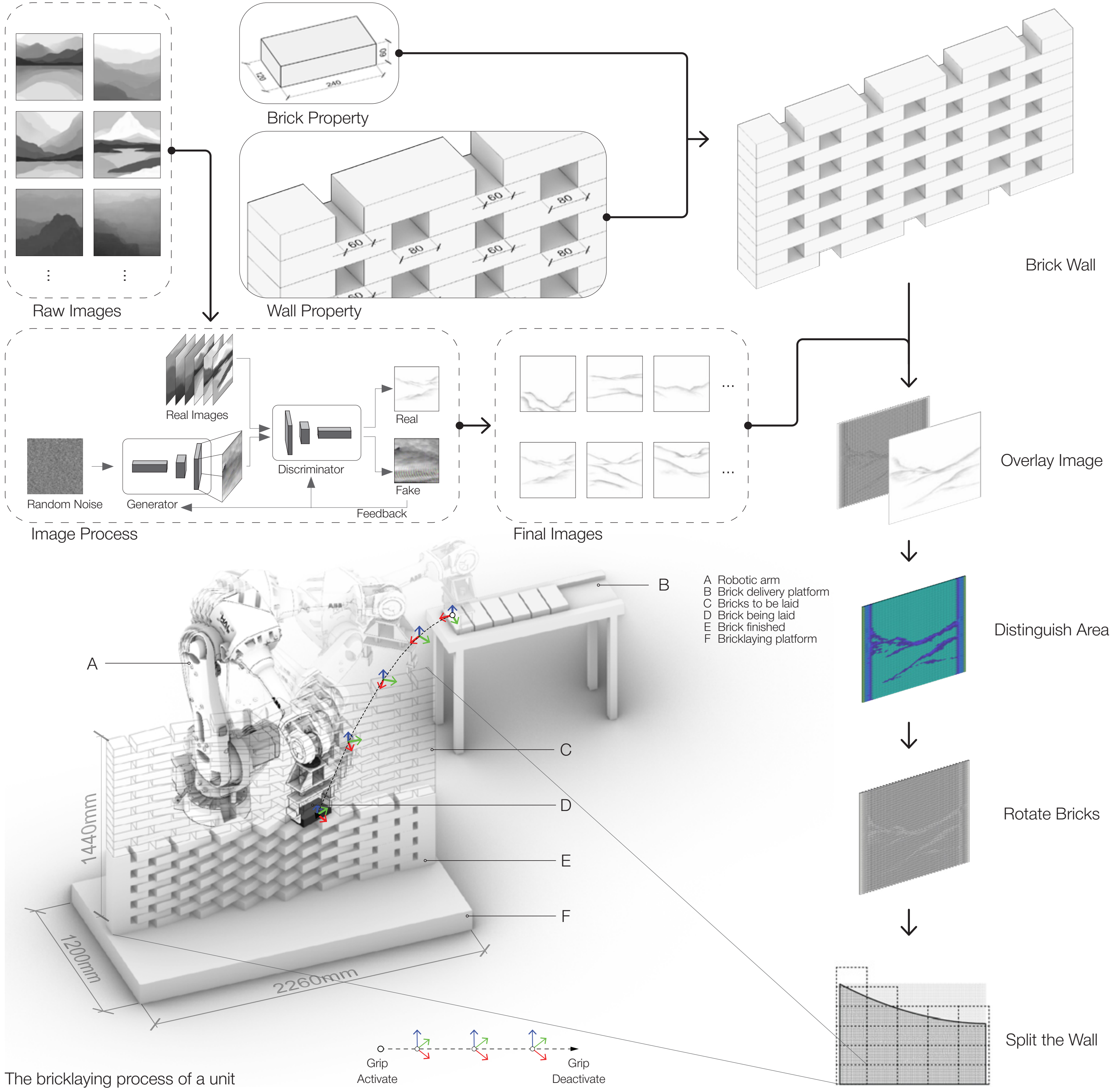
Flowing

Retail Complex Design and Parametric Brick Flowing Wall Fabricated with Robotic Arm
Architecture Project, Taizhou City, Zhejiang Province, China | 2024

Designer: Hanning Liu
Solo Work: Prototype Design, Diagram Drawing, Prototype Robotic Fabrication



• Workflow Overview of Cultural Elements to Brick Wall Components Fabrication



The bricklaying process of a unit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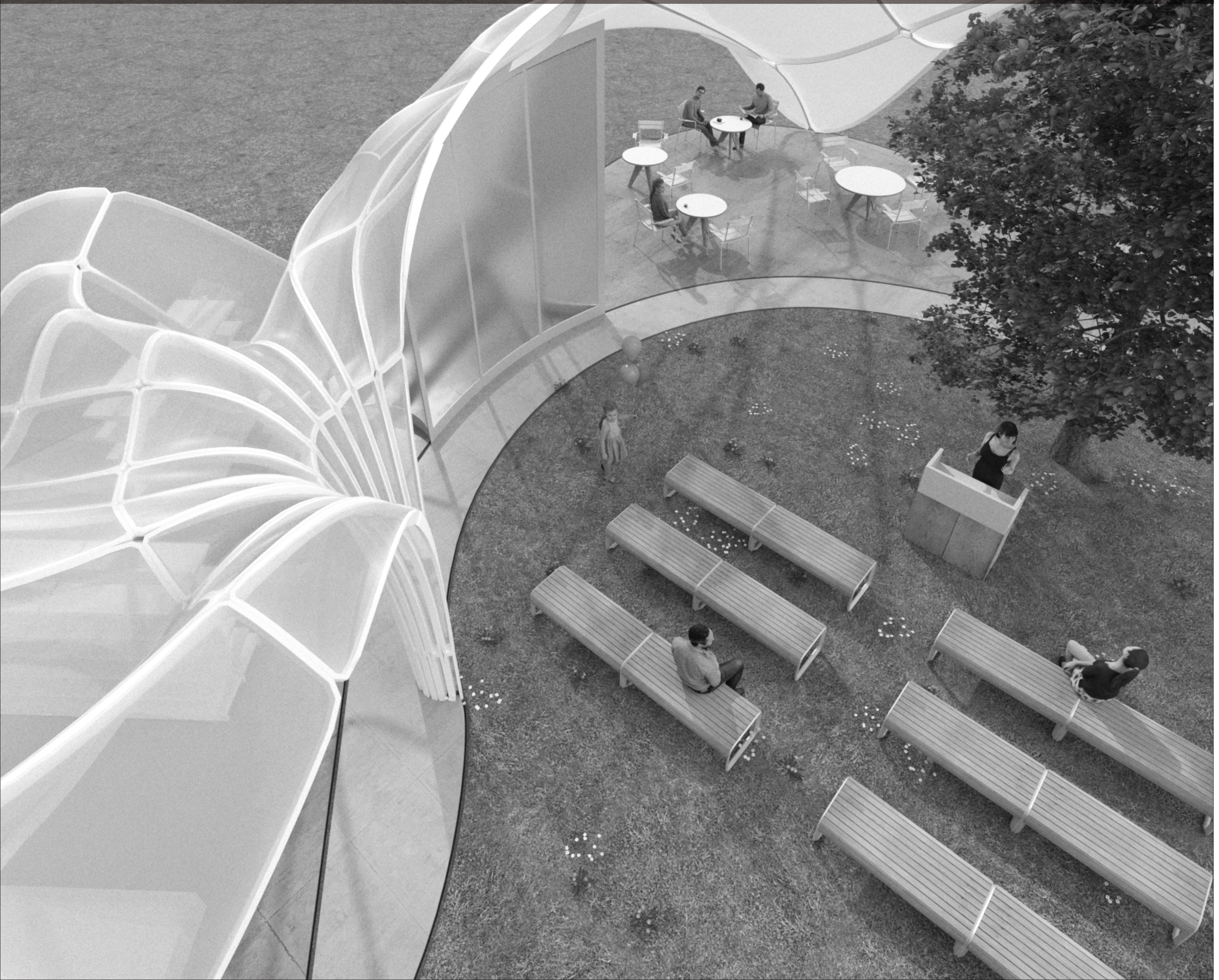
04

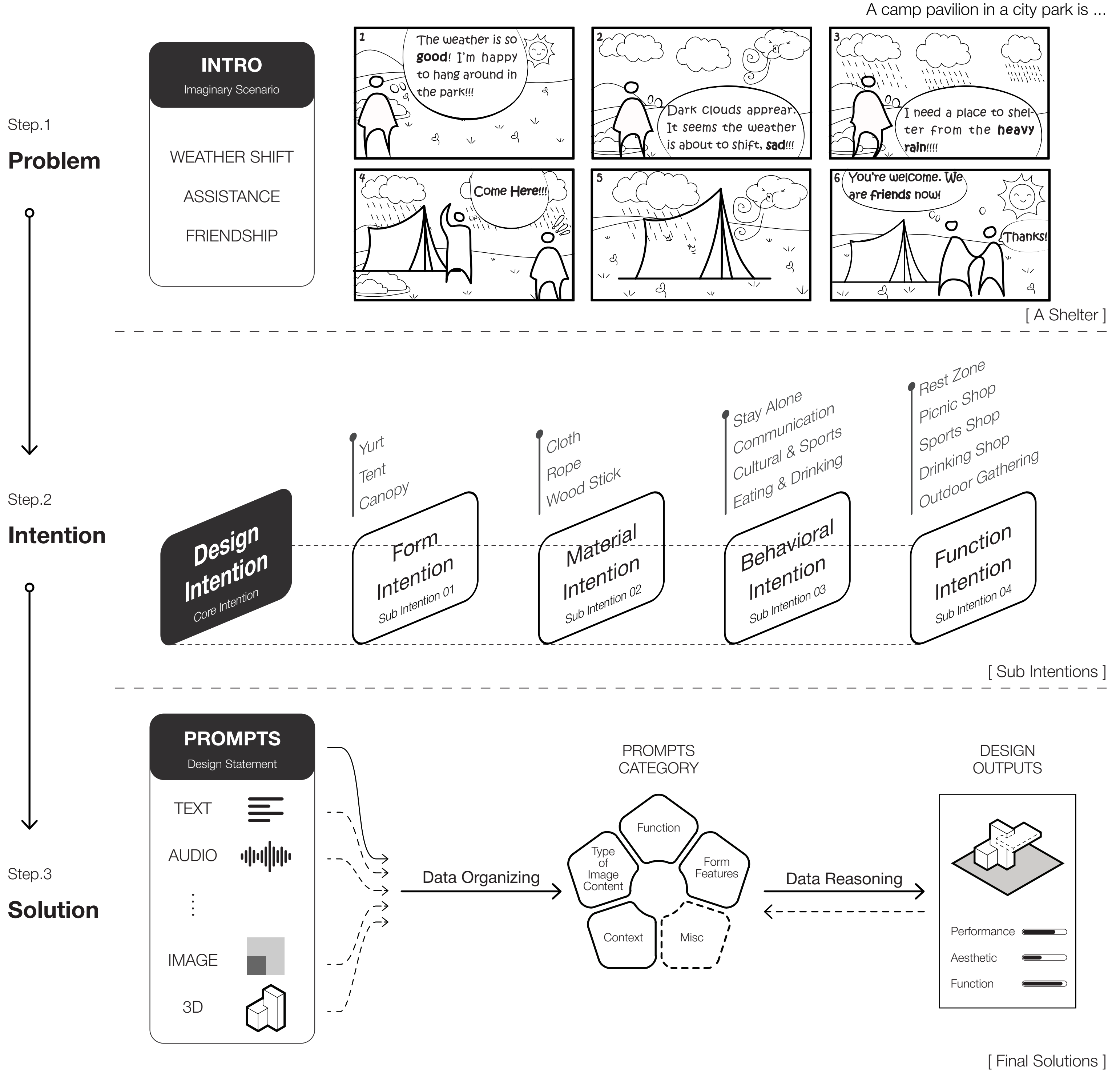
Embracing Tent

A Pavilion in a Park Using Artificial Intelligence-Generated Content (AIGC) Tools with Text and Image Prompts
Tongji University | Spring 2023

Instructors: Philip F. Yuan, Hao Wu, Xingjie Xie, Menghao Yuan
Designer: Hanning Liu
Solo Work: Prototype Design, Diagram Drawing



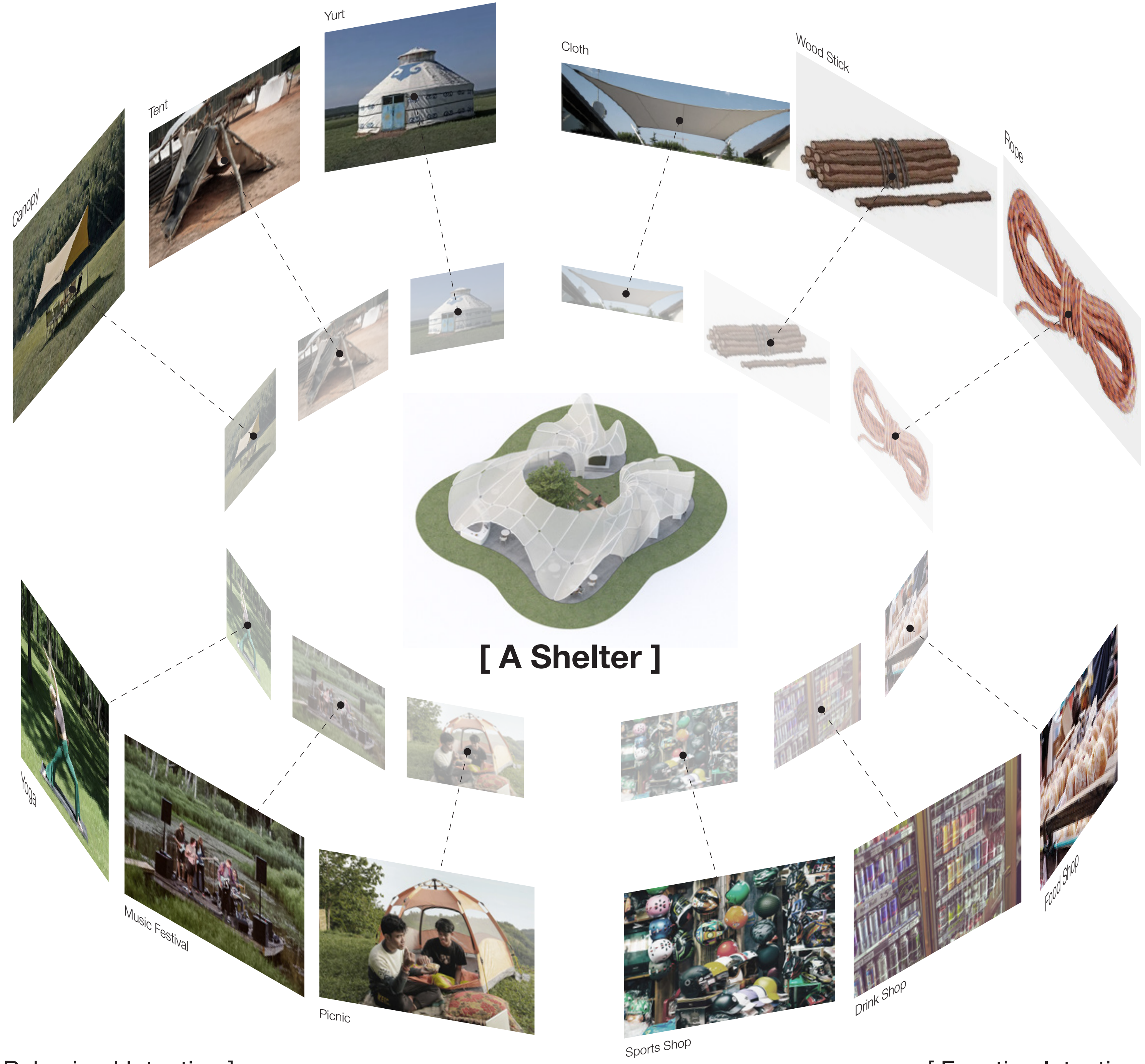
• AI-Assisted Design Workflow



• Design Intentions

[Form Intention]

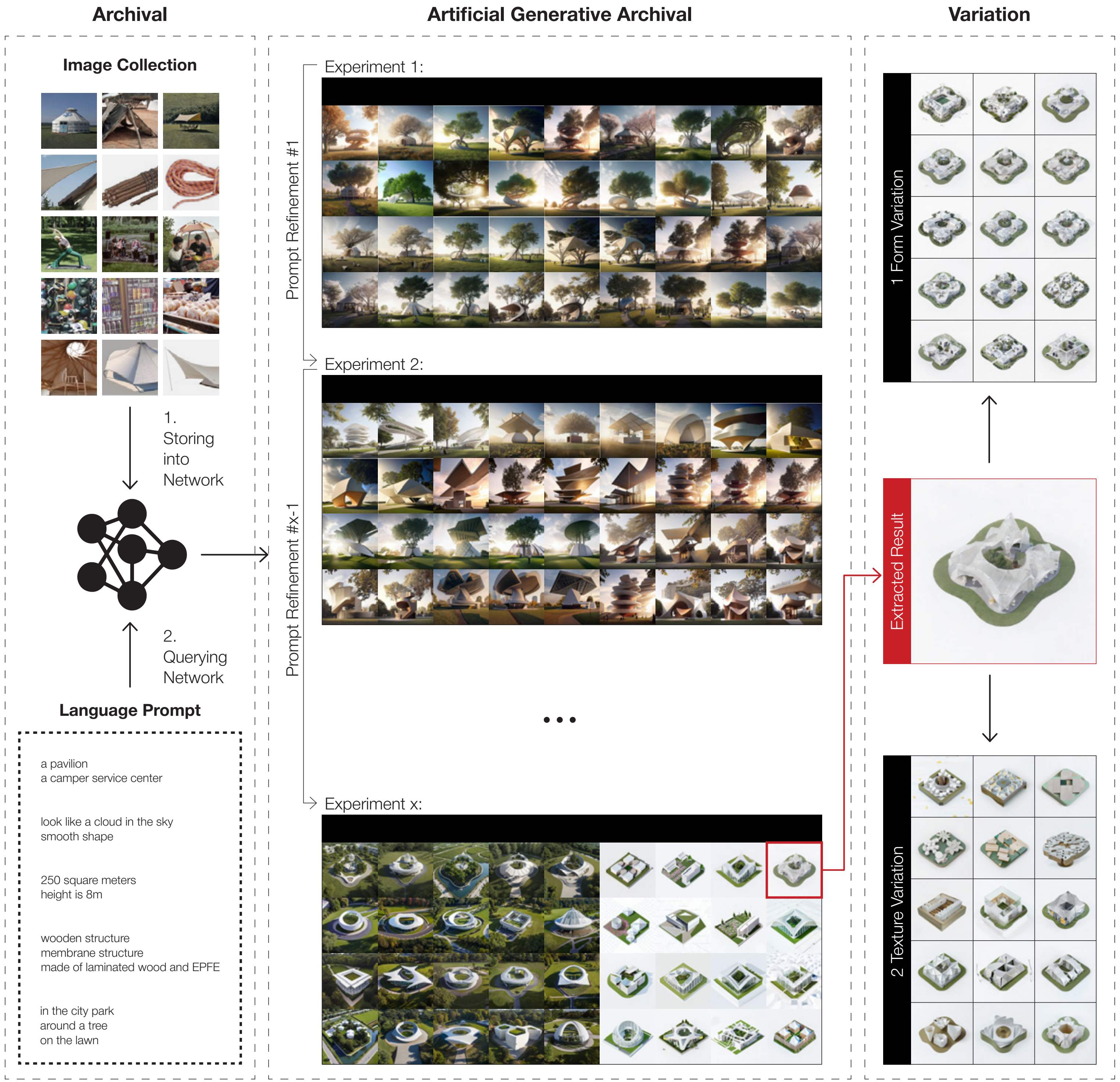
[Material Intention]



[Behavioral Intention]

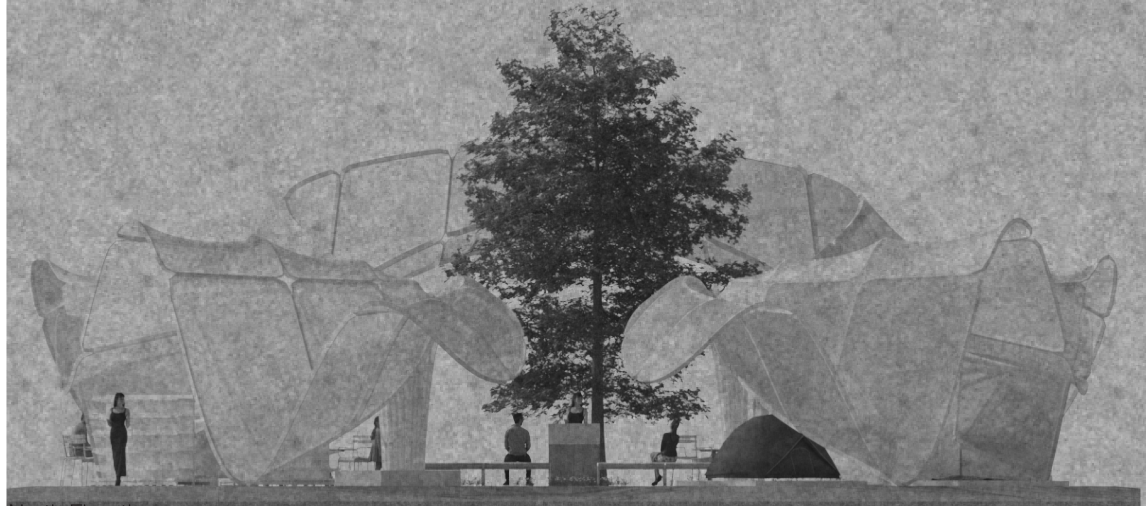
[Function Intention]

• Design Solutions

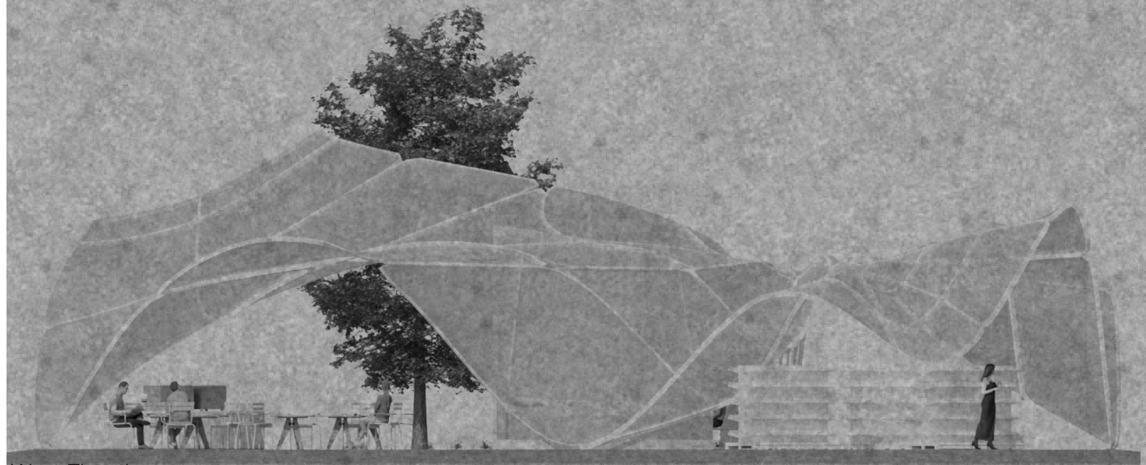


• Schematic Drawings

South Elevation

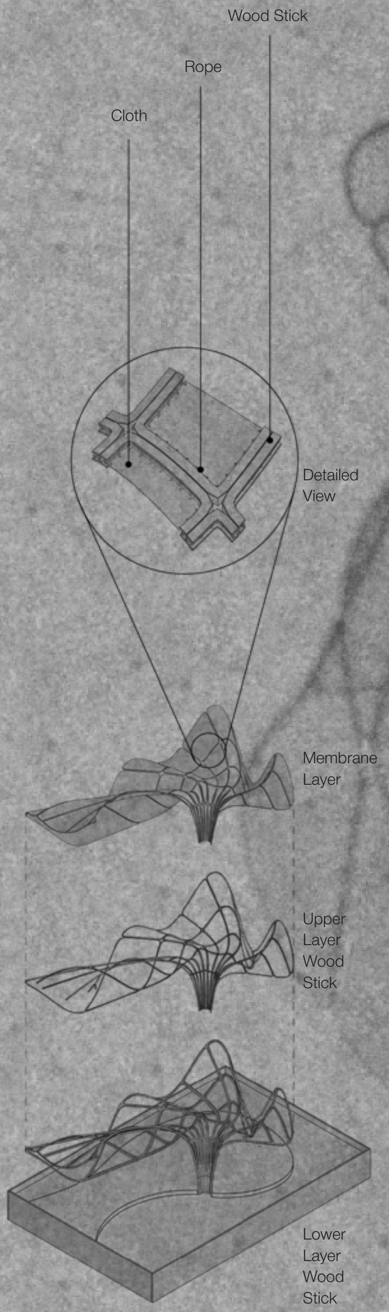


North Elevation

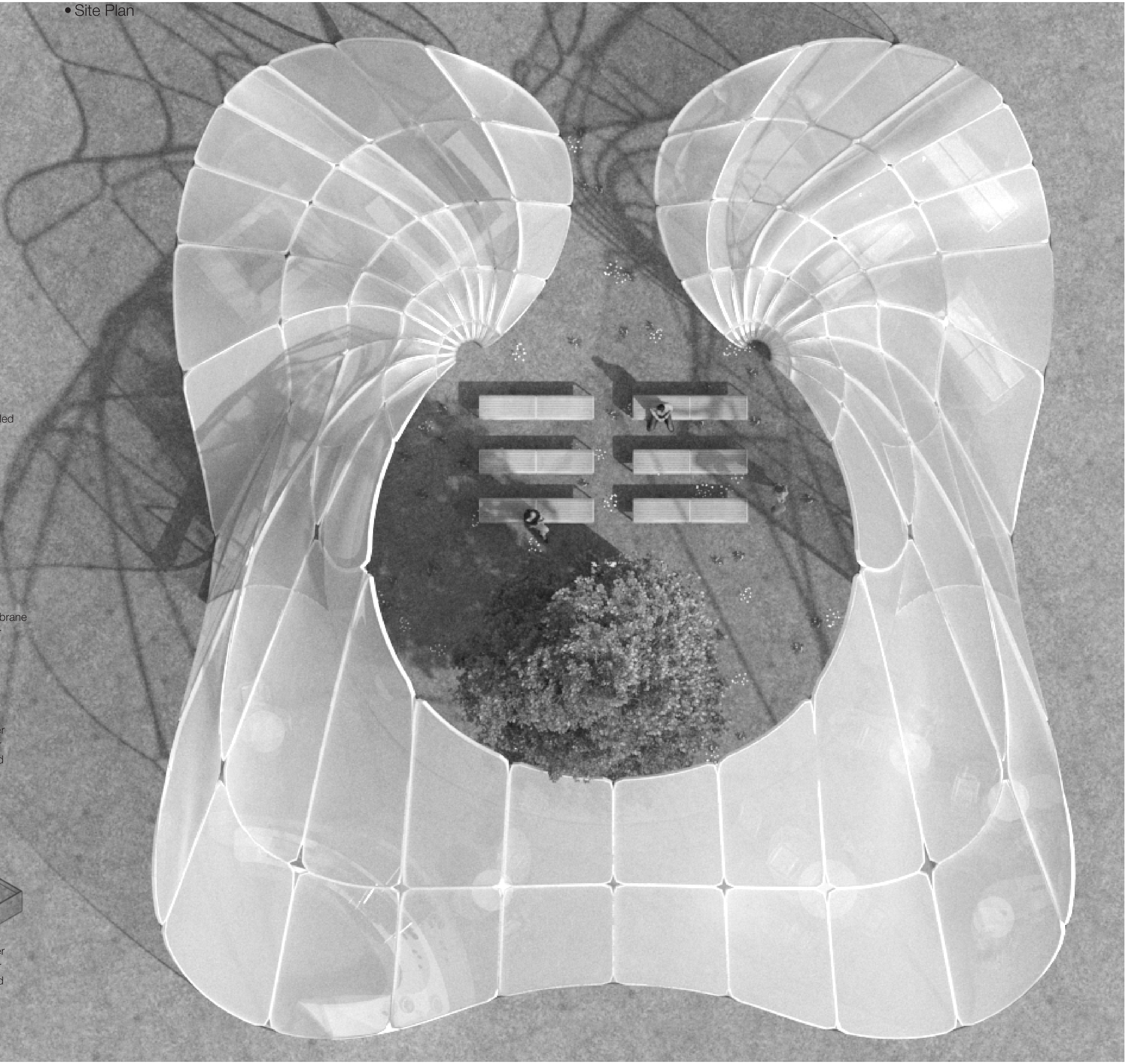


West Elevation

• Tectonic Detail



• Site Plan

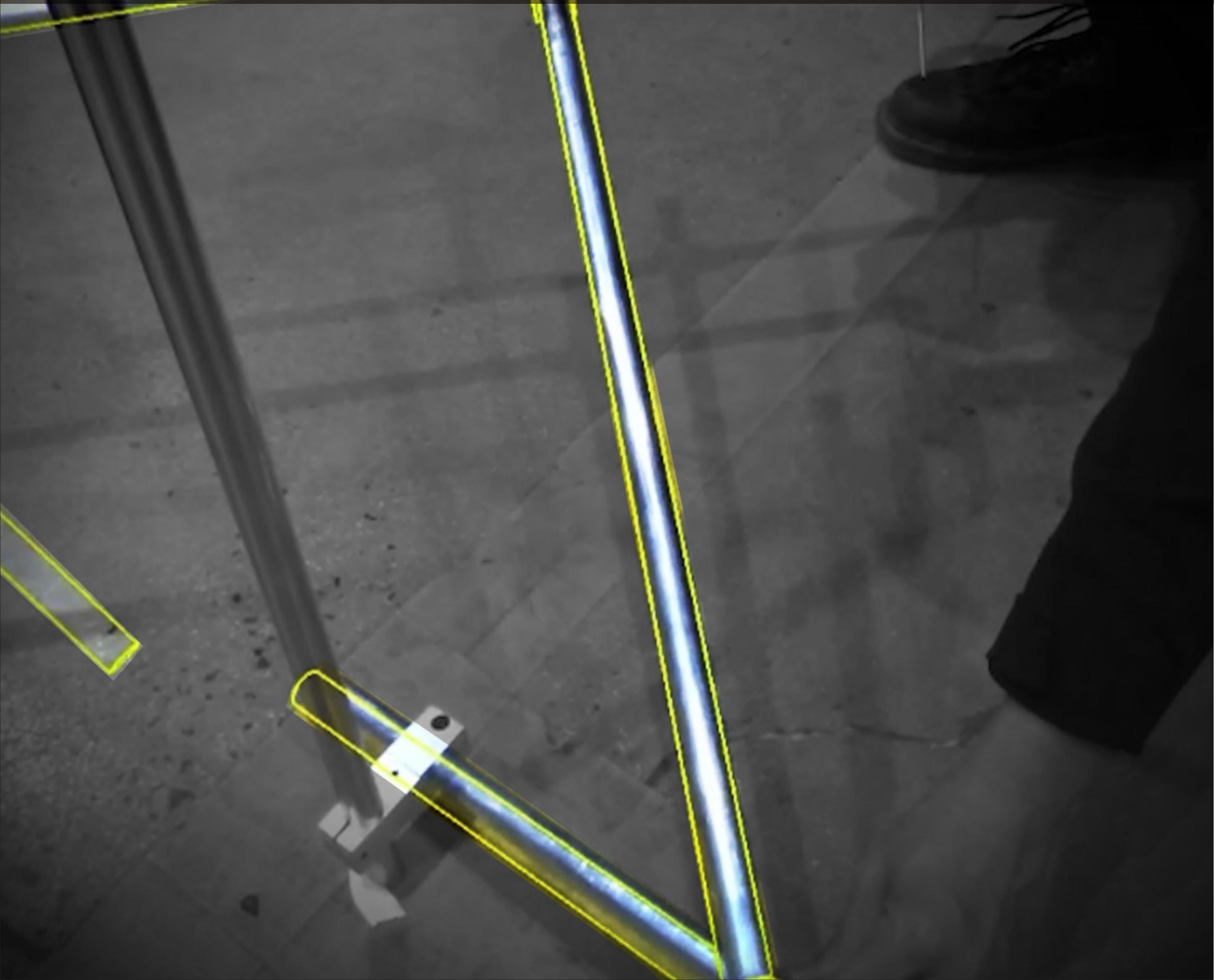


05

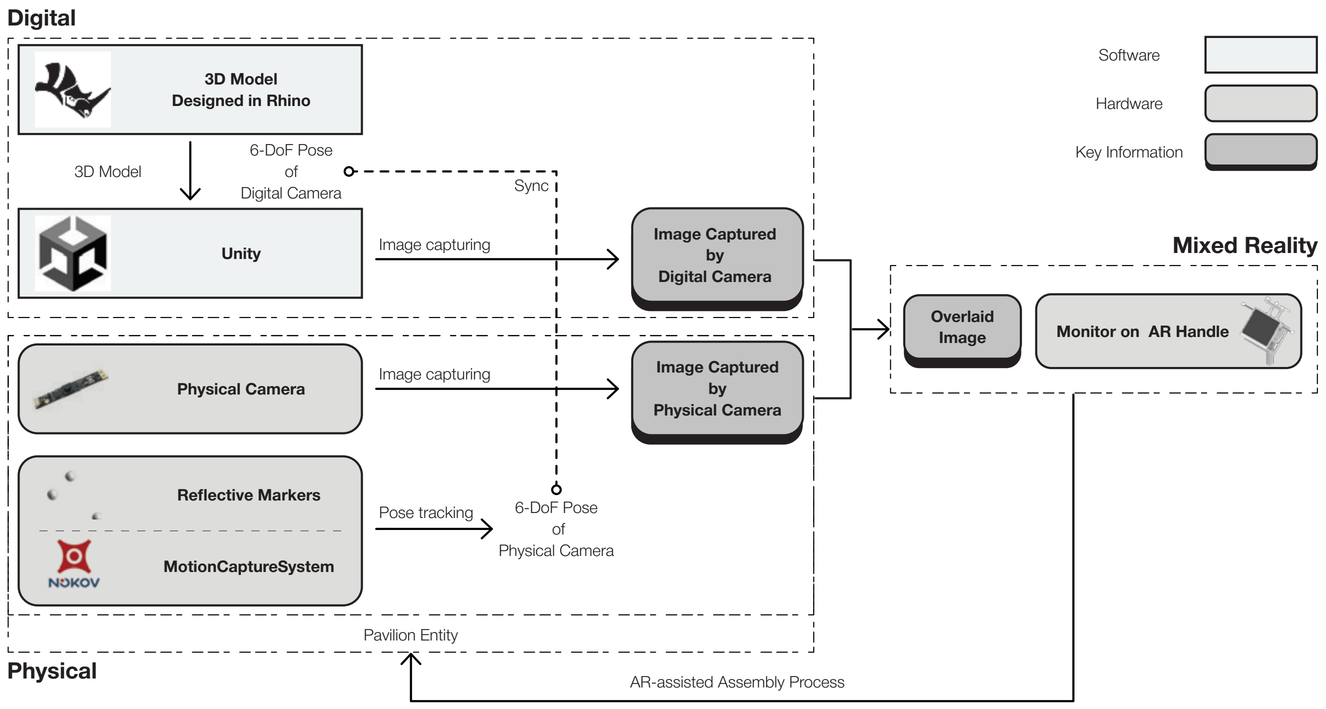
Scattered Tubes

High Accuracy AR-assisted Assembly with Motion Capture System
Tongji University | Spring 2024

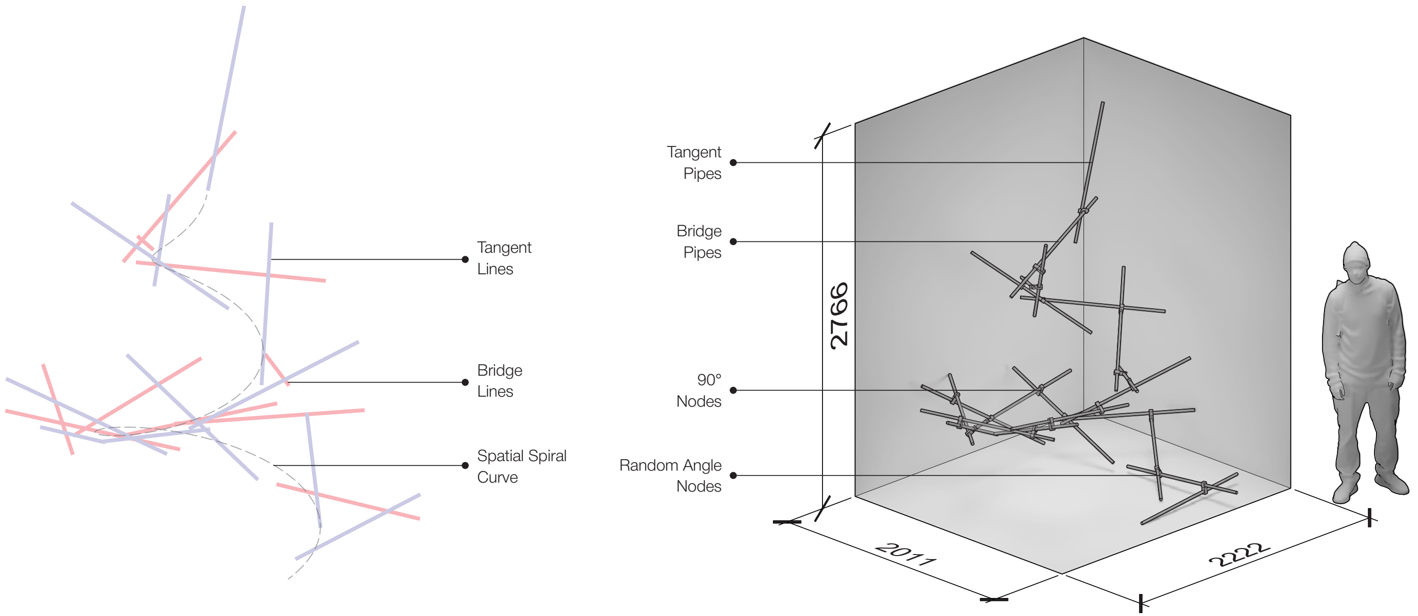
Researcher: Hanning Liu
Collaborator: Xingjie Xie, Yujiao Li
(Team Work) Personal Contribution: Prototype Design, Diagram Drawing, AR-assisted Assembly



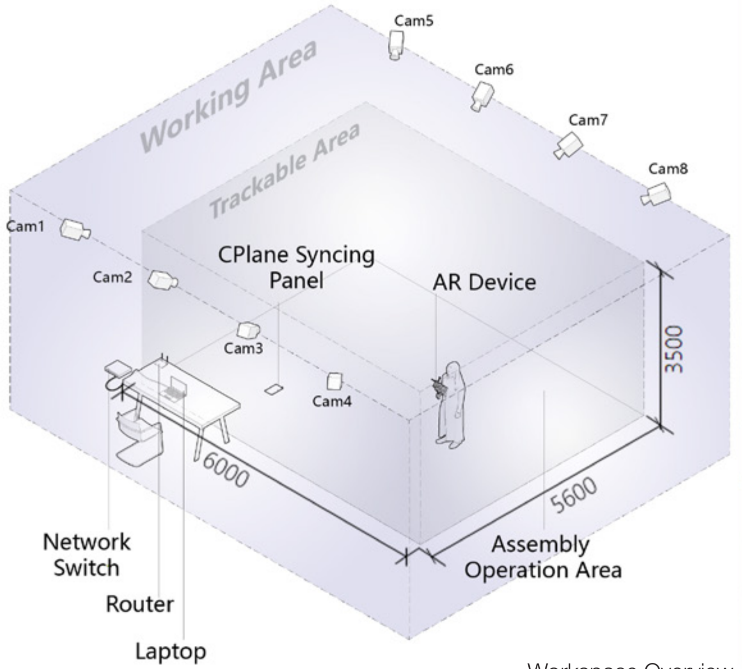
• AR-Assisted Assembly Workflow



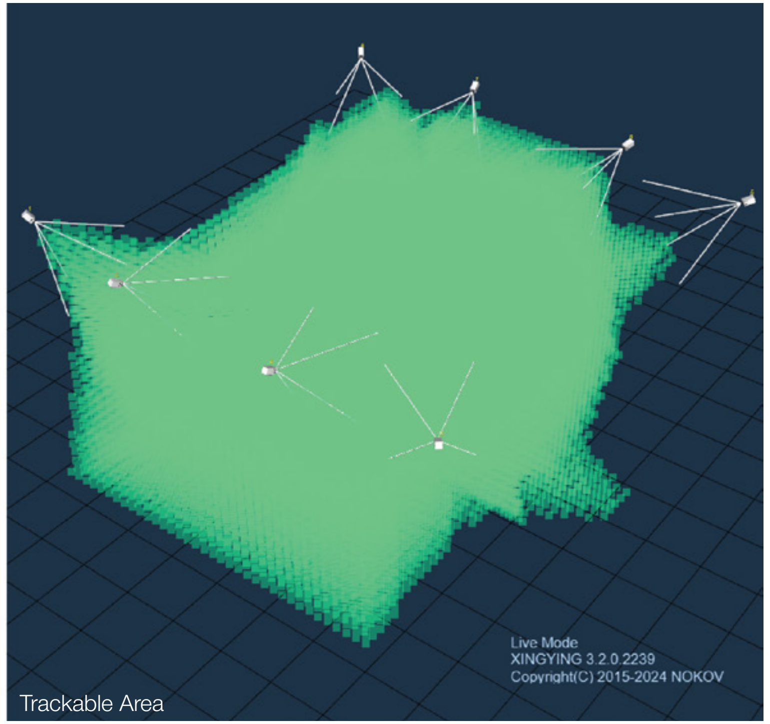
• Case Study Design



• System Setup



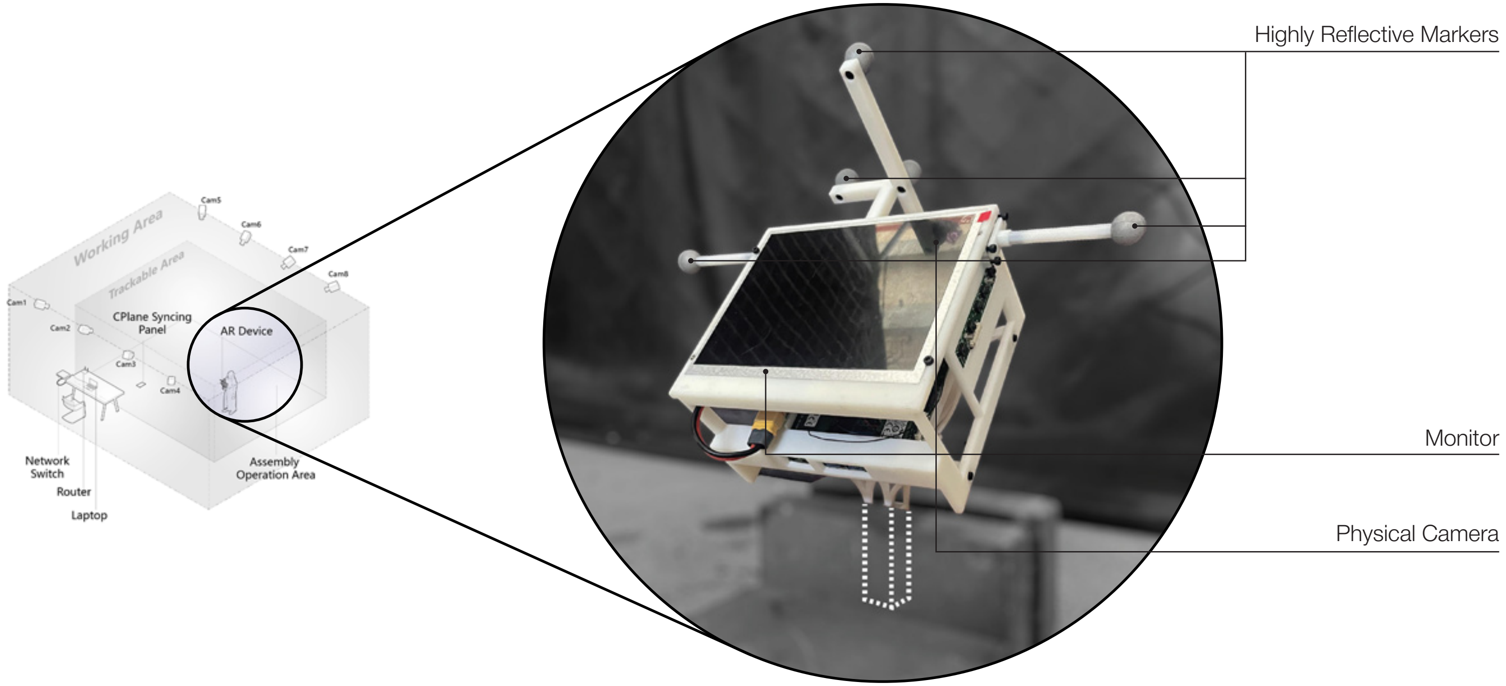
Workspace Overview



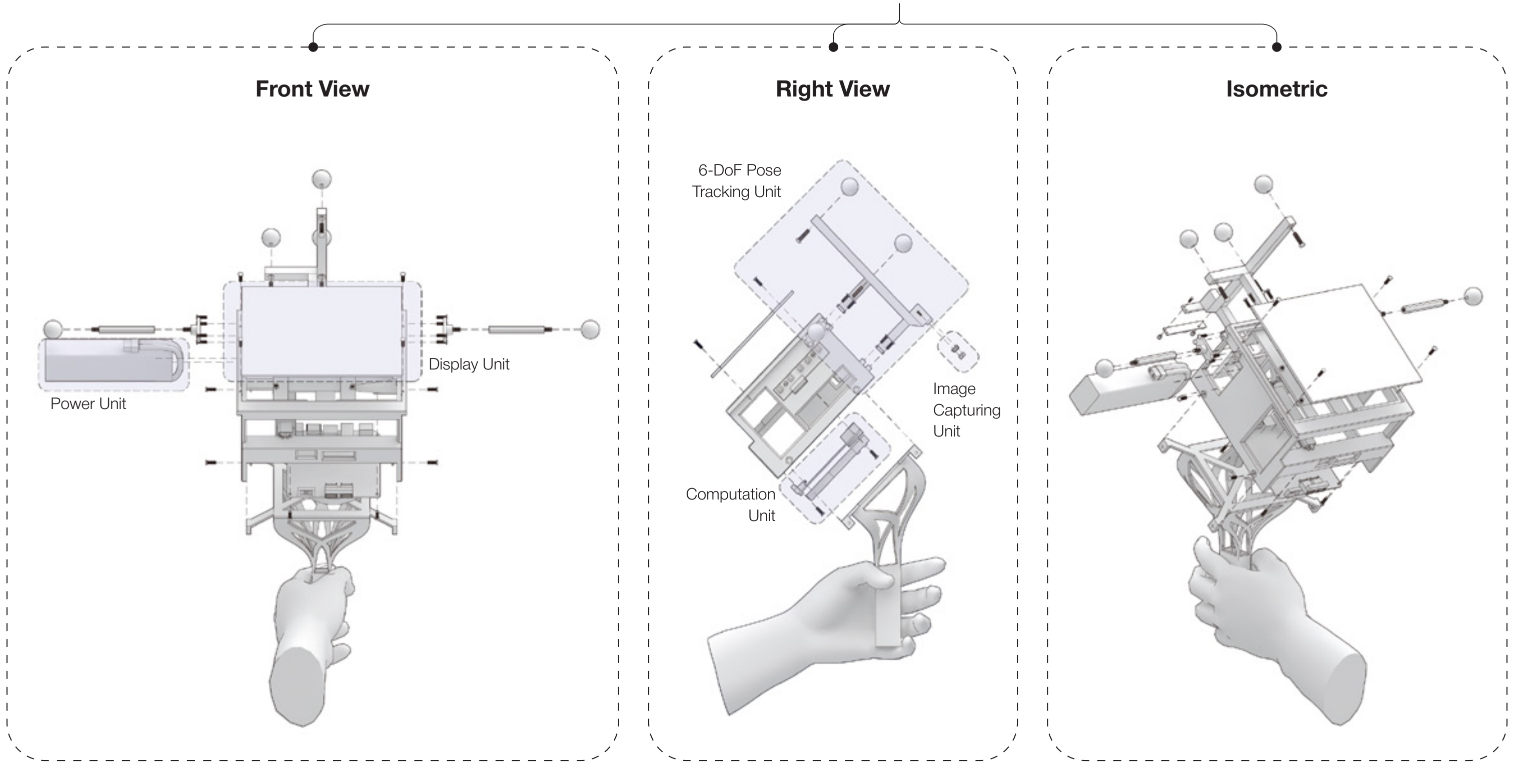
Trackable Area

Key Equipment

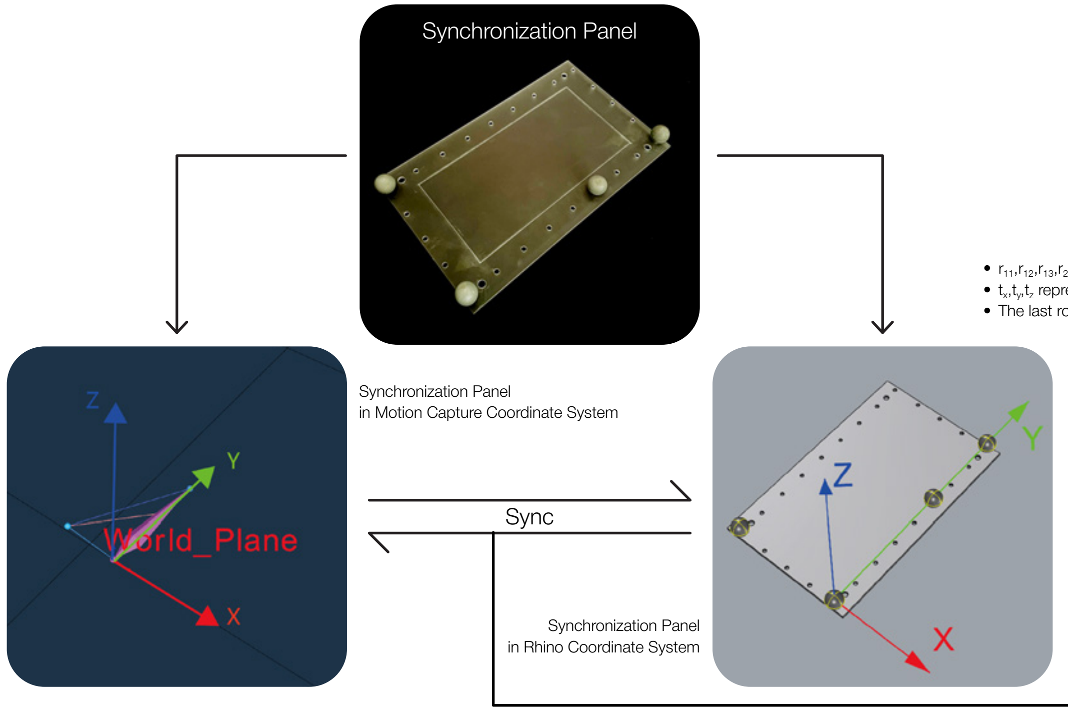
• Customized AR Hardware



AR Device



• Coordinate System Synchronization

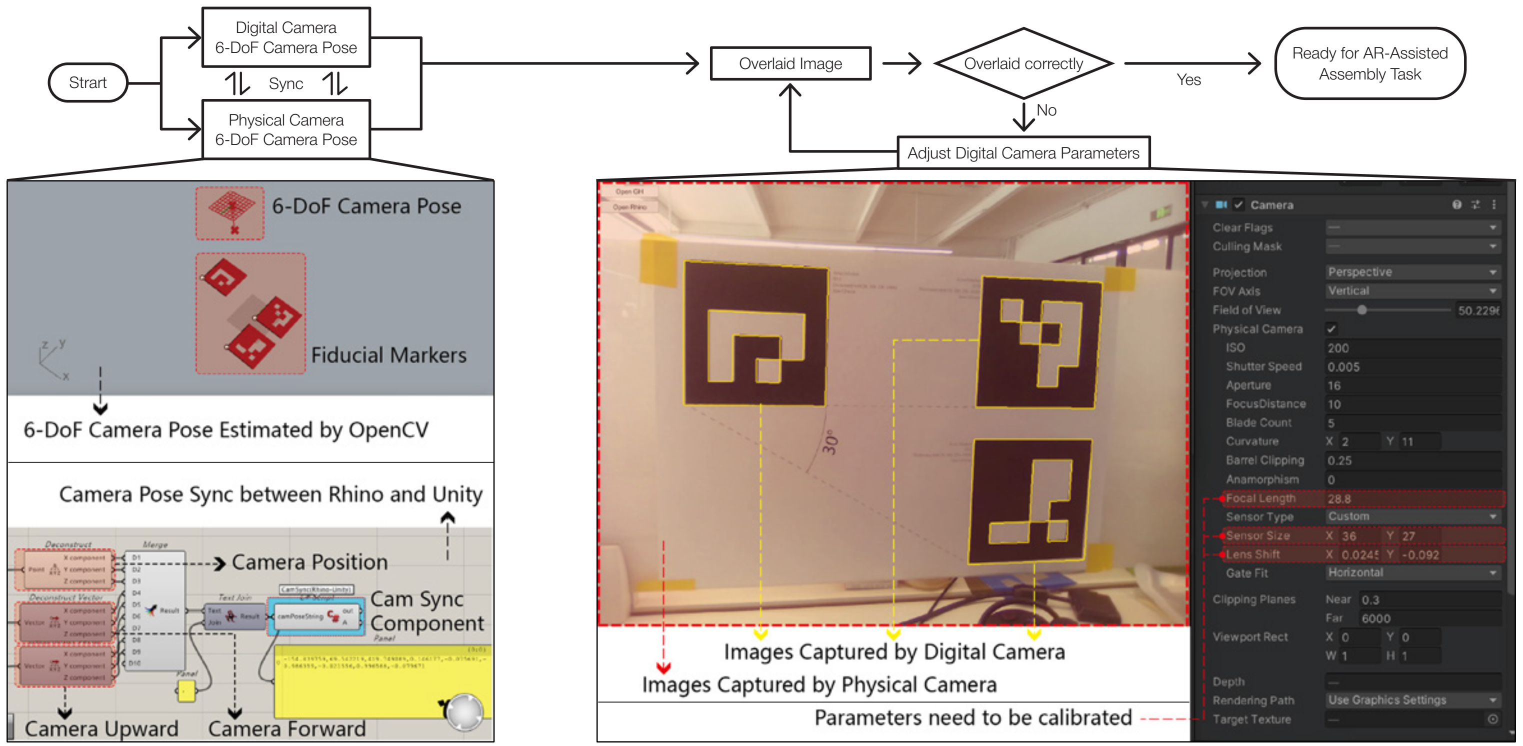


$$\begin{pmatrix} r_{11} & r_{12} & r_{13} & t_x \\ r_{21} & r_{22} & r_{23} & t_y \\ r_{31} & r_{32} & r_{33} & t_z \\ 0 & 0 & 0 & 1 \end{pmatrix}$$

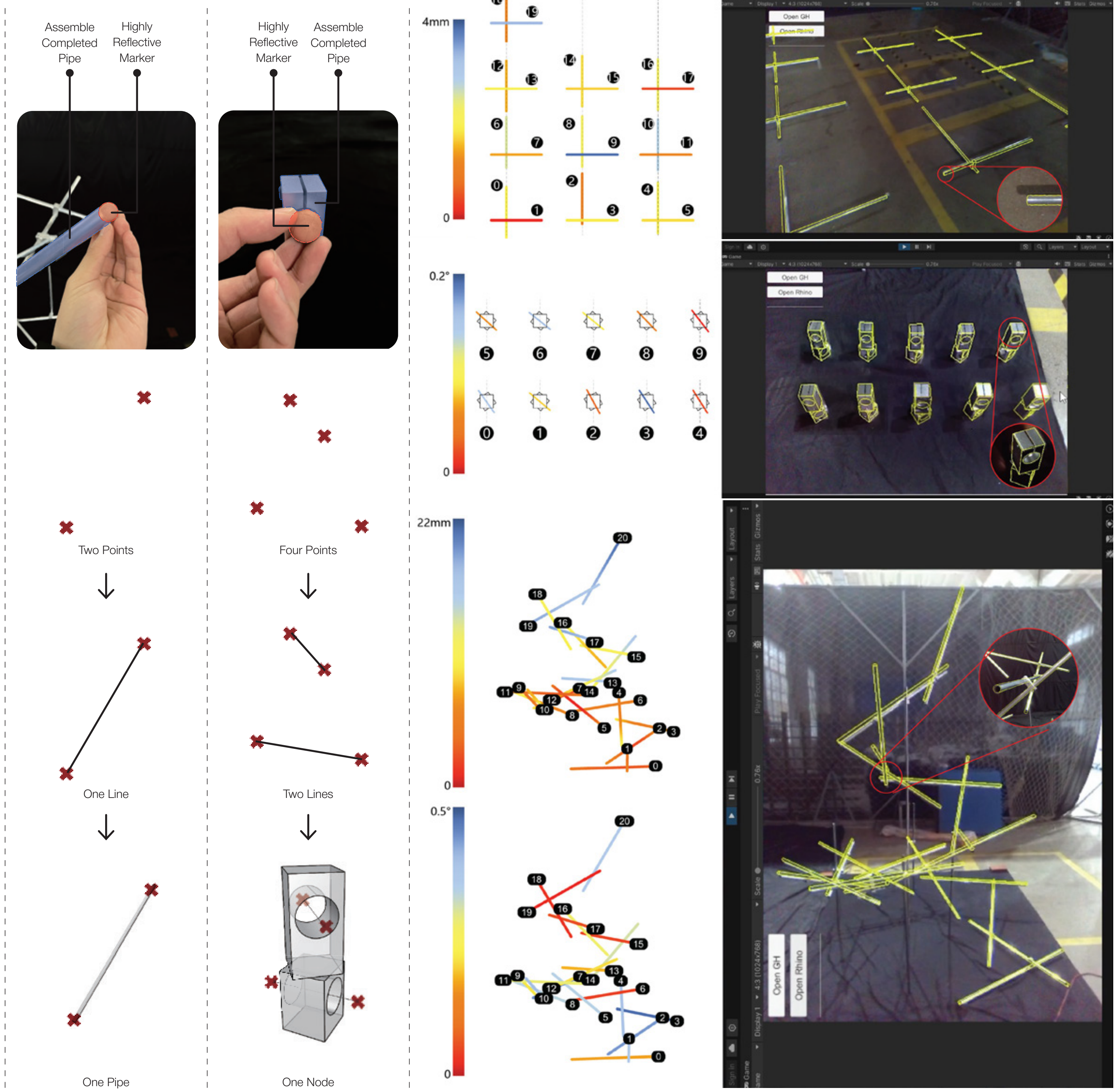
4x4 Transformation Matrix

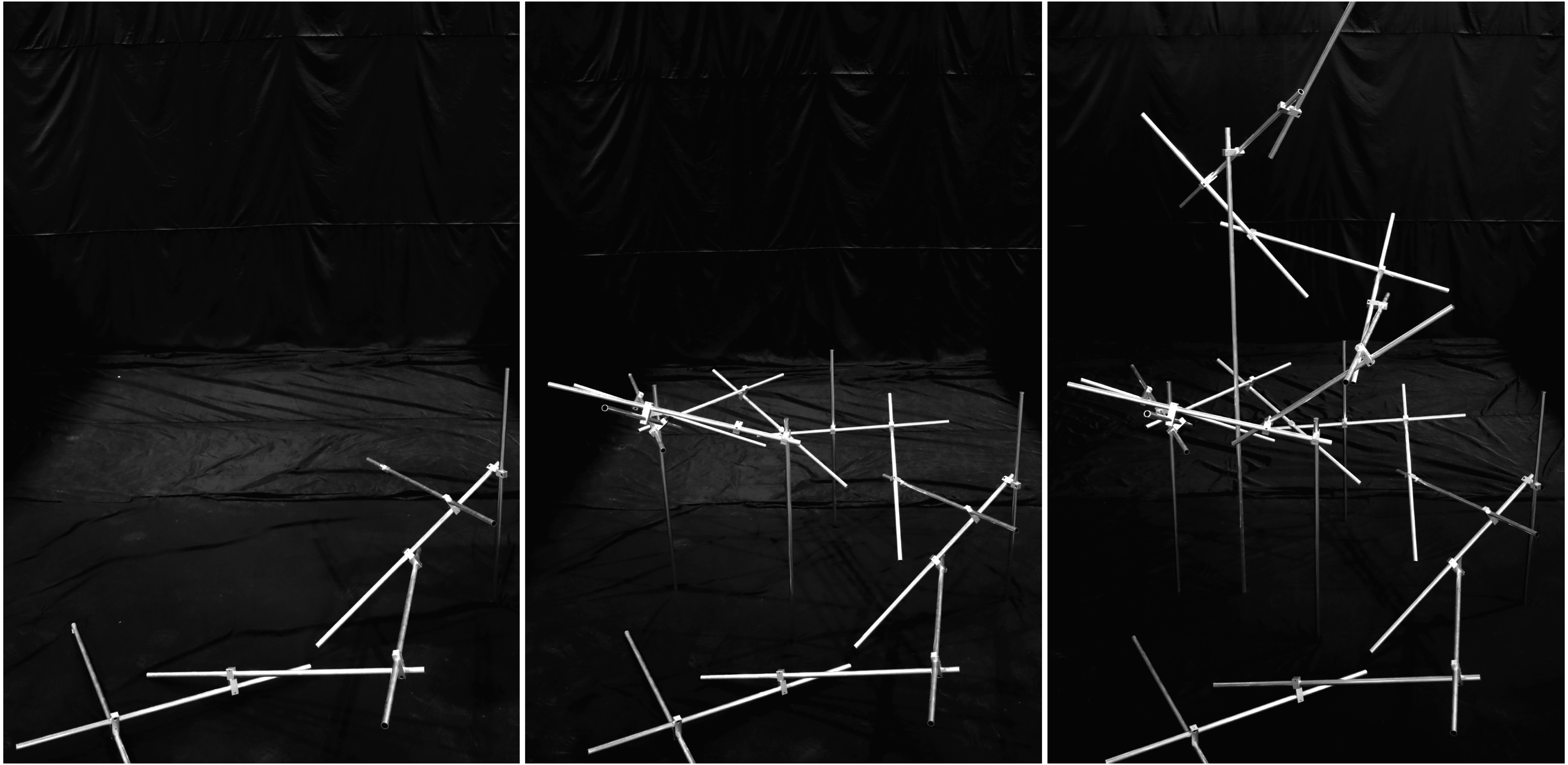
- $r_{11}, r_{12}, r_{13}, r_{21}, r_{22}, r_{23}, r_{31}, r_{32}, r_{33}$ represent the rotation and scaling components.
- t_x, t_y, t_z represent the translation components along the x, y, and z axes.
- The last row ensures that the matrix can be used for affine transformations.

• Camera Parameter Calibration



• Deviation Check



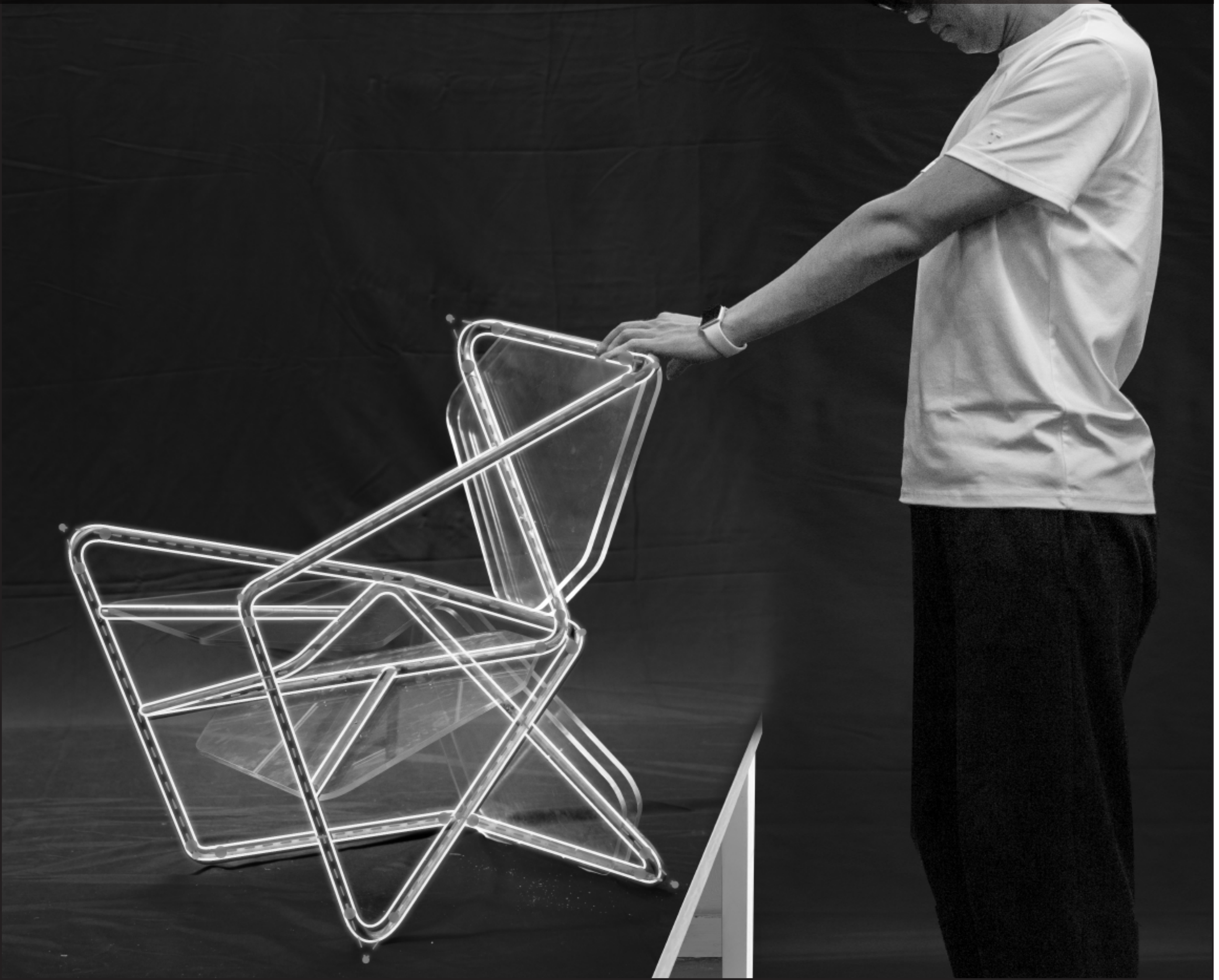


06

Bending Form

Gesture-Based Design and Bending Form Fabrication with XR
Tongji University | Spring 2024

Researcher: Hanning Liu
Collaborator: Chao Yan, Xingjie Xie, Tianyu Zhang, Ruyi Yang
(Team Work) Personal Contribution: AR-assisted Design and Fabrication Tool Development, Diagram Drawing

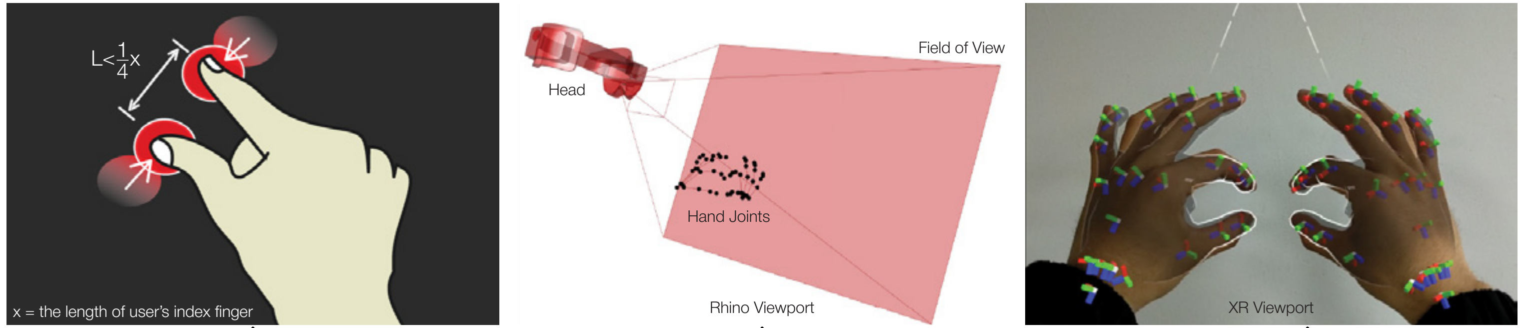


• Comparison of Different Design Methods

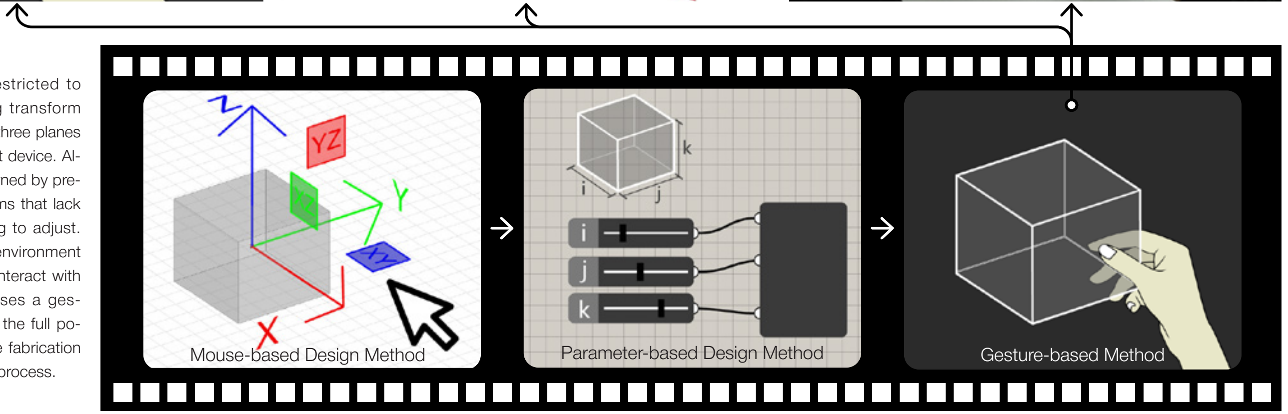
The "pinch" gesture is recognized when the distance between the user's index fingertip and thumb fingertip is less than one-quarter of the length of the user's index finger, a measurement that varies from one individual to another.

The position and oriention of the head could be calculated in real time and displayed in the Rhino viewport. The hand joints of both left and right hand could also be display in the same viewport. And each hand consists of 25 joint points.

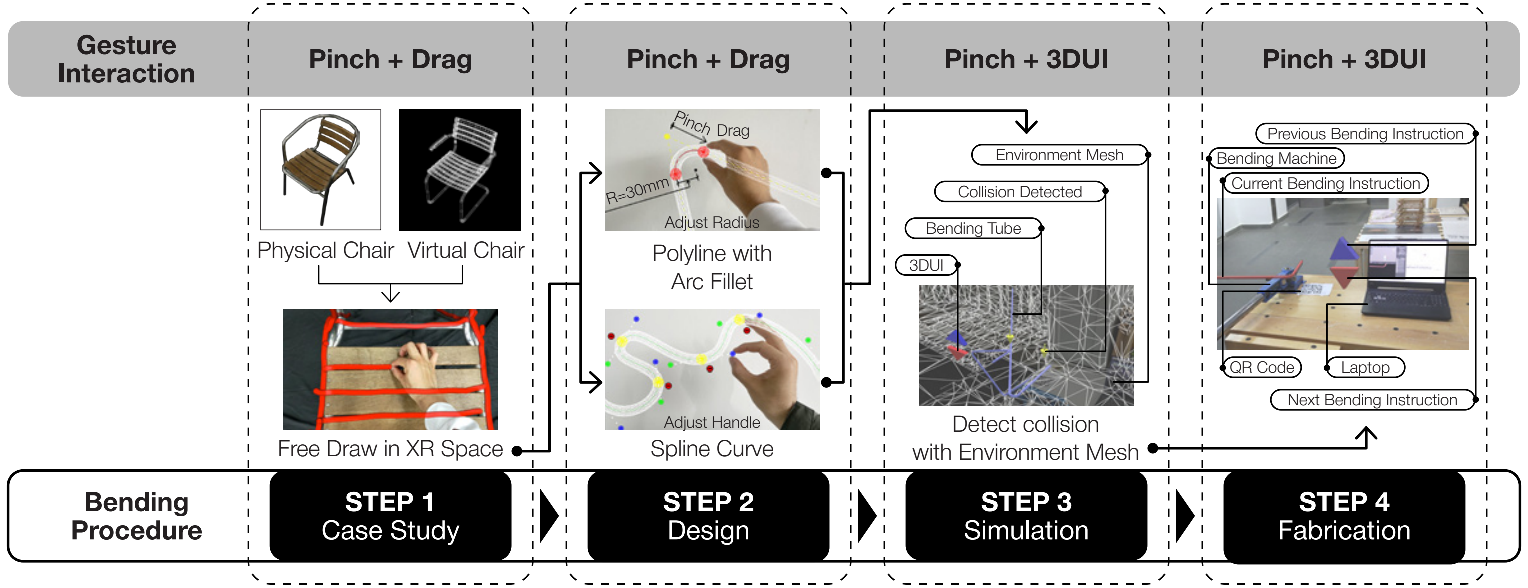
The hands can be detected and displayed as transparent mesh objects. The position and orientation of each hand joint can be represented by a three-axis icon. When a pinch gesture is recognized, the thumb and index finger will be highlighted.



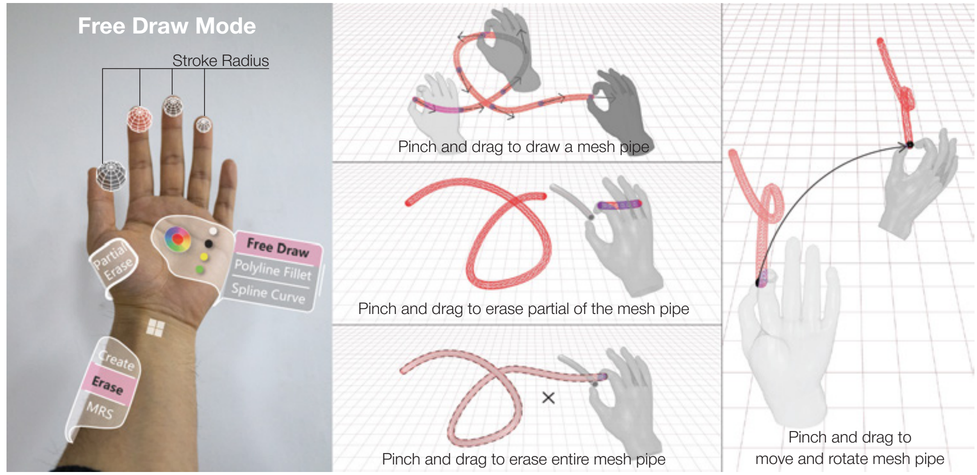
Nowadays design tools are restricted to manipulating geometries using transform manipulator along three axes or three planes with the help of a mouse as input device. Alternatively, designs may be governed by predefined parameters and algorithms that lack intuitiveness and are challenging to adjust. In order to offer an immersive environment where designers can intuitively interact with 3D models, this project proposes a gesture-based workflow to unleash the full potential of XR, facilitating both the fabrication process, and the intuitive design process.



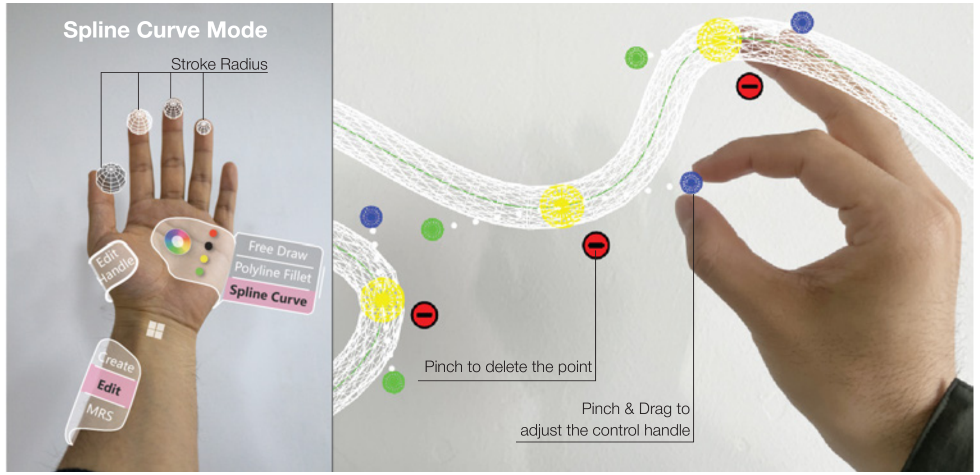
• Bending Form Design and Fabrication Workflow



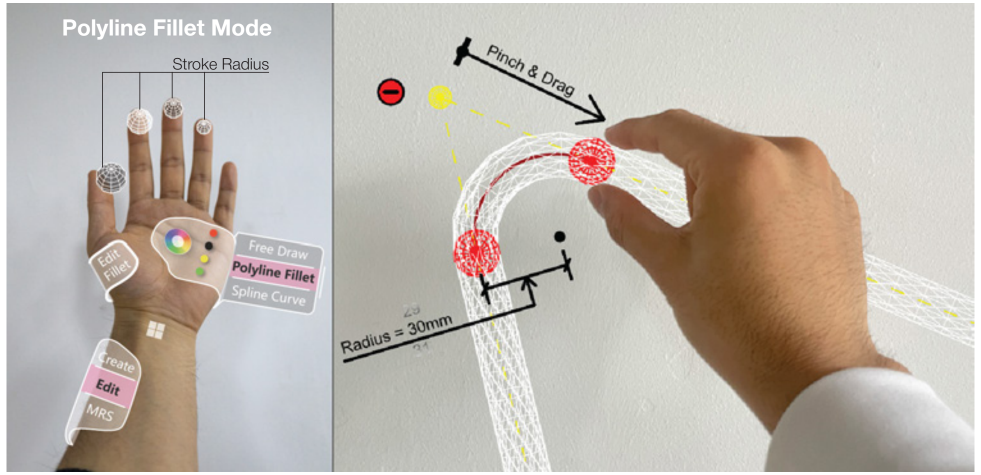
• Three Drawing Modes



Before initiating chair design, designers utilize XR technology to conduct case studies using the "pinch" gesture, "drag" gesture, and the "Free Draw" mode. The hand menu UI of the "Free Draw" mode is meticulously designed to appear on various parts of the hand, such as fingertips, palm, and wrist. A floating white bar will appear at the right side of the palm when the HoloLens sensors detect the left hand's palm. All menu contents will appear after the floating bar is pinched and dragged out. When the "Create" button is activated, designer can pinch and drag in the air to generate new mesh pipes based on the position of the pinch gesture. The new point is recorded only if its distance from the previous point exceeds 8mm, preventing excessive point accumulation which could affect the performance of the software. If the "Erase" button is activated, it automatically switches to "Partial Erase" mode. When the user pinches and drags in this mode, an invisible mesh pipe is drawn to detect collisions with existing drawing strokes. If a collision is detected, the affected portion of the existing stroke will be removed. Alternatively, toggling to "Erase Entire" mode removes the entire existing stroke upon collision detection (Figure 5d). If the "Move, Rotate, Scale" button is pressed, the user can manipulate the mesh pipe intuitively using pinch and drag gestures.

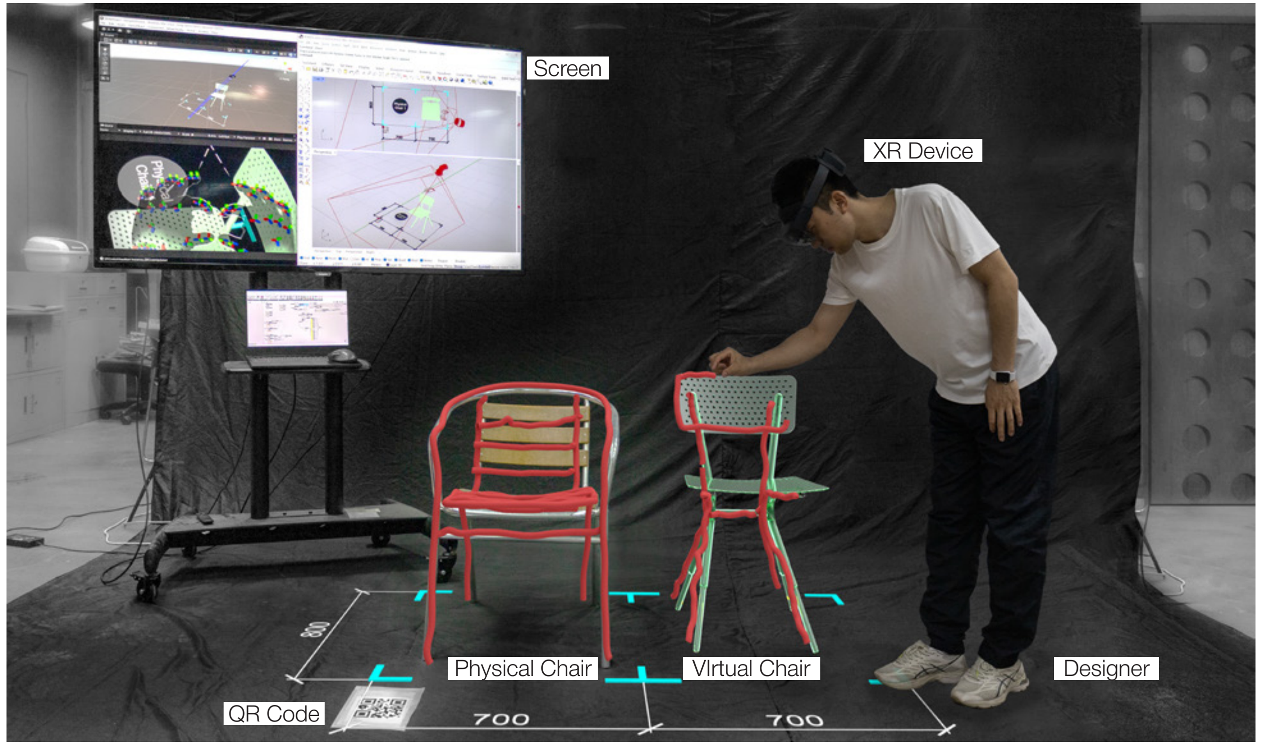


Freeform and streamline design is becoming increasingly popular, necessitating the precise description of complex shapes using spline curves. To cater to this demand, the "Spline Curve" mode has been developed, offering designers advanced tools for creating and manipulating smooth, flowing curves. Users can easily switch to this mode by selecting the third button on the right side of the hand menu. Once in the "Spline Curve" mode, designers can create spline curves by pressing the "Create" button. The system captures the position of the pinch gesture and automatically generates a control handle, which serves as a critical anchor point for the curve. As users continue to pinch and drag, additional control points are created, allowing the spline to form organically in response to the designer's movements. After creating the initial spline, users can refine the curve's shape by selecting the "Edit" button. This action reveals control handles at each point along the spline, enabling designers to make precise adjustments. By pinching and dragging these handles, users can modify the curve's tension and direction, achieving the desired aesthetic and functional outcomes. In addition to editing control handles, designers can delete unnecessary points by pinching the red icon associated with each point, simplifying the curve and reducing complexity.

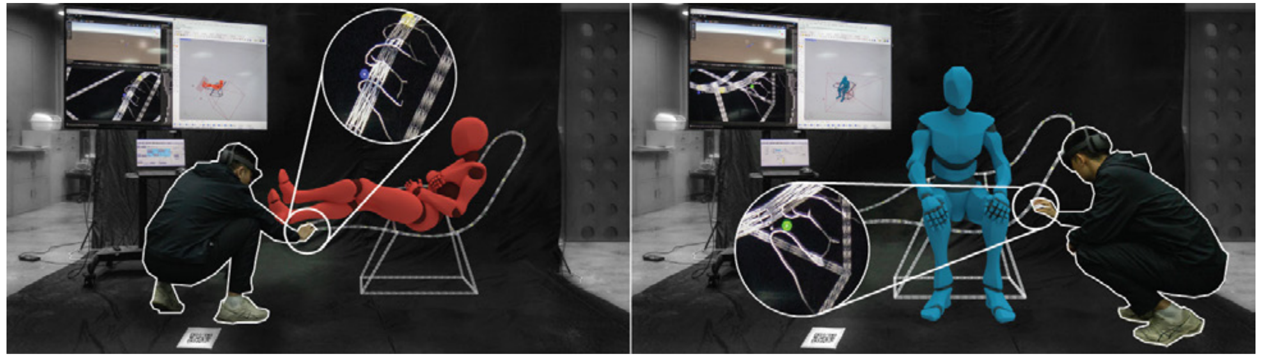


Since steel tube materials are initially straight and require bending to assume spatial shapes, bending machines typically utilize a round-shaped disc to bend the steel tube at a specific radius. Therefore, the "Polyline Fillet" mode is specifically designed to align with this fabrication method. To switch to this mode, select the "Polyline Fillet" option on the hand menu. The "Create" button is activated by default for users to create polyline. The system records the average position between the thumb fingertip and index fingertip upon recognizing the pinch gesture, subsequently drawing a polyline. Users can preview new polyline segments while pinching, with the segment being finalized upon releasing of the pinch gesture. If users need to draw additional polylines, they must toggle between the "Create" button and another manipulation mode before continuing to draw new polylines. The main distinction in the menu compared to the previous "Free Draw" mode is the "Edit" section. Pressing the "Edit" button automatically activates the "Edit Fillet Radius or Delete Point" option. Users can then use pinch and drag gestures to adjust the fillet radius or pinch on the red circle with a dash in the center icon to delete a point from the polyline. To adjust the position of a point on the polyline, users need to switch to the "Edit Polyline" option within the hand menu.

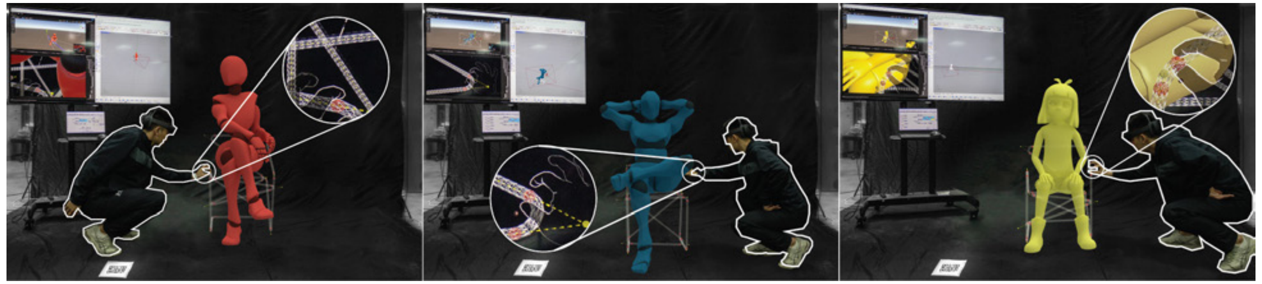
• Practice of Three Drawing Modes



Both physical and virtual chairs can be seamlessly integrated into the XR space at 1-to-1 scale. This enables users to explore the connection details of steel tubes with various materials such as wood plates, plastic, or fabric. For clarity, we present the case study results of two chairs, one representing a physical chair and the other a virtual chair. Besides, the QR code is used to sync the coordinate system between the XR space and the real world, and the designer's view and the real-time pose are synced to the big screen. While we demonstrate on two chairs for illustrative purposes, our study encompassed approximately twenty chairs to find out the average length of steel tubes used. For instance, the steel tube length of the physical chair measures 6.3 meters, whereas the virtual chair has a steel tube length of 3.16 meters. These observations provide valuable insights into the required tube length and the visual impact. This analysis offers a preliminary estimation of the length of tubing necessary to ensure the rationality of the chair design.

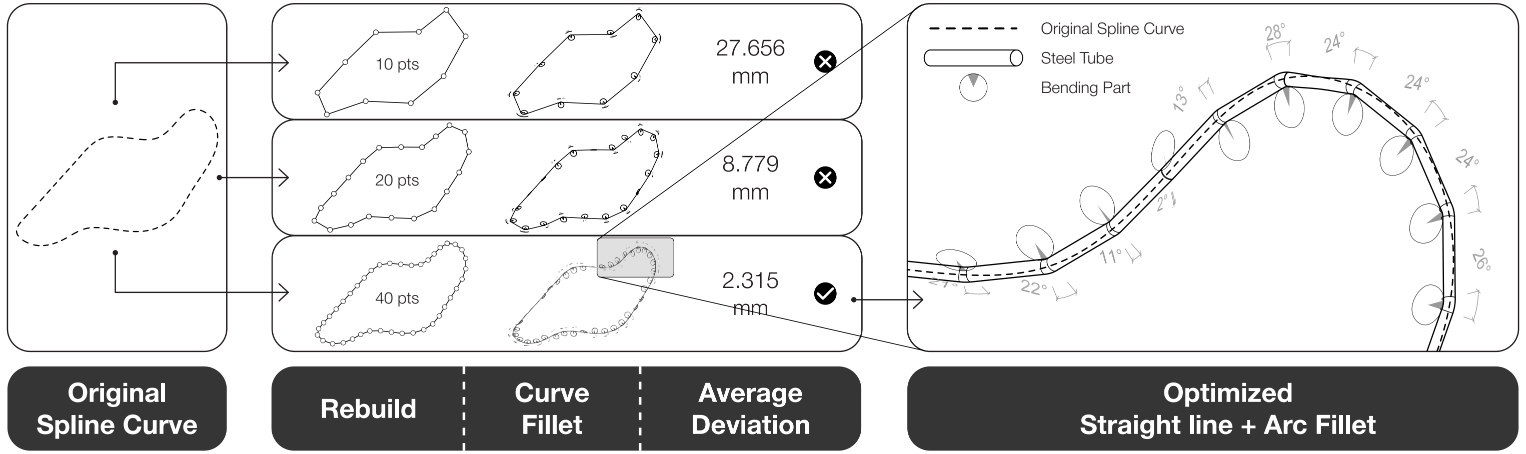


This chair aims to provide a comfortable experience for various postures, including sitting and lying posture. Given the unique requirements of the lying posture, which demands a shape that conforms to the curves of the human body, the "Spline Curve" mode is well-suited for this task. To facilitate the design process, 1-to-1 scale virtual human models are incorporated into the XR space as references. Designer can raise the left hand and switch between "Create", "Edit" and "MRS" mode to finish the design task.

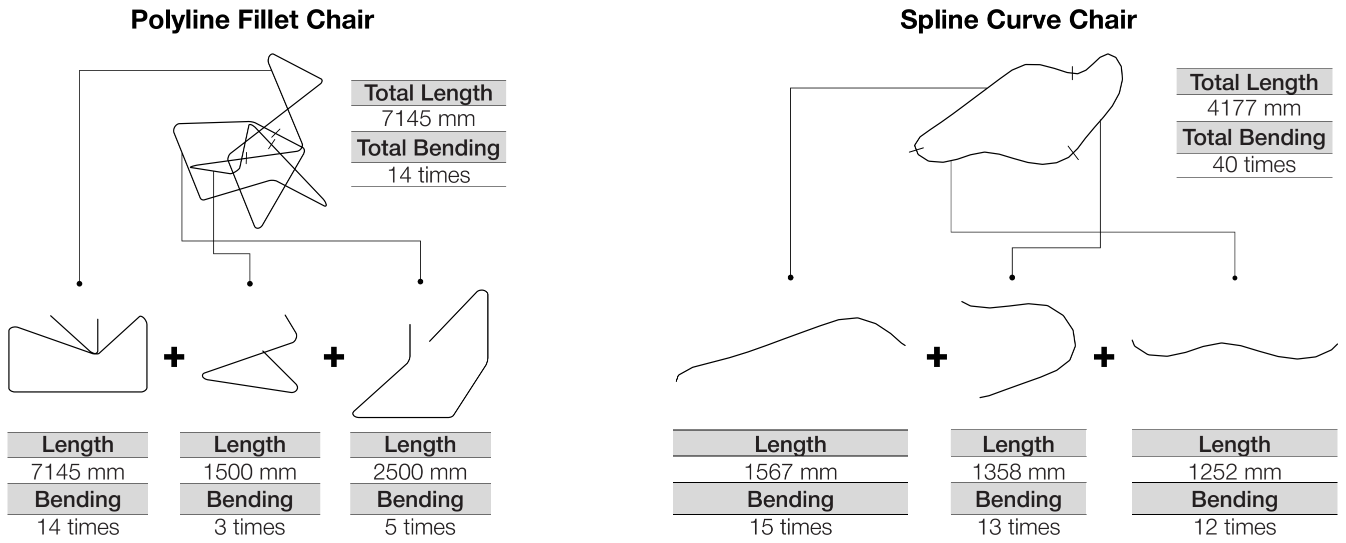


The design strategy for this chair focuses on its mobility and rotatability to accommodate various sitting postures. This approach allows for the adjustment of different sitting surface heights and back surface angles, catering to the diverse needs of users. Leveraging XR technology, 1-to-1 scale human models assume different postures within the XR space, serving as references during the design process.

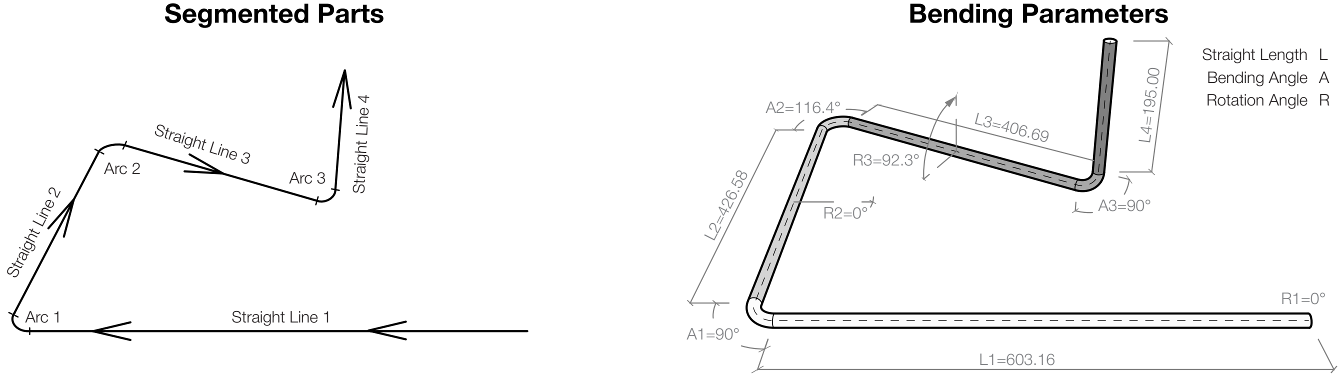
• Optimization of spline curve



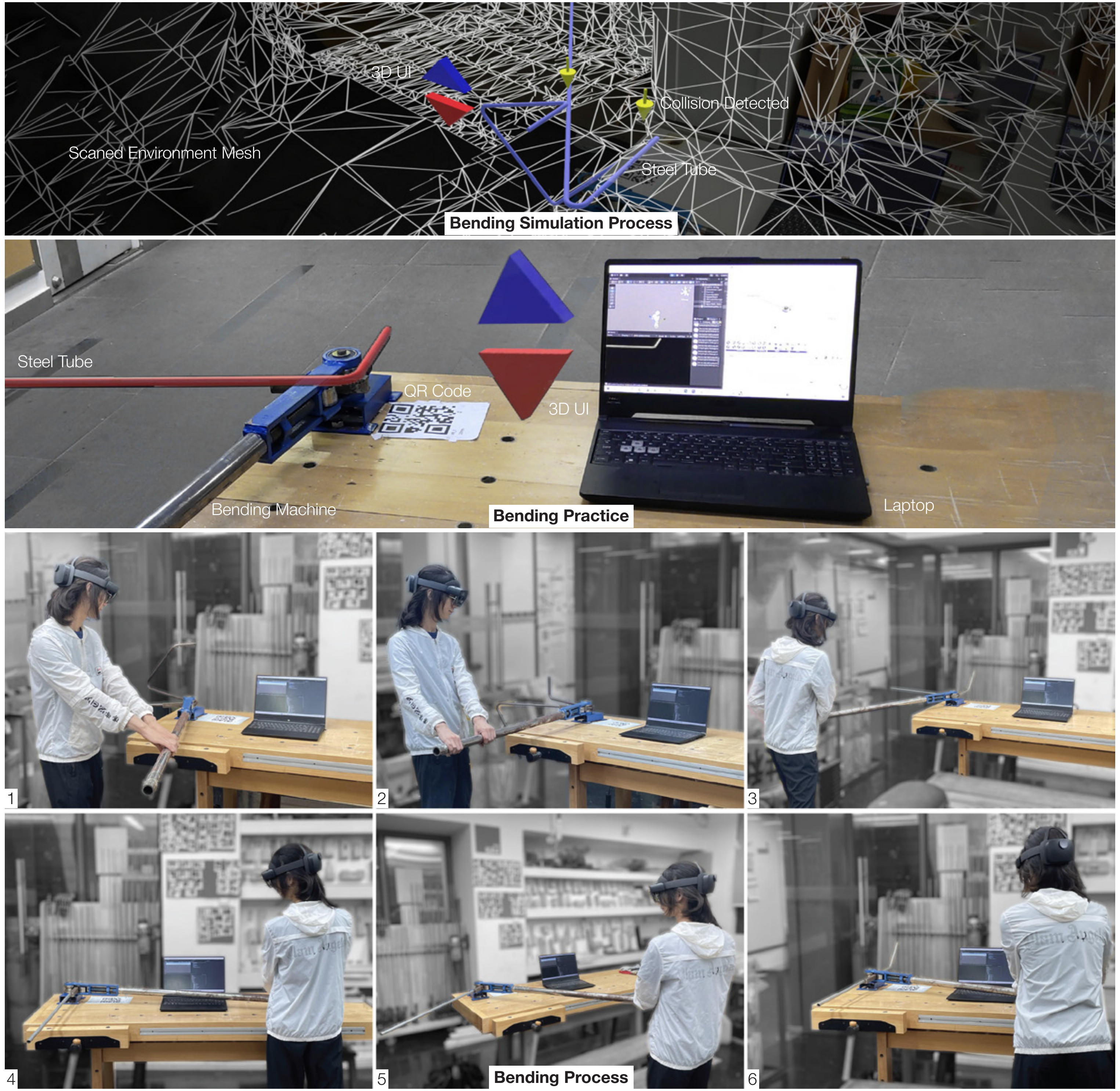
• Segmented Parts for Bending Fabrication.



• Segmented Parts to Bending Parameters



• Bending Simulation and Practice Process







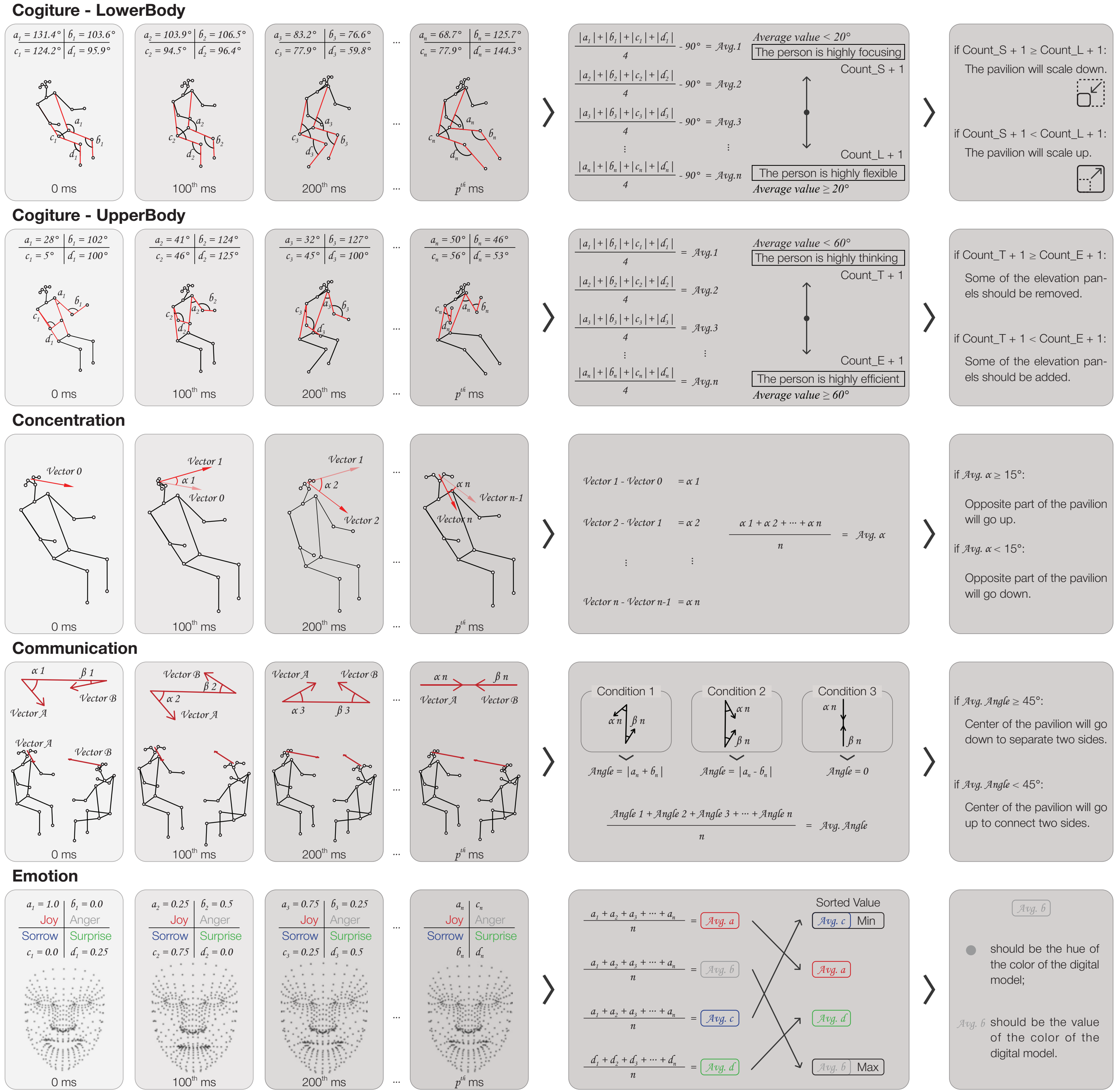

07

SenseBox

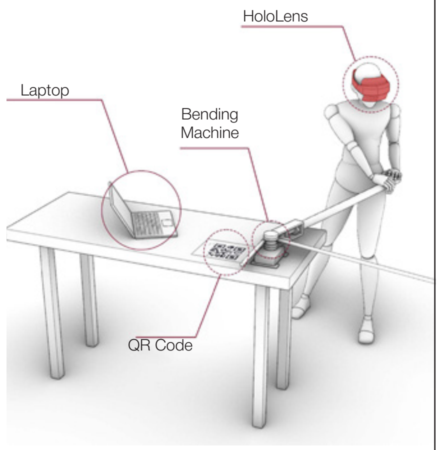
Bending Form Fabrication and Interactive Pavilion with XR and AI
Tongji University | Summer 2024

Researcher: Hanning Liu
Collaborator: Chao Yan, Jintong Li, Tianyu Zhang, Jieshi Chen, Ruyi Yang, Menghang Liu, Luqi Feng
(Team Work) Personal Contribution: AR Tool Development, Interactive Design Idea Proposal, Diagram Drawing

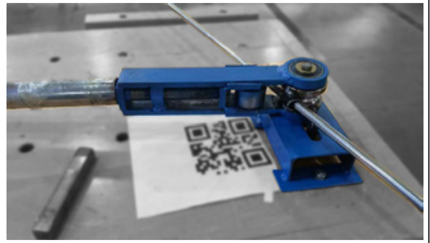
• Human Factors Data Interpretation



• XR-assisted Fabrication

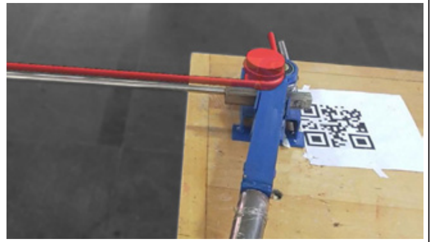


Bending Operation Space



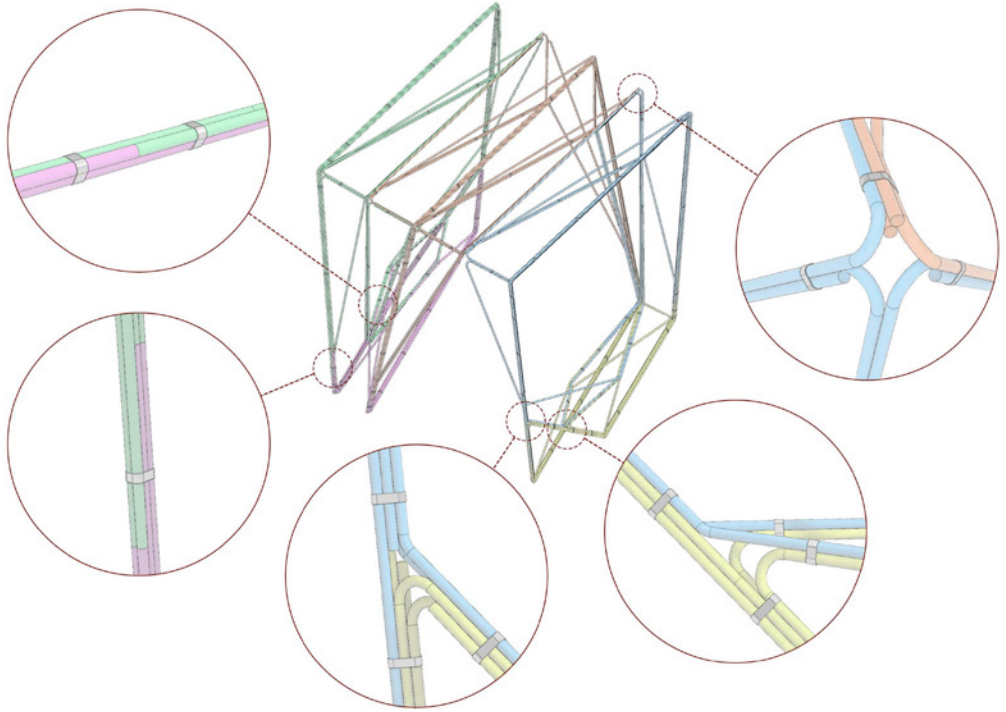
Bending Machine

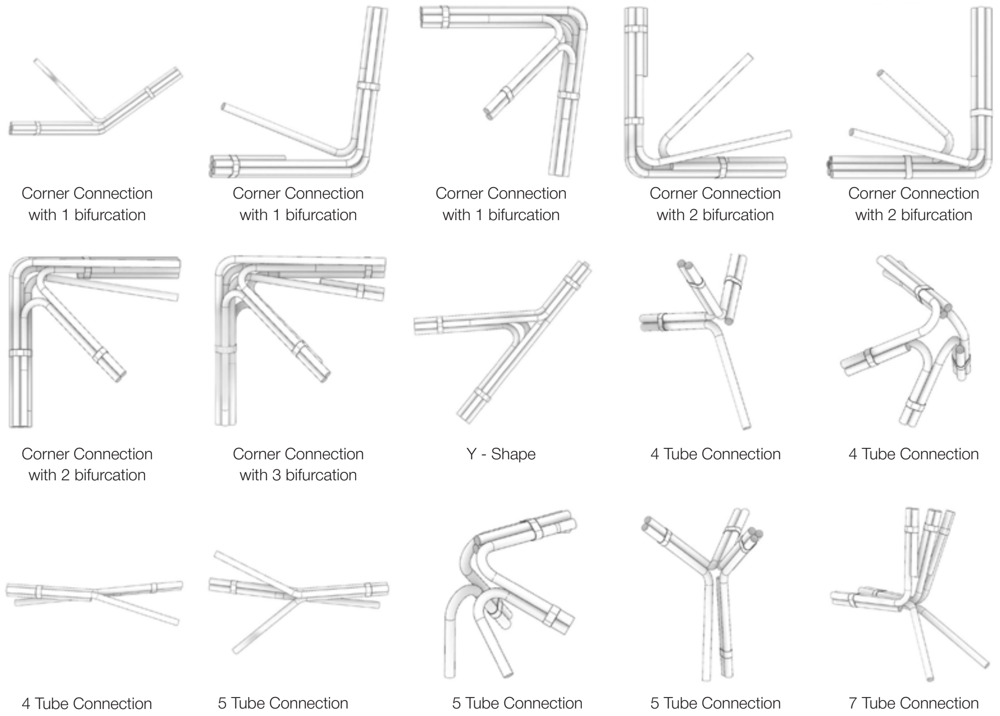
Bending Process



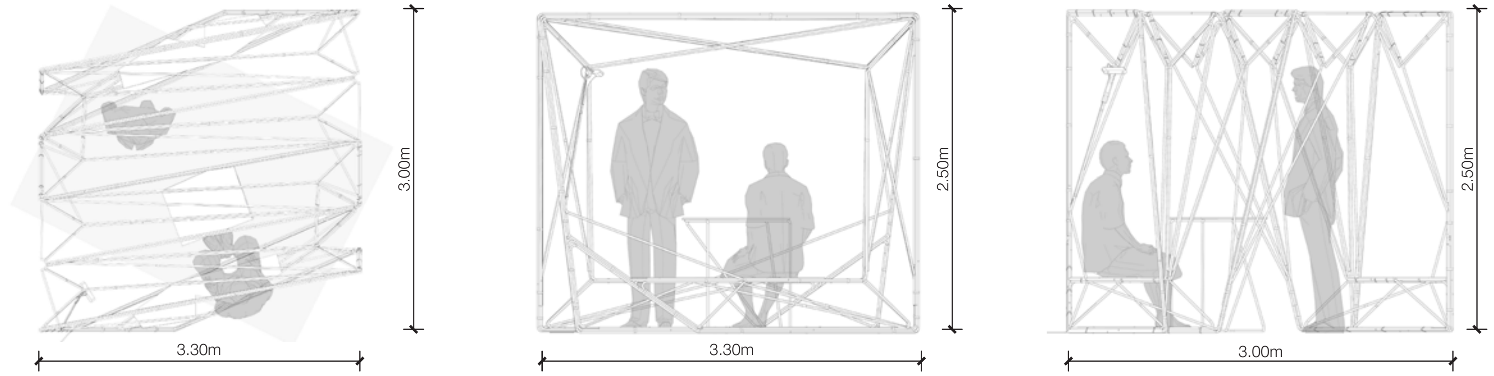
Screenshot of HoloLens

• Connection Detail





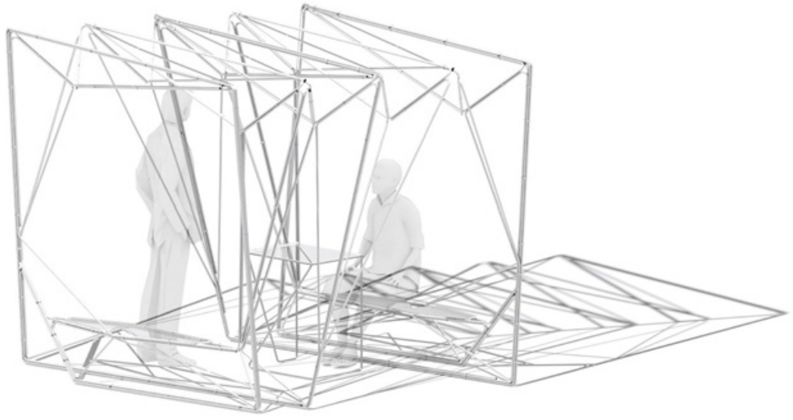
• Schematic Drawings



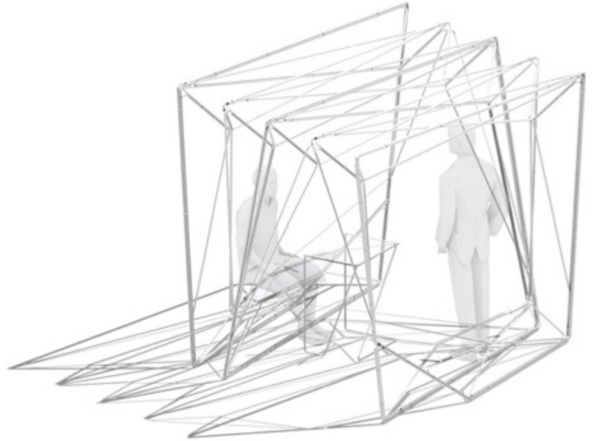
Plan

Elevation Front

Elevation Right

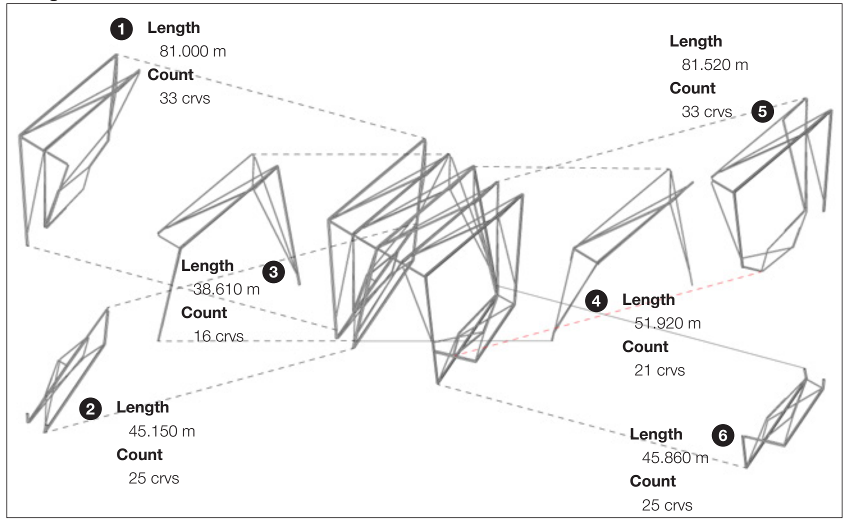


Northwest Isometric



Southwest Isometric

• Segments to Assemble

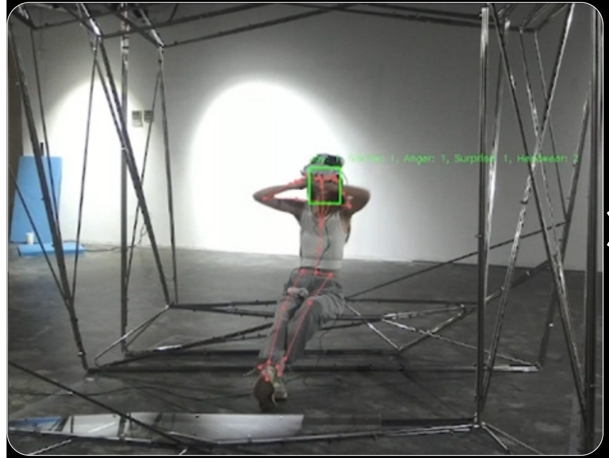


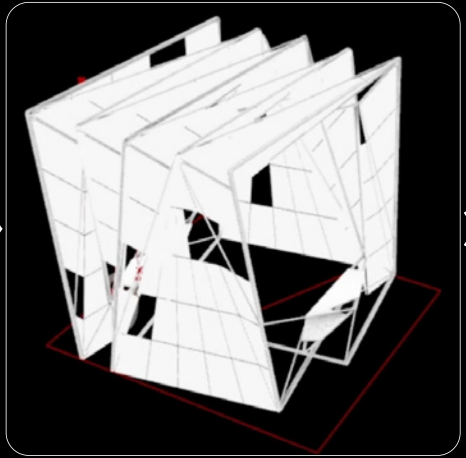
• Assembly Process

• Cybernetics Feedback Loop Workflow

Feedback Loop

Capture Human Behavior in Real World → Interactive Digital Model → Experience with XR Headset





• Digital Model Response Category

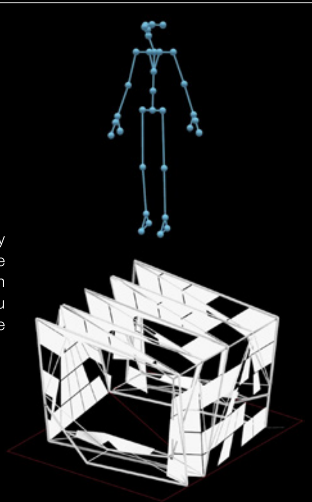
1

Model Property

Spatial
Openness

Response Rule

When your body posture is tired, the space will open up more for you to look into the distance to relax.



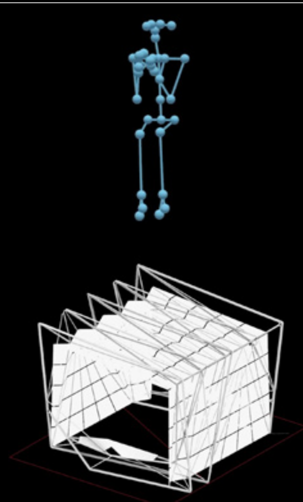
2

Model Property

Enclosure
Regularity

Response Rule

When you are thinking positively, the space will become flatter to reduce interference. When your thinking is lacking, the space will become strange to stimulate your thinking.



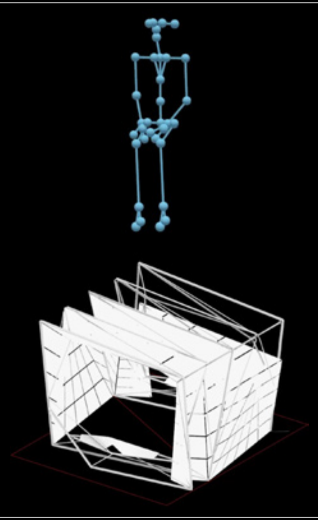
3

Model Property

Contralateral
Height

Response Rule

When you focus, the space on the opposite side decreases to reduce distractions from the outside world.



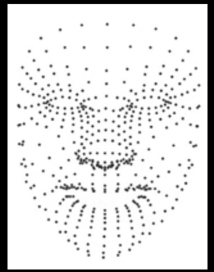
4

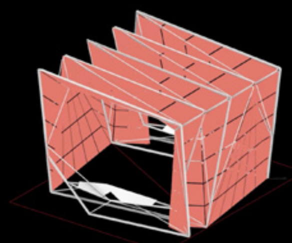
Model Property

Enclosure
Color

Response Rule

The space changes colors according to your mood, and in this way create a positive effect on your mood.





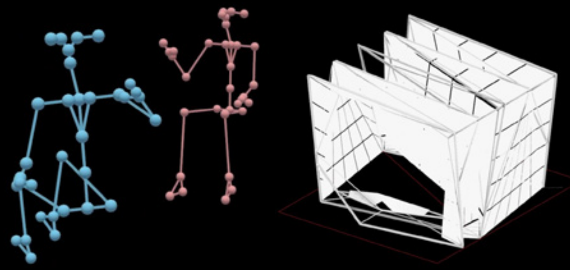
5

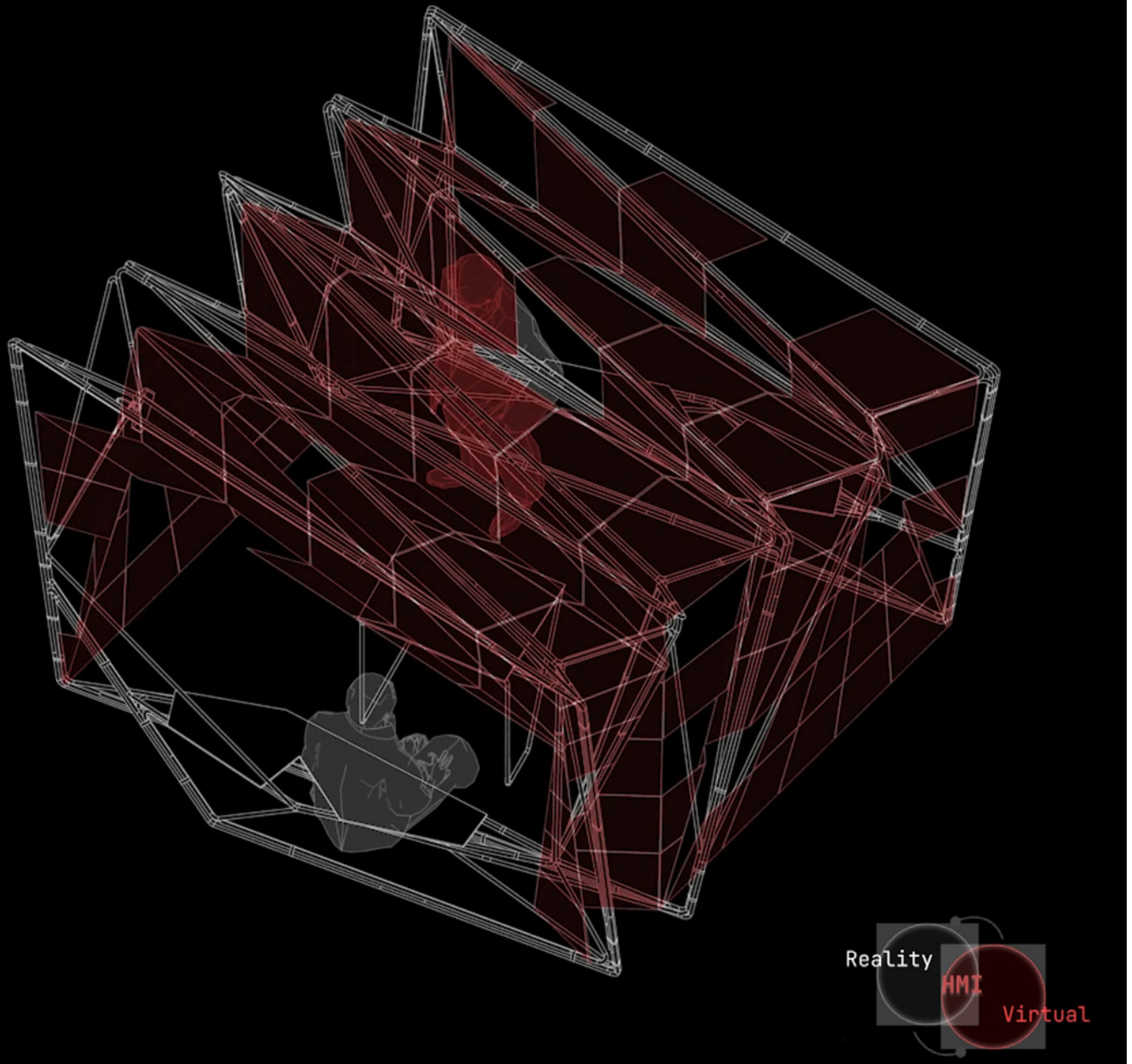
Model Property

Separation
Mode

Response Rule

When you need staying alone, it will create a separation. When you need disscussing, the separation will disappear.





08

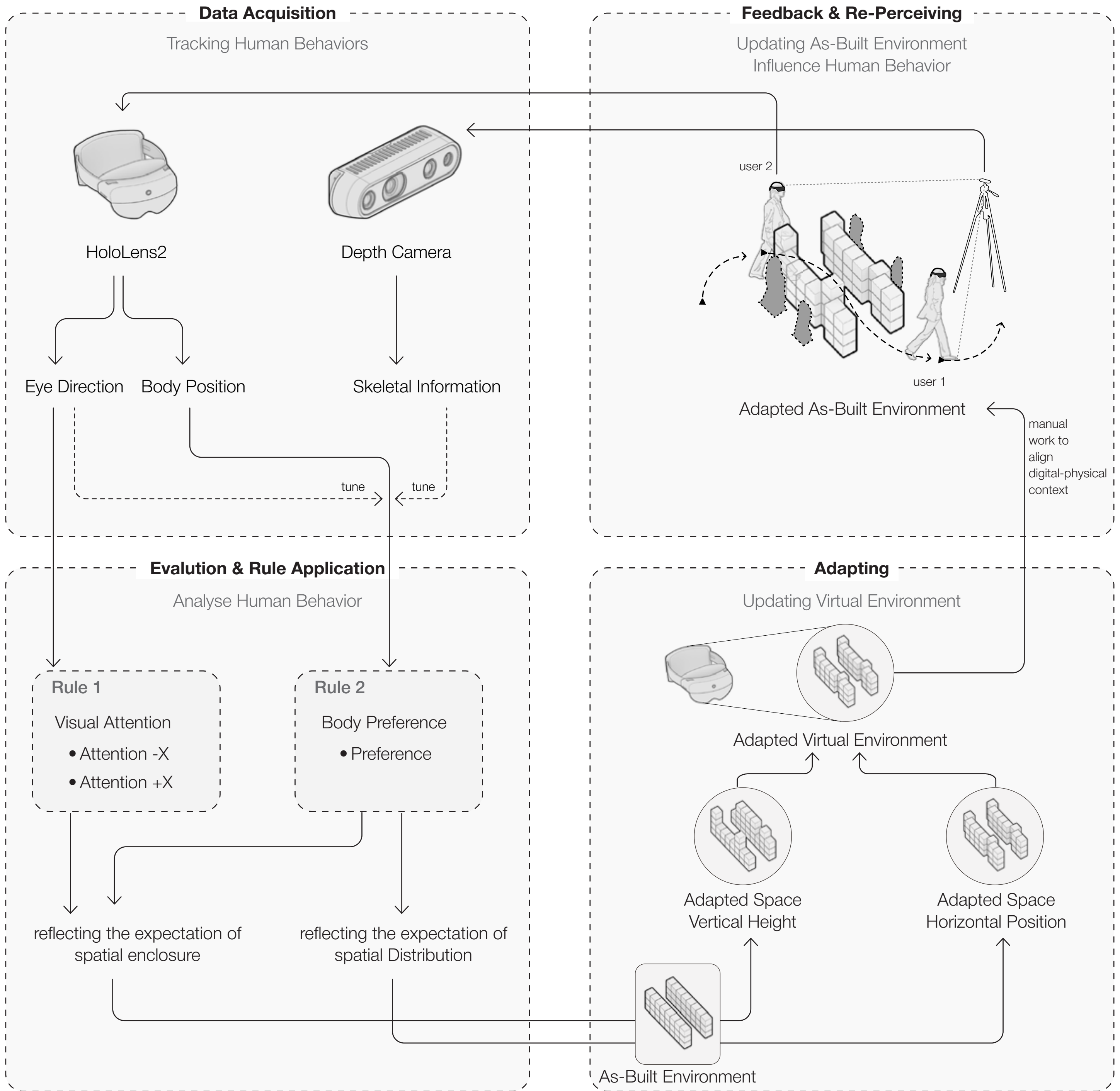
Dynamic Blocks

The Co-evolution of Visitor and Built-environment in Exhibition Space
Tongji University | Summer 2024

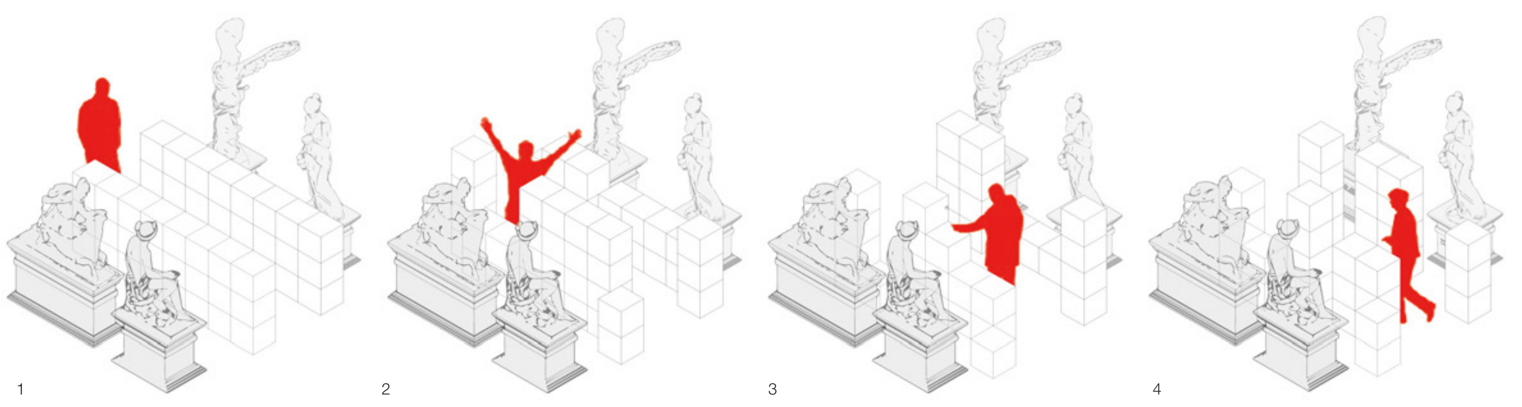
Instructor: ChaoYan, Hanning Liu, Te Li
Team: Yuhao He, Xiaojie Wang, Weixian Jian, Xlaoxu Leng, Yutong Tang, Koyu Chi, Jiarong Li, Ruihan Gui, Yue Wu, Kexin Hu, Ziru Wei
(Team Work) Personal Contribution: AR Tool Development, Design Idea Proposal, Experimental Implementation

• Cybernetics Feedback Loop Workflow

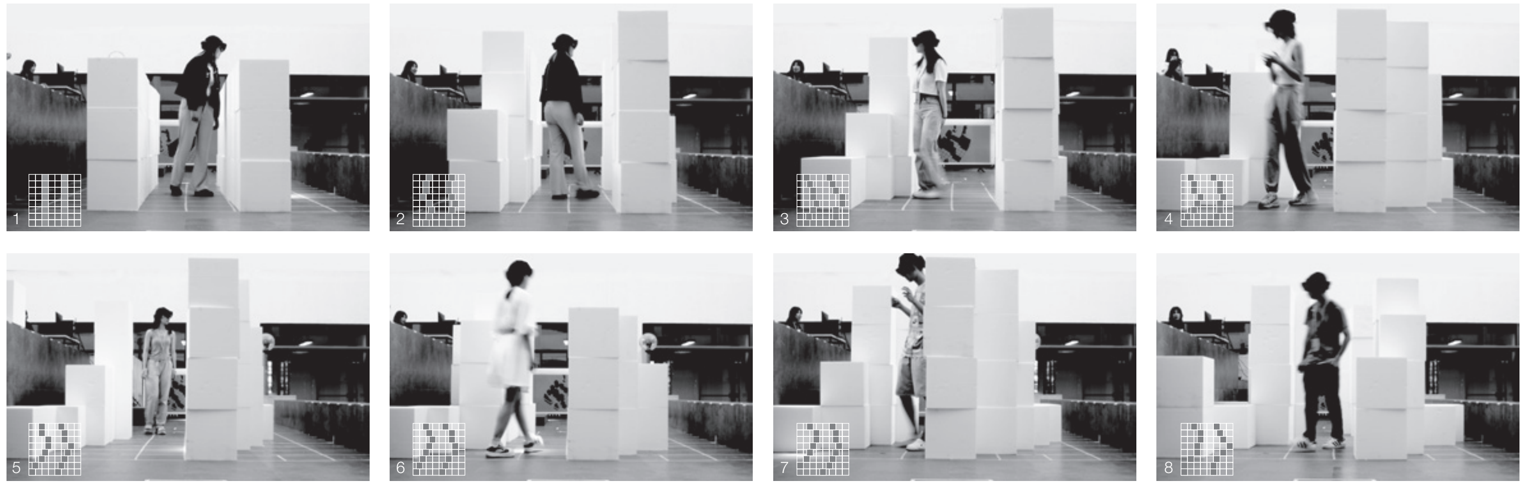
The continuous mutual influence, change and adaptation of people and the built environment leads to a process of co-evolution for both sides.



• Experiment Process



• Photos of Experiment Process



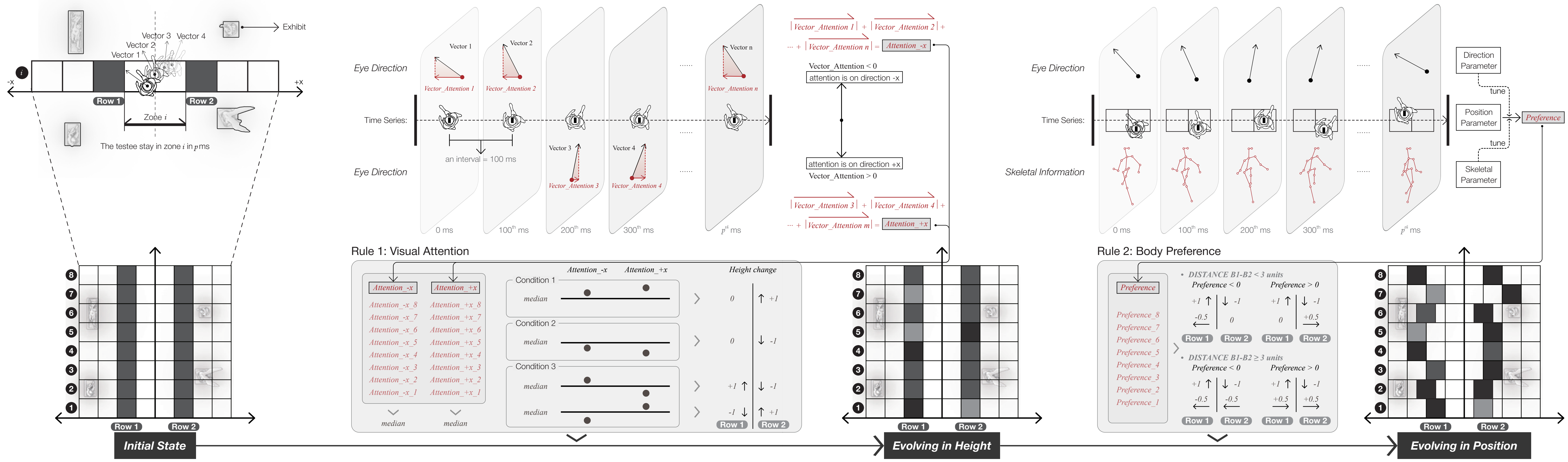
• Spatial Behavior Computation

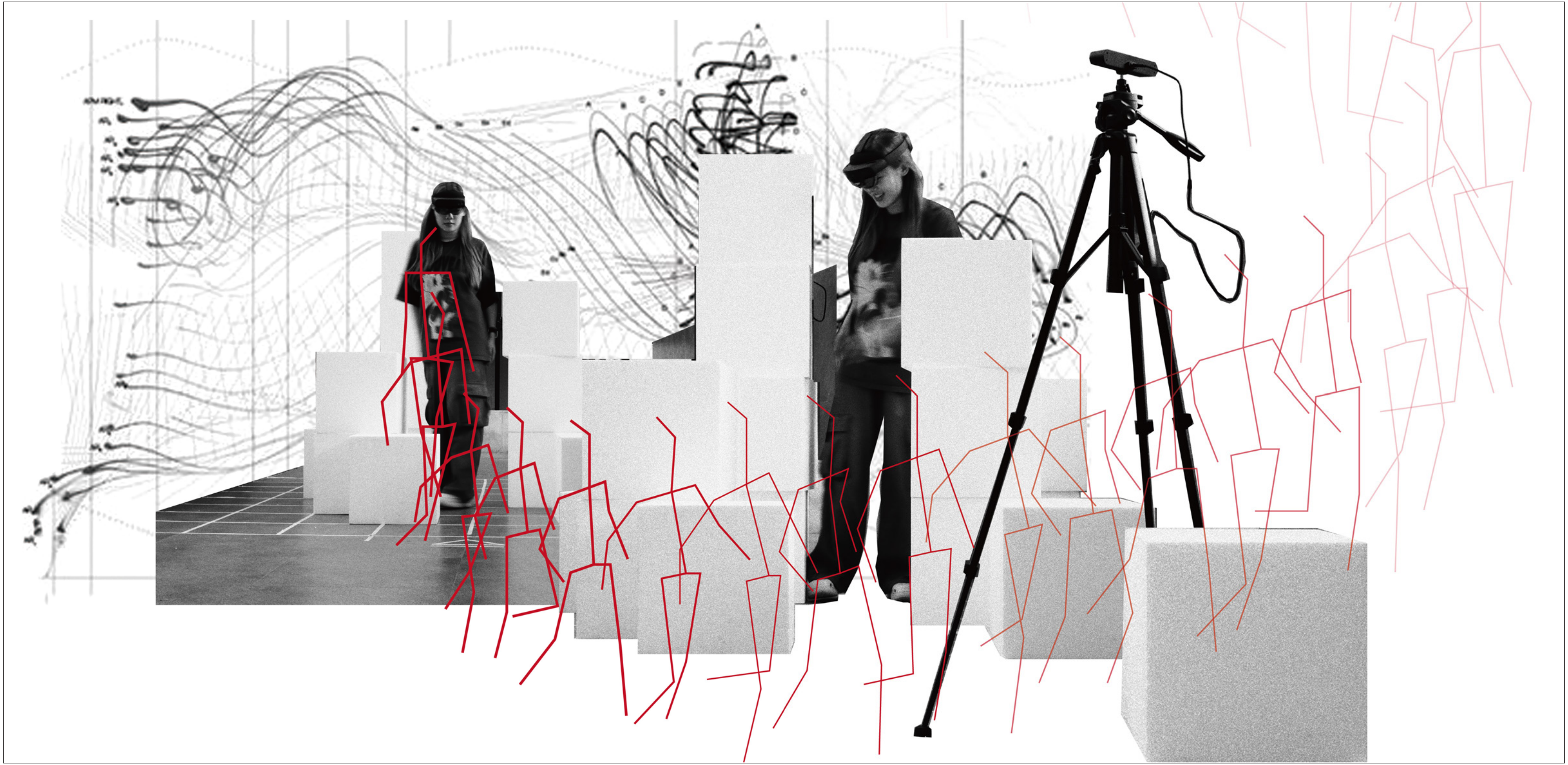
1/ Quantifying visual attention

vector_Attention n : projection of the unit vector of the line of sight in the x-axis direction
vector n : the unit vector of the line of sight

2/ Quantifying body preference

Preference n : Eye Direction, Body Position, and Skeletal Information influence the Preference simultaneously. The Body Position parameter has the largest weight.





Hanning Liu

Tongji University
College of Architecture and Urban Planning
NO.1239 Siping Road, Shanghai, P.R. China

Tel. (+86) 187-2939-0225
E-mail: liuhanning@tongji.edu.cn
Website: hanning-liu.github.io

EDUCATION

Tongji University **Sep. 2022 - Jun. 2025 (Expected)**
Master of Architecture (M.Arch) *Shanghai, China*
Thesis: "Improving Accuracy in AR-Assisted Plastic 3D Printed Panel Assembly"
Advisor: Philip F. YUAN
GPA: 4.81/5

Xi'an University of Architecture and Technology **Sep. 2017 - Jul. 2022**
Bachelor of Architecture (B.Arch) *Xi'an, China*
Overall GPA: 3.93/5 Ranking: 3/192

PUBLICATIONS

1. **H Liu**, C Yan, X Xie, T Zhang, R Yang, H Wu, Y Zhang, PF Yuan*, "Bending Form in Extended Reality: A Gesture-Based Workflow of Chair Design and Fabrication", (accepted by ACADIA **2024**).
2. **H Liu**, X Xie, Y Li, X Gao, H Wu, Y Zhang, PF Yuan*, "Leveraging Motion Capture System for High Accuracy AR-Assisted Assembly" (accepted by the 6th International Conference on Computational Design and Robotic Fabrication (CDRF)), **2024**. **(BEST PAPER AWARD)**
3. H Chai, L Orozco, F Kannenberg, L Siriwaedena, T Schwinn, **H Liu**, A Menges*, PF Yuan*, "Agent-Based Principal Strips Modeling for Freeform Surfaces in Architecture", *Nexus Network Journal*, 26: 369–396, **2024**.
4. PF Yuan*, **H Liu**, "Spatial Implementation of Behavioral Performance: Tourist Center of Shanghai Xuhui West Coast", *Chinese and Overseas Architecture*, 01: 8-13, **2024**.
5. J Wang, **H Liu**, L Qian, H Wu, X Xie, M Yuan, PF Yuan*, "Prestressed 3D Printed Reinforced Concrete Composite Structure Design and Construction: A Case Study of Experimental Bridge Building", In 2023 *Computational Design Symposium and the Annual Conference of Computational Deisgn Academic Committee of the Architectural Society of China*, **2023**. (Outstanding Paper Award)
6. **H Liu**, H Wu, X Xie, M Yuan, PF Yuan*, "Prompt Writing Approach in GAI Tools Aided Architectural Design: Taking Urban Camp Center Design as an Example", In *Proceeding of 2023 National Architectural Academy Department of Architectural Digital Technology Teaching and Research Academic Symposium*, 433-436, **2023**.

Under Review and In Progress: (Working paper available by request)

1. X Xie, X Gao, **H Liu**, M Yuan, PF Yuan*, "Aerial Robotics Fabrication: Precise and Flexible Assembly with 6-DOF Parallel Manipulator", (abstract under review for CAADRIA **2025**).
2. **H Liu**, S Wang, X Xie, PF Yuan*, "AR-Assisted Workflow in Free-Form 3D-Printed Panel Assembly: A Fusion of Virtual and Real Components", (abstract under review for CAADRIA **2025**).

RESEARCH EXPERIENCE

Tongji University **Feb. 2024 - Jul. 2024**
Research Assistant (with Prof. Chao Yan) *Shanghai, China*
Humanizing Mixed Reality—Spatial Behavior Computation based on AR Media

- Utilizing head-mounted display device (HoloLens 2 & Quest 3) to design and construct adjustable mixed reality spaces for supporting iterative optimization experiments on physical spaces.
- Conducting mixed reality spatial experiences to collect human behavior data, involving micro-level eye and head movement data, meso-level body posture data, and macro-level multi-target locomotion data.
- Conducting multi-dimensional environment-behavior coupling analysis and ultimately using virtual media for the visualization of the research outcomes.

Tongji University **Sep. 2023 - Mar. 2024**
Research Assistant (with Prof. Philip F. Yuan) *Shanghai, China*
Research on Positional Tracking Technology

- Developed a Grasshopper plugin for pose estimation with fiducial markers (ArUco and AprilTags) and a monocular camera.
- Implemented real-time positional tracking using SLAM with stereo depth cameras (ZED 2i & RealSense D455), eliminating the need for fiducial markers.
- Integrated motion capture pose tracking system into the assembly workflow for high accuracy using custom hardware and Unity3D-developed software.

RESEARCH INTERESTS

- Develop design and fabrication tools on the spatial computation platform to streamline the process.
- Investigate methods to enhance the accuracy of XR-assisted assembly workflows in challenging outdoor conditions, such as bright sunlight and random human movement.
- Integrate AI technology with XR to optimize object recognition and streamline the assembly process.
- Explore methods for translating human behavioral data into instructions for robotic fabrication processes.

SKILLS

Languages

- Chinese, Native (Mandarin Grade 2A)
- English, TOEFL iBT 101 (R: 29 L: 27 S: 21 W: 24)

Professional Skills

- Programming: C#, Python, Anaconda, HTML, Git, Unity3D, Visual Studio, Docker.
- Design: Rhinoceros, Grasshopper, Blender, Photoshop, Illustrator, Indesign, Premiere, AutoCAD, Vray, D5.
- Fabrication: Robot Control, Extended Reality, Curve Crease Folding, Tube Bending, Hot-wire Cutting, 3D Printing.