Robotic High Rises No.02: Design Research Studio 2013 PART 2

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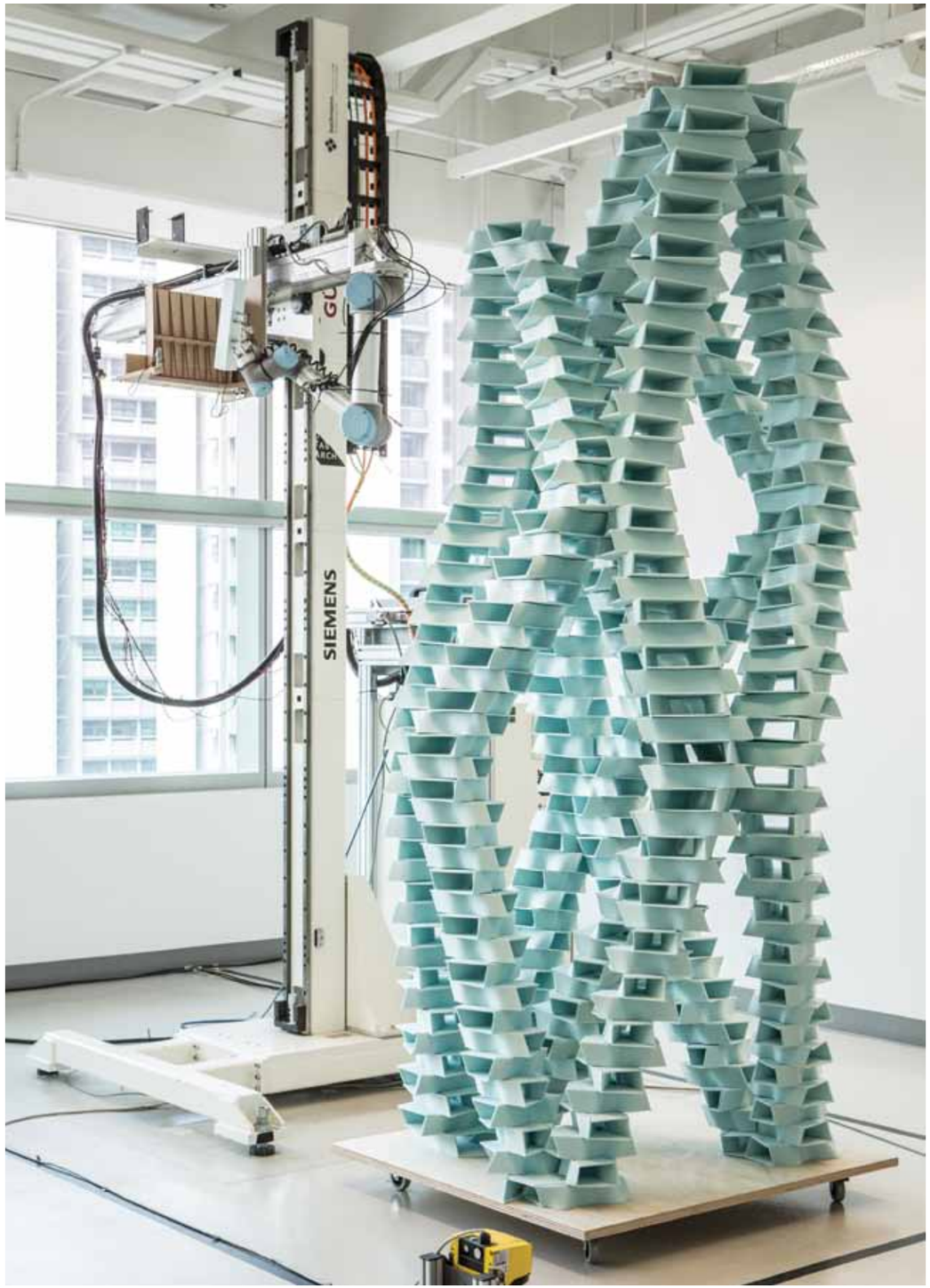
Project 2

Mesh Towers

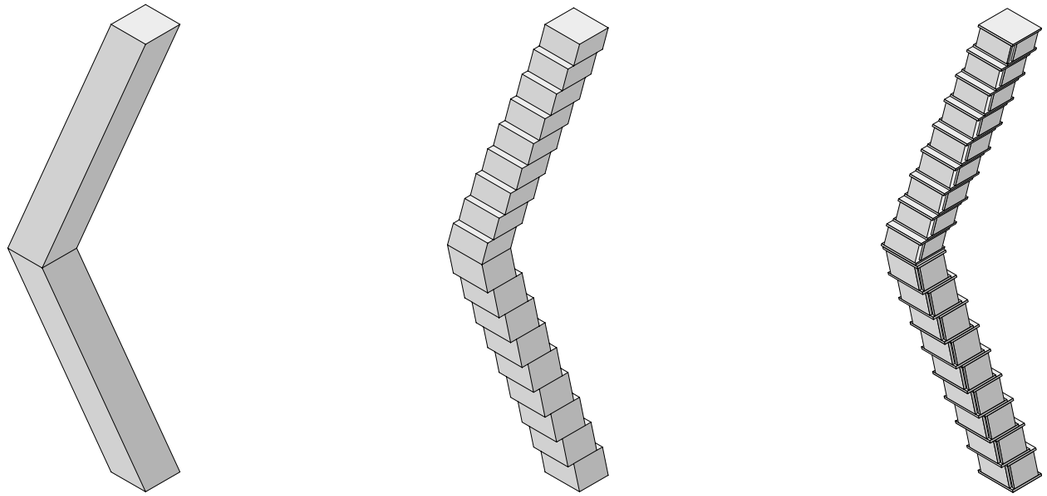
Tiong Bahru Area

Students: Petrus Aejmejlaeus-Lindtsröm, Pun Hon Chiang, Ping Fuan Lee

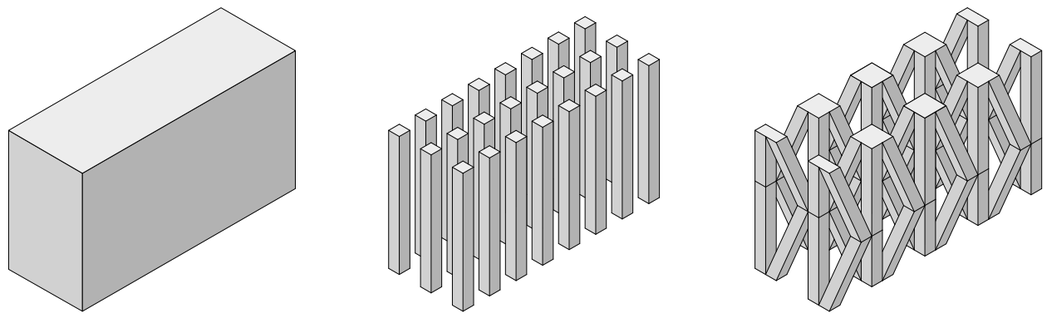
Mesh Towers is based on the computational design and robotic assembly of several slender towers, which merge and separate as they grow in height, structurally supporting each other. Each tower strand is constructed out of stacked Styrofoam units that are oriented away from their immediate neighbouring elements. These units are constructed from geometrically differentiated structural elements, taking advantage of the robot's capability to accurately move a Styrofoam block free in space: the robot picks one element and moves it through a hot wire along a computationally generated path to fabricate a geometrically complex wall element, ready for assembly. In fact, the intricate wall (and unit) designs follow structural guiding curves to achieve continuous load transfers throughout the whole tower. As such, their dimensions are locally adjusted according to their specific position within the tower, and, in addition, provide a large variety of public programmes connected through a network of bridges and trails.



Design Concept



Since the students were initially limited to build models from two standardised cardboard elements, they dissolved the tower strands into a simple floor and wall system



Volumetric studies to compare a solid block to pencil towers and a mesh tower structure

Design Iterations

Tower 1

Tower 2

Tower 3

Tower 4

Final Tower

Tower 1 The tower consists of only two different elements, floors and walls, which are assembled in a simple pick and place process.

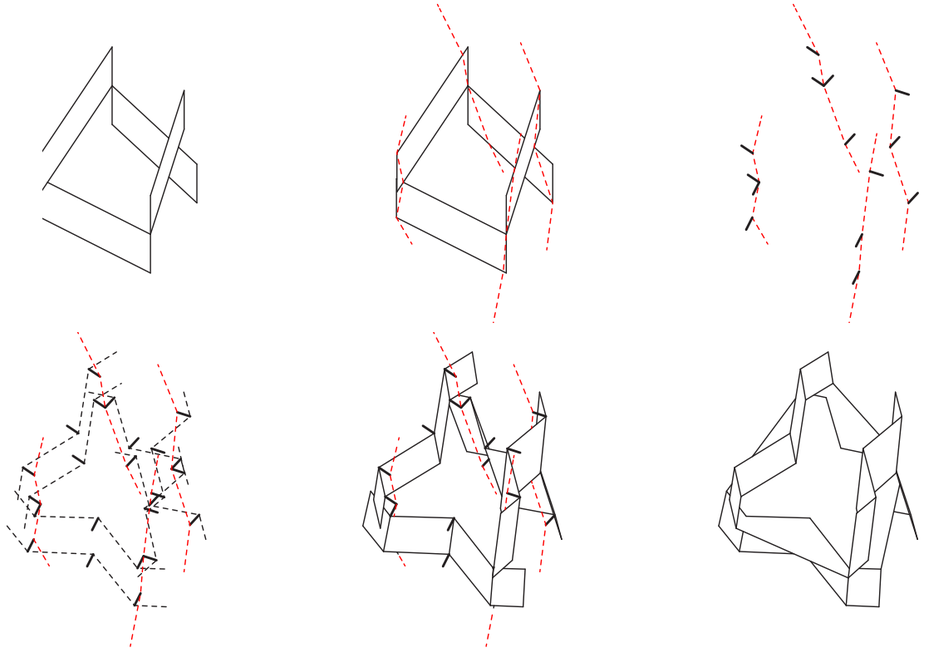
Tower 2 Duplex stacking – the units of the previous tower were enclosed by four walls. In this tower the group reduced the number of walls per unit to only two walls in order to provide openings. This made it necessary to rotate each unit by 90 degrees to make the towers structurally stable. To keep the strands as thin as possible the group decided to design each apartment as duplex unit in order to create an appropriate overall floor area.

Tower 3 Rotation – in the previous tower every second unit directly faces a neighbouring unit. To avoid this lack of privacy the group introduced a rotation of the tower strands to orient neighbouring units away from each other.

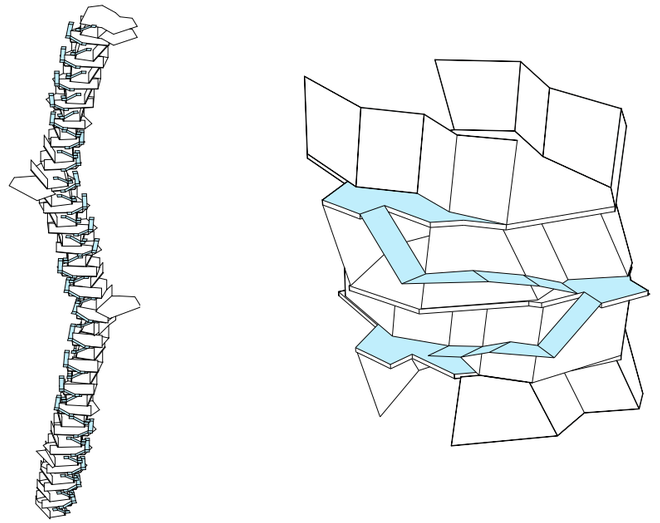
Tower 3

Tower 4 Folding – thin cardboard sheets proofed to be too unstable to construct a mesh of thin towers. The group started to fold the walls corresponding to the force flow, in order to thicken the walls at structural intersection points.

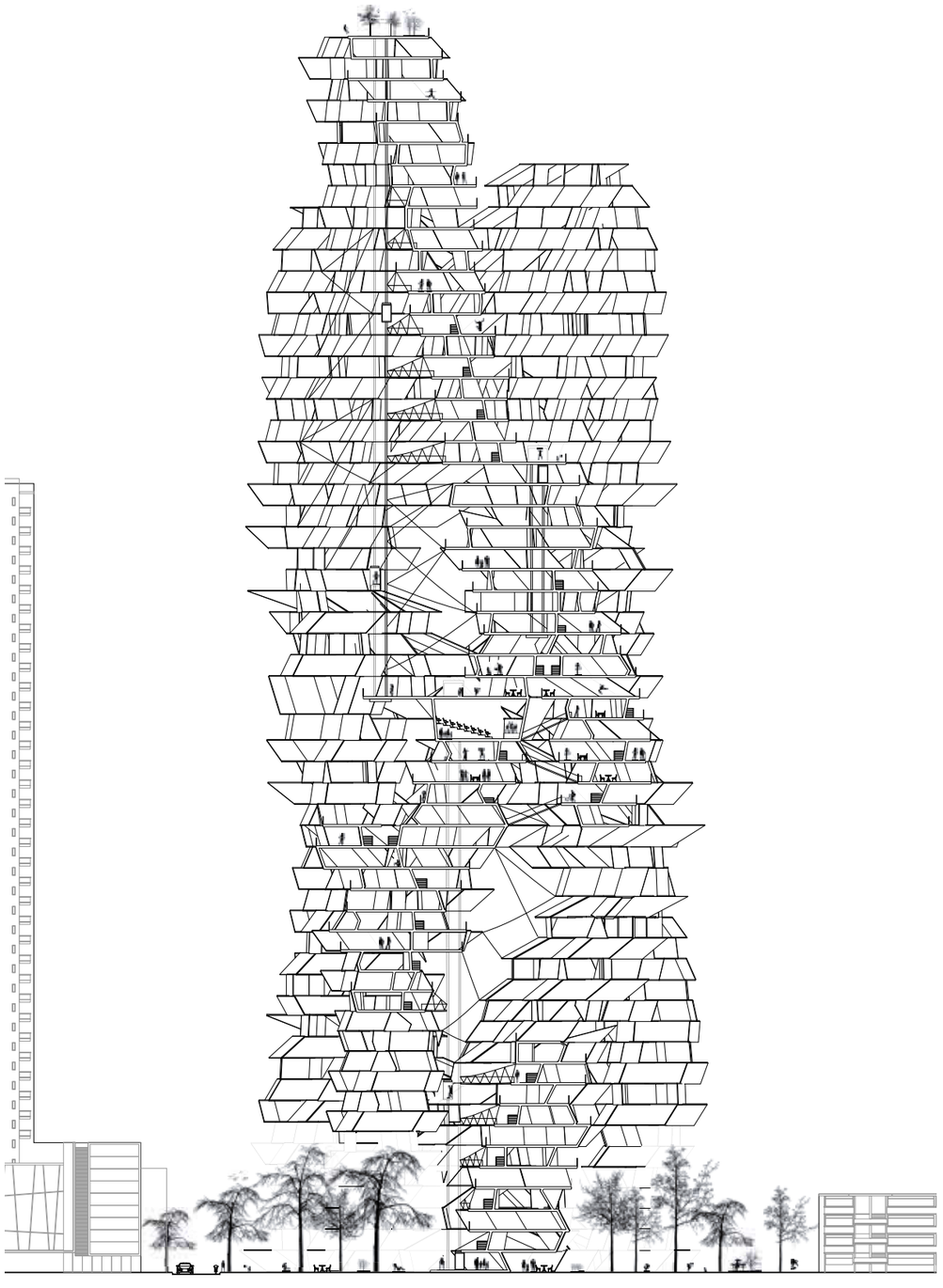
Tower 4 – Computational Design



Folded wall generation – the angles for the cardboard folding are calculated from the vertical force flow through the towers. The geometry of the folds follows the direction of the loads and transfers it directly to the lower walls



Circulation system – an external staircase spirals around each tower strand, connecting the public nodes of the overall structure

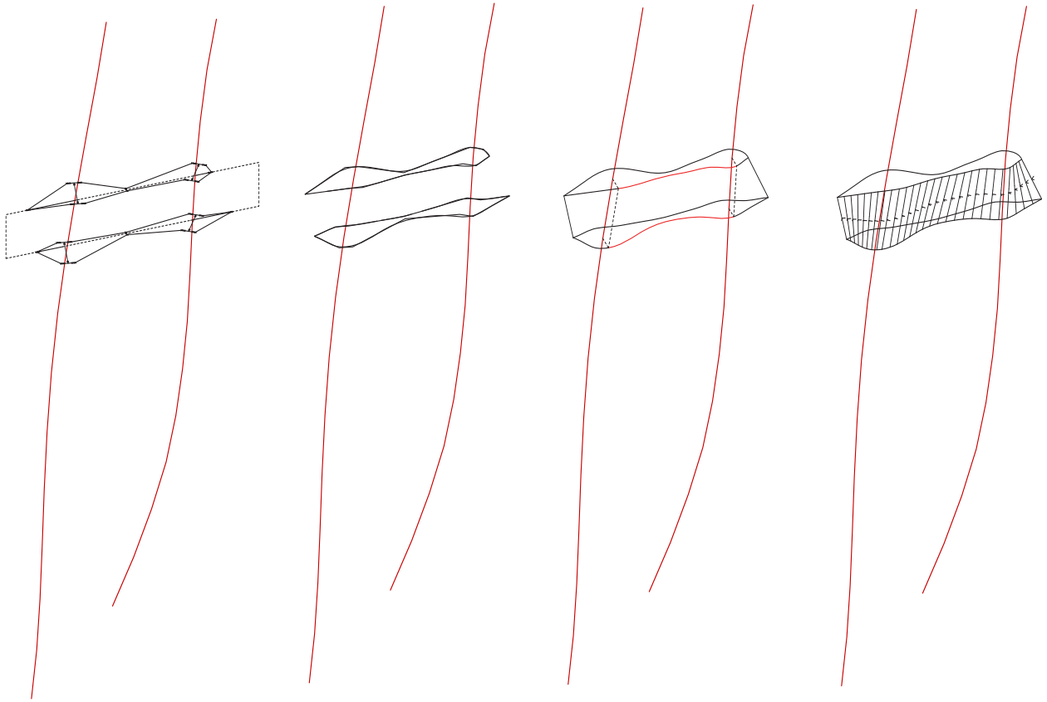


The situation of the tower between low-rise and high-rise typologies in its immediate vicinities

Tower 4 consists of 620 individually folded cardboard walls

Final tower Since robotic folding of cardboard elements turned out to be heavily restricted regarding structural performance and geometric freedom, the design and fabrication exploration was expanded towards volumetric materials, which, ultimately, led to the development of a unique robotic foam cutting process.

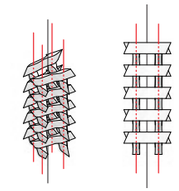
Final Tower – Computational Design



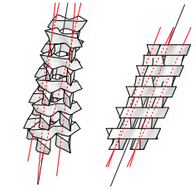
Wall generation – each wall consists of two components. An algorithm defines a flat centre plane for the fabrication process, since the end-effector is picking the elements from the flat side and creates the curved outlines by moving through the hot wire cutter

Sample wall geometry – one of two components, which are individually cut by the robot and glued to comprise one complete wall element

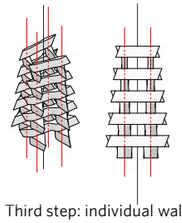
First assembled model – overall, each unit consists of six pieces: Two floor plates and four wall elements



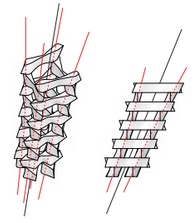
First step: uninformed walls, generated along a guide curve



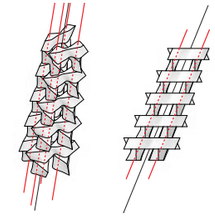
Second step: tower strand with rotation



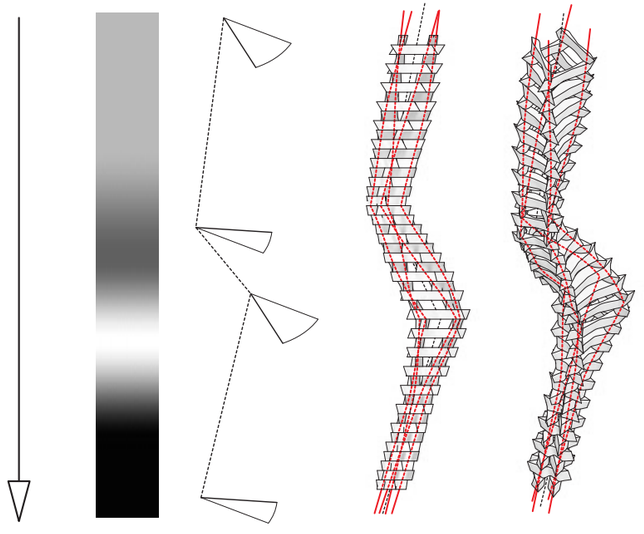
Third step: individual wall configuration, scaled according to the loads



Final step: tilted tower strand with scale change

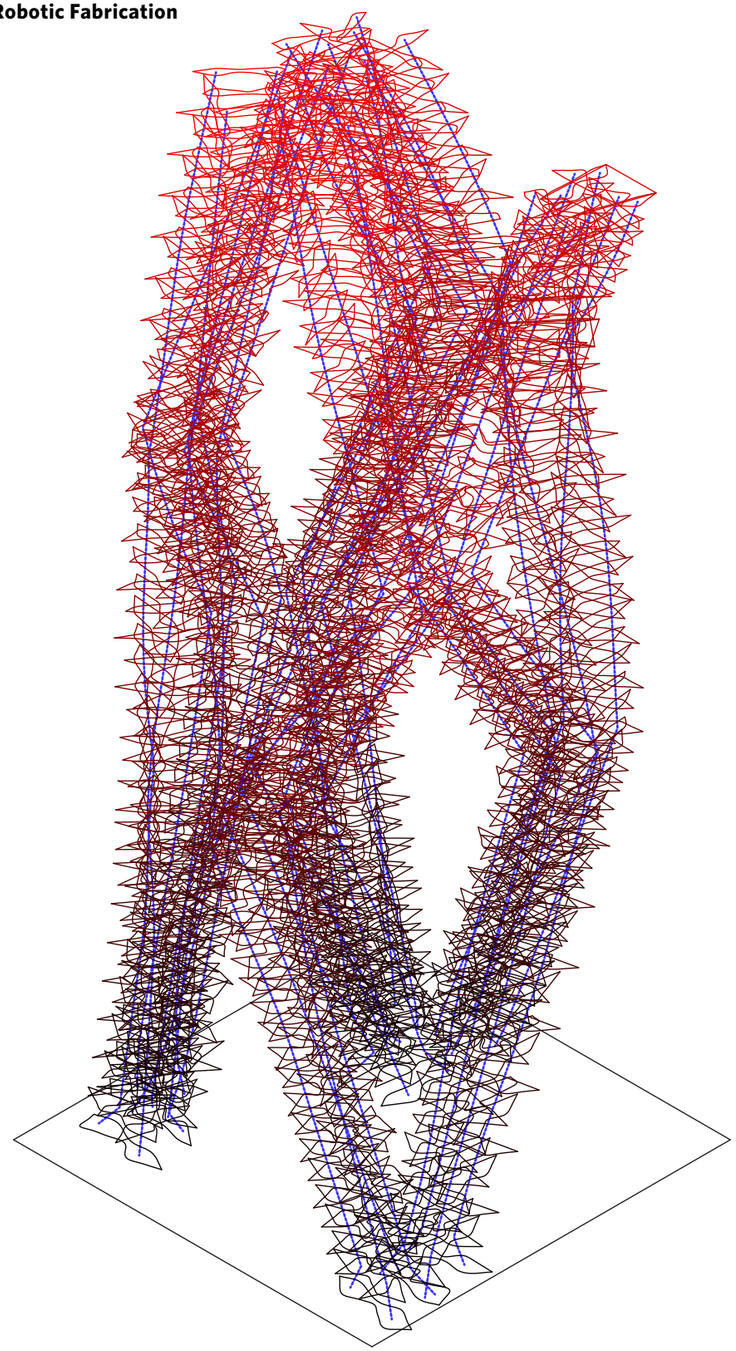


Tilted tower strand without scale change

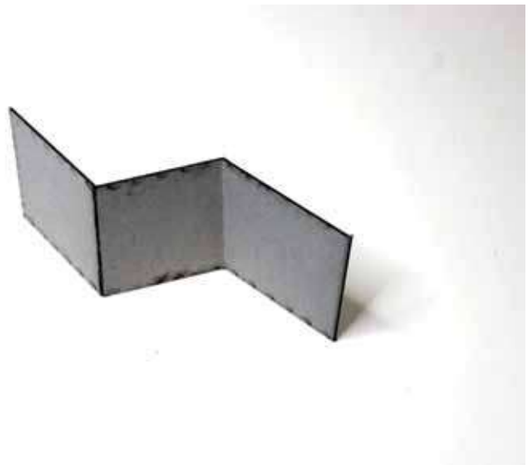


Final computational design engine – the towers are informed by a gradient map, indicating the dimensions of the units, and a set of orientation vectors for the rotation of each duplex unit

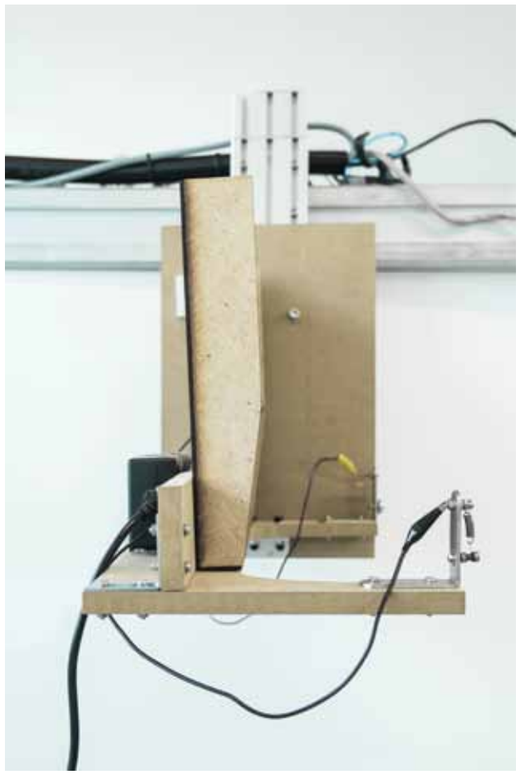
Final Tower – Robotic Fabrication



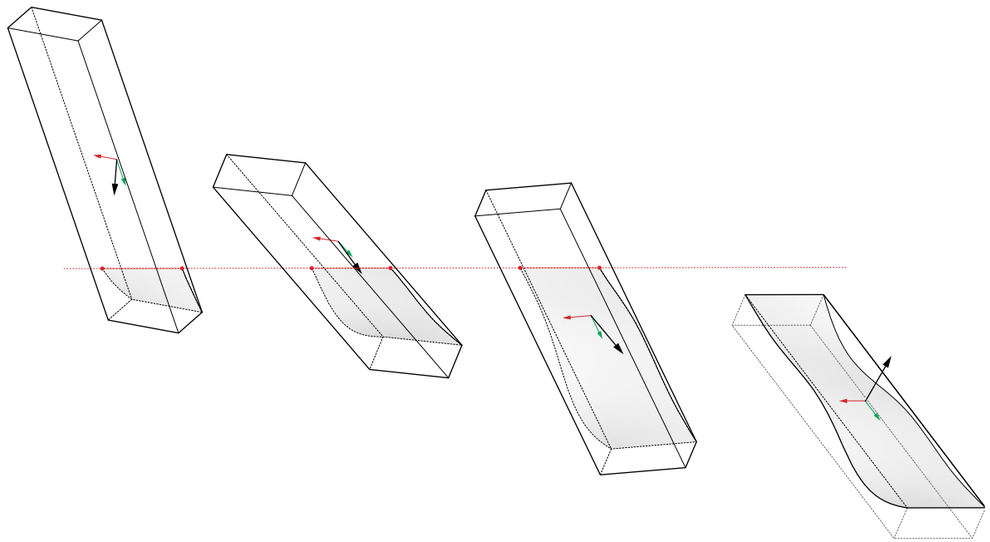
Wall production data – the robotic process needs two profile curves and two force lines for each wall to calculate and cut their individual shapes



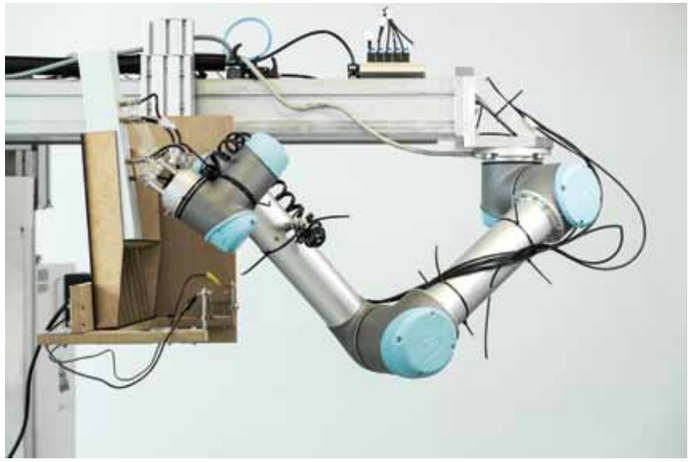
Robotic cardboard folding – the laser cut cardboard sheet is placed in the clamp, the robot bends it to the desired angle, hot glue is then applied to stabilise the fold and avoid retraction. The piece is rotated 180 degrees and to create a second fold

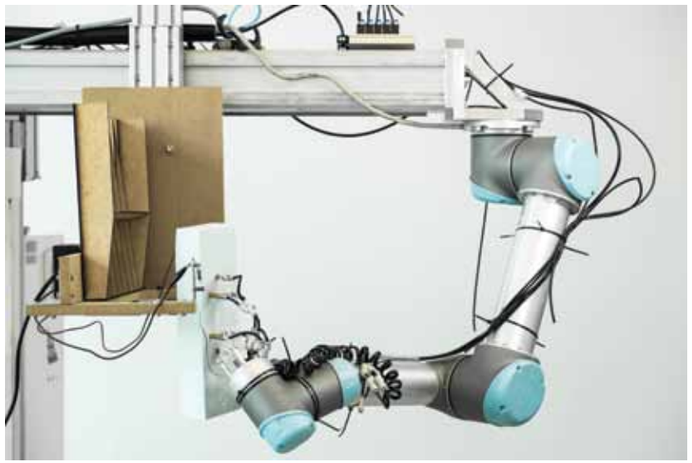


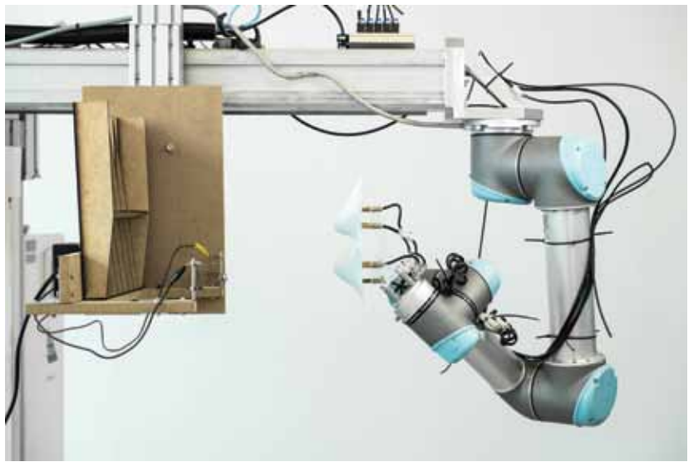
Feeder System and Hot Wire
The hot wire is tensioned with a spring. This makes the wire more flexible and thus durable



Sequential diagram of the foam-cutting process







Robotic Foam Cutting
The robot picks the piece and moves it through a hot wire along a computationally generated path to fabricate each wall element

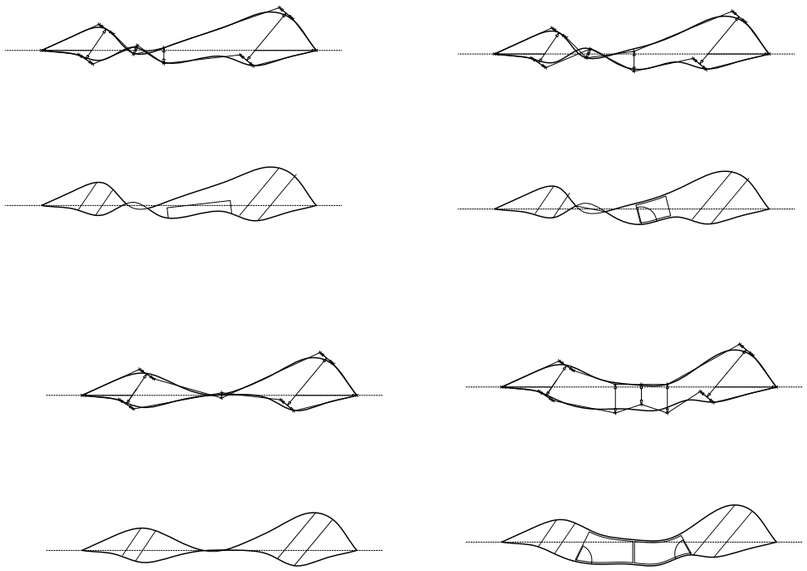
Final Tower – Robotic Fabrication

Final Tower – Context

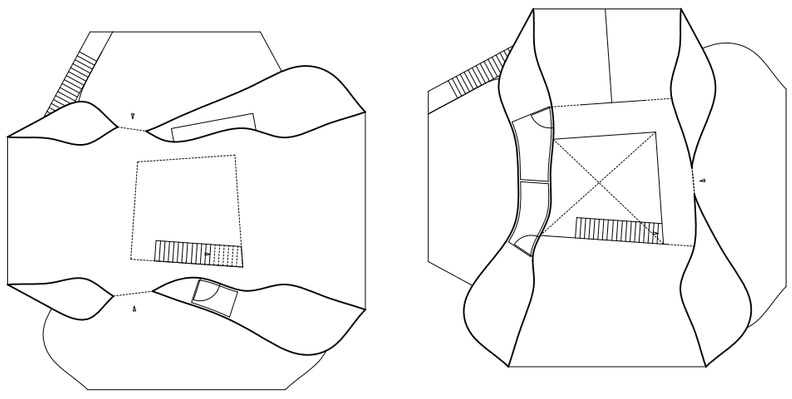
The mesh towers are located in a dense and architecturally historically 'sensitive' area in Tiong Bahru. At the time of the studio in 2013 the project site was estimated as the most expensive in Singapore up to date. The tower typology attempts to have as little footprint as possible in order to maintain the lower density of the adjacent buildings to the East

Final Tower – Elevation

Final Tower – Floor Plans

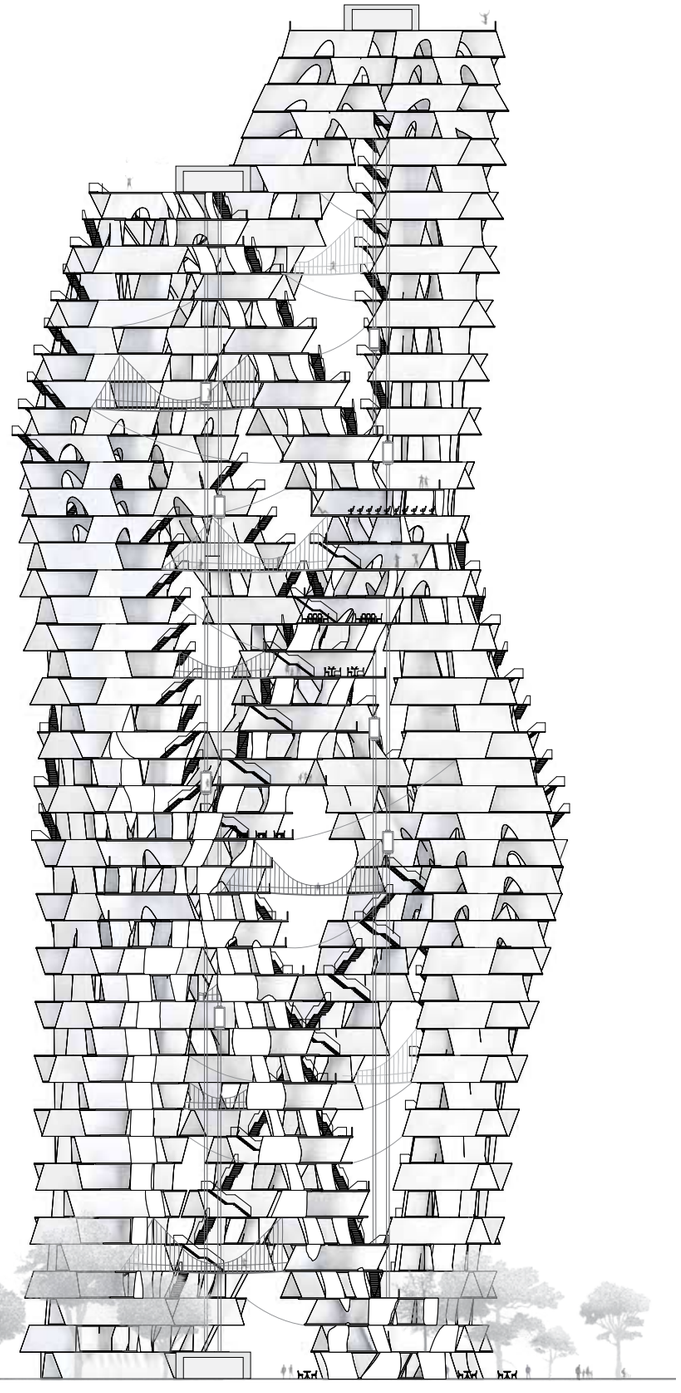


Wall type generation – the walls articulate specific architectural functions of the apartments, like kitchens or bathrooms



Duplex unit floor plan – the entrance to the duplex units is located at the bottom floor. The second level, containing the private rooms, is accessible through an inner void. Both floors have exterior spaces

Final Tower



Cross section of final tower

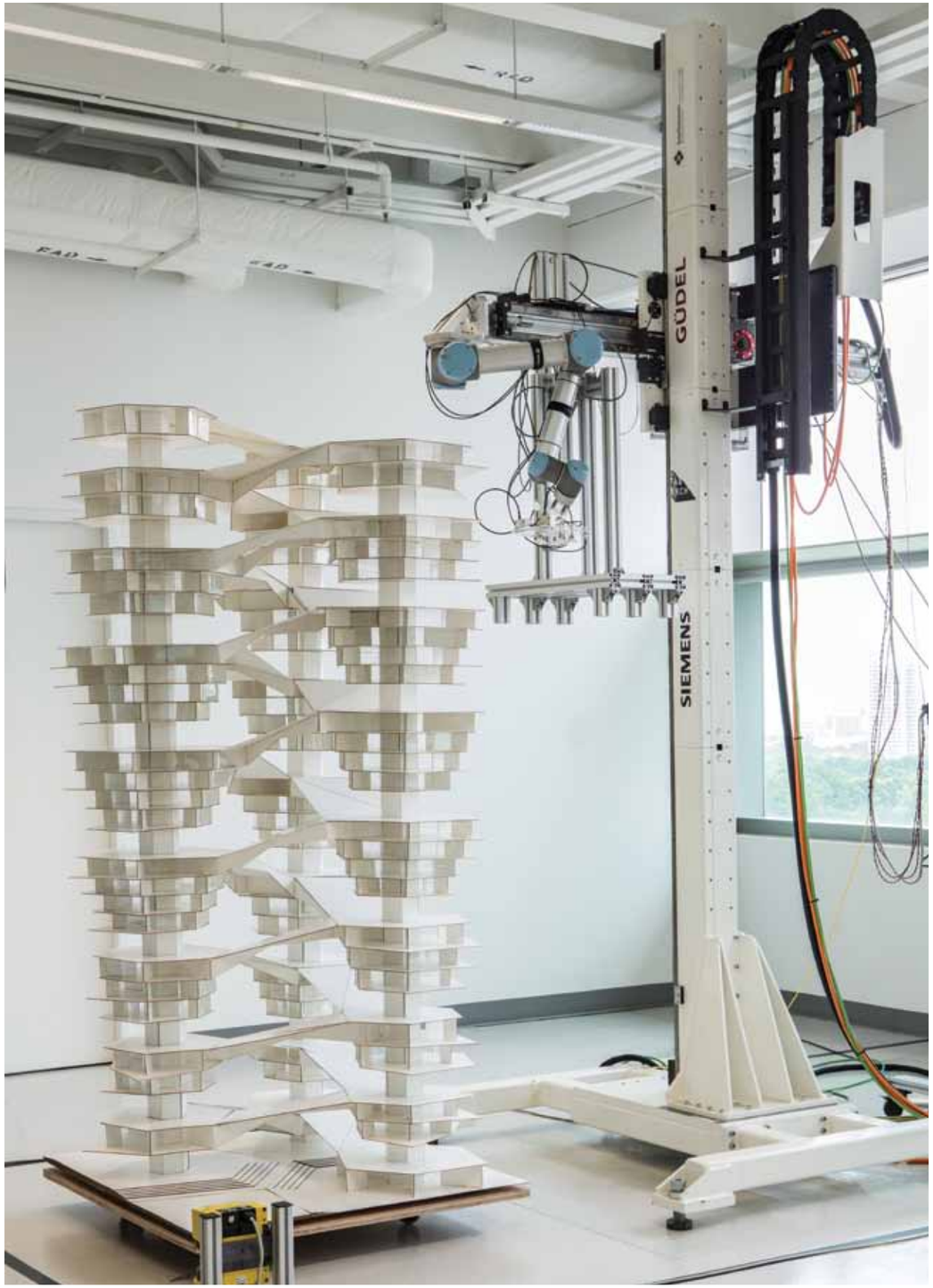
Project 3

Vertical Avenue

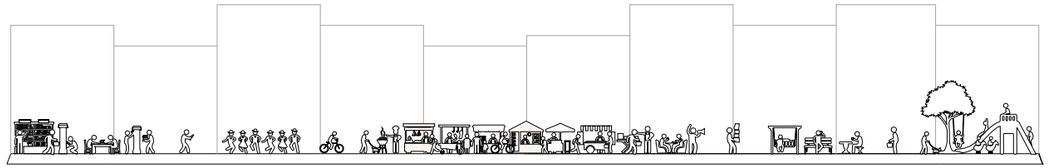
Rochor Area

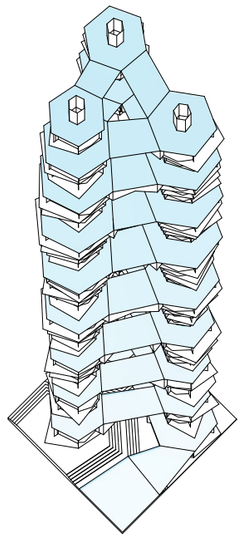
Students: Kai Qi Foong, Lijing Kan
Andre Wong (1st term)

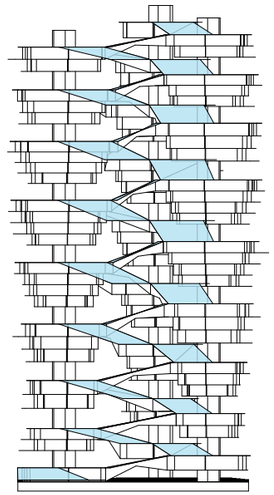
The project Vertical Avenue proposes a spiralling circulation system with a range of different public programmes distributed vertically throughout the tower. The computationally designed spiralling ramp system connects several structural cores where residential units are arranged in clusters. The integration of sensors allowed for both matching the needed precision in the placement of components as well as the seamless integration of manual processes complementing the robotic manipulation. Additionally, the project makes use of digitally controlled thermal deformation and assembly of facade elements. This design and fabrication concept ensures a robust yet open approach towards robotic assembly, allowing the physical manipulation of a multitude of building elements into a differentiated high-rise structure.



Design Concept







Concept diagram – the concept of the void deck is transformed into a spiralling circulation system by computationally controlling and distributing public spaces along three tower strands

Shop houses represent the oldest urban typology in Singapore, containing shops, restaurants or cafes on their ground floor with residential unit on top

Void decks – the ground floors of Singapore's public housing blocks are usually left empty for public programmes

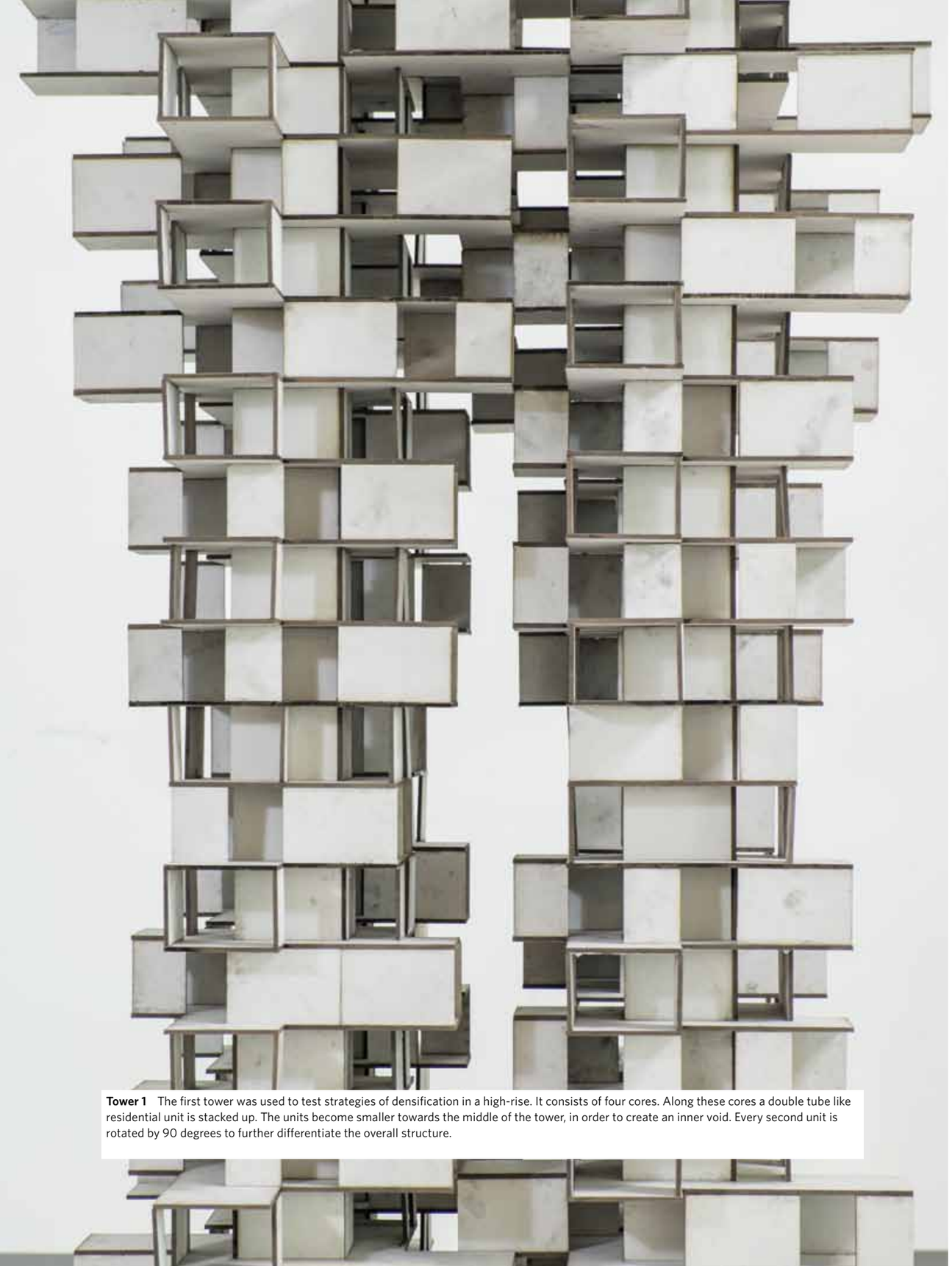
Design Iterations

Tower 1

Tower 2

Tower 3

Final Tower



Tower 1 The first tower was used to test strategies of densification in a high-rise. It consists of four cores. Along these cores a double tube like residential unit is stacked up. The units become smaller towards the middle of the tower, in order to create an inner void. Every second unit is rotated by 90 degrees to further differentiate the overall structure.

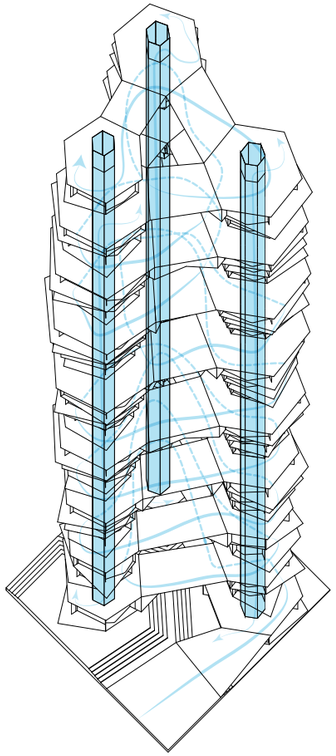
Tower 2 In the second tower the void decks are introduced. Every sixth floor is left empty, articulating clusters of residential units. These clusters act as Vierendeel trusses, leaving the void decks free of structure. The apartments rotate freely around their centre, creating different views and trying to connect to the next void deck cluster.

Tower 3 In the third tower the group realised their idea of the spiral. They inverted their computational design from trying to create a spiral by rotating each unit to first creating the spiral and from that the void deck clusters. The facade is set back in order to provideself shading. If the facade is set back to deeply it is split to create a balcony.

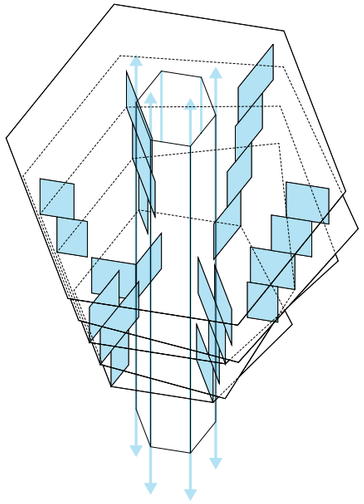
Tower 3

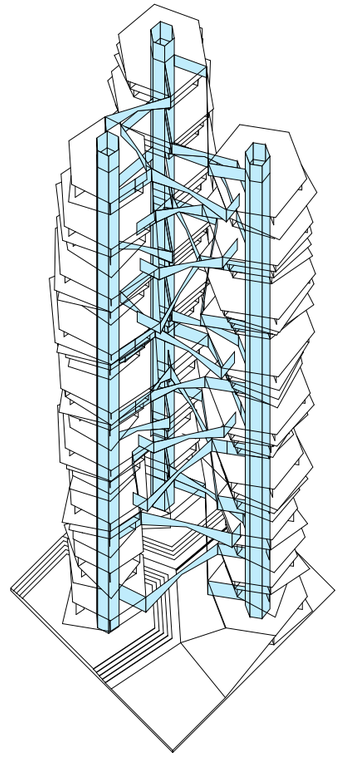
Final tower In the final design, the group added a acrylic sheet bending process to their robotic fabrication setup in order to further differentiate the towers' facades.

Final Tower

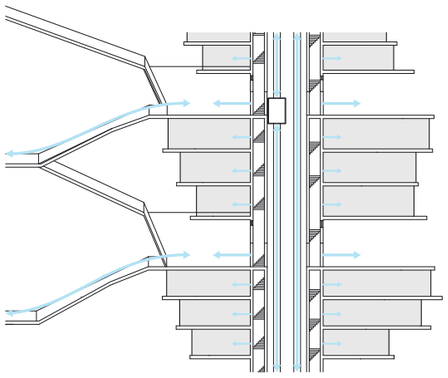


Spiral ramp – the ramp connects seamlessly to the surrounding streets, extending the street into the vertical





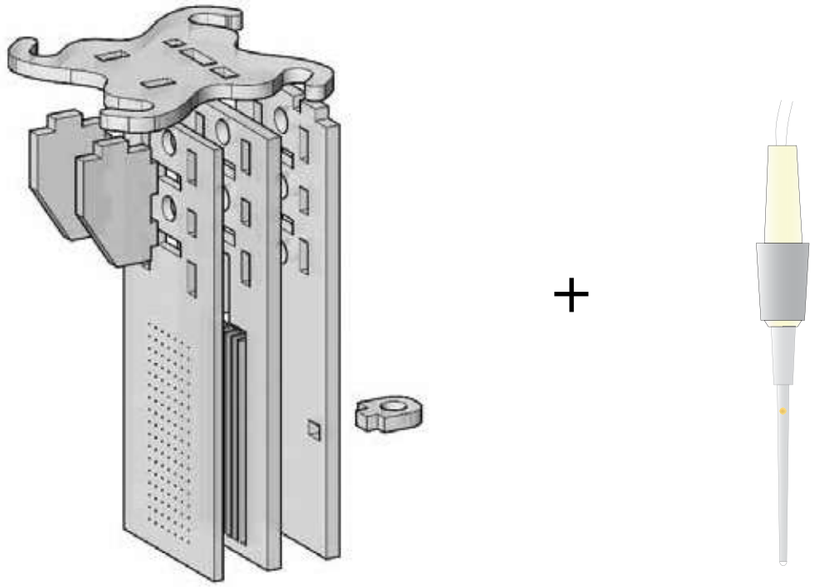
Structural system – each of the void deck clusters supports itself, acting as a Vierendeel system. The three thin cores are stabilised by the ramp



Circulation system – the three cores are the primary circulation system. The elevator stops only at each void deck. Residents use a secondary spiralling staircase to reach their apartments

Structural tests – without a system to transmit the weight of the walls to the core, the walls sack down

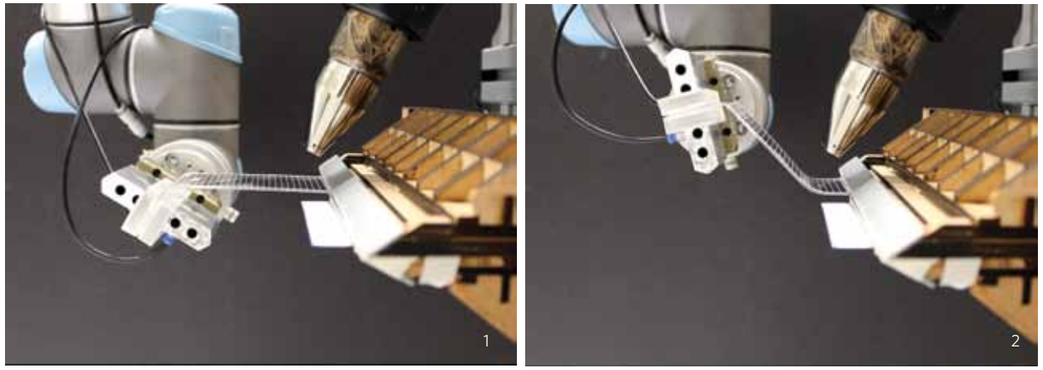
Final Tower – Robotic Fabrication



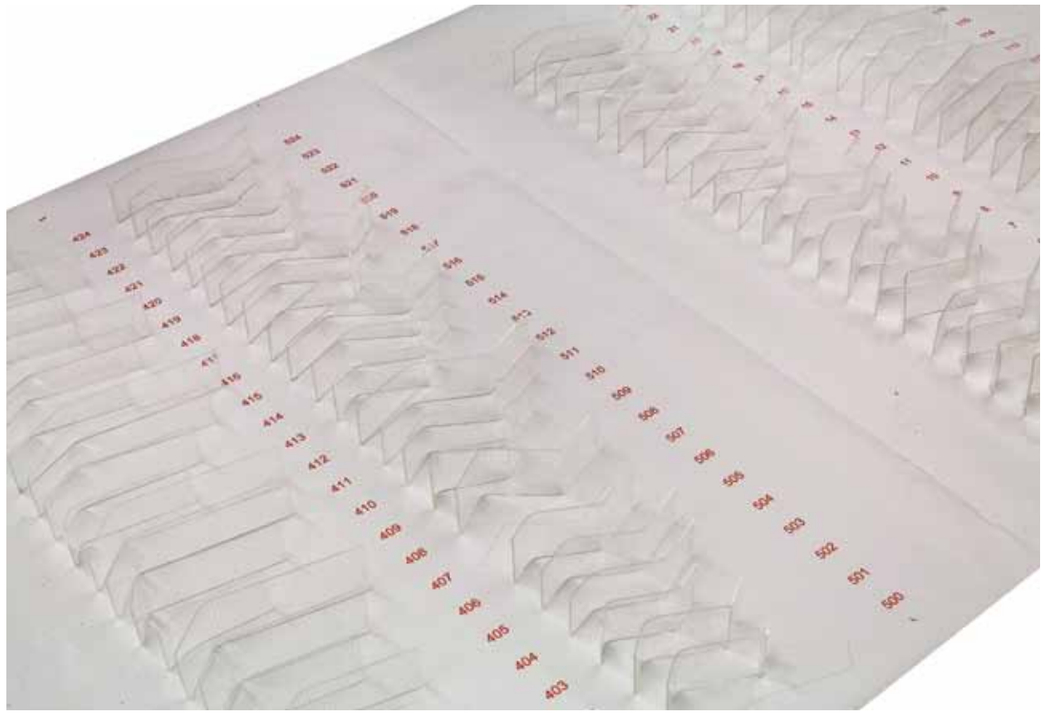
Sensor vacuum gripper – the sensor integration in combination with the flexible vacuum gripper lead to an increase in placing accuracy from 25% to over 90%

1: The robot moves to the correct position of the wall to increase building speed, where the students manually feed the cardboard piece and apply glue

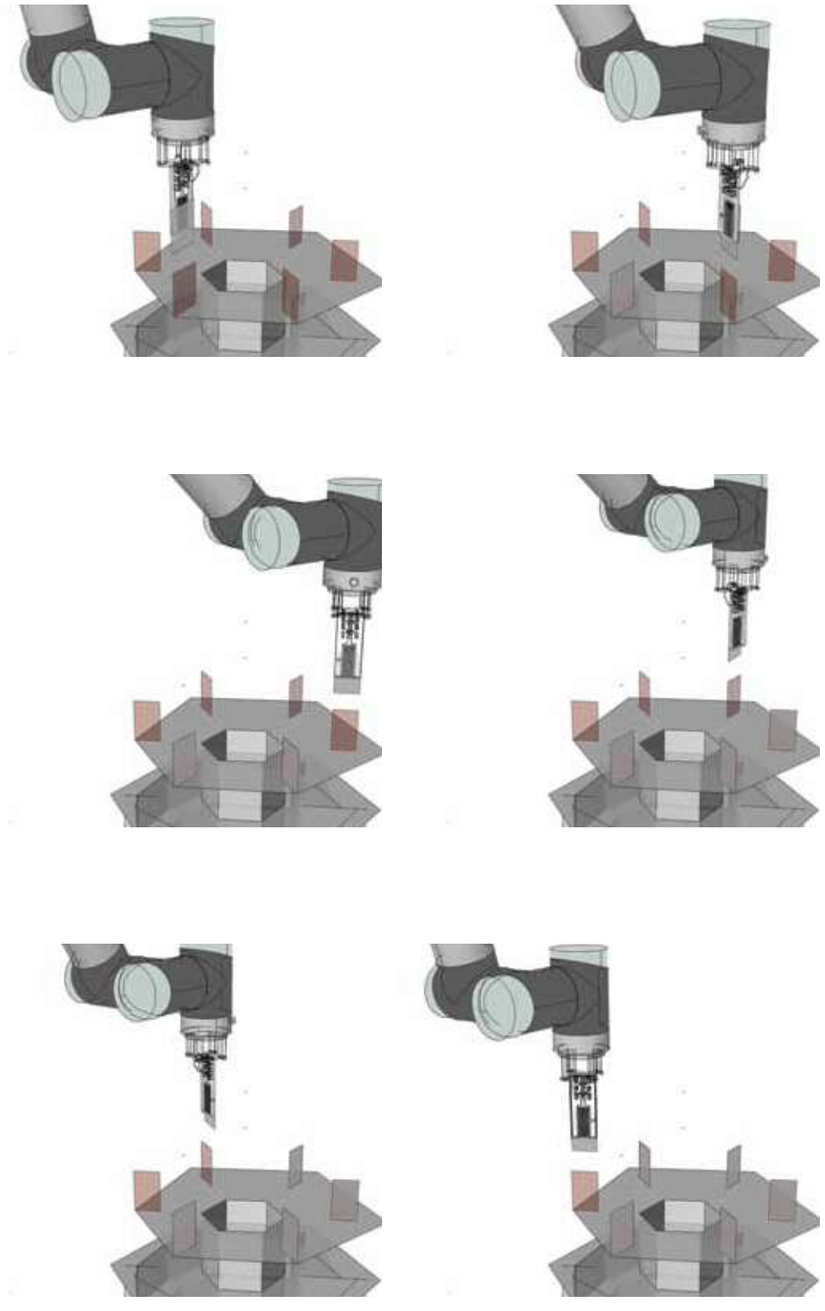
2: The sensor detects the floor and alters the placing position accordingly, compensating for tolerances, and then places the wall



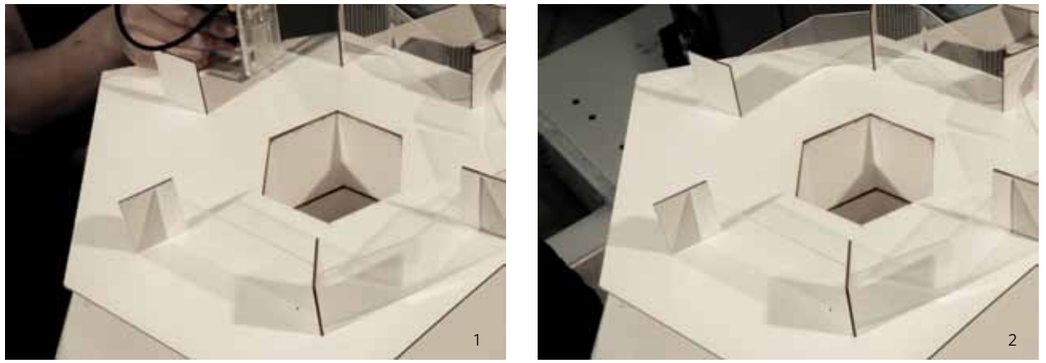
The robot bends each acrylic stripe one or two times, depending on the amount of reflection desired in the facade. The piece is placed in a clamp, controlled via the fabrication script. It is then heated to 300˚C for about 20 seconds (1). Once the material is flexible enough the robotic arm bends the piece to the required angle



Prefabricated facade elements – since the gripper for the bending process is radically different than the one used to place the walls and assemble the tower, all the facade pieces had to be prefabricated. After being bent the element is placed on a numbered print of it's generated outline to check for accuracy and to sort them in the correct order



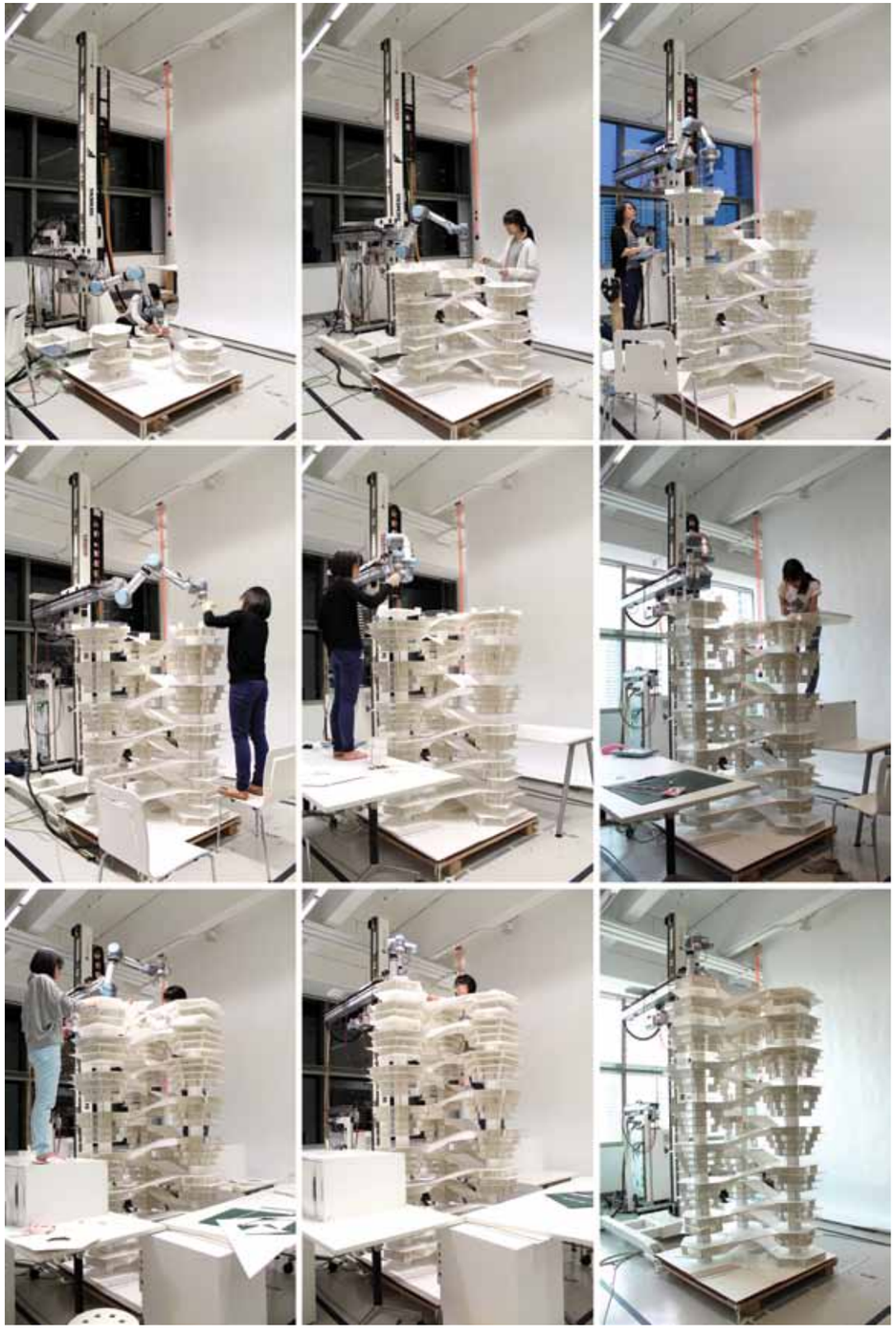
Wall placement process – the robot places each storey's walls in a radial sequence to avoid collision with the model. After finishing one cluster of residential floors it moves upwards, along the tower spiral's trajectory and commences the assembly of the next units



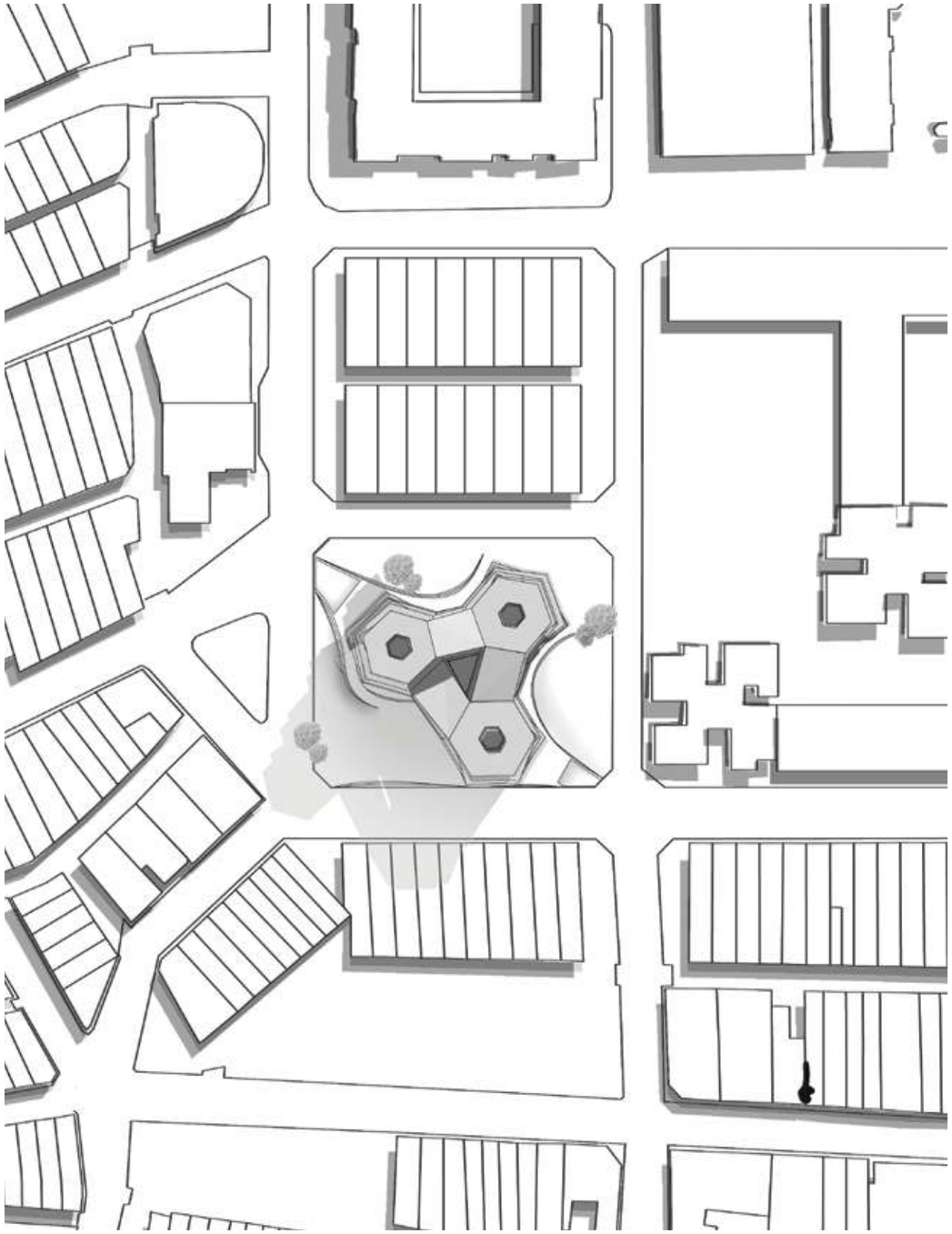
Facade placement process – the robotic arm indicates the position of the prefabricated facade element's fold. The acrylic piece is then glued manually to increase speed

Production data for the final tower – all data needed for the production of the final model is generated in the Grasshopper computation design environment: The laser cut file for each piece, including the scorn pattern for the facade engraving, the bending data for the robot as well as the placement data

Final Tower – Robotic Fabrication

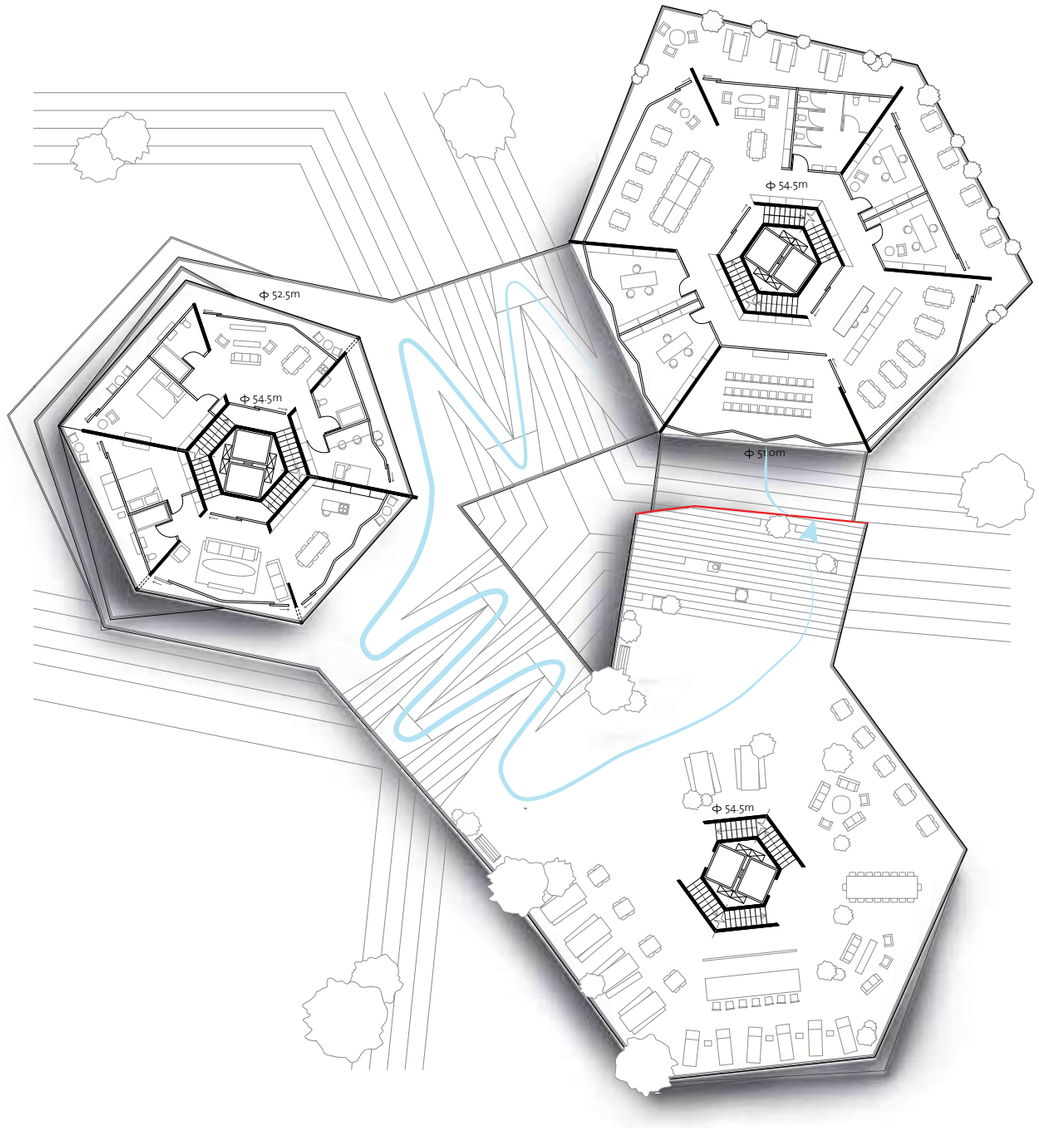


Final Tower – Context



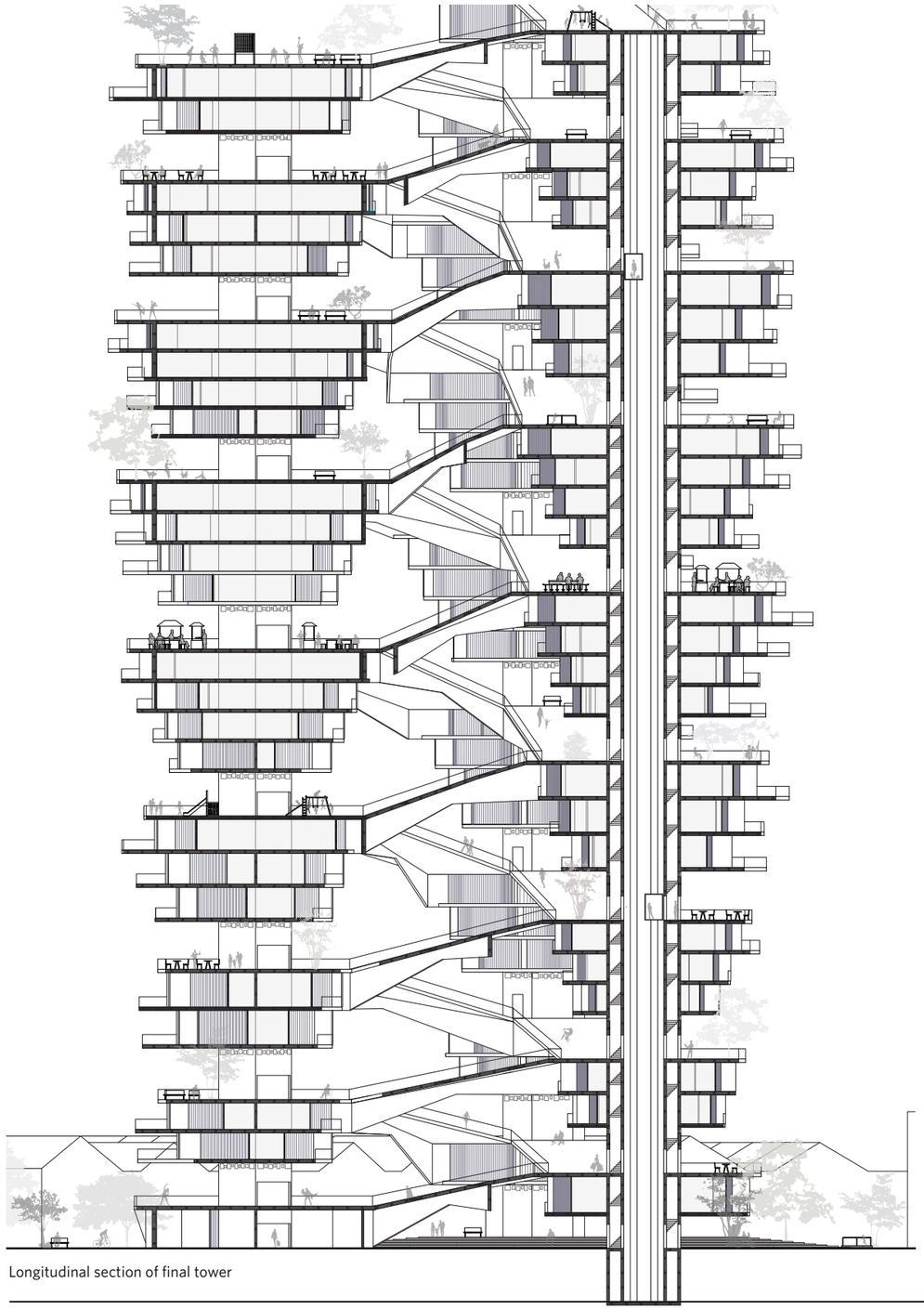
The group identified the main access corridors around the site and positioned the building in a way to direct the pedestrian streams into their spiralling park. The project continues the surrounding streets to the sky

Final Tower – Floor Plan



The continuous ramp is free from structure and can house any public programme, from hawker centre to playground. The circulation system adapts to the inclination of the connection surface between the individual tower strands. A low inclination is an open ramp, increased steepness requires serpentine

Final Tower



Longitudinal section of final tower

Addendum – Studio Impressions

Colophon

Design of Robotic Fabricated High Rises No.02
Design Research Studio 2013

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Marina Abramovic, works with Ulay: page 32 (source:
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