Tangible Grasshopper: Collaborative Tangible User Interface for Parametric Design

Yiwen Shen
Technical University of Eindhoven
Eindhoven, the Netherlands
y.shen1@student.tue.nl

ABSTRACT
The research project presented in this paper discusses the development of an intuitive and interactive TUI (tangible user interface) for parametric design. Three prototype iterations are described, tested by the users and evaluated by using the Rich Interaction Framework [6]. The purpose of the project is to explore how to design a TUI for parametric designers and what determines whether the interactions provided by this TUI are considered to be aesthetic interactions. The TUI creates a physical medium offers multiple-person to perform digital modelling. In addition, it provides a user-friendly approach for users to control multiple variables, do testing and directly manipulate digital models in real time. The prototype aims to develop tangible computational methods to extend the boundaries and capabilities of digital design and fabrication tools.

Author Keywords: Parametric Design, Tangible User Interface.

INTRODUCTION
Parametric design offers architects, industrial engineers and industrial designers with a powerful, logical and flexible medium to generate complex 3D geometry and simulations [19]. It also enables designers to quickly alter certain design characteristics and interactively preview them in real-time. Therefore, designers no longer need to create geometry or complex simulations in the traditional way, but instead, to create connective visual algorithms to automate the entire design process to replace the intensive labour work and repetitive interactions. However, the creation of visual algorithms is challenging to master and very specific towards the different design requirements. Thus, the operation of the parametric design is limited only to specialists, which results in a linear process, where evaluations were executed only after the design process for validation purposes, rather than for assisting in the process of design [13].

On the other hand, parametric software such as Grasshopper is based on a graphical user interface (GUI), the problem of interacting with the GUI in Grasshopper: 1) does not encourage collaborative use [7] between co-designers and people from different fields, 2) does not provide designers with the interaction that naturally occurs in the physical environment [8], 3) does not allow direct manipulation of multiple variables. Additionally, parametric designers are also limited to existing tangible artefacts to interact with the digital environment [13]. In recent years, there have been several attempts [1][2][11][13][15] to bridge the gap between parametric designers and other stakeholders involved in the design process, for example, VR-Edge [15] and Mindesk [11]. Both of them are Grasshopper plug-in's which deal with models and data visualization directly in Virtual Reality [11][15]. However, creating a VR simulation requires additional specialisation and higher budgets on the device and equipment, moreover, the interactive experience offered by VR device sometimes cause motion sickness, which can have a negative impact on the user experience [18].

This research paper aims at expanding the boundaries of current tangible artefacts and pipelines to achieve a novel approach for engaging parametric designers and co-design by using a tangible user interface. The proposed prototype enables tangible interaction to take place in the physical situation and provide real-time response and feedback to the designer and other stakeholders.

In this research report, we describe the iterative design process of creating three TUIs. We first review the development on the intersection of tangible interaction [8], rich interaction [6] and aesthetic interaction [16]. Then elaborate on the process that guided the design decisions. Each design was tested by users and evaluated by applying the Rich Interaction Framework. We discussed the

evaluations and insights of each iteration and applied them to the next iteration for improvements. Finally, conclusions are presented with suggestions for future research.

THEORETICAL BACKGROUND

Interacting digital information by using windows, menus or icons has become a predominant approach in the design of HCI [6][8]. Therefore, the term of TUIs was proposed by Ishii and Ullme [8] as an alternative for GUIs. Tangible Interaction is an interaction style that utilises physical objects as mediums to directly manipulate and interact with digital information. They discussed that rich affordances offered by graspable objects allow users directly manipulate and control the digital information in a seamless manner [8].

Frens [6] took the theory of affordances and tangible interaction to a further step, which he coined as Rich Interaction [6]. He discussed that any interactive product can be seen as an integration of the three following properties: 1*) form, 2) interaction and 3) function*. Moreover, he defined that Rich Interaction *starts from respecting human's skills, aiming at achieving* ***Aesthetic interaction*** [16] *through the unity of* ***form, interaction and function*** [6] (Figure 1).

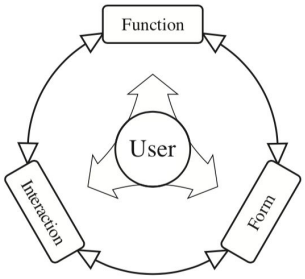

Figure 1. Rich Interaction Framework (Frens, 2006)

Ross and Wensveen [16] further explored the notion of Aesthetic Interaction and proposed four principles to guide designers to design a product or system. They stated in the four principles that ***Aesthetic Interaction*** *involves practical use, dynamic form, social and ethical implications and involves the whole human being [16].*

In this project, we aim to implement these principles into our design process and evaluate resulting prototype in terms of form, function and interaction. The design goal of this TUI is to explore:

"How to design a TUI that would not only allow users to operate Grasshopper, but would also invite Aesthetic Interaction?"

RELATED WORKS

Previous research [1][2][13] has shown the possibility of establishing a tangible artefact that is capable to bridge the gap between the physical and digital environment and provide designers with an intuitive, real-time visual feedback and collaborative solution.

Emad et al. [1] developed several prototypes that were combined with a mobile application that allows the architects to mimic the motion of the facade in response to sunlight. The entire platform consists of computing systems, sensors, actuators and microcontrollers. The communication between software and hardware was established by using a Grasshopper plug-in named *Firefly* [14] that is developed by Andy Payne. However, the project was mainly focused on providing tangible interaction that is specific to architectural design, especially the design of the facade, which is not suitable for parametric designers working on different parts of construction design, e.g. stress calculation.

Boris et al. [13] developed an interactive system called CDP (Collaborative Design Platform) that allows people who are involved in the design process to physically place the objects on screen to create a large scale virtual urban environment. The project also allows data to be captured and then transferred to the central system that will be severed for future analysis. This platform opens up opportunities for architects to have an interactive and intuitive way of designing together with their clients and co-designers. However, this physical size of this platform is not applicable to all situations or professions, the aim of the interface should also be easy to use and mobile.

We discovered that most of the existing solutions were proposed to solve only the architectural design problems. Less attentions were given on the design of the interface and general user experience, and none of them were suitable for an everyday use scenario. Therefore, we aim to design a universal prototype that not only fits an everyday use for different parametric designers, but also for non-design oriented users who want to operate Grasshopper without in-depth knowledge of parametric design.

METHOD

This research project is conducted by using research through design method [9], which can be described as the generation of knowledge through the iterative process of designing and testing experiential prototypes. The communication method to perform data exchange between software and hardware is achieved by using the similar approach that Emad et al. [1] proposed in their design. However, the significance of this research is that we went through three iterations of prototype. In each iteration, the qualitative user data were gathered by utilising different field research methods, including co-constructing stories [3], contextual interviews [4] and diary studies [5]. Each iteration was designed that differ in shape and interaction and function.

In order to find out what type of interaction offered by this TUI is perceived as aesthetic interaction, hence providing aesthetic interactive experience, three iterations along with different themes (Figure 1) were defined. Each theme was defined to cover a specific area of the potential solution domain. When designing this TUI, we interviewed different specialists, which ranging from architects, industrial designers and fashion designers. This serves the researcher to find a balance between different Grasshopper users.

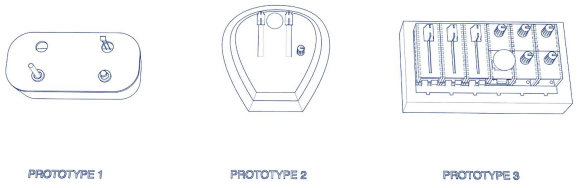

Figure 2. Artistic impression of each prototype

Three themes are:

1. **Pilot prototype:** A symmetric bimanual interface that offers two handed interaction
2. **Ergonomic prototype:** A textile interface that offers one handed interaction
3. **Modular prototype:** A modular sandbox that allows users to customise the interface depending on the project.

Prototype 1: Pilot Prototype

The pilot prototype aimed to elicit user experience and define design criteria. The shape of this prototype is originated from a lunch box that has a symmetric from. It has also a proper size which allows two-handed interactions for the users. Three input devices are connected to an Arduino Uno board and installed on surface of the lunchbox: a light sensor, a rotary potentiometer and a push button (Figure 3 & 4).

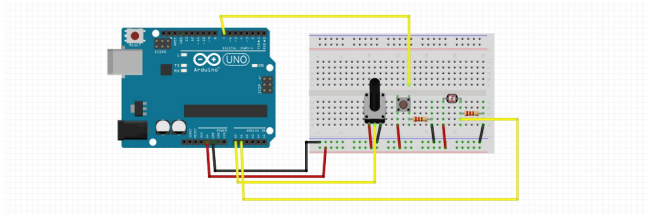

Figure 3. Input devices setup

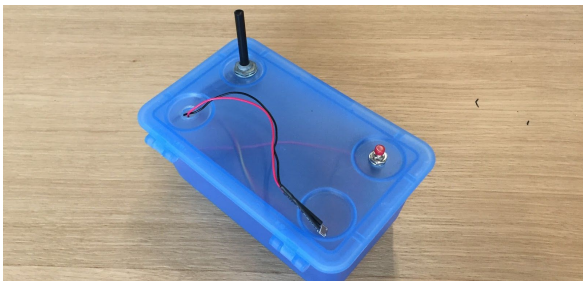

Figure 4. Pilot prototype

In Grasshopper, functionality is usually achieved by connecting different components and variables. The manipulation of variables is mainly operated by sliding the corresponding *number slider component* (Figure 5) horizontally.

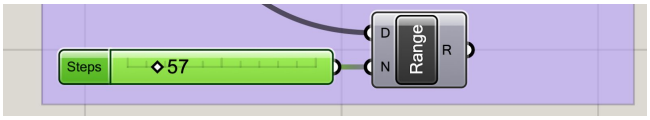

Figure 5. A number slider component

To establish the connection between the input devices and Grasshopper code, *Firefly Uno Read component* was used to replace the function of *number slider component* (Figure 6). Each input value was remapped to a suitable range to serve design purpose.

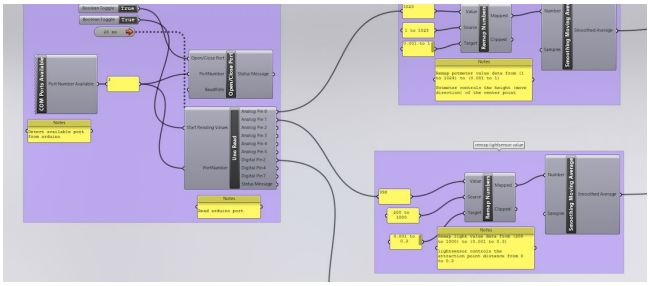

Figure 6. A number slider component

Two Grasshopper examples (Figure 7 & 8) were created for users to interact with. The input devices were connected to Grasshopper to perform the predefined functionalities.

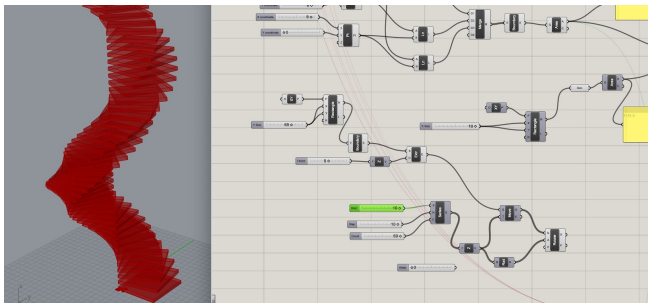

Figure 7. Example 1 is a simple simulation that allows users to 1) rotate geometry, 2) move geometry and 3) extrude geometry to a certain height (Shen, 2019).

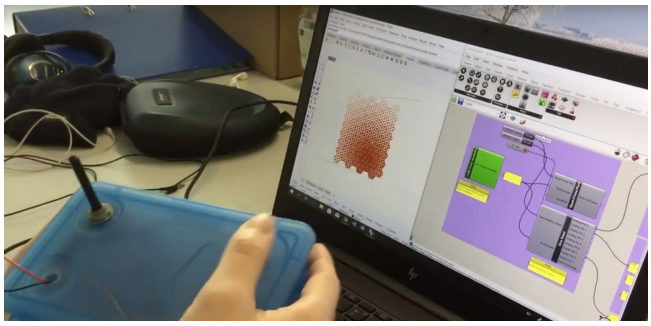

Figure 8. Example 2 is a facade simulation that allows user to 1) change the movement of sunlight by rotating the rotary potentiometer, 2) "open" and "close" facade by changing the density of the light sensor and 3) change color of facade by pressing the push button (Shen, 2019).

- Data collection & Analysis

5 participants took part in this study. All participants were chosen based on the fact that they have some experience with parametric design. Two participants are from the Built Environment Faculty majoring in architecture design, the other participants are industrial design students from Industrial Design Faculty.

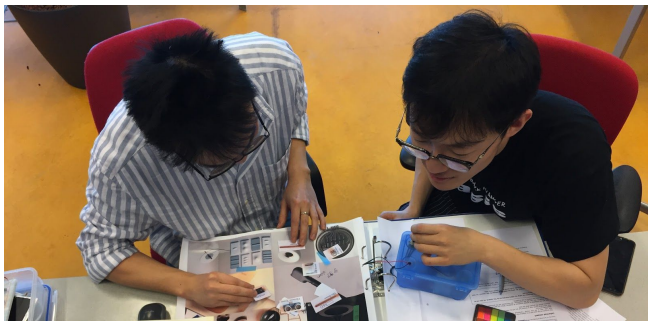

Figure 9. User test with one participant, who studies Architecture design

The participants were asked to interact with this prototype and perform actions to achieve predefined functionalities in Grasshopper. Their actions and behaviors were observed by us. A semi-structured qualitative interview (Appendix 1) was also organised after the experience. Each interview was recorded and labeled with the different color, their quotes were codified into different descriptive terms that can be easily recognized (Figure 10, see Appendix 1). The affinity diagram [4] was used to arrange the insights into a hierarchy that reveals similarities and common issues across all the participants. The co-constructing stories method [3] was used to stimulate them to conceptualise design criteria in terms of form, function and interaction. The collected codes were categorized in order to get refined themes. The software Marginnote [11] was used to visualize these themes, this helped us to discover the logical relationship such as similarities between these refined themes.

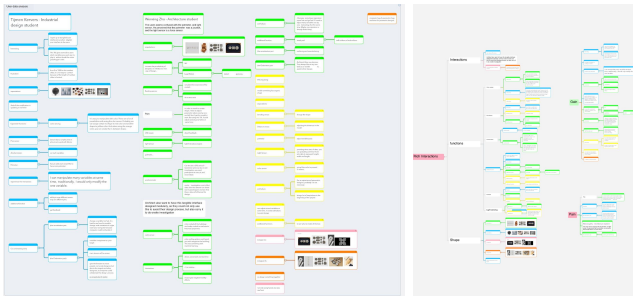

Figure 10. Data visualization by using Marginnote (left: Raw data, Right: themed data)

- Evaluation

The qualitative data were categorized into 4 themes: We list some major findings here in terms of interaction, form function and aesthetic interaction.

Interaction:

- Participant green and yellow, two architecture students, concluded that only the rotary potentiometer can be seamlessly integrated during operation of given examples based on the fact that it provides angles of rotation. They stated: *[...] the size of number slider component in Grasshopper is too small, for me it is hard to manipulate its variable in a large range of numbers. For example from 0 to 1000, using this potentiometer helps me to fine-tune these variables in a more precise and natural manner ...* However, the action offered by the rotary potentiometer was perceived to be unnatural by participant blue, he stated: [...] *for me*

it will feel more natural if you use a slider potentiometer to map the functionality of extrusion ...

Form:

- The form of the potentiometer was perceived as a joystick by participants yellow and green, we believe this was because of the inappropriate affordance was perceived by them.
- The form of this pilot prototype failed to offer aesthetic interaction. Participant blue, an industrial design student concluded that two-handed interaction is a problematic way when operating grasshopper. He stated: *[...] It is not handy work with this interface on both hands. I also need to use a mouse to navigate Grasshopper…*

Function:

- The function of the push button failed to provide user aesthetic interaction because it has no practical use. It only provides digital input (0 and 1) which can not be utilised effectively in Grasshopper.
- The function of "open" and "close" facade by changing the density of the light sensor was perceived as aesthetic interaction in the facade simulation example. Participant yellow mentioned that: *[...] that is great, I can observe the movement of the facade according to the density of light, and it is real -time rendering...* However, the end result could not stay because of light sensor always turning back to the same value after removing a hand. Participant pink states: *[...] I want to keep this result but after I remove my hand, it goes back ...*

Aesthetic Interaction:

- This prototype also has social dimensions. Participant yellow mentioned: *[...] This tangible interface allows me to design something with my classmates maybe clients in the future, this will save me a lot of time on discussion...*

- Insights

From this pilot study, we have learnt that the pilot prototype has practical use and social dimensions. However, the design failed to respect human's bodily skills, bimanual interaction doesn't seem to be user friendly based on our observation.

We also discovered that if the users perceive that the predefined functionality in Grasshopper maps naturally the action that the input device affords, this will promote aesthetic interaction in the design or a TUI. Which Norman defined as the term of "Natural mapping" [21] and Djajadiningrat, Wensveen and Overbeek defined as "Feedforward" [22]. We took our findings from this pilot study and visualized a functionality mapping framework (Figure 11) as follows to our next iteration:

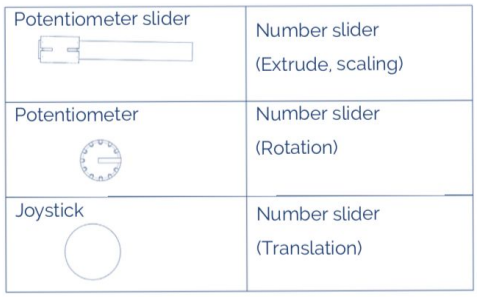

Figure 11. Increasing or decreasing functionality such as Extrusion or scaling is mapped to the sliding the slide potentiometer, rotation is achieved by the rotary potentiometer and translation is achieved by using a joystick.

Prototype 2: Ergonomic Prototype

This prototype (Figure 13) was developed based on the design insights concluded from the pilot study and functionality mapping framework. In this iteration, we aimed to design our prototype that offers an ergonomic experience, allowing users to interact with one hand, navigating Grasshopper to inspect 3D models with the other hand. This prototype is embedded with two slide potentiometers, a joystick and a rotary potentiometer on an Arduino Uno (Figure 12). Slide potentiometer serves to map the functionality of increasing or decreasing variables to perform extrusion and scaling. The joystick aims to perform the multidirectional translation and the rotary potentiometer aims to achieve rotation.

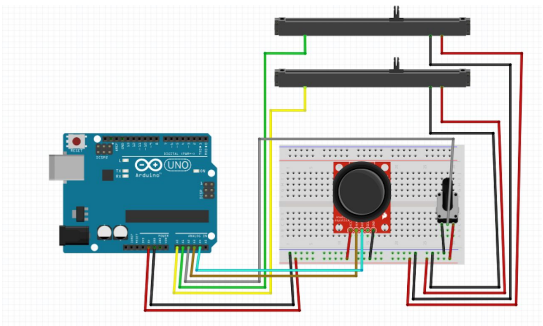

Figure 12. Input device setup

Figure 13. Ergonomic prototype

- Data collection & Analysis

In total, five participants took part in this study, three of them are the same participants from the pilot study: one student majoring in architecture design and two students from Industrial Design. The remaining two participants are garment designers graduated from Industrial Design who run a design startup named Labeledby. They have experience with 3D fabrication and but not very experienced in using Grasshopper.

The participants were asked to interact with this new prototype and perform actions in the Grasshopper examples that were provided in the pilot test to achieve predefined functionalities. Their actions and behaviors were observed by us. Follow- up interviews were organised and the affinity diagram (Appendix 2) was used to visualize data in order to get refined themes (Figure 14).

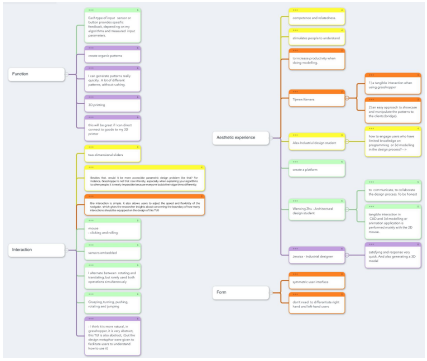

Figure14. Designer was using TUI to generate patterns

Furthermore, different design assignment ((Figure 16 & 17) was requested by the Labeledby [9]. They would like to a few pattern generators (Appendix 7) that allow them to: 1) quickly iterate patterns, 2) quickly alter certain design characteristics and interactively preview them in real-time, 3) the generated patterns can be exported to STL format and printed on the textile. Therefore, the predefined functionalities were more than just performing rotate or extrude a geometry, the pattern generators need to designed that enable them to create patterns with aesthetic appeal for quick iterations and production.

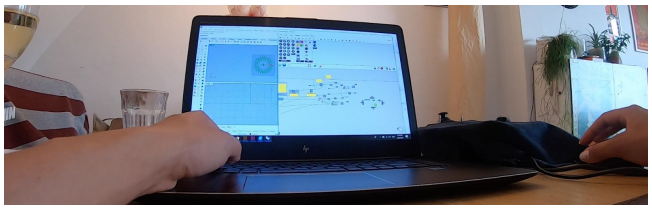

Figure 15. Designer was using TUI to generate patterns

A diary study was conducted with the Labeledby. Our reasoning to use diary study was to capture and understand the user's behaviours and intentions in situ. They were asked to take pictures with their mobile phone and record video footage with GoPro during their design process (Figure 15).

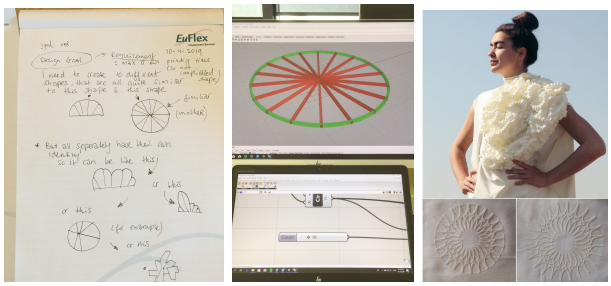

Figure 16-18. Design requirement, grasshopper code and end results (from left to right)

Figure 19 Generated patterns printed on fabrics

Figure 20. The created garments were delivered to Bangladesh Fashion Summit (Labeledby, 2019).

- Evaluation

Interaction

- The functionality mapping framework we developed in previous pilot study has succeeded in creating good interpretation, especially the use of slide potentiometers. Participant orange stated: *[...] the slide potentiometer vividly mimics the sense of control provided by the number slider component in the Grasshopper...*
- The joystick provides a flexible way to manipulate geometry. One garment designer mentioned: *[...] I can navigate patterns vertically and horizontally, this allows us for a quick exploration ...*
- Rotary potentiometers provide aesthetic interaction only when rotating geometry. Participant purple mentioned: *[...] for me it feels more natural to perform rotation with this rotary potentiometer ...*

Form:

- The form of TUI concept failed to provide aesthetic interaction because it did not respect human's bodily skill. Participant purple mentioned: *[...] the size of this interface is too big, and this is designed for left-handed users, what about the right-handed? ...* Furthermore, she also mentioned: [*...] All the input devices are fixed on this interface, I can not operate rotary potentiometer with my thumb. And what about people with smaller hands?*

Function:

- The joystick was introduced in this iteration, some participants found that the function of joystick maps naturally to the functionality that was predefined in the given Grasshopper examples. Participant green stated: *[...] I can move an object in any direction ....* However, others felt differently, participant organe stated: *[...] This is a self-turning joystick, I cannot develop my trust on it...* furthermore, one garment designer also mentioned: [...] *using the joystick, I can do quick explorations, but if I want to have a pattern, I need to hold my figure still to keep this pattern, this is frustrating...*

- Insight

In this iteration, we have learnt that by interacting with a fixed interface was perceived to be unnatural. The actions that took place on this interface should require less effort to perform. Therefore we concluded that TUI should have a dynamic form, which allows users to be able to customise the layout by themselves. On the other hand, the functionality mapping framework derived from previous research seemed to be an effective framework to map the predefined functionalities. Therefore, we intend to inherit this framework into our final prototype.

Prototype 3: Modular prototype

This TUI (Figure 22) runs on an Arduino Mega board (Figure 21) that comprises a modular tray in which tile modules can be placed. The left three tile modules aims to provide users with function of increasing or decreasing input values. They are also the physical mapping [8] of *number slider component* in Grasshopper. The joystick is placed in the second row of tray, which offers participants two-dimensional manipulation. The rest of the tray is equipped with the rotary potentiometers, they are considered to be the default modules. Concerning about different professions may use different sensors to perform design tasks, the default module can be replaced with other module for instance, a light sensor or a stress sensor in architectural design to perform force analysis in Grasshopper. This modular prototype aims to open more possibilities of integrating modules on the TUI as they are not limited to one fixed interface.

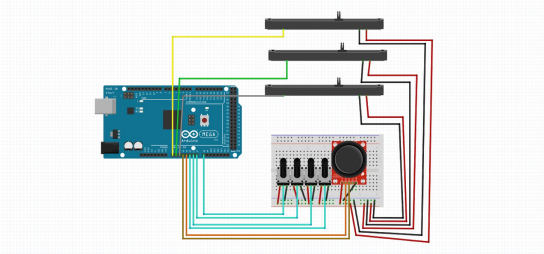

Figure 21. input devices setup

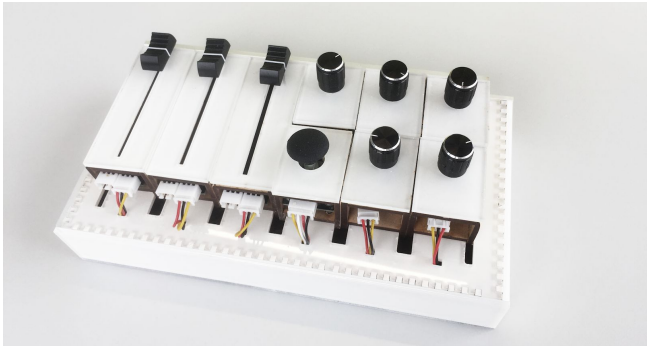

Figure 22. Modular prototype and its input devices setup

- Data collection

The modular prototype was exhibited alongside other student projects on the Final Demo Day at the University of Technology Eindhoven. The experience started with asking visitors to perform a simple task in Grasshopper that contains functions of rotation, translation and extrusion. Then we introduced the pattern generators we developed for the design startup Labeledby to gather more qualitative data. Additionally, the participants who study architecture design from the previous two iterations were also invited to experience the new prototype.

- Evaluation

Interaction

- The mapping of slide potentiometer seems to be an unnatural interaction when performing extrusion on this interface when it is placed horizontally. *[...] It would make more sense if you place this module vertically.*
- Each input device mapped only on one function. We did not concern about to map several functions into one device, which resulted in a linear mapping. *[...] it is possible to map extrusion and scaling into one input device, why I need to interact two devices to achieve something that one input can do?*
- *[...]Linear mapping eliminated a lot of freedom...*

Form

- The problem that was argued the previous prototype was addressed in this iteration. This TUI allows users to customize interfaces based on their individual context, rather than a fixed interface. The garment designer mentioned: *[...] I don't need to hold my hand still to get a pattern, this is more comfortable to use…*
- The modular prototype supports simple reconfiguration of input device. Input devices can be added or removed into any position on the base tray to adopt users with habits, for example right handed or left handed users *[...] I am right-handed person, I change this interface that is more comfortable for me to use...*
- However, some visitors perceived a missing link between prototype 2 and prototype 3 in terms of form, they stated *[...] there is a big transformation from the previous prototype... [...] the form of prototype 3 did not inherit the same design language from prototype 2...*

Function

- We also discovered that it seems to be problematic to differentiate the function of each module because there is no label or icon to explicitly explain their functions. *[...] The slide potentiometer modules look all the same, how can I differentiate which one is for extrusion and which one is for scaling?*

DISCUSSION

In this project, we explored how to design a TUI that respects human's skills, aiming at achieving aesthetic interaction through the unity of from, interaction and function [6]. We would like to discuss here what we have learnt through these three iterations:

From the perspective of interaction, we discovered that if the users perceive that the predefined functionality in Grasshopper maps naturally the action that the input device affords, this will promote aesthetic interaction in the design of the TUI. Prototype 1 used a simple setup that allows participants to establish a connection between digital and physical analog input. As results, we developed a functionality mapping framework as design criteria. This design criteria was further explored in the development of prototype 2 and 3.

From the perspective of function, throughout the entire research, we only implemented with a few types of input devices, which are potentiometer, pushbutton, joystick and light sensor. However, feedback was received from last evaluation that people from different professions would like to have controls to utilize different input devices to achieve certain functionalities. For example, In architectural design, architects would like to use a flex sensor to perform stress analysis and sound sensor to visualize the dynamic movement of noise and sound reflection. We also envision a centralised & distributed system can be developed allows user to create data during their design process locally or remotely, the generated data will be stored and transferred to the central system to achieve more advanced functionality. For instance, visualizing sound data in a remote area, at the same time, the central system is performing data visualization with a shape changing facade.

From the perspective of form, the functionalities in Grasshopper seems to be limitless, which requires a complex natural mapping framework to the form of the input devices. Therefore, we developed a functionality mapping framework to help us and users to interpret. However, this framework seems to be a design-case-specific framework that based on the narrative of a parametric designer. It can only be interpreted by the end-users in an explicit scenario based on the design requirement. On one hand, this can be a problematic situation which requires parametric designers always need to collaborate with the end-users. But on the other hand, it also opens up more opportunities and design challenges for industrial designers to explore the shape-changing interface that offers end-users some controls to accomplish their action. For example, using different color or material to differentiate modules that have the same form, or use different LEDs to indicate functionality explicitly.

CONCLUSION

This research project focuses on developing a TUI for parametric designers. A functionality mapping framework was developed to facilitate parametric designers to map the functionalities from Grasshopper to the TUI in order to perform certain functions. However, this framework seems to be a linear mapping mechanism that yet needs to be further explored.

In summary, the proposed prototype opens up the possibilities of establishing a tangible interaction that is capable to bridge the gap between the physical and digital environment. It provides parametric designers with an intuitive, real-time visual feedback and collaborative solution, but also reduces the threshold for non-specialists to learn and operate Grasshopper.

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Appendix 1. Data transcribing & analysis

Week 2, 21-02-2019

Crafting everyday soft things

User data analysis

In order to draw conclusion, the researcher needs to process the audio files that were being recorded during the interview.

The researcher first explained the concept of using this TUI (tangible user interface) as a facilitator for grasshopper designer. After that users operated this TUI with grasshopper and exchange the user experience. In the end, Researcher use co-construction method to draw a user scenario. This technique elicited feedback about the future concept which is both deep and specific to the concept. Designers find such feedback both useful, as it is inspiring and trustworthy, and usable, as it is specific to the concept and structured. Besides that, this technique still effective, as participants can talk about two to three cases in twenty minutes and reveal several anecdotes.

Tijmen Kervers - Industrial design student

Shen: How do you think about having this TUI when using grasshopper?

Tijmen: I think it is interesting, Having this TUI open up an (tangible) user interface to another (digital) user interface to the users. When you showcasing your grasshopper application. You could actually show user the number slider in grasshopper user interface, but sometimes this 'crazy spaghetti' (grasshopper code) frustrate users and confuses them. People still would not understand how to use it. This TUI gives controls to users which variables you want user to playl it, without break the entire grasshopper code.

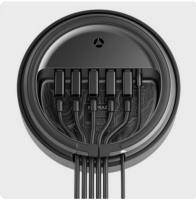
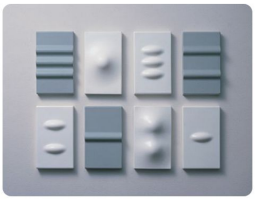
Shen: Yes, I also found out, sometimes go from 0 to 1000 on the number slider, it is not easy to control because of the length of number slider is limited. Sometimes if you change it too fast, it might crash your application. Because the number slider is actually just a digital bar. .

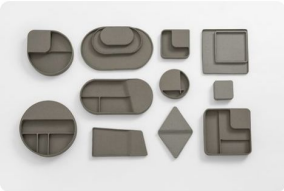
Tijmen: yes, I agree, and also I can remap the input values to any range I want. For instance, this potmenter is ranging from (0 to 1023), I can remap it from (0 to 360) to achieve a natural interaction. And all the modification in updating in real time.

Shen: what would be your expectations when using this TUI? I can give you some hit, because I like to have a modular shape, but also something with the fabrics.

Tijmen:

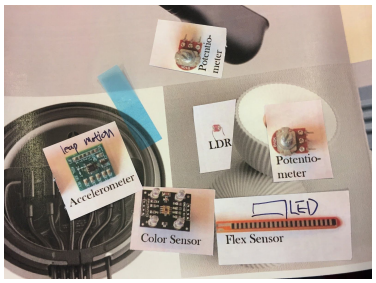
The 1st one, I like the setting of one, for no reason. (maybe possible to make this as “what inside of box” ? The 2nd one, for some reason I like its shape changing interface. The 3rd one and 4th one, I like its modular shape, so i can add or remove any electronics components. The last one I like its shape changing characters.




Shen : What functions you would like to add one this TUI in order to reach to your design goal when using grasshopper? For instance.

Tijmen:
color sensing: It is **easy to manipulate with color.** These are a lot of possibilities with using the color sensor. Probably you can assign certain to shape to red color and another shape to yellow color. And when using the orange color, you can create the in-between shape.
Flex sensor: You do bend it fast or smaller, then it also nice to work with fabrics.
Accelerometer: This gives you so much variables. I am curious how to implement it.
Potmeter: Easy to add, but I would like to have more potmeter.



Tijmen: I concern this could be the first step for people who wants to learn programming, especially the grasshopper. I think you can use this tool, for users, slowly to play around it. Make them familiar with grasshopper user interface. Then go further with more advanced level of programming. Like an icebreaker of learning visual programming.

Shen: How did you experience the interactions, as a grasshopper user:

Tijmen: What I like most about this TUI, I can manipulate many variables at same time, traditionally,
I would only modify the one variable.

Shen: what additional function you would like to add one this TUI?

Tijmen: I would say add more sensors, and see the potentials after adding these sensors.

Shen: what additional function you would like to add one this TUI in the future?

Tijmen: I would say add ability to map different sensor map on different pins. Because there would be more sensors being added on this TUI, for people who don't have knowledge of electronics. This could be hard to do.

Shen: How did you think about the interactions?

Tijmen: sometimes I would also like to get feedback if i change the value with sensor, or potmeter, I would like to see the the direct feedback. Maybe only in the grasshopper canvas, besides, that , the reaction can also be the light, when I turn this thing, the value is the updating, this aims to give insights to the users how to use grasshopper. It will be more intuitive. People can see what is changing, what is updating.

Co constructing story:

Shen: (the sensitization part) now in your mind, you will create a scenarios that you have never seen this box, what would be the bad interactions or bad user experience that you concern, when using grasshopper?

Tijmen: as I mention, if you change a variable too fast, it is hard to see how the models change and sometimes it might crash your computer because computer could handle it. You can not really the change in real time.

Shen: now you also think about in what form you would like have this TUI? For instance, like a bag shape or like a mouse?

Tijmen: I see it more should more like a box with buttons, like what I did in the first week. Maybe more in the modular, wireless, so you can carry this, move it, what if you add more complex interactions, like shake your devices, do what a mouse can not do with this device. Or squeeze this surface, so you might be able to bend the surface of the facade in the 3D models. Something grabble, or when hold it. Like a mouse.

Shen: (the Elaboration part) Now envision a future scenario, what this TUI makes you life easier, in terms of what aspect? Like creating a pattern? Or in your design project. You can also think about using different sensors to reach to your design goal, maybe put a part of the modular component on your target? For instance, adding a bending sensor on your target, and using this to generate the curvature of the body from your target users?

Tijmen: I think the main stream will be sensor, maybe give the freedom to more people, not a soly designer, but also to the targets and other designers, so everyone could collaborate the design process. So you can quickly have 20 variations, this can be used as a strong collaborative design

tool. User no longer need know about grasshopper, but yet they still can be involved into the design process. For instance, generate a facade in a smaller scale. Probably in the future, you can even customize your own design as a clients, together with designers and engineers.

Wenxing Zhu - Architecture student

The researcher explained the initial idea why he wants to design such TUI for parametric user. The hypothesis is, the researcher assumes that fashion designers or architects have few or no experience with electronics and sensors. To design such TUI would facilitate them in their design.

The users seems confused with the potmeter, and light sensor, He perceived that the potmeter was a joystick, and the light sensor is a force sensor.

Shen: are you familiar with parametric design?

Zhu: yes. I used it to generate organic patterns or models.

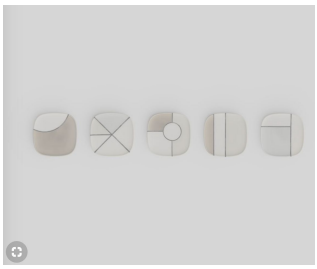
Shen: Did grasshopper reach to your design goal?

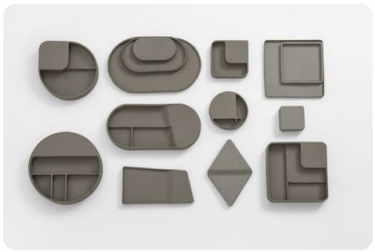
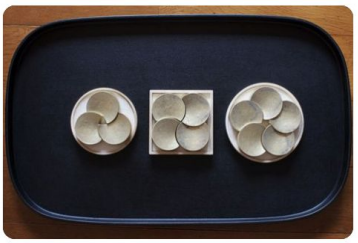
Zhu: Yes and no, most of time I use grasshopper to design the basic shape, however, I always need to modify it in Rhino to get the shape I want to have. Grasshopper is just a means of modelling, Ideally, you can use grasshopper to design all the models, but you still need it modify with Rhino.

Shen: How do you feeling about this TUI?

Zhu: Interesting.

Shen: what would be your expectations when using this TUI?



Zhu: I thinking using this tool box could increase the productivity of designer, or introduce a new way of design. We usually design with computer and paper, also with mouse. But of these are the only tools we use in our design. Recently, people propose the VR as a new means of design, it provides an immersive using experience, however, sometime it cause motion sickness. Probably using your design, we could build a model on hand?

Shen: Yes. I can see the possibilities. For example using Leap Motion. Leap motion can detect gestures. What functions you would like to add one this TUI in order to reach to your design goal when using grasshopper? For instance.

Zhu: Bending sensor: for instance when I want to do a stress test. Or the stress level between two beams. Having this bending sensor could probably simulate the movement of the models.
Also in some situation, in order to reach to certain shape, I have to adjust parameter values one by one, and still don't get the models i want. But using this TUI, I could adjust several parameters at same time.

Shen: I also also add a LED screen, it gives you direct feedback.

Zhu: maybe also using LED lights to indicates certain range of pressures.

Zhu: light sensor, In architectural design, sometimes we need do light & shadow analysis. Using software could generate the light & shadow area in a building. But using this TUI probably could offer us a more direct feedback.

Zhu: potmeter. Indeed this is handle.

Shen: How about the accelerometer. (after long explanation what is that.....)

Zhu: Can this be a GPS sensor? Sometime when we do on-site investigation, we need participants to carry it, and record data. (what about the data that collected can give input to grasshopper?)
Is this a humidity sensor? Sometime we need to get data of humidity level in certain area. Or temperature data, what about if we take this TUI box to the place where we do onsite investigation, and collect data, then the data we can direct use in grasshopper and see how these data will influence the design.

Shen: How about the color sensor? This detects colors.

Zhu: This reminds me of a project I used. I need to color-coded all the buildings and make models to evaluate its historical properties. That was a lot of works. I don't know how this color sensor could assist me with my design. Each building has its properties, to decide whether this build need to remove or keep, we give different level of red color, in the end, this building with the strongest color needs to be kept.

Shen: I have seen one video, that a guy assigned color to different buildings, and when he scan the the card on the color sensor, the models appears on Rhino, maybe this color coding system could assist you with categorise the building. This was something with machine learning.

Zhu: Yes. maybe using grasshopper, you can generate which building we need to keep or remove. Because color code building on location cost us a lot of time.

Zhu: In grasshopper, this is function called point interruption, if using accelerometer, I can maybe do this in a 3D environment.

Shen: How did you think about the interactions?

Zhu: direct, convenient and real time. It is inspiring me. It add values to my design. Because sometimes inspiration come fast and go fast. If I need to adjust many variables one by one, insteading of at the same time. Maybe my inspiration is already faded away. This also reminds of me **frank gehry** architecture, he makes his sketch very fast and his inspiration. If this TUI could weaponized architects to make models, this could be very powerful. Use you hand as digital weapon, and design the model in real time. Efficiency

Shen: How did you experience the interactions, as a grasshopper user:

Zhu: It is intuitive, I consider that using mouse give negative healthy effects. Maybe having this will bring a better working style

Shen: However, adopting a idea is not easy, you need to adopt but not try to change.

Shen: what additional function you would like to add one this TUI?

Zhu: Maybe a touch pad? You can maybe also have it with soft surface or hard surface.

Shen: (the Elaboration part) Now envision a future scenario, what this TUI makes you life easier, in terms of what aspect?

Zhu: In grasshopper, It is so confusing and overwhelming. And make groups, finding the right number sliders. And I need to adjust one by one, sometime when you adjust one parameter, Probably you need to adjust two parameters, then you know what is the problems. Sometimes, I overused the parameters, and it add more calculation works on my computer.

Shen: (the Elaboration part) Now envision a future scenario, what this TUI makes you life easier, in terms of what aspect? Like creating a pattern? Or in your design project.

Zhu: In grasshopper. Architects likes new devices, They always likes to try new devices or toolkit to assist to their design.

ShiLong Liang
Shen: do you know Generative arts?
Liang: what I know about using programming language to assist design is Unity

Shen: How do you use grasshopper in order to reach to your design goal?
Liang: When you need to model something has organic shape, there are several options. Like 3D Max, Revit. Rhino or grasshopper. Grasshopper is using parametric way of thinking, it is real time.

Shen: Did grasshopper reach to your design goal?
Liang: yes, but sometimes you find out your design was modified by shaping the parameters.

Shen: I perceived that user was confusing with joysticks and potmeter. Besides, the light sensor seems like a press sensor.

Shen: what would be your expectations when using this TUI?

Liang: bending sensor, I can use this bending sensor to change the shape. Distance sensor is used for adjusting the distances in the model.

Liang: potmeter, this is used for adjust variable ipout. Light Sensor providing three sets of data, you can probably use these three sets data to represent height, width and length.

Shen: why would you like to use this distance sensor,

Liang: It is important in architectural design, that you need to develop a sensor for the space and dimensions, it is important for us to know foresee our design in such context.

Shen: actually, you can also use color sensor to do this, maybe using blue color to present 5 meters, and then using machine learning algorithms to obtain the correct dimension.

Liang: I think this could also build connection between users and designers, they could customize the patterns or the facade dimensions by themself.

Shen: Do you think this add values to your design work? Or design process?As a parametric designer.

Liang: I think for an experienced parametric designer, probably it is not necessary. But i think this could bring a lot of inspirations in the beginning of the project. Because you can adjust several variables at same time. It could add values to assist design.

Shen: how did you experience the inetraction when using this box**?**

Liang: it is somehow many sense, but this is still in conceptual phases, when you reach to a certain status design, it may make more sense when using it.

Shen: what would be the additional functions that you want to add?

Liang: from what I see this box, this is a close box, I would also like to see what is inside of this box. Maybe some light indication in side? I also want to be able to customize this box.

Shen ： What interaction you like to add? Like mid wheel in a mouse?

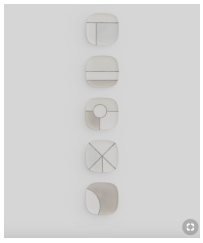
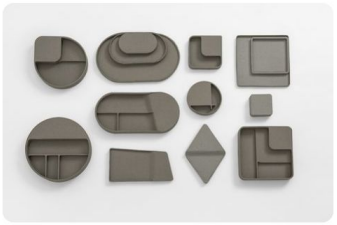
Liang: gestures or posture? As a wireable device?

Jiangcai Liu & Jiangxue Xu

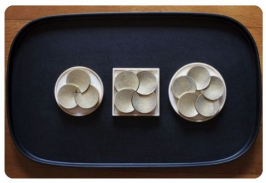
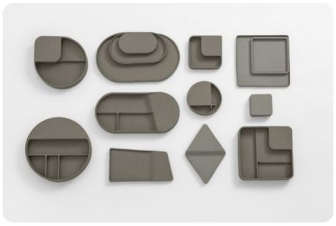
Xu: I like the interaction of having push button, I like to have tangible feeling.

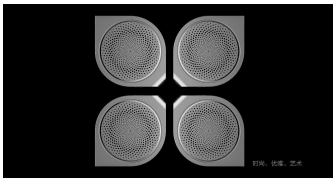
Shen: What will be your expectations when designing such tangible interaction?

Xu:

Jincai:



Shen: How do think having such control in parametric design?
Jincai: I think this probably requires more understanding and knowledge of grasshopper,

Xu: you can co design something together.

Jincai: I did not discover that you can use manipulate several variable. I think you can also involve your foot, not only using hands, but also use foot.

Xu: we are use to use our hands, but it was never been like that.

Shen: what will be your expectation?

Xu: yes. I don't like to bring my mouse, i feel it is big, maybe you can make it like a bag, or it can also be a computer bag. A parametric bag exclusive for parametric designer?

Jincai: maybe like a game controller? If you can give people a gamified experience, that i think will be easier to be accepted .

Shen: how you do experience the interaction?

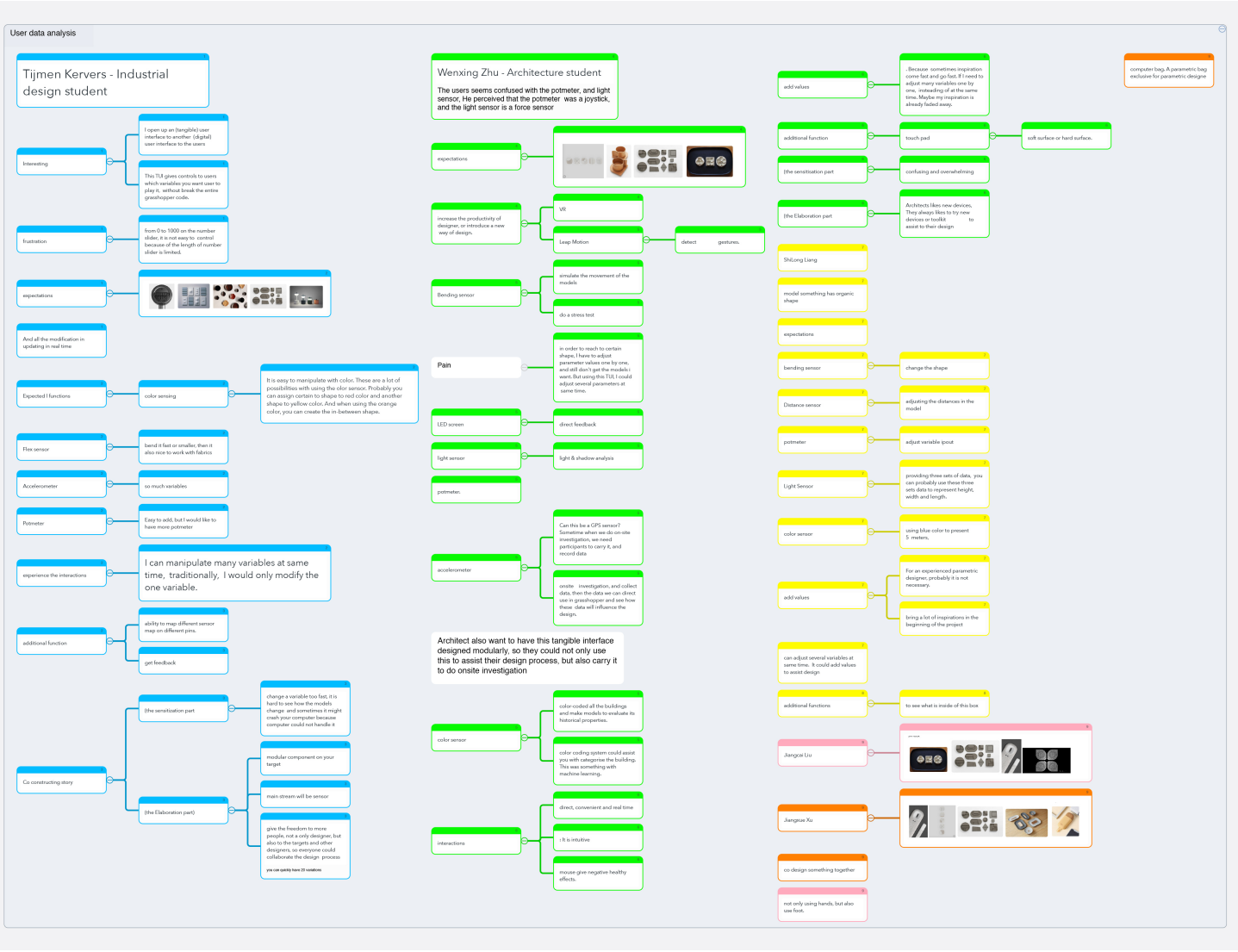
Xu: sometimes you need to view the your control panels, because when using mouse, you like right and left click, but using your control panel, you need to check which one your are operating.

And it confuse the me how to use it.

Shen: what additional function you like to add?

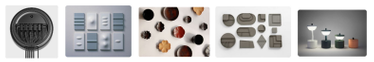
Xu: maybe you can also add some other function? Like put in my sandwich? Maybe also add some feedback mechanism. Maybe you can see your parameter values on your control box.

Appendix 1. Data transcribing & analysis



User data analysis

Tijmen Kervers - Industrial design student

- Interesting
  - I open up an (tangible) user interface to another (digital) user interface to the users
  - This TUI gives controls to users which variables you want user to play it, without break the entire grasshopper code.
- frustration
  - from 0 to 1000 on the number slider, it is not easy to control because of the length of number slider is limited.
- expectations
  - 
- And all the modification in updating in real time
- Expected I functions
  - color sensing
    - It is easy to manipulate with color. These are a lot of possibilities with using the olor sensor. Probably you can assign certain to shape to red color and another shape to yellow color. And when using the orange color, you can create the in-between shape.
- Flex sensor
  - bend it fast or smaller, then it also nice to work with fabrics
- Accelerometer
  - so much variables
- Potmeter
  - Easy to add, but I would like to have more potmeter
- experience the interactions
  - I can manipulate many variables at same time, traditionally, I would only modify the one variable.
- additional function
  - ability to map different sensor map on different pins.
  - get feedback
- Co constructing story
  - (the sensitization part)
    - change a variable too fast, it is hard to see how the models change and sometimes it might crash your computer because computer could not handle it
  - (the Elaboration part)
    - modular component on your target
    - main stream will be sensor
    - give the freedom to more people, not a only designer, but also to the targets and other designers, so everyone could collaborate the design process

      you can quickly have 20 variations

Wenxing Zhu - Architecture student

The users seems confused with the potmeter, and light sensor, He perceived that the potmeter was a joystick, and the light sensor is a force sensor

- expectations
  - 
- increase the productivity of designer, or introduce a new way of design.
  - VR
  - Leap Motion
    - detect gestures.
- Bending sensor
  - simulate the movement of the models
  - do a stress test
- Pain
  - in order to reach to certain shape, I have to adjust parameter values one by one, and still don't get the models i want. But using this TUI, I could adjust several parameters at same time.
- LED screen
  - direct feedback
- light sensor
  - light & shadow analysis
- potmeter.
- accelerometer
  - Can this be a GPS sensor? Sometime when we do on-site investigation, we need participants to carry it, and record data
  - onsite investigation, and collect data, then the data we can direct use in grasshopper and see how these data will influence the design.

Architect also want to have this tangible interface designed modularly, so they could not only use this to assist their design process, but also carry it to do onsite investigation

- color sensor
  - color-coded all the buildings and make models to evaluate its historical properties.
  - color coding system could assist you with categorise the building. This was something with machine learning.
- interactions
  - direct, convenient and real time
  - : It is intuitive
  - mouse give negative healthy effects.

- add values
  - . Because sometimes inspiration come fast and go fast. If I need to adjust many variables one by one, insteading of at the same time. Maybe my inspiration is already faded away.
- additional function
  - touch pad
    - soft surface or hard surface.
- (the sensitisation part
  - confusing and overwhelming
- (the Elaboration part
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computer bag. A parametric bag exclusive for parametric designe

- ShiLong Liang
- model something has organic shape
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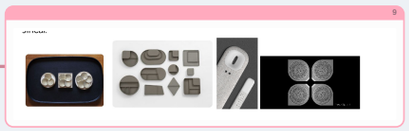
- additional functions
  - to see what is inside of this box
- Jiangcai Liu
  - 
- Jiangxue Xu
  - 
- co design something together
- not only using hands, but also use foot.

Week 4, 01-03-2019

Crafting everyday soft things

User data analysis

Pain point 1: In grasshopper, it is impossible to manipulate multiple variables at the same time. The core functionality of “variable” which it is called number slider in grasshopper, is to give numeric input to a component.

Gain solution 1: Using this TUI, it allows designers to manipulate multiple variables simultaneously. This can also create an "emerging" phenomenon when multiple components share a variable input. For instance, when giving the same numeric input to scale and rotation, or scale and translation, the resulting patterns can be very different.

Pain point 2: when adjusting variable input over a wide range (from 1 to 1000), it is difficult to observe geometric changes, which can sometimes cause a computer to crash.
“*The size of the ‘number slider’ in grasshopper it is too small, for me, it is hard to manipulate it when I need to work on a large number”*

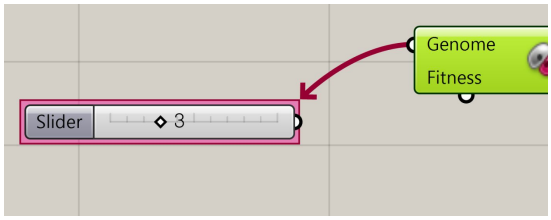


Figure 1. Number slider

Figure 1. Slide potmeter

Gain point 2: Using potmeters of similar electronics provides physical control to the users. Regarding the feedback from the participants, this adds a variety of interactions, (traditionally the only interaction between designer and grasshopper is a mouse), increases the joy of using grasshopper and also offers them more chance to observe geometry during the design process.

Gain point 3: this TUI adds values to the design process, especially as it increases the productivity and usability of the design process (for example, all modifications are updated in real time). The architects pointed out that this TUI introduces

- a new design approach, especially during the exploration phase of the design process,
- a healthier way of working style considering the use of the mouse can sometimes have a negative impact on the human body, such as WMSD.

Gain point 4: This TUI also bridges the gap between different stakeholders, allowing designers and customers to collaborate on the design process without breaking the entire code.

Gain point 5: This TUI also received positive feedback on the interaction, "convenient, direct, and intuitive quotes from the architect students".

<Rich Interaction>

Based on the framework established by Joep Frens in his thesis, Rich Interaction, is the unification of shape, interaction and function. Therefore, the researchers compiled the collected data from the following three aspects:

From the perspective of **shape**:

1) it appears that parametric designers both from architecture design and industrial design would appreciate having a **modular approach** of a tangible user interface. By using a modular approach, by using a modular approach, designers have more flexibility in controlling the customization of this tangible user interface.
2) The envisioned choice of material could be wood, plastic, fabrics or mixed of them.
3) A part of this modular TUI can also be a wearable device, which aims to collect onsite data. The data could be collected and generated by users or the location. The data could be directly used in grasshopper.

From the perspective of **function:**

The researcher introduced various types of sensors and actuators before the interview, after a short explanation of the function of each sensor and actuator, researcher and participants concluded that following sensors will be appreciated when using this TUI during the design process:

1) Light sensors (In the context of architectural design, light and shadow analysis is sometimes required, or simulating the change of light density and observing the impacts.)
2) Flex sensors (flex sensors give opportunities in both fields of study, especially offers a lot of potential functions in the field of wearable design, which simulates the stress test in the textile industry and construction engineering)
3) Accelerometers (Since this accelerometer offers a huge set of data and it has not been explored yet)
4) Potmeters (this mimics the digital number slider, which is a very important component in grasshopper, and it is easy to operate and give good interaction)
5) Colour sensors (this colour sensor offers machine learning opportunity, which could elicit surprising insights about data usage)
6) Others, like a digital LED numeric display (feedback)

From the perspective of **Interaction design**:

1) The mainstream of this TUI will be a sensor.
2) The choice of current potmeter confused all the participants, who they consider to be a joystick, encouraging the researcher to reconsider the choice of potmeter. (A Joystick offers control over x, y-axis in a 2D surface. A slide potmeter could mimic the digital number slider in grasshopper. This may reduce confusion)

Week 7, 29-03-2019

Crafting everyday soft things

User data analysis

Background: *this iteration prototype was made on week 5 for the midterm demo day. Many feedbacks were received from the clients as well as my mentor.*

Research Objective

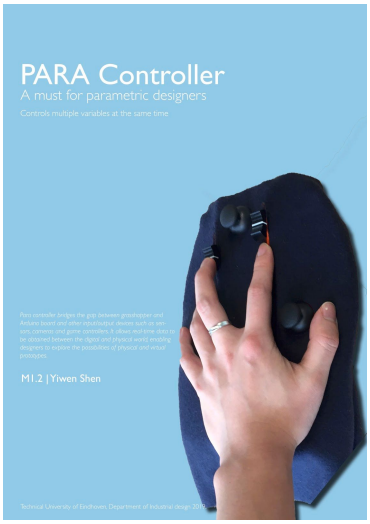
The aim of this research was to test whether the second iteration of this Tangible User Interface could be an effective tool for the parametric designer. The research objectives were to assess how well parametric designer could

- a) **manipulate parameters**
- b) **collaborate with other users**
- c) **build grasshopper algorithms with TUIs.**
- d) **perceive the affordances of design decisions (shape, design metaphors)**

In order to access the effectiveness of the TUI for parametric designers, especially with different interests, such as patterns design, facade design or architectural design, I conducted a series of user studies observing and then evaluating how well that participants performed these basic design tasks using TUI.

Product (prototype) description:

In this iteration, two slider potentiometers and joysticks are added. Slider potentiometer serves to mimic the 'number slider' component in the grasshopper. Joystick serves to provide users with multidirectional control ability. After parametric designers finish the algorithms, they could connect their algorithms with the Firefly components, and then connect TUI. Designers have full control to decide which numeric components to analogue inputs.



The reason to use slider and joysticks was they offer a higher kinesthetically sense and flexibility, it was also perceived more intuitive to operate the software.

Participants

In this experiment, 5 participants (students) were asked to perform different tasks based on their context, they all have experience with using grasshopper but focus on different areas. Two students are interested in creating fashionable patterns; two students prefer creating organic 3D models; last but not least, a student with the architecture background is currently doing research on the interaction between human and environment.

Tijmen Kervers - Industrial design student

Shen: I would like to ask you to try the new prototype, this prototype

Shen: okay, this iteration of the prototype is meant to use with your left hand. Especially when you use a mouse with your right hand.

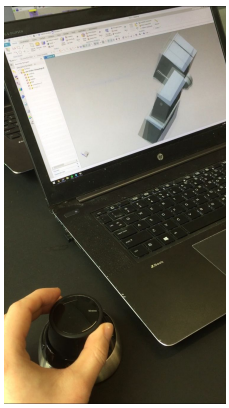
Tijmen: okay, but I usually use Space mouse with my left hand. Do you know Space mouse? Let me show you:

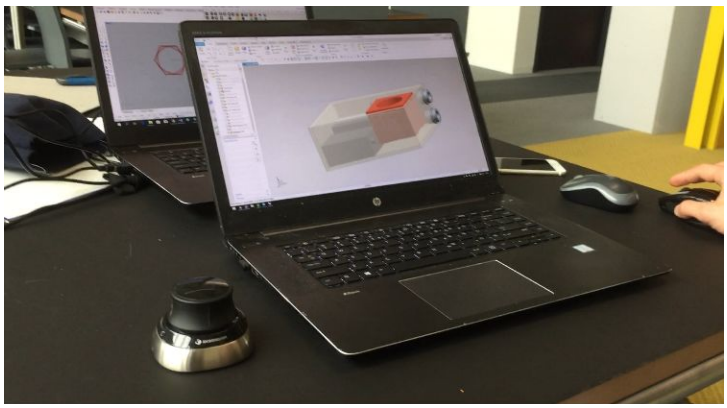
(3d connexion space navigator)

Shen: How do you use this?

Tijmen: It is used for navigating the 3D modelling space. I like to use it because it helps me to increase productivity when doing modelling.

Shen: can I make a video when you use it? (Observing Tijmen was using the 3D navigator)





(the interaction is simple, it also allows users to adjust the speed and flexibility of the navigator, which gives the researcher insights about concerning the boundary of how many interactions should be equipped on the design of this TUI)

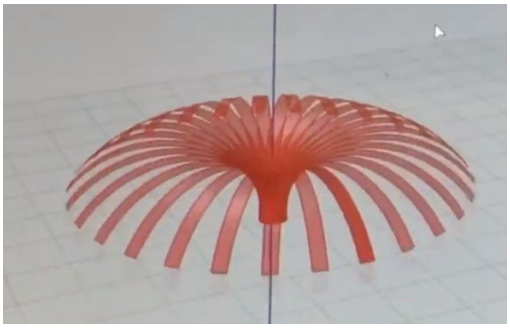
Shen: Okay, how do you think about this version?

Tijmen: I can see this as an addition for grasshopper.

Shen: Yes, maybe for the next iteration, I will use Lilypad, the size will be like a mouse, this TUI is a bit too big.

Tijmen: The super expensive version has a **symmetric user interface**, which you don't need to differentiate right hand and left-hand users.
(Maybe to make it modular it is a good idea. Or adaptive UI for people to adjust it)
Tijmen: is this TUI aiming for the designers to design the algorithms?
Shen: it provides designers with
1) a tangible interaction when using grasshopper
2) an easy approach to showcase and manipulate the patterns to the clients (bridge).
Tijmen: The shape of this design is good, It fits my fingers, but maybe you need to also consider for some people with smaller hands. I also think that using joysticks (the self-returning) is interesting.
Shen: actually in the previous version, there was a potmeter but everyone perceived it as a joy sticker, (wrong perceived affordance) It is so random, it is good to have a flexible device, especially for gaming, but for parametric design, it is a serious modelling or work, people need to develop **trust** on the device they use. (Link to the "design for trust" theory from the frog design)

(**Observation**: when the participant was using the TUI, I discovered that he really appreciated the 3D surface demo. It was perceived as an intuitive 3D modelling and animating experience. Comparing with the 3D space mouse he uses, the TUI introduces more forms of interaction, he particularly liked the sliding interaction, however, he is expecting that joystick could give some controls also on navigating the canvas, which was not designed in the TUI)



Alex-Industrial design student
Alex: The slider is very useful in grasshopper, maybe it is also important to have it in Rhino. So you can change the view. A lot of time when I use grasshopper, I also need to have two screens. If I use this TUI, I don't have to jump from on interface to another interface.

Shen: From my other user test. The joystick interaction in this prototype was perceived as not user-friendly for people who have smaller hands, maybe it is just not a good idea to design such TUI based on which hand the users usually use.

Shen: what would you think this will add value? I asked several fashion designers about the potential usage of having such a box. But the answer was only like generating patterns? Also from the other user test, the current design is perceived given too many interactions, maybe it would be a good idea to explore what is the limit amount of interaction.

Alex: I don't think the interactions are too much, I really don't think so. I think there are not only one-dimensional sliders, but two-dimensional sliders, you can use the joystick to navigate that.

Besides that, would it be more accessible parametric design problem like that? For instance, Grasshopper is not that User-friendly, especially when explaining your algorithms to other people, it is nearly impossible because everyone builds their algorithms differently.

Shen: can you give me some general feedback about this tangible user interface?

Alex: I am looking for added values, people are not necessary to know what is Grasshopper, I think this stimulates people to understand how the code means.

Shen: if you look back from the UX course we had, the 10 user candidate needs: competence and relatedness.
Shen: As a grasshopper designer, how would you design or having such TUI?

Alex: As a coder, I learn grasshopper from the coding aspect, if a grasshopper designer is experienced enough, honestly I don't think she or he needs this tangible user interface.

(maybe a sub-question: how to engage users who have limited knowledge on programming or 3d modelling in the design process?---> maybe design sort of elements as the visual representation of certain part of the code, and then add tangible user interfaces)
And the TUI still functions as the bridge between a user and designer.

Alex: When you communicate with your client, you can give some constraints, I don't see the value to wear it to demonstrate it, I think a remote controller or a game controller could be?

Shen: the remote controller is not aesthetically appealing.

(**Observation & reflection:** The participant has a background in both psychology and technology, he gave more concerns about how to fulfil the psychological needs. The user experience can be designed, probably on the UX aspect of this research project, I should apply the UX framework that
-Marc Hassenzahl states in his thesis:

- **Why?** Be goals (holistic experience, the needs, the emotions from parametric designers)
- What? Do goals (functionality)
- How? Motor goals. (Interaction)

Always thinking about the "why" through the entire design process. Then design "what" and "how"
- Psychological Satisfying human needs for users (Autonomy, Competence and Relatedness)
The participant also suggested interviewing people who have no experience with Grasshopper and see how this could contribute his or her design project

Wenxing Zhu - Architectural design student

Shen: Okay, here is the second iteration, in this iteration of user test, I would like to observe the new experience.

Zhu: maybe you can go a bit deeper to the area of interaction? Because what I found the most valuable aspect of this design is to create a platform for me and clients to communicate, to collaborate the design process. To be honest, when I need to make grasshopper algorithms in order to reach a specific goal or a design pattern, I am used to using grasshopper interface. Even though it is not very user-friendly.

Shen: okay.

Zhu: But I do see the value in this a novel tangible interaction, today, tangible interaction in CAD and 3d modelling or animation application is performed mainly with the 2D mouse. Which means that there are only two types of interactions: clicking and rolling that are provided. What about grasping, turning, pushing, rotating and jumping when interacting with the application?

Shen: like Nintendo Wii, I think why Nintendo Wii is so successful is because it provides more than only one interaction, also has sensors embedded which provide user good user experience.

Zhu: yes exactly.

Shen: what else you like about this interface.

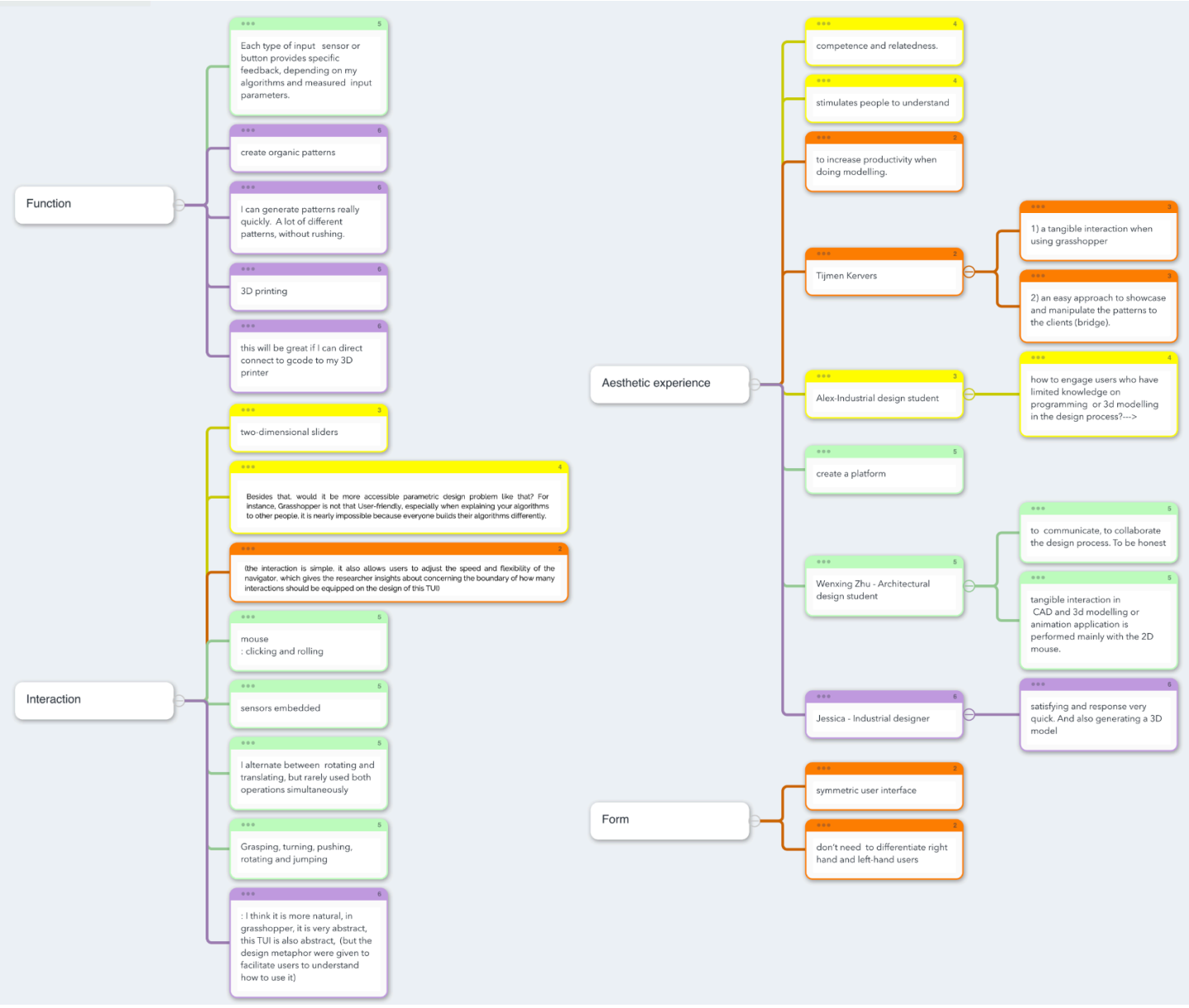
Zhu: I simply just like the idea of having such a tangible for my work. Each type of input sensor or button provides specific feedback, depending on my algorithms and measured input parameters. For example, this slider potemeter perfectly matches the tasks of the number slider in grasshopper. I prefer this type of interaction instead of dragging my arrow over the canvas, this gives me a more natural feeling of use. (Each input sensor may rely on different human senses or sensors).

Shen: Have you ever heard about Spacemouse?

Zhu: yes, I used to use Spacemouse, when using a Spacemouse, I alternate between rotating and translating, but rarely used both operations simultaneously, besides, I concern that most of Spacemouse are made for right hands, I really don't like they differentiate the users based on the user's preference.

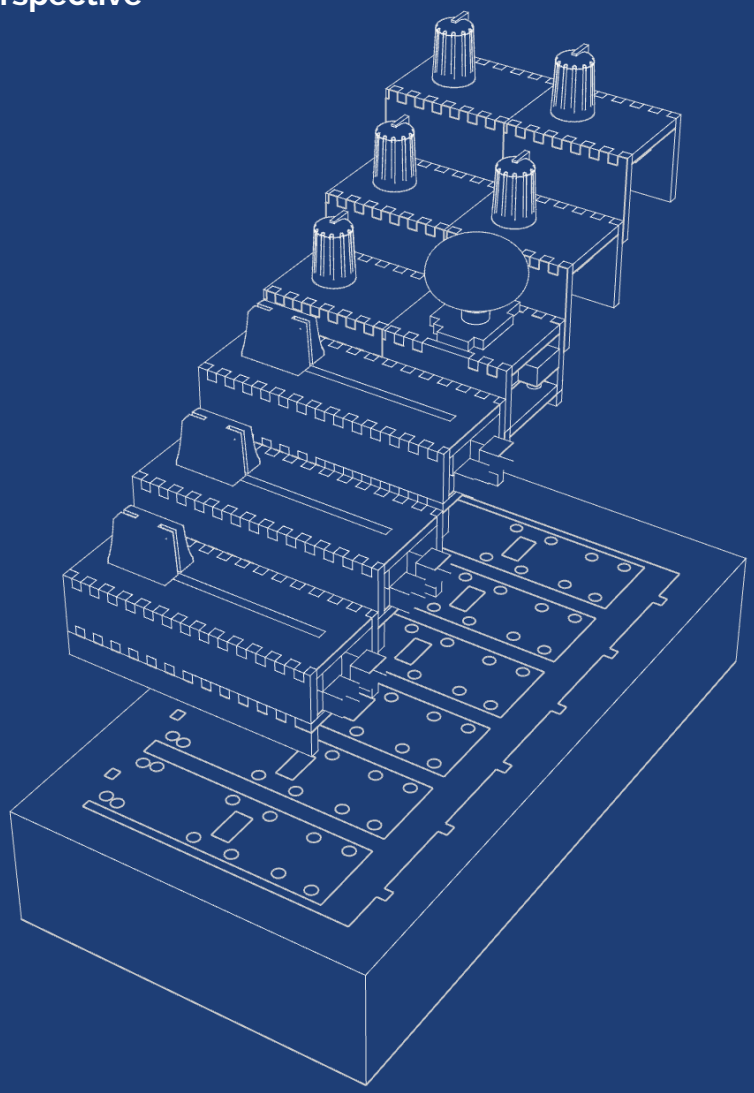
Jessica - Industrial designer **(Next Wednesday (week8) another meeting after the workshop that was host in week 6)**

Shen: How did you use grasshopper to reach your design goal?
Jessica: to create organic patterns
Shen: How do feeling about the interaction of this TUI?
Jessica: Satisfying, because you can have a tangible control to make the patterns, but also the density of the pattern.
Shen: what would be your expectation when using this TUI?
Jessica: I can generate patterns really quickly. A lot of different patterns, without rushing.
Shen: how do thinking to have such TUI when using grasshopper?
Jessica: I think it is more natural, in grasshopper, it is very abstract, this TUI is also abstract, (but the design metaphor were given to facilitate users to understand how to use it)
Shen: How you think about the interaction?
Jessica: satisfying and response very quick. And also generating a 3D model.
Shen: What additional function you would like to add on this TUI? How do you see this TUI adds value in your design? In your own context.
Jessica: I think more in the 3D printing, like we 3D a lot on texture, and we design a lot of patterns and print them on fabrics, I can also think about the performance,
Shen: show the 3D model one,
Jessica: for them, this will be great if I can direct connect to gcode to my 3D printer.
Shen: how would you design this TUI?
Jessica: it is nice to have it, I will probably use more respect for bodily skill. I would like to have a bit simple.


Function
Each type of input sensor or button provides specific feedback, depending on my algorithms and measured input parameters.
create organic patterns
I can generate patterns really quickly. A lot of different patterns, without rushing.
3D printing
this will be great if I can direct connect to gcode to my 3D printer
Interaction
two-dimensional sliders
Besides that, would it be more accessible parametric design problem like that? For instance, Grasshopper is not that User-friendly, especially when explaining your algorithms to other people, it is nearly impossible because everyone builds their algorithms differently.
(the interaction is simple, it also allows users to adjust the speed and flexibility of the navigator, which gives the researcher insights about concerning the boundary of how many interactions should be equipped on the design of this TUI)
mouse
: clicking and rolling
sensors embedded
I alternate between rotating and translating, but rarely used both operations simultaneously
Grasping, turning, pushing, rotating and jumping
: I think it is more natural, in grasshopper, it is very abstract, this TUI is also abstract, (but the design metaphor were given to facilitate users to understand how to use it)
Aesthetic experience
competence and relatedness.
stimulates people to understand
to increase productivity when doing modelling.
Tijmen Kervers
1) a tangible interaction when using grasshopper
2) an easy approach to showcase and manipulate the patterns to the clients (bridge).
Alex-Industrial design student
how to engage users who have limited knowledge on programming or 3d modelling in the design process?--->
create a platform
Wenxing Zhu - Architectural design student
to communicate, to collaborate the design process. To be honest
tangible interaction in CAD and 3d modelling or animation application is performed mainly with the 2D mouse.
Jessica - Industrial designer
satisfying and response very quick. And also generating a 3D model
Form
symmetric user interface
don't need to differentiate right hand and left-hand users

Appendix 3. A4 posters

Product Visualization
Perspective



PARA Controller

M1.2 / DRP / Crafting Everyday Soft Things
Tangible User Interface for Parametric Design

PARA CONTROLLER

Parametric design offers architects, industrial engineers and designers with a powerful, logical and flexible medium to generate complex 3D geometry and simulations. The creation of grasshopper algorithms is difficult to master and very specific towards the different design requirements. Thus, the operation of the parametric design is limited only to specialists, which results in a linear process, where the evaluation is only executed after the design process for validation purposes, rather than for assisting in the process of design (Al-Qattan et al., 2016).

The Para Controller creates a physical medium with digital modelling. In addition, it provides a user-friendly approach for parametric designers to control, inspect and directly manipulate algorithms in real time. The Para Controller aims to develop tangible computational methods to extend the boundaries and capabilities of digital design and fabrication tools.

Student: Yiwen Shen

Project Coach: Loe Feijs

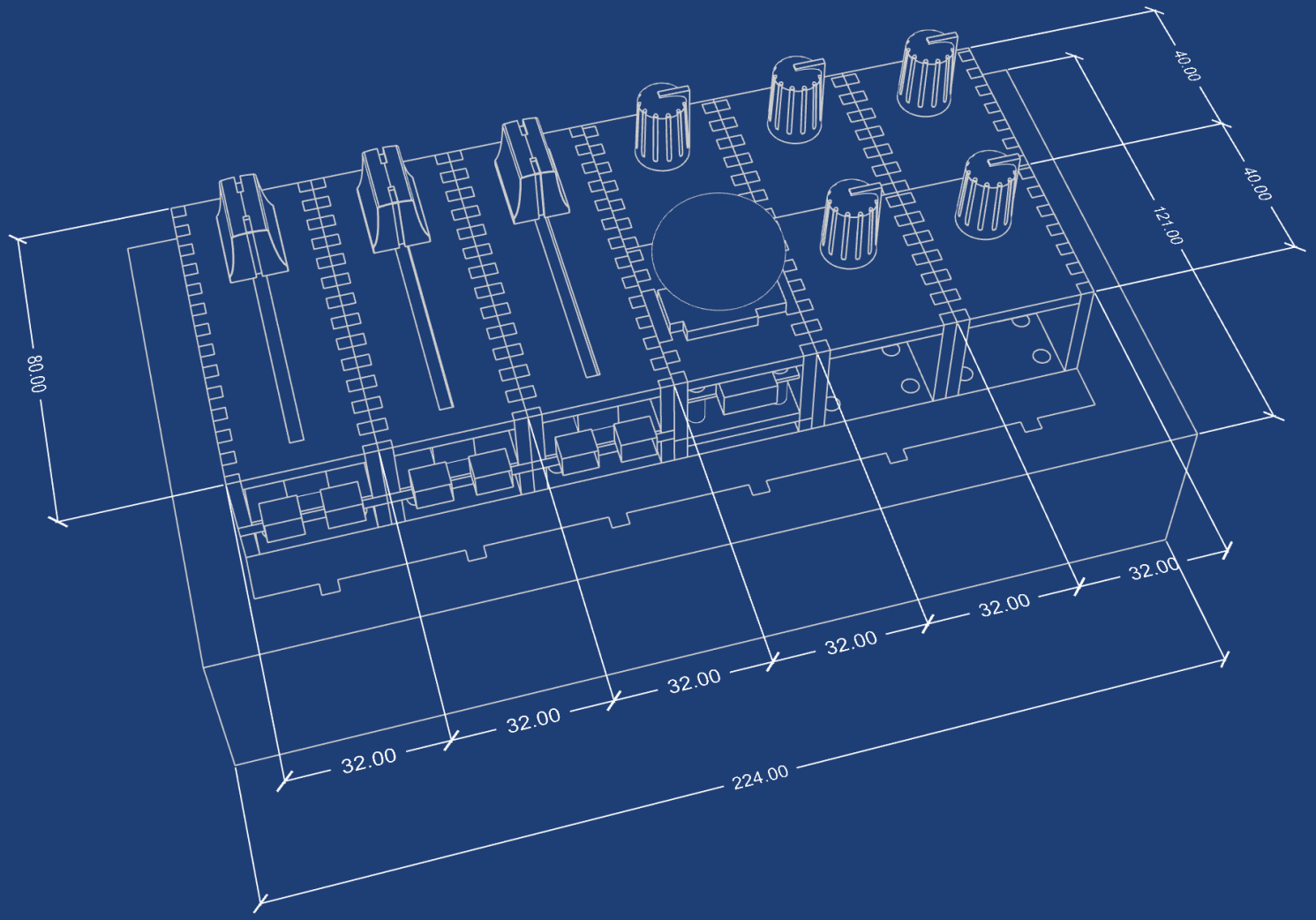
PARA Controller

Squad
Crafting Everyday Soft Things
Type
M1.2 | Research Project
Name
Yiwen Shen
Coach
Loe Feijs
Year
2018 - 2019
Department
Industrial Design

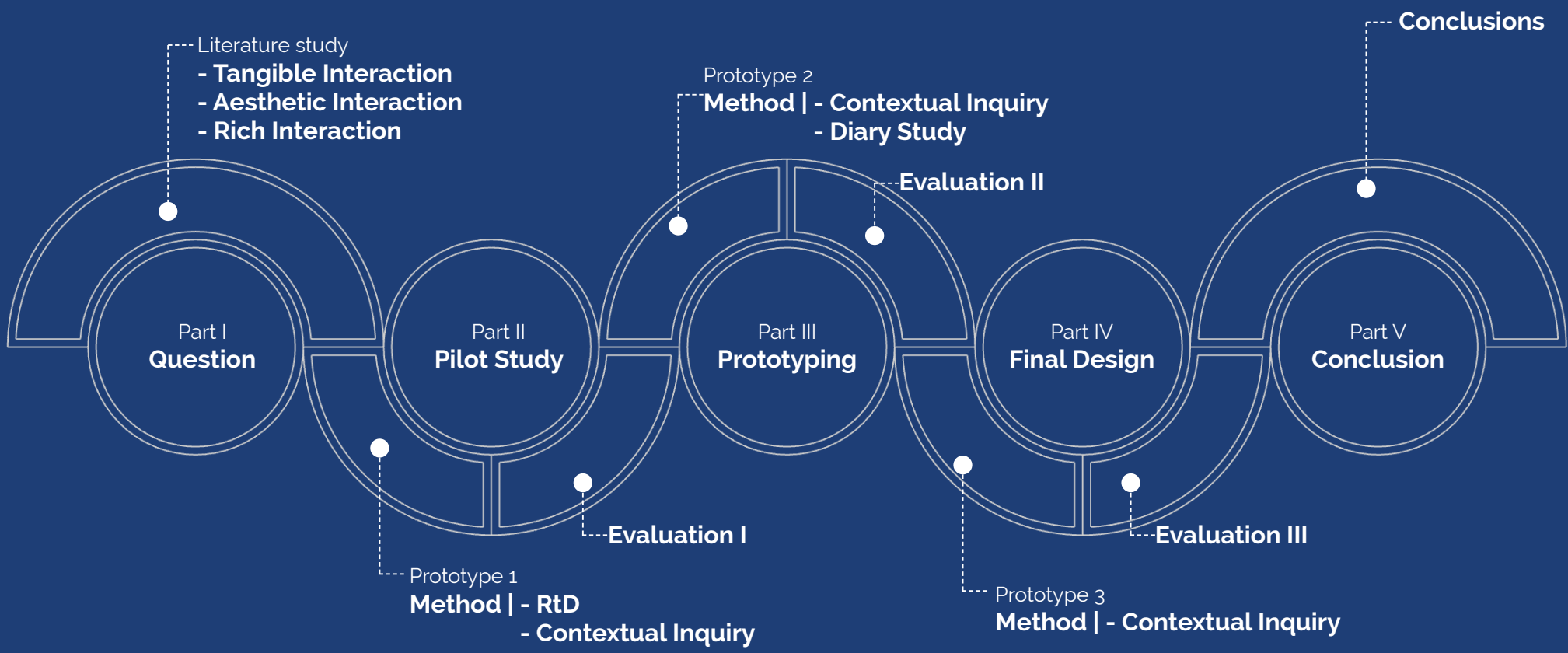
TU/e EINDHOVEN UNIVERSITY OF TECHNOLOGY

The **Para Controller** creates a physical medium with digital modelling. In addition, it provides a user-friendly approach for parametric designers to **control, inspect and directly manipulate algorithms in real time.** The Para Controller aims to develop tangible computational methods to extend the boundaries and capabilities of digital design and fabrication tools.

Product Visualization
Perspective



PARA Controller



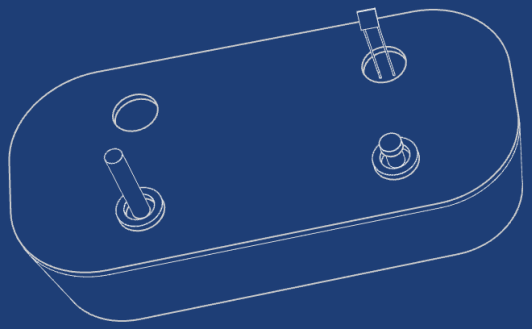
Research Process

How to design a Tangible User Interface for Parametric Design?

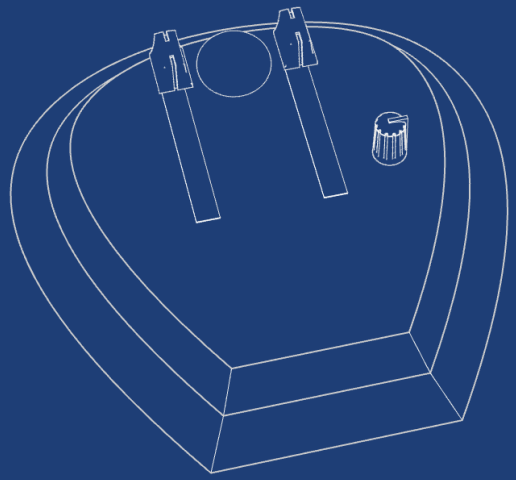
"What determines whether the interactions provided by this TUI are considered to be rich interaction?"

"How can this TUI to designed to be able to add values to a parametric designer's workflow?"

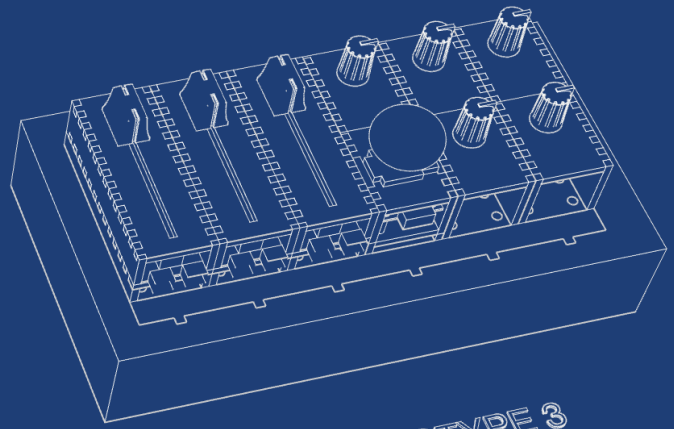
RESEARCH QUESTION



PROTOTYPE 1

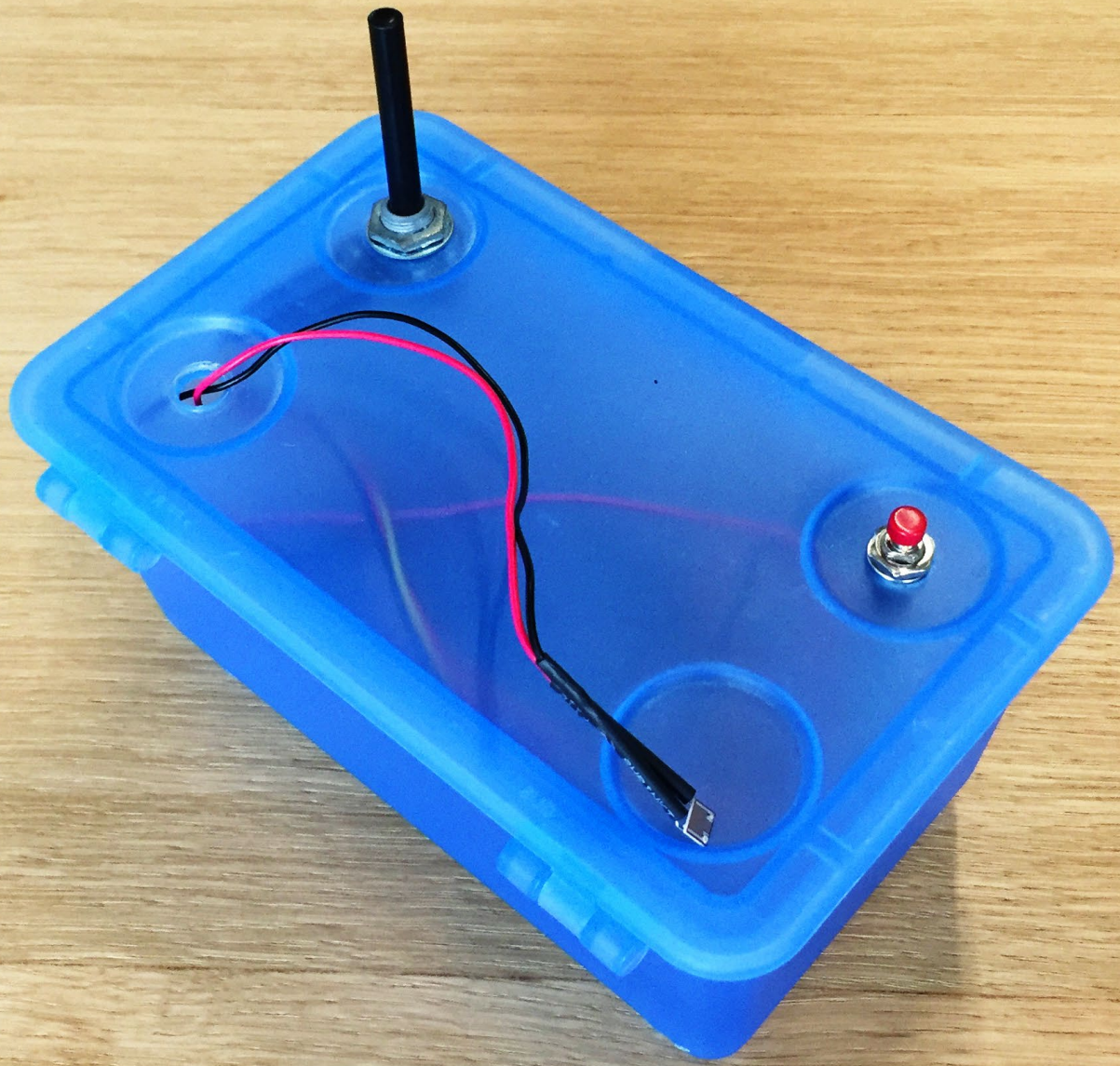


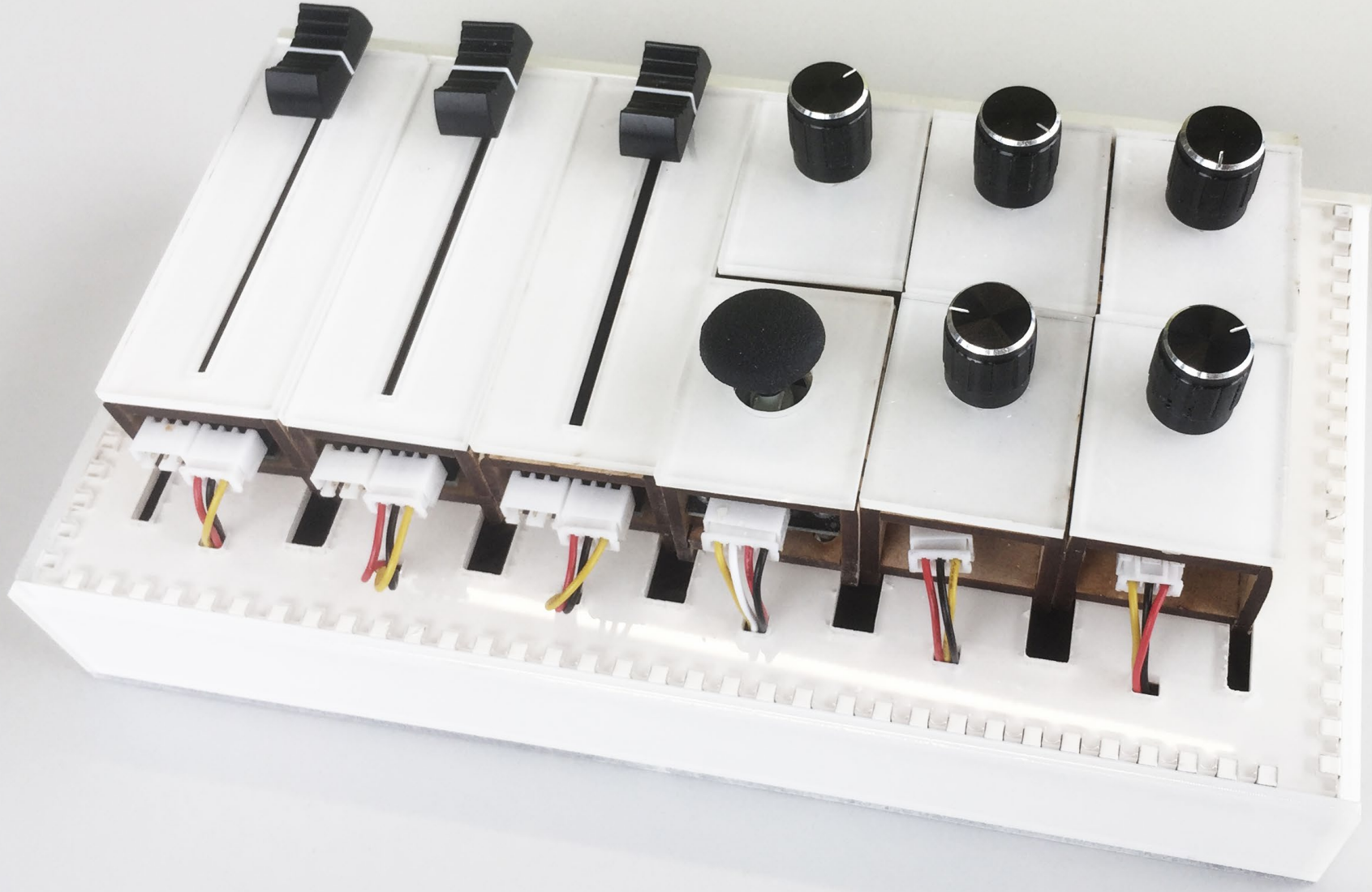
PROTOTYPE 2

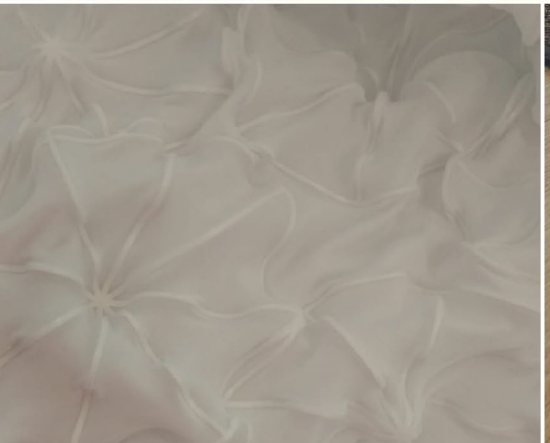


PROTOTYPE 3

DESIGN EVOLUTION







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