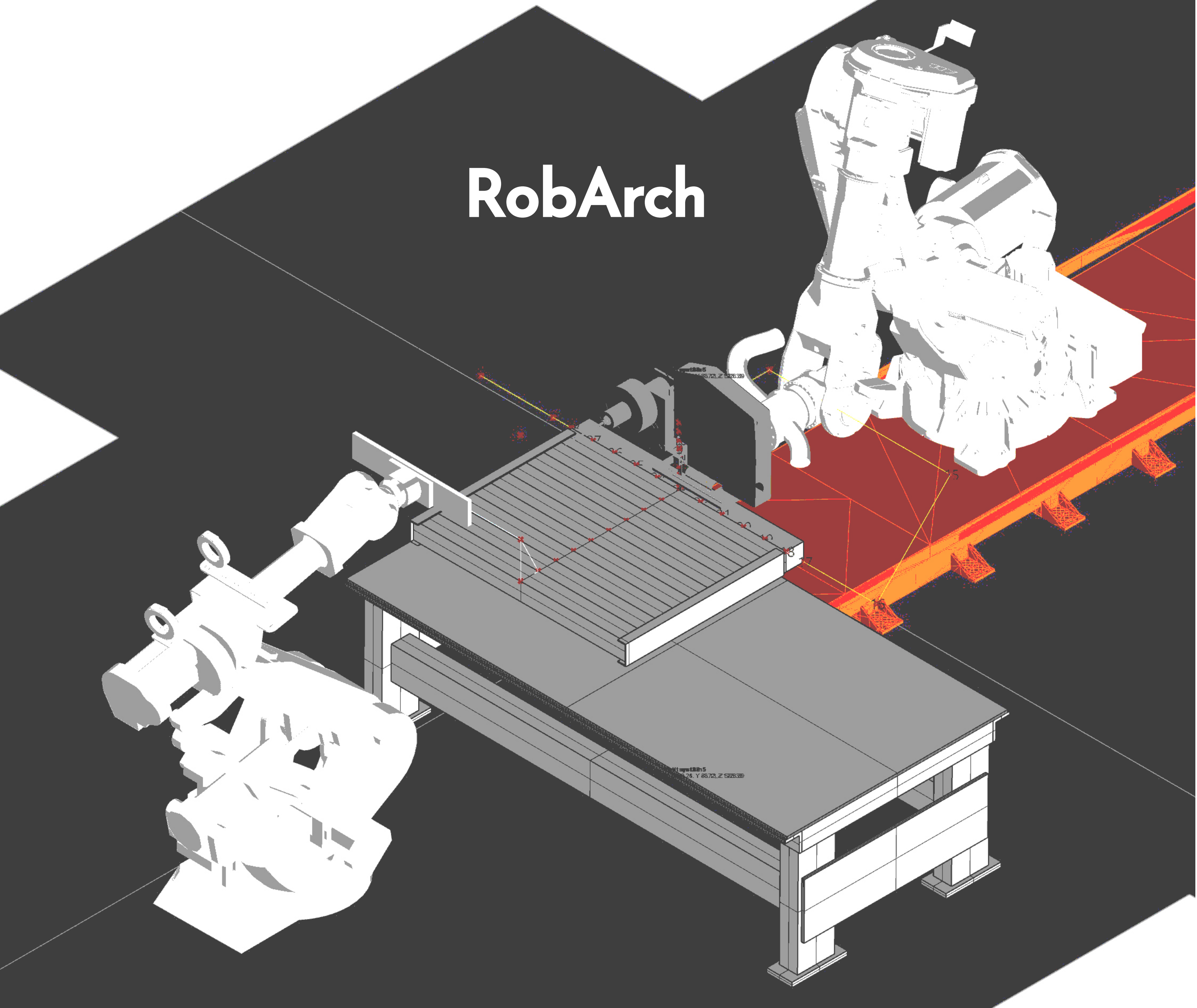
RobArch



RobArch:
Integrating robotics in architectural production

RobArch is a research project for understanding the potentials of constructing large scale structures using an industrial robot. In doing so, the project considers a niche of designing a joinery system utilized in a deployable timber structure and creating a workflow for robot surrounding this joint.

Proposal By:
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Why is this project relevant?

As compared to Architecture, Robotics has been used more widely in other manufacturing industries such as automobiles, furniture, etc. **Why is it so? Why have we not been able to leverage this advancing technology in the workflows of mass-produced architecture?** The barriers in implementation of automation in architecture corresponds to a number of factors with the largest contributor being the incompatibility with existing practices and current construction operations.

But as we face a world crisis today, fighting against the COVID-19 where we are under the influence of social distancing, there is a huge potential for automated construction.

The idea here is to use robotic arms and create a deployable system that would require dedicated craftsmanship and a complex workflow but can be easily assembled by one person with simple guidelines, eg: traditional japanese joineries. This would minimise the number of people that is required on site, which would reduce the chance of people getting infected.

The joinery system should be flexible enough to be able to create complex forms and be easily disassembled, therefore, the elements would have a longer life cycle.

What is the importance of the project?

Today isn't the first time we are fighting for survival. We have been in this situation every time there has been a natural disaster, war or epidemics. And every single time, the people who are impacted the most are the ones who had least contribution for any of these to take place. They are the underserved sections of society who battle with everyday crises. As we face the COVID-19 pandemic, we are privileged to have a house to be quarantined in, to self-isolate in, to keep ourselves and our families safe. But what about those numerous homeless people who don't have a roof on their heads or a wall to lean on? This project is investing into looking for an equitable solution built off-site and assembled by individuals adding to the idea of social sustainability.

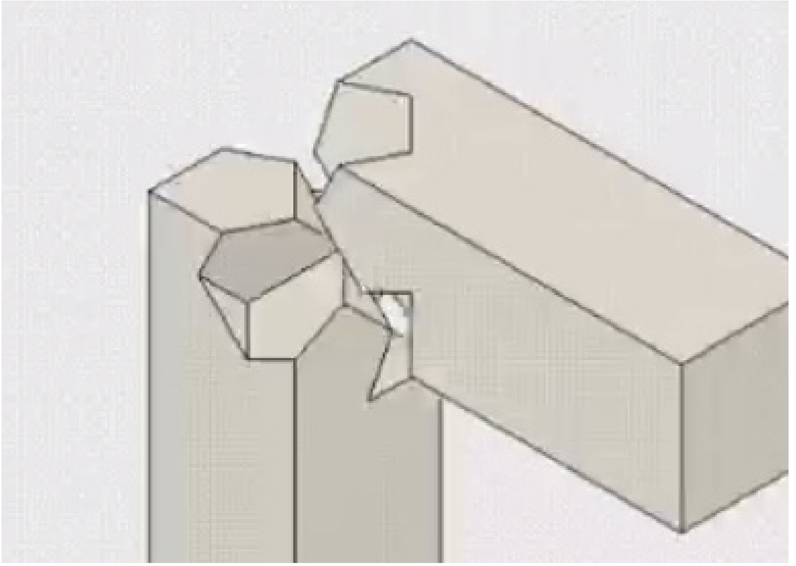
Along with this, the workflow also contributes towards environmental sustainability. The system being deployable, increases the embodied energy within the elements hence reducing the carbon footprint. The automated production increases efficiency, reducing the wastage and once again contributing towards sustainability.

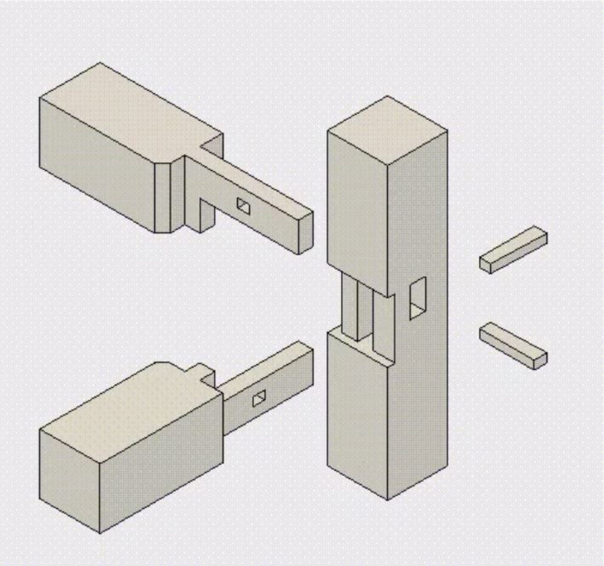
What is the use-case scenario?

Our end goal is to create a timber frame structure that can act as a shelter in emergency situations. It will be based on traditional post and beam technique. This structure will have the same joinery repeated a number of times to create a complete frame. The idea here is to set up a workflow for creating this joinery using a robotic arm.

The interlocking joinery system will have a mortise and tenon joint supported with a wooden peg. Alternatively the complex geometry of the joint will allow a ball-joint kind of a scenario to introduce the idea of flexibility.

Inspiration for the joinery: https://twitter.com/i/status/781824036355518464

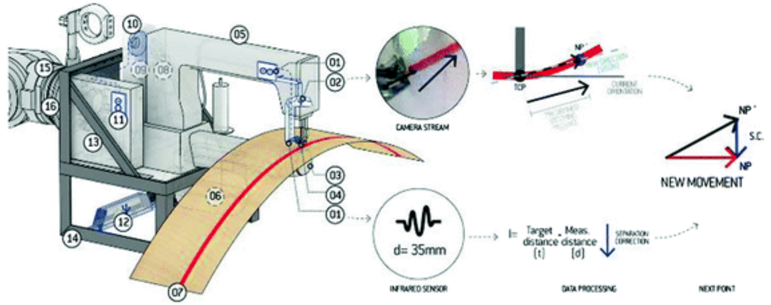


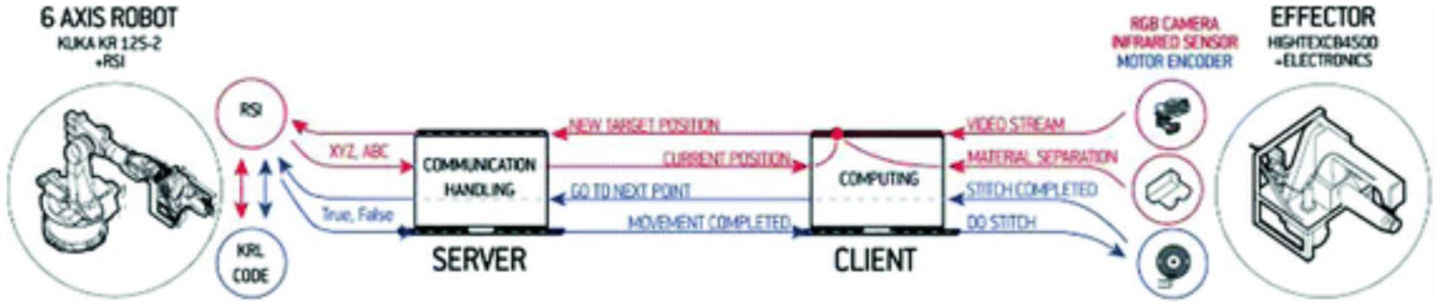


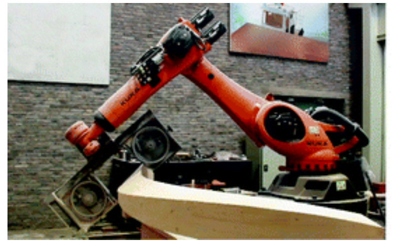
Robotic Timber-Framed Incremental Housing, Rob Arch 12

Precedents:

Tailored Structures, Robotic Sewing of Wooden Shells (Alvarez M.E. et al. (2019) Tailored Structures, Robotic Sewing of Wooden Shells. In: Willmann J., Block P., Hutter M., Byrne K., Schork T. (eds) Robotic Fabrication in Architecture, Art and Design 2018. ROBARCH 2018. Springer, Cham)

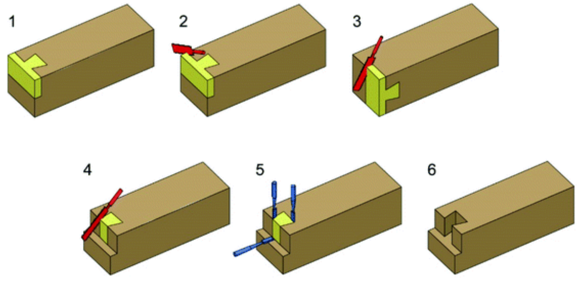


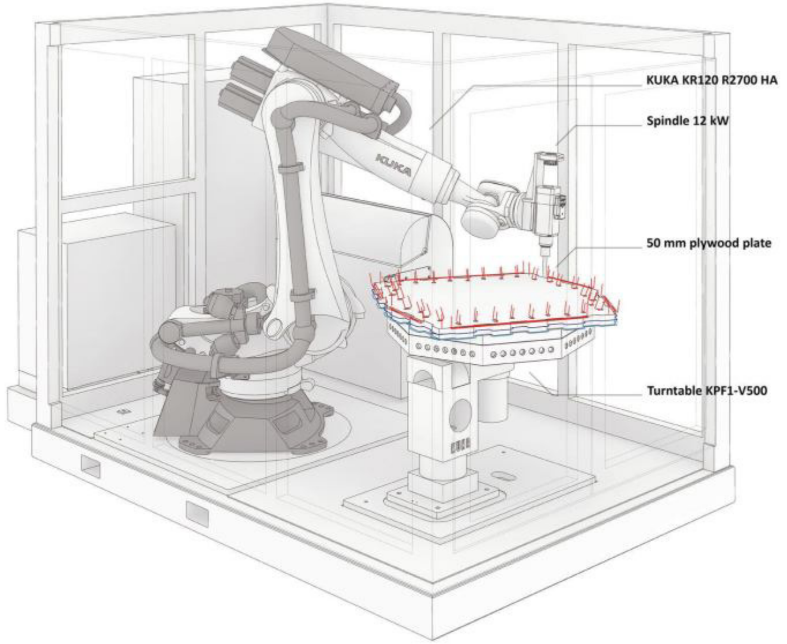




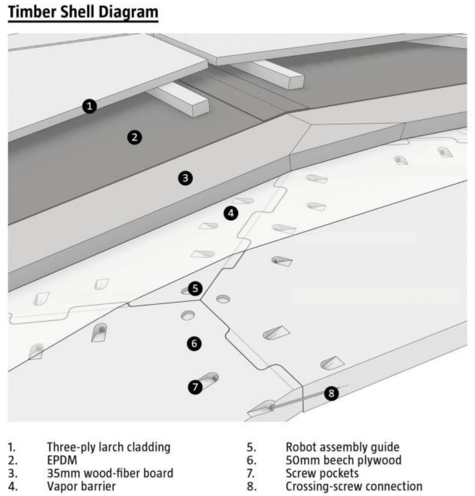
Investigations on Potentials of Robotic Band-Saw Cutting in Complex Wood Structures (Chai H., Yuan P.F. (2019) Investigations on Potentials of Robotic Band-Saw Cutting in Complex Wood Structures. In: Willmann J., Block P., Hutter M., Byrne K., Schork T. (eds) Robotic Fabrication in Architecture, Art and Design 2018. ROBARCH 2018. Springer, Cham)

Versatile Robotic Wood Processing Based on Analysis of Parts Processing of Japanese Traditional Wooden Buildings (Takabayashi H., Kado K., Hirasawa G. (2019) Versatile Robotic Wood Processing Based on Analysis of Parts Processing of Japanese Traditional Wooden Buildings. In: Willmann J., Block P., Hutter M., Byrne K., Schork T. (eds) Robotic Fabrication in Architecture, Art and Design 2018. ROBARCH 2018. Springer, Cham





Landesgartenschau Exhibition Hall, ICD (https://www.architectmagazine.com/technology/detail/made-in-germany-by-robots_o)



Adaptive Automation Strategies for Robotic Prefabrication of Parametrized Mass Timber Building Components (https://www.iaarc.org/publications/fulltext/ISARC_2019_Paper_119.pdf)

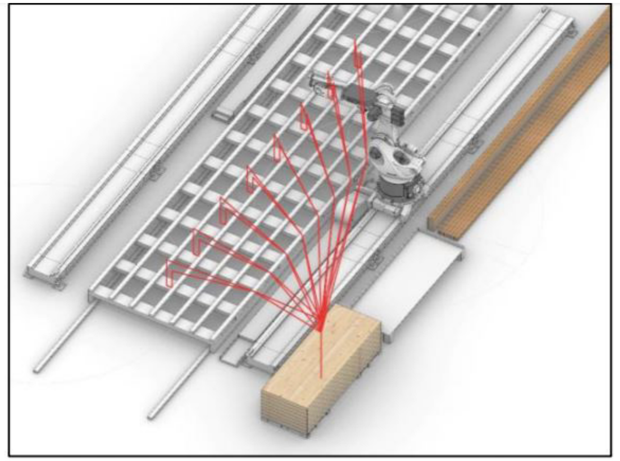


Figure 4: Diagrammatic overview of the robotic assembly process with the highlighted tool path of a robot for handling a stack of CLT panels during assembly

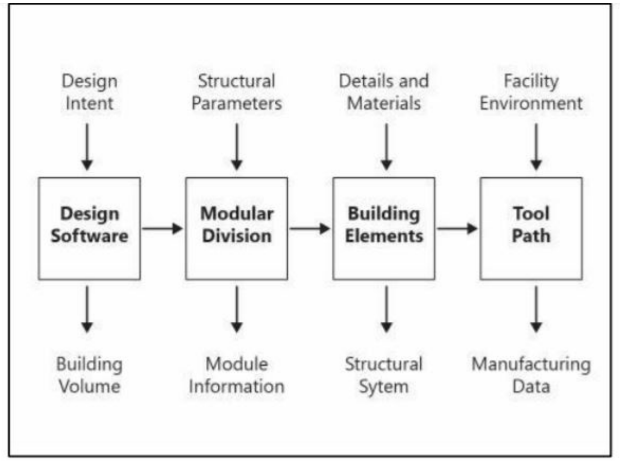
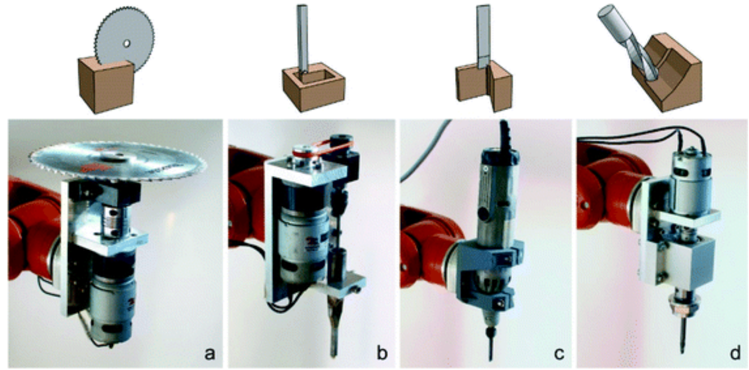
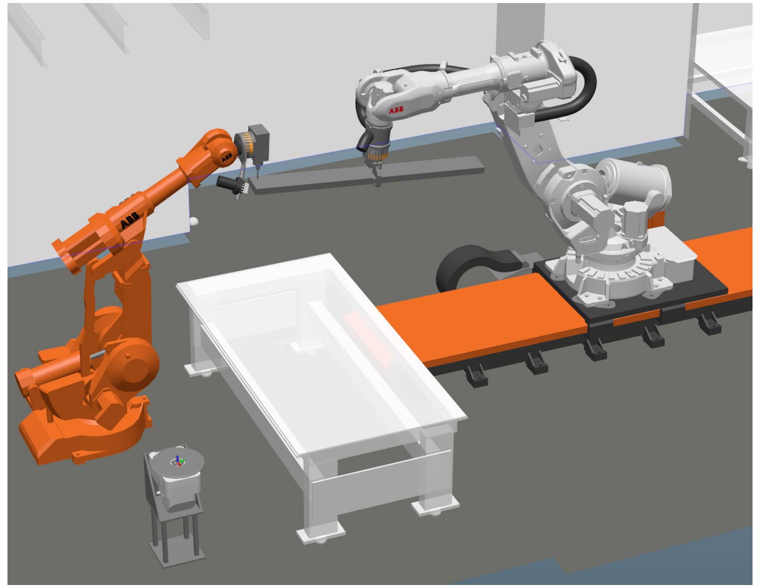


Figure 5. Flow chart of the design process towards the fabrication model. The early design model gets transferred to a modular division, its building elements and finally machine data





Design of Potential Workflow

Case study: Analysis

Phase 1:
The research by Hiroki Takabayashi and others in the paper Versatile Robotic Wood Processing Based on Analysis of Parts Processing of Japanese Traditional Wooden Buildings represented a number of tools tested in various projects done for employing robotics and automation in wood processing. This includes circular saw, square chisel, vibration chisel and router.

However, the whole point of replicating the process is to reduce the amount of manual labor and assistance required in the project. And so, we are planning on creating a toolpath solely using a router as its tool. This will reduce the complexity in the workflow as well as the production process. In case it is absolutely necessary to use multiple tools, automatic tool changes must be employed.

Referring to the DFAB HOUSE by ETH Zurich, the idea of using multiple robots to mill in one orientation and place in another is an essential one. This technique can also be used in the current context for creation of complex geometry in reaching out to the cuts inaccessible from one side of the timber block.

Phase 2:
The DFAB HOUSE case study also provides insights in using the iGPS technique to accurately place the timber positions in place. But with the advancements in technologies like Mimic, is this workflow simplified?

How are you going to do this project?

- Research on various possibilities of production methods using automated processes
- Derive an appropriate production method based on the current concept
- Design a joinery system for deployable structures
- Test the adaptability of the joinery system for various forms.
- Design a toolpath that allows the robot to fabricate this joinery system.
- Teach the robot to assemble the elements. (if it is feasible considering the time we have for the semester)

What do you need to have (hardware and software) to finish this project?

Hardware:

- Materials and tools to test the joinery system
- KUKA handheld CNC router / 3D print of the same
- Different size and shapes of drill bits

Software:

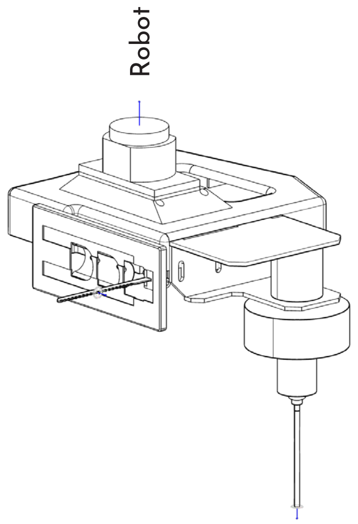
- Rhino
- HAL
- Robotic studio

Material system:

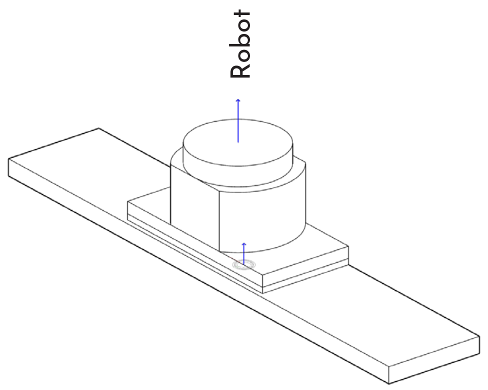
- We will be using Laminated Veneer Lumber for sustainable reasons. This will be explained in later sections.

Tool design:

For restricting the number of tools and tool changes required in the process, we have minimized the number of tools to jigsaw cutter for cutting larger sections and routers for creating holes and indents. We have also created a hybrid assembly of these tools to avoid tool changes.



Hybrid tool for jigsaw cutting and CNC milling



Tool to push the larger log of wood further

Technical Challenges:

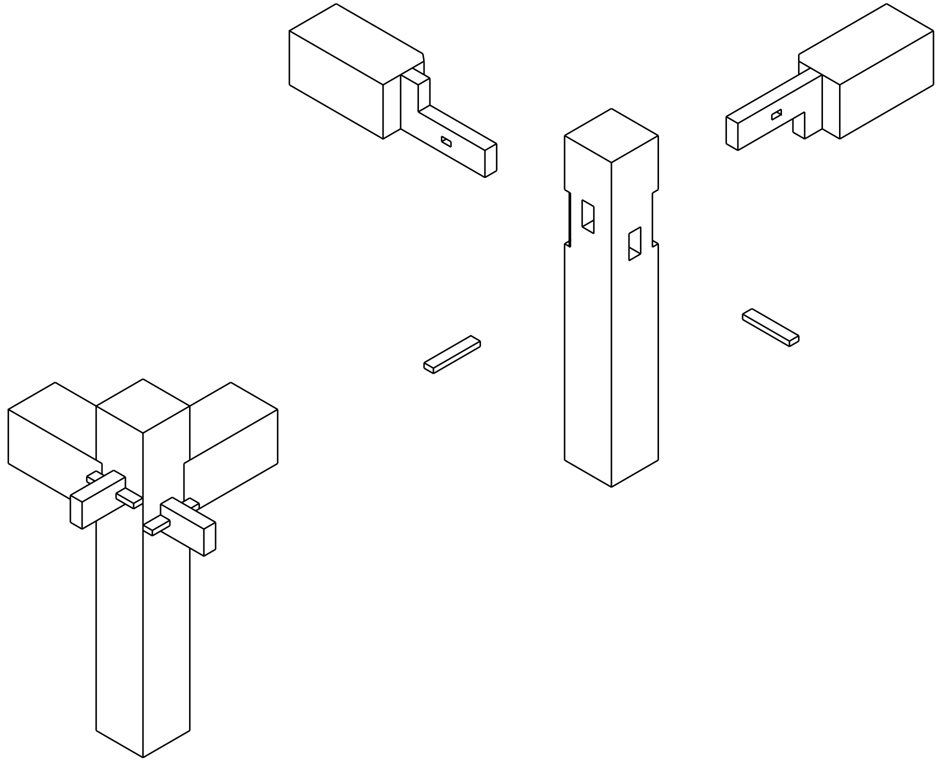
- From Evan Atherton's presentation, it seems like Mimic can be really beneficial for carrying out functions similar to what we are trying to. So based on the project description, what would be a better software to work with: HAL or Mimic?
- If Mimic is beneficial, can we have access to some tutorials for learning the software? And as for the license I am assuming our Autodesk student licenses should be enough, is that right?
- If we use 2 robots for milling the joint, will the wooden log from a robotic arm fly-off or break due to thrust of milling?
- Are chisels better to use than milling drills?

Straight edge cut with chisel

Rounded edge milled using router

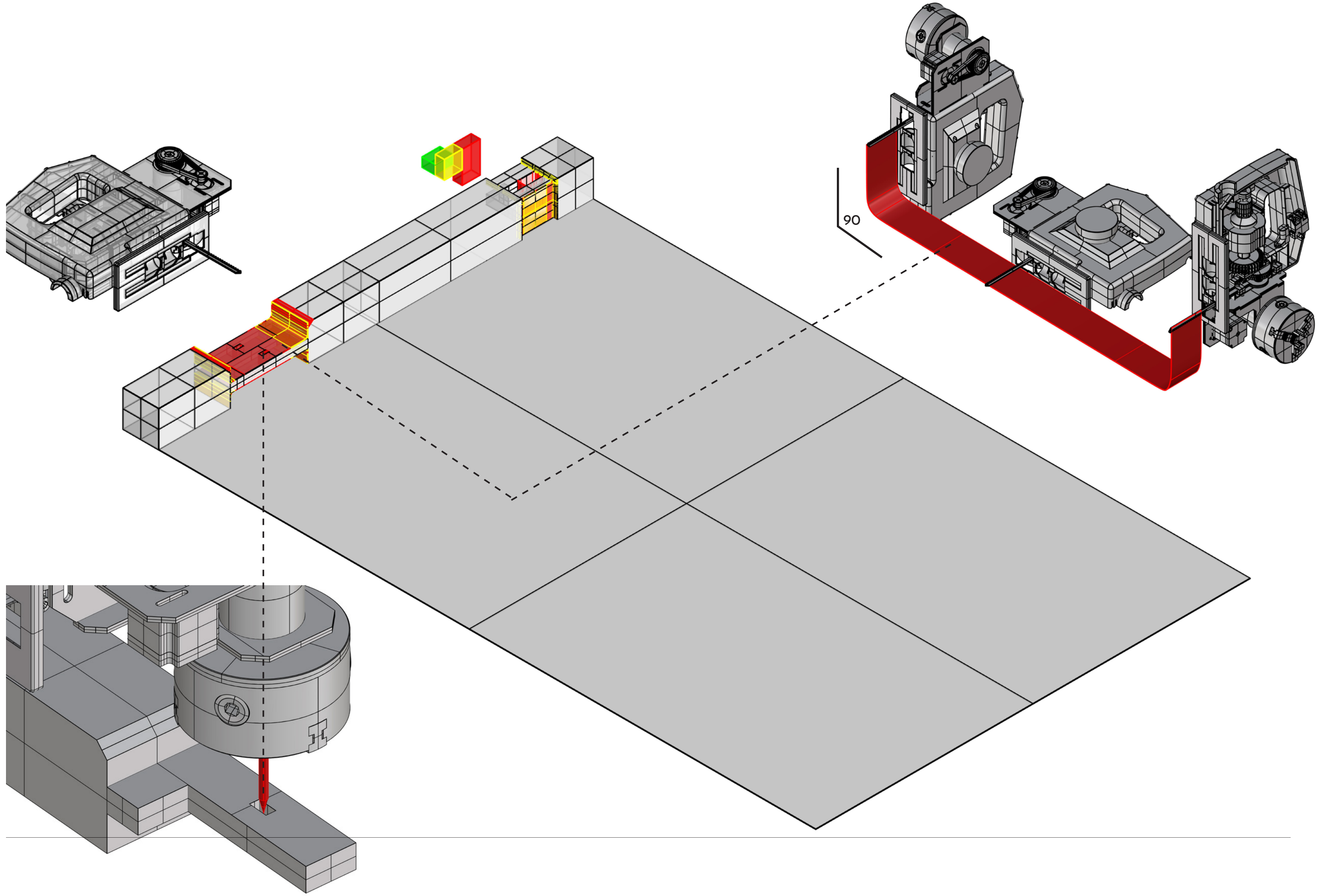
Assembly design:

The structure design is based on the traditional beam and post system with tenant and mortise joinery. As mentioned earlier, the project advocates adoption of sustainability. For this reason, the material chosen is here is LVL (Laminated Veneer Lumber) which is a composite product that maximizes the wood yeild from timber log. The residue produced as a part of this production can be recycled and re-incorporated in the next batch.



Fabrication Workflow:

The jigsaw blade is connected to the robot at a 90 degree rotation. If the blade was set perpendicular to the surface, it would have to rotate a 180 degrees to execute the scooping. In order to avoid complications involved in this process, its zero position is set at 90 degrees to surface, requiring only a 90 degree rotation in each direction.

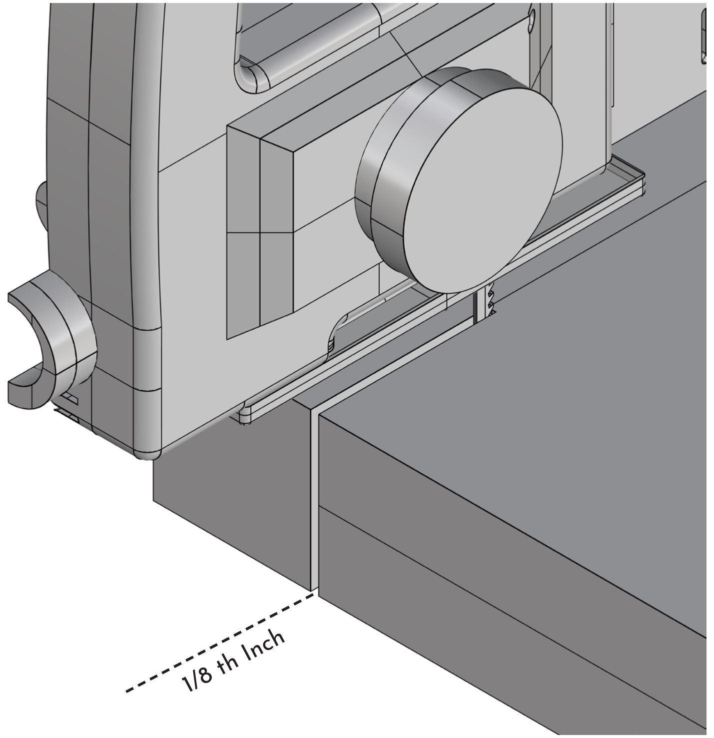


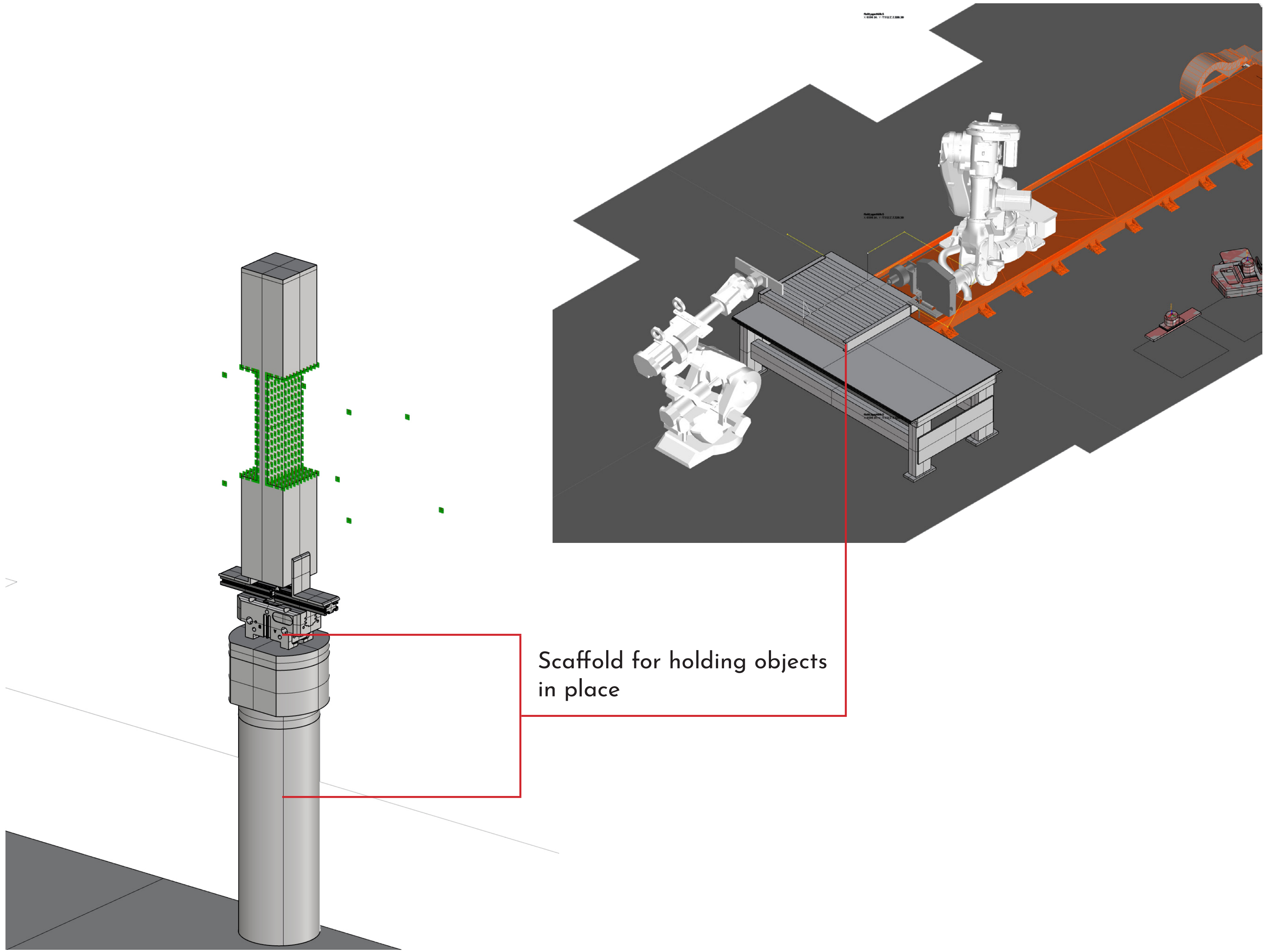
Additional Structure + Material:

The defined system requires routing and drilling holes. If this is done by laying the wood flat on the table, there is a high possibility that the drill bit will hit the table and damage the table as well as the robotic arm. So for safety reasons, a scaffold will be installed on the table to raise the section before processing.

The scaffold represented here is a framework to hold the objects in place while the process is on. We are aware that this might not b enough infrastructure to hold the object under pressure of milling, but a simplistic approach has been chosen to reduce the complexity of the workflow.

As shown in the figure, when using a jigsaw blade, the cut makes an 1/8th inch gap. In regards to this, all of the sections should be considered with a buffer of 1/8th inch.



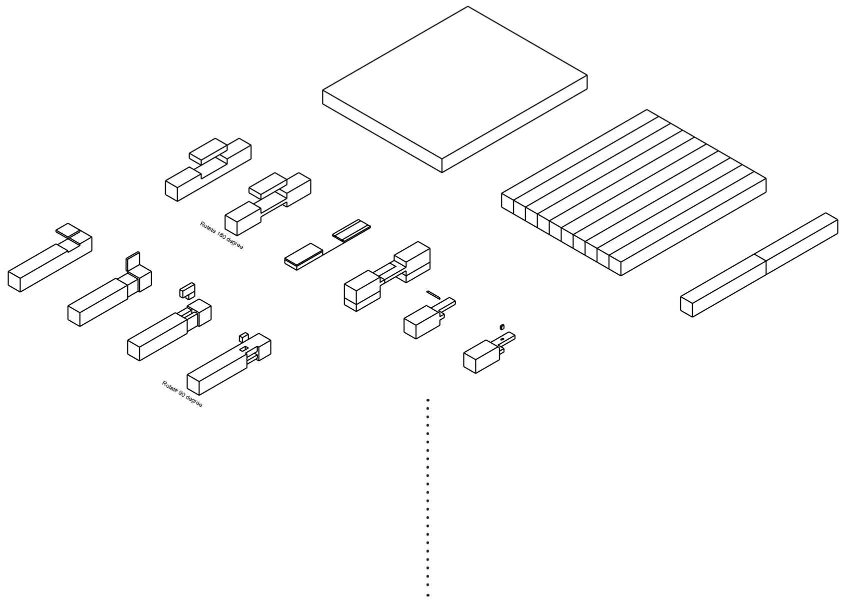


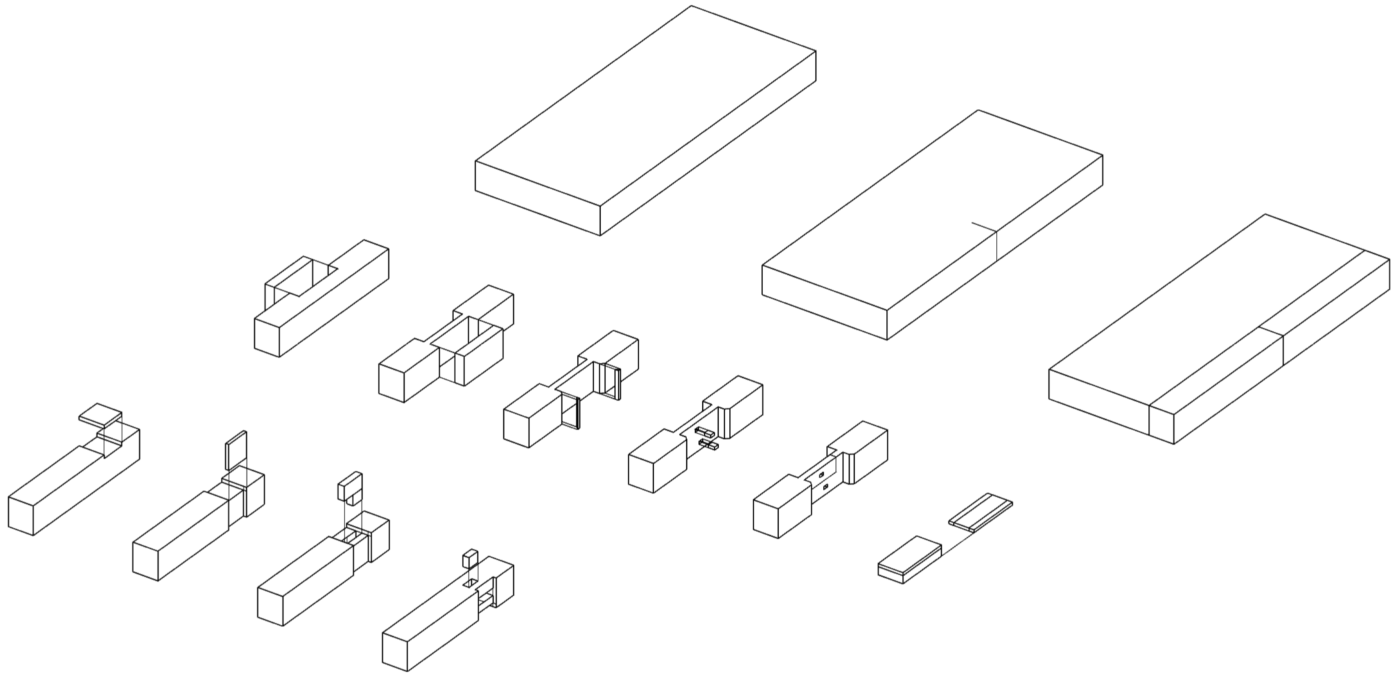
Fabrication Sequence:

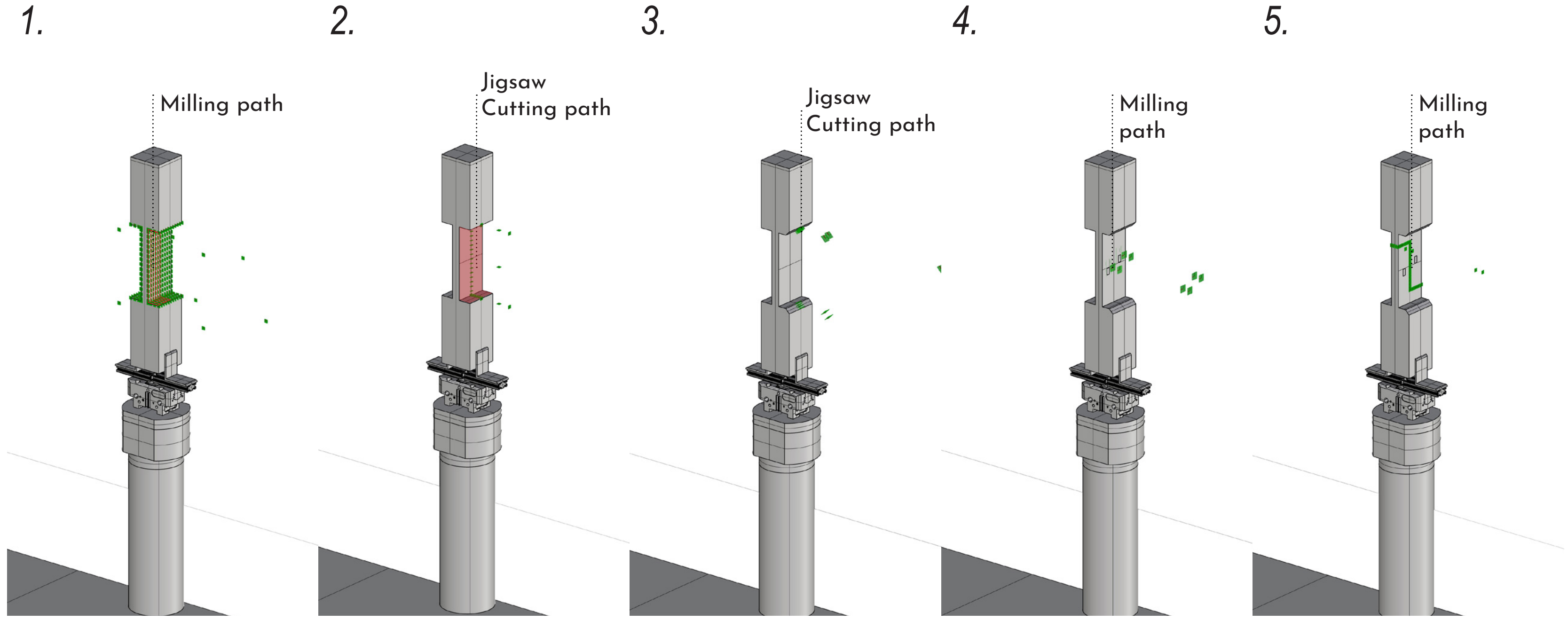
The assembly sequence represented here incude the following steps:

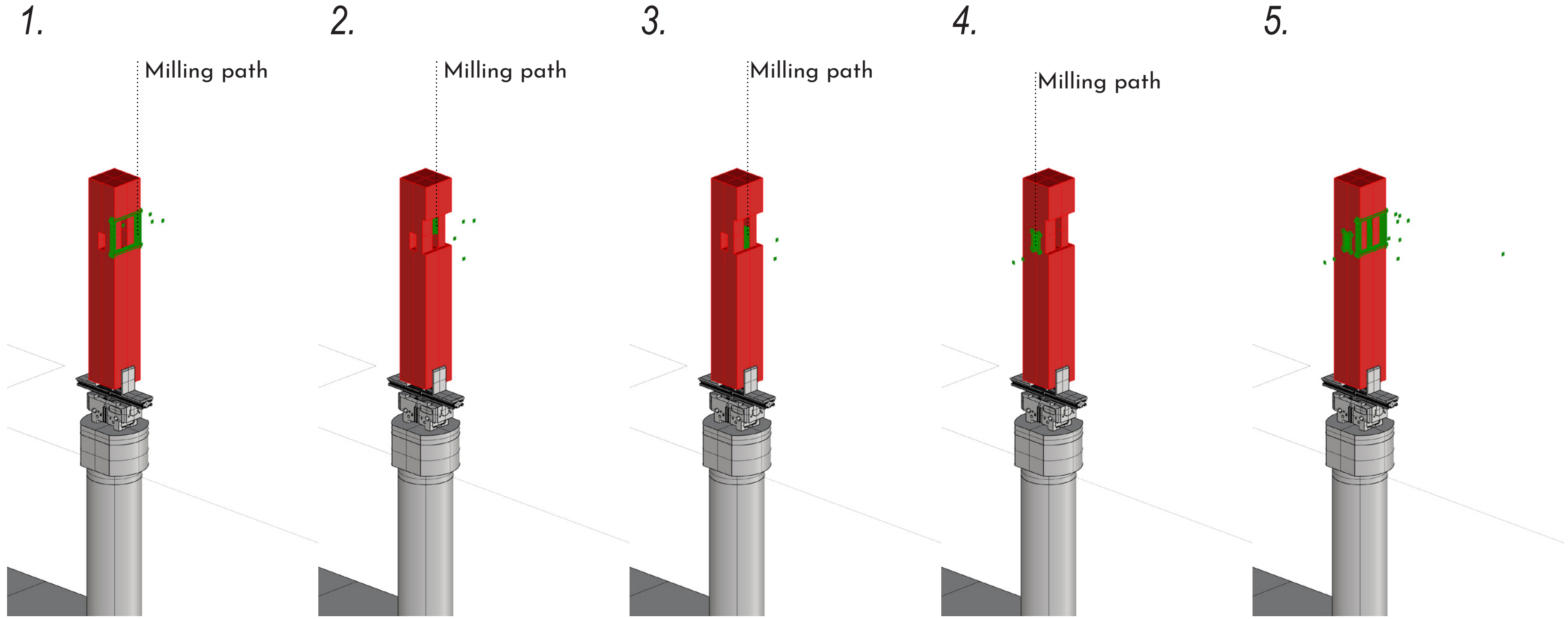
- Cutting down a larger wooden bed into desired pieces
- Removing larger sections using jigsaw blade
- Once above process is performed, the jigsaw will be used to clean the edges from the processed area
- Using router to mill the smaller sections and drill holes

*A number of rotations are performed during the entire process as the section needs processing from 3 orientations

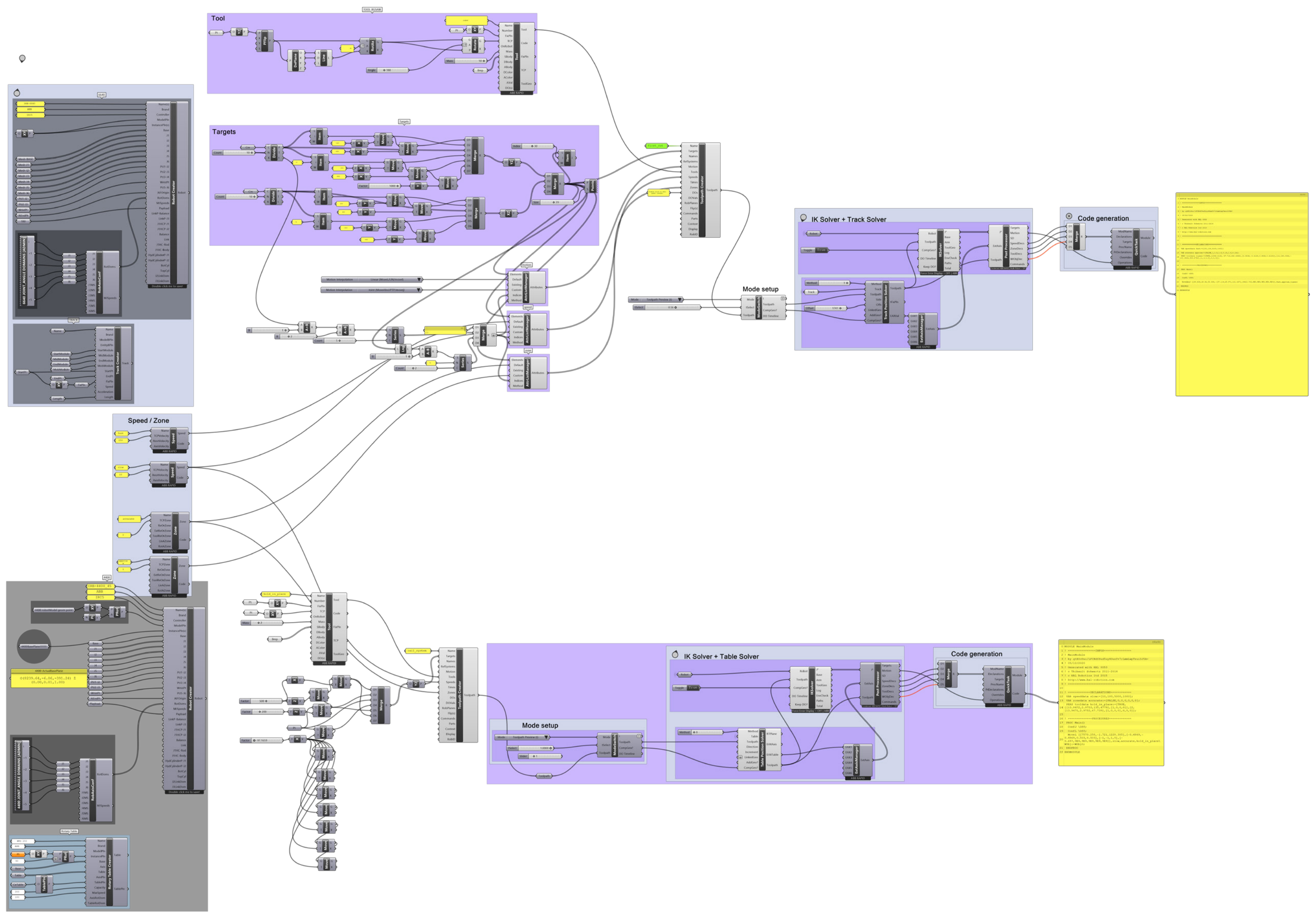


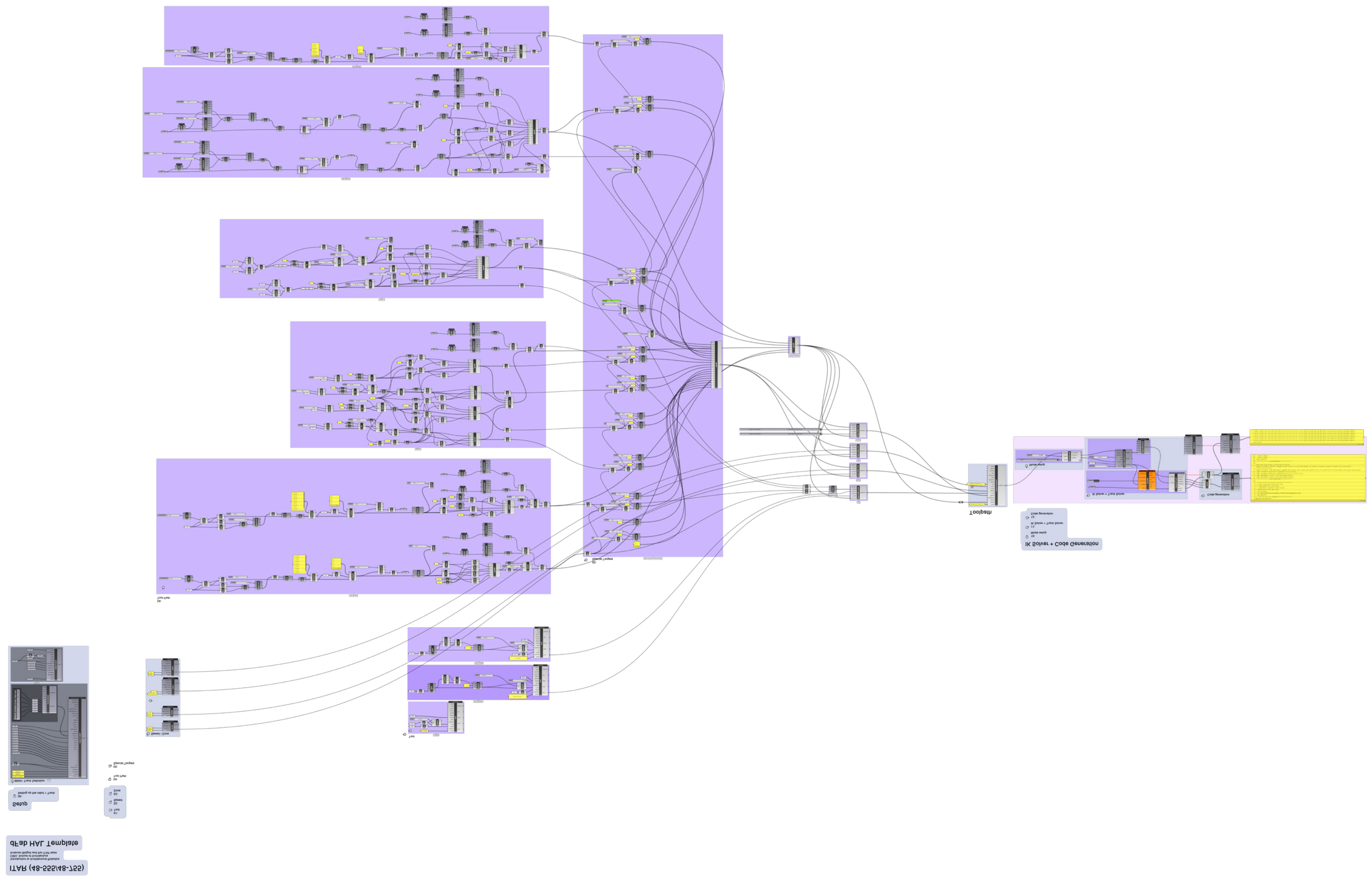






Workflow samples:





Challenges Faced:

Design Related Challenges

- We choose a complex geometry and over that set up a few many constraints which resulted in a complex workflow for cutting the sections
- For reducing the number of tool changes, we designed a hybrid tool comprising of the tools required for this project. This reduced the recurring tool changes, but introduced many conflicts due to the large size of this hybrid tool creating hinderances in performing rotational motions to reach the targets.

Technical Challenges

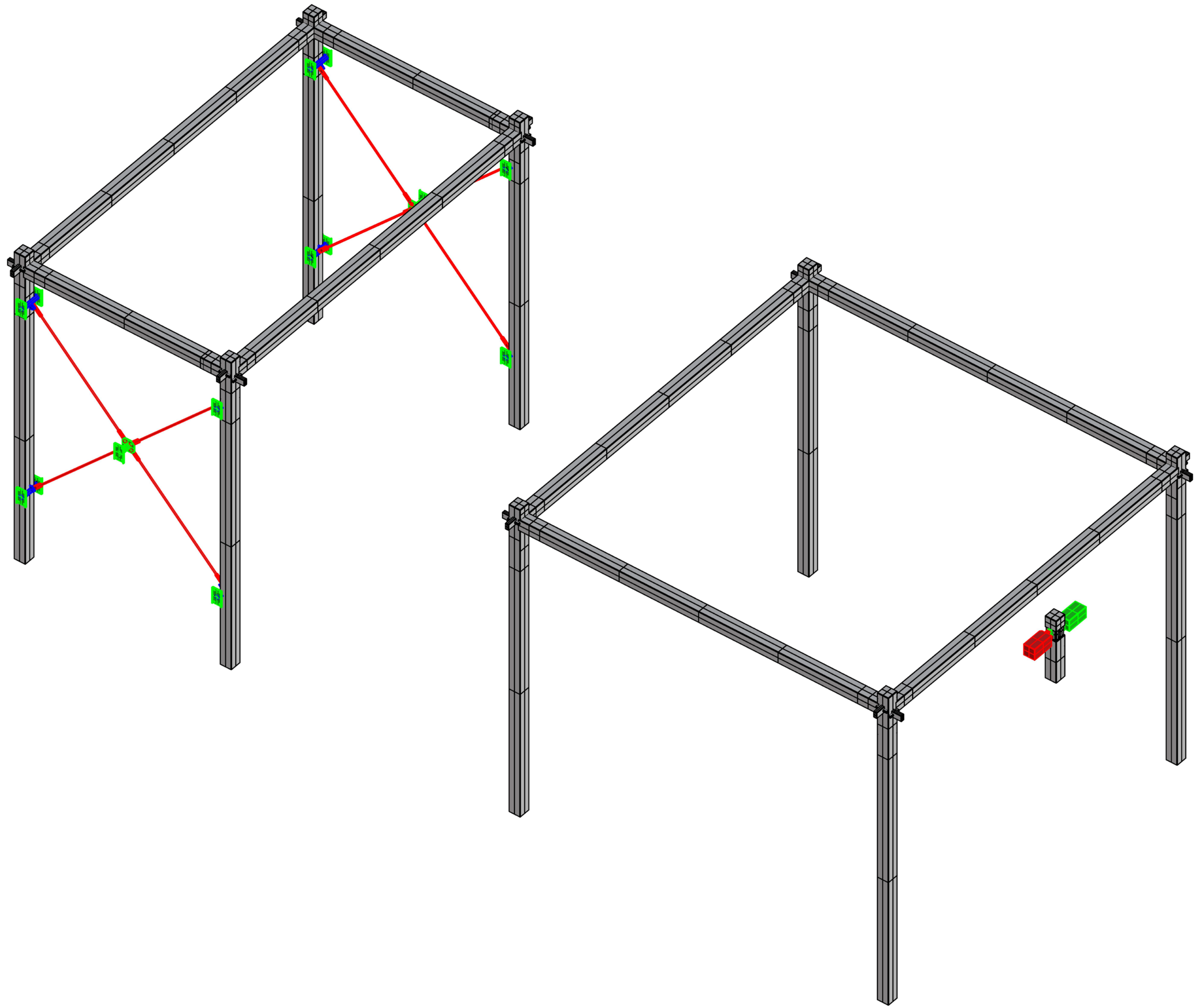
- As both the team mates have limited knowledge with data structure and coding, the resulting workflow is really complex
- Certain aspects of the project required conversation between 2 robots which would have been easily resolved when working hands-on with the Robots. But due to the COVID-19 crisis, few parts of the project use an alternative solution for representation purposes.

Further Development:

With the current joinery system, the only possible structure is a simple post and beam skeleton. In order to extend its possibilities, either external hardware parts like the braces shown in the figure can be used or a connection joint must be designed.

For the future development, the project will explore these alternative joints which can provide flexibility and adaptability to these spaces that are supposed to cater the masses.

This circles back to our idea of the relevance of this project.

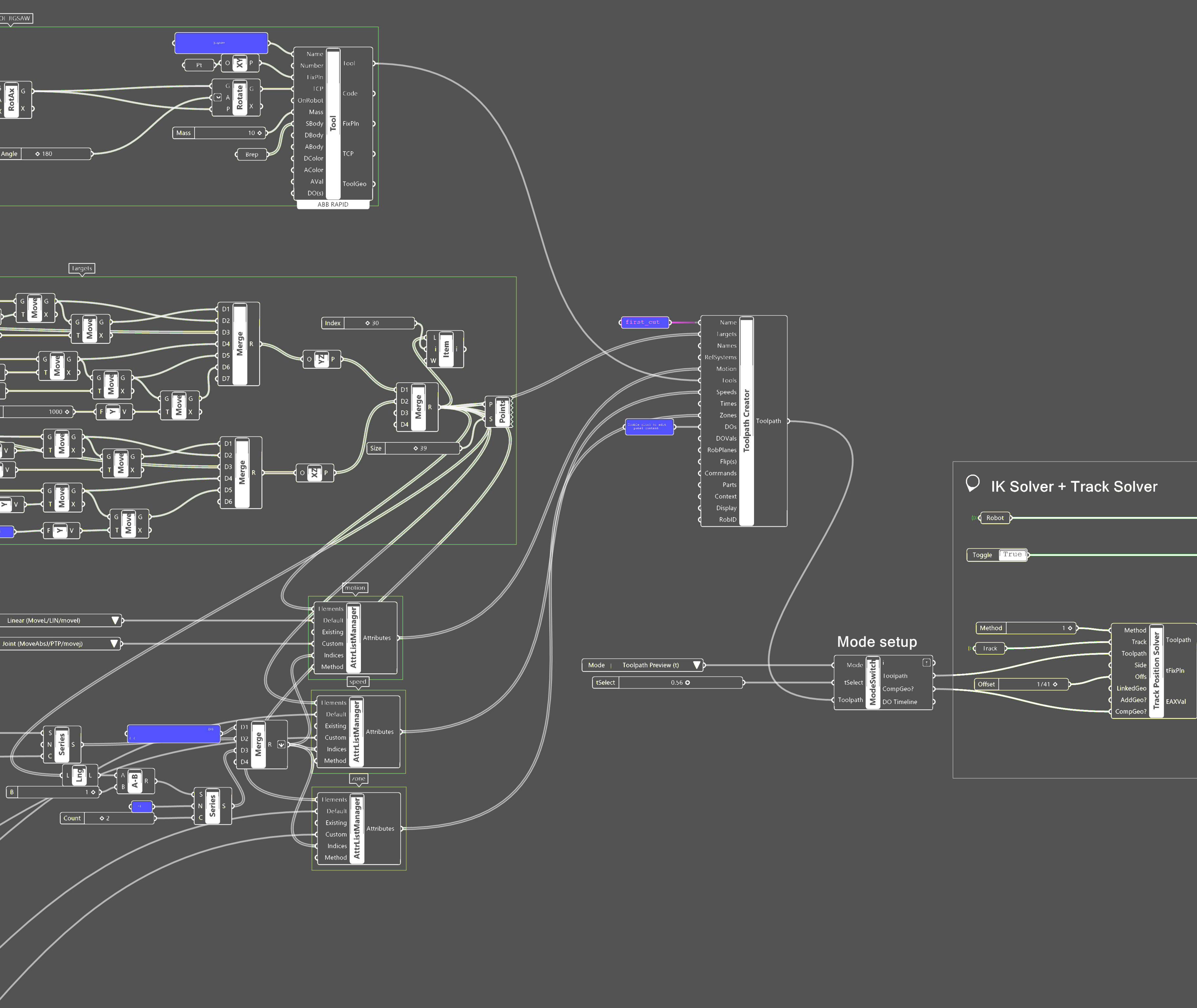


Time table

- Now - April 16th — Research and design of the joinery
- April 16th - April 23rd — Test the joinery system for various forms + Build the tool required for its production
- April 23rd - April 30th — Design a toolpath for the robot to fabricate the joinery system
- April 30th - May 7th — Teach the robot to assemble the elements & Documentation

References:

- Willmann, Jan. et al. Robotic Fabrication in Architecture, Art and Design 2018 Foreword by Sigrid Brell-Çokcan and Johannes Braumann, Association for Robots in Architecture . 1st ed. 2019. Cham: Springer International Publishing, 2019. Web.
- https://www.architectmagazine.com/technology/detail/made-in-germany-by-robots_o
- https://www.iaarc.org/publications/fulltext/ISARC_2019_Paper_119.pdf
- Robotic Timber-Framed Incremental Housing (https://vimeo.com/288362721)
- ETH Zurich builds DFAB HOUSE using robots and 3D printers (https://www.designboom.com/technology/eth-zurich-dfab-house-robots-3d-printers-06-30-2017/)
- Deep Timber (https://gramaziokohler.arch.ethz.ch/web/d/forschung/369.html)



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RobPlanes
Flip(s)
Commands
Parts
Context
Display
RobID
Toolpath Creator
Toolpath
IK Solver + Track Solver
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Joint (MoveAbsJ/PTP/movej)
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