UNIVERSITY OF MUNICH
Department "Institute for Informatics"
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Master Thesis

Web-Based Creator for Activity Sculptures

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Abstract

The recollection of personal activity data has been greatly facilitated by the increasing amount of applications and devices that encourage users to measure their activity with the primary goal of health improvement. These devices range from mobile applications taking advantage of smartphone sensors to dedicated fitness trackers presented as modern watches and bracelets. Apart from the analytical insights about the data obtained through classic data visualizations, it is also possible to visualize the information through physical objects also known as activity sculptures. It has been shown that activity sculptures have a positive influence in users making them feel rewarded for their active lifestyle. To further study the process of visualizing activity information into sculptures an web-based activity sculpture creator was developed. This tool takes advantage of modern web technologies and offers a platform in which users can export their data and allows them to experiment creating variations of an activity sculpture which can also be exported for 3D printing. For the development of the configurator current product customization platforms where analyzed for gathering best practices in user interface and interaction design. In order for users to have a sculpture with a high degree of variability for the data to be mapped on 4 different sculpture prototypes were developed. For the validation of the configurator an online version was released and a user study was performed. User feedback showed that our prototype was easy to operate and that the obtained sculptures were appealing and meaningful them.

Zusammenfassung

Die Sammlung persönlicher Aktivitätsdaten wurde durch die zahlreiche Anzahl an Anwendungen und Geräte enorm vereinfacht. Diese Anwendungen und Gerätschaften, die hauptsächlich das Ziel haben, Nutzer zu einem aktiven Lebensstil ermutigen, können in Smartphones, wo sie die Vielfalt an Sensoren ausnutzen oder als tragbare Accessoires wie moderne Uhren oder Armbänder gefunden werden. Abgesehen davon, dass klassische Datenvisualisierungen Einblicke in den Aktivitätsdaten verschaffen können, ist es auch möglich den Datensatz durch physikalische Objekte, auch als Aktivitätsskulpturen bekannt, zu visualisieren. Es wurde bewiesen, dass Aktivitätsskulpturen Nutzer positiv beeinflussen, da die Nutzer sich für ihren aktiven Lebensstil belohnt fühlen. Um den Prozess der Visualisierung von Information in Skulpturen weiter zu forschen wurde ein Web-Konfigurator für Aktivitätsskulpturen entwickelt. Durch die Nutzung moderner Web-Technologien erhält der Nutzer eine Platform die ihm es erlaubt seine Daten unkompliziert zu exportieren und ermöglicht ihn die Gestaltung einer 3D druckbaren Skulptur. Für die Entwicklung des Konfigurators, wurden aktuelle Konfiguratoren analysiert mit dem Ziel Best-Practices im Bereich des Interface- und Interaktionsdesigns zu erkennen. Um den Nutzer eine breite Vielfalt an möglichen Anpassungen für die Skulptur, wurden 4 verschiedene Skulptur-Prototypen entwickelt. Letztendlich wurden für die Validierung des Prototyps eine online Demoversion veröffentlicht und eine Nutzerstudie durchgeführt. Die Resonanz der Nutzer zeigte, dass unser Prototyp einfach zu bedienen war und, dass die entstandene Skulptur ästhetisch und sinnvoll rüberkam.

Task Definition

Activity Sculptures are physical (3D printed) representations of personal tracking data (e.g. step count) that dwell between the artistic and the abstract. For this master's thesis the student will develop a web configurator that will allow to individually create said activity sculptures (a similar example can be seen in www.shapeways.com/creator/statement_vase).

The focus of the thesis will be the development of interaction concepts and their implementation in the configurator. The concepts will be examined and improved in smaller iterative user studies. Another important aspect is a seamless and easy import of external tracking data (e.g. export data from tracking apps). The result should be a stable working prototype that can be used for follow-up works.

Possible research questions

- What interaction concepts are possible? What are their advantages and disadvantages?
- What degree of freedom is possible and meaningful while designing a visualization?
- What is a possible design space for said activity sculptures?

Tasks

- Research and related works (e.g. data visualization, configurators)
- Development of interaction concepts
- Concept implementation
- Planing and executing several small user studies
- Written thesis and presentation of work

Requirements

- Programming skills in web development and computer graphics

I confirm that I independently prepared the thesis and that I used only the references and auxiliary means indicated in the thesis.

Munich, May 27, 2015

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Contents

1 Introduction

The presented work deals with two major topics: web customization platforms and activity sculptures. For the former topic interaction processes and usability aspects applied in current projects are of great interest as they provide a foundation on which the author's prototype will be built upon. The latter will help the user explore and engage with their activity data in a meaningful way, first in virtual and later in physical 3D space. The following sections offer an background information to the topic and a define the problem addressed in this work. To conclude this chapter a general overview of each chapter will be provided.

1.1 Background & Problem Definition

At its core, the problem to solve in this work is a data visualization problem. The field of data visualization is tightly interlaced with other fields such as statistics, psychology, design, human-computer interaction, computer and cognitive sciences to name a few. This makes it a science that requires a broad set of skills to master. Due to its multidisciplinary nature it is also difficult to define. A definition of data visualization suitable for this work would be the one described by Card et al.[7]:"The use of computer-supported, interactive, visual representations of abstract data to amplify cognition". In other words this definition states that the existent knowledge about a specific dataset can be increased by mapping the data to a visual space and by interacting with it through a computer system

The interrogatives and curiosities about a dataset are the start point of every visualization. This work aims to answer some questions about activity data and the possible forms of representing it in a physical sculpture. But why activity data? We are living in a time where there is more data flowing every second through the internet than all the data stored in the internet 20 years ago[29]. It is estimated that the measure of digital created data will grow by a factor of 300 from 130 exabytes in 2005 to 40,000 exabytes in 2020[12]. This forecast shows how the analysis of big data is playing an important role in the way how decisions are made in the industry. The large scale nature of big data observing how millions of users behave can also be put into a much smaller scale namely the quantified self. Big data and the quantified self could be compared to a telescope and a microscope. Both use the same principles to amplify the ability of humans to observe but on totally different magnitudes. The quantified self is a movement of people that make use of self-tracking tools to measure physical performance or vital signs for self improvement and was first described by Wired editor Gary Wolf[52]. Noticing the great momentum the movement was having Gary Wolf founded together with his fellow editor Kevin Kelly the Quantified Self Labs[53]. Even though people have been tracking themselves through the centuries and the improvement of performance by solely knowing one is being observed has been also been studied[30], the technological improvements in sensor development has made the process of gathering activity data much easier. So much that anybody with a smartphone can start tracking his own activity. Advocates of the quantified self movement see in this practice a tremendous potential for solving health challenges through big data[42].

It is therefore of great interest to develop new visual representations for the increasing amount of personal data available. The challenge for these visualizations is that they can engage people in a more deeper level as the data treated is a reflect of their own behavior. For this purpose designers and engineers have been taking advantage of digital fabrication systems, in particular 3D printing, to translate their visualizations from the screen to physical space. Activity sculptures have shown to be a suitable visualization for communicating abstract data into a tangible object. While it can be discussed about the usefulness of such an object is mainly determined by the information it can convey[54], activity sculptures have shown to influence people's behavior positively[26]. Other valuable characteristics of activity sculptures is the interaction possibilities and their physical properties[54]. Simply by being physically constructed they can approach the natural instinct

of interacting with objects through touch, by feeling its material and exploring its surface and structure.

As discussed before, one key aspect in the process of modern data visualization is that the interaction with the visual representation of the data occurs on a computer-aided system. One approach that has proved to be efficient in aiding users to manipulate objects to their specific need is the configurator. This tool supports the product configuration process satisfying every design and configuration constrain set by the manufacturer[14]. The development of configuration systems originated from the mass customization paradigm, that establishes a business model in which companies massively manufacture individually customized goods[10]. This paradigm is divided in different methods that offer each different degrees of freedom to customers. Out of this method the collaborative customization or the co-creation method uses of software tools that allow the customer to transfer their preferences directly to the product[37, 36]. Most of the configurators are deployed as web applications, in large due to the scalability and accessibility of web systems. Advancements in web technologies allow manufacturers to build more complex configuration systems. Because the configurator's degree of user friendliness can have a positive or negative impact on the completion of a sale, it is important to companies to understand how to guide the customer in a meaningful way to complete the sale[40, 2]. The work-flow proposed in research is usable to ensuring the successful guidance of the user throughout the process of developing a product suited to his needs. This same knowledge could be applied to the development of a visualization system.

To summarize this section, the motivation of this work could be resumed as follows. The increasing desire to quantify every aspect of the self and the advancements in digital fabrication open the field for a new kind of visualizations residing in physical space out of the constrains of the screen. This is a challenge for the data visualization field that can be addressed through co-creation production techniques and best practices to develop a software tool that includes the user in the process of achieving a visualization that is aesthetically and functionally meaningful.

1.2 Goals

The main goal of this work is to develop a system that can guides intuitively the user in each process of the visualization of his activity data. This all includes importing the activity data of the user and processing it in order to be visualized in a sculpture which will be further manipulated to users preferences and exporting it for 3D print. The aim of the web configurator is to perform all these tasks providing the user the best experience possible. For this the development of interaction concepts, that guide users through each step of the configuration process, plays an important role in the achievement of an enjoyable platform. Another goal is to ensure the interaction concepts in the prototype are understandable and easy to grasp. In order to achieve this goal users feedback was taken into account through user studies and questionnaires. The diversity of users chosen for the studies was made possible through local testers and through an online demo of the prototype. Furthermore the design of an activity sculpture that shows high variability in the configuration possibilities was an objective kept in mind throughout the prototyping phase. In order for the system to respond fast to user input a special set of technologies was needed. This work aims to take advantage of current edge technologies by implementing them in the prototype.

1.3 Content overview

The presented work takes the following structure. Chapter 2 presents current configurators in different fields of the industry and academic research. Further on current projects related to activity sculptures will be discussed. The final section of the chapter presents an analysis of activity data sources and current implementation of available fitness tracker APIs. In Chapter 3 the prototype design process will be presented. For this sketches and concepts for both sculptures and the configurator will be explained concluding with final thoughts about the final decision making. Chapter

4 deals with the development and implementation of the prototype. In this chapter the prototype's architecture and special features will be discussed. Chapter 5 is focused on the design and execution of the user study concluding with a discussion about the results and findings of the study. Chapter 6 concludes this work and chapter 7 states the ways on which this work can be further developed.

2 Related Work

In this chapter projects related to product configurators and activity sculptures will be presented. Each work presents a unique solution to the addressed problem, the approach each author took will be discussed and the adaptation of useful knowledge to this work will be explored. To conclude the chapter an overview of available vendor API for data import will be presented.

2.1 Web-based Interactive Product Visualization

This work has a particular interest in product configurators that make use of 3D computer graphics to visualize the product. The majority of modern web configurators are image based and make use of well designed backgrounds to place the product in well perceived environment. For example the UNU electric scooter configurator puts the scooter on a street background that changes as the user moves to the next step of the configuration (fig.2.1). Other systems may opt for a more minimalistic look, and will try to isolate the product and place it in a white background as seen on figure 2.2. Although this might work for some products the user still misses some of the benefits of interacting with a spatial representation the products[47]. One of the main challenges of developing configurator systems is the modeling of the relation between the product configuration and its visual representation and the correct rendering of the visual representation in real time[11]. The advantage of a 3D visualization system over an image based one, is that the different configurations can be generated on the fly instead of using complex logic systems to retrieve the correct image combination from an image database. On the following section, three product configurators will be presented that use novel 3D visualization technologies to offer users a robust interactive tools for designing unique products.

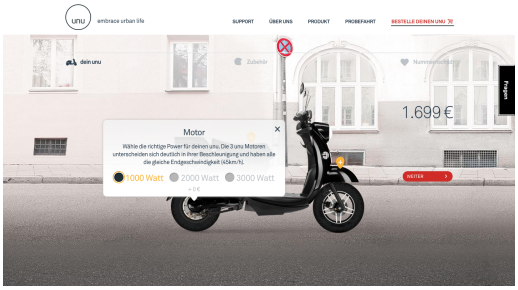

Figure 2.1: UNU electric scooter web configurator[13]

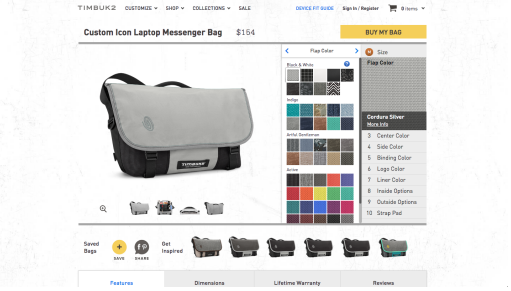

Figure 2.2: Timbuk2 bag web configurator[44]

2.1.1 Gates 3D Configurator

As part of an action-research project from Living Lab[33] Rolland et al.[40] developed a gate configurator for the French company Groupe Maine's gates. The objective of the authors was to showcase the possibilities of 3D Web technologies in e-commerce applications. The developed tool was build with the Unitiy3D[43] game engine, a flexible tool principally build for game development but it has proved to be also useful for architectural visualization and graphic intense web applications. After a user has logged in to the configurator, the platform allows customers to select from a variety of gate styles visualized as 3D models placed on the right side controls (see fig.2.3). The user has also the option of setting the environment in which the gate is being placed (left side controls). This can happen by either selecting a predefined environment of by uploading a picture of the user's home or place where the gate shall be installed later. Customers can position the gates in the uploaded photograph by operating dedicated slider controls. The main advantage of allowing customers to upload their own images is that this allows them to have a better idea

of how the selected gates will look in the final environment making them feel more comfortable about their decision. The authors state that they preferred the superimposition of a custom image rather than letting the user customize the environment with threes or buildings to make it look as close as possible because of the possible frame rate drop produced of handling many models and generating and because it is quite rare that somebody has a 3D model of his home.

One of the main aspects of the gates configurator in respect to the research purposes the authors had, was that of developing a tool that improved the visualization of products with the end of encouraging the purchasing of the product in an on-line medium. To validate the design ideas behind the gate configurator and analyze the impact it had on customers, the authors performed an empirical evaluation. The results of the 27 evaluated participants showed that the manipulation of objects in 3D space seem naturally and was also confirmed to be important to the participants to have this option. This shows that having a realistic view of the product improves the chances of sale.

Figure 2.3: Groupe Maine's gates configurator[40]

The gates configurator is a great example of how companies can make use of 3D visualization technologies to present their product to customers in a more convincing way. The authors of made a great choice of working with the Unity3D game engine as it allows them to port to other platforms as well, in this way developed software tools could be very easily ported to other mobile platforms like tablets or smartphones with bigger screens without the need of starting from scratch. This technology also offers desktop like frame rate performance in the web. The configurator has not many configuration possibilities which makes it easier for customers to understand but it excels at providing different visualization environments which in this case takes advantage of navigating in 3D space. One key statement of the authors was that tools like the configurator promote customer's participation in the developing of products. It was a shame there is no actual configurator in the Groupe Main's webpage for testing and it is unknown if the configurator was ever implemented in their website. The authors of the gates configurate see a great potential of 3D visualization technologies in fields such as e-learning, simulation and education.

2.1.2 The MakerVis Fabrication Tool

The MakerVis fabrication software is, in the words of its creators: *"a prototype tool that integrates the entire process of creating physical visualizations, from data filtering to physical fabrication"*[41]. If somebody attempts to visualize their information they will have to use a wide range of tools to achieve this. This is cumbersome and impractical as it requires a great amount of effort and in general it is a very conflict prone way of working with data. This motivated Swami-

nathan et. al to develop MakerVis as an attempt to offer a platform that unifies the needed tools to extract data, filter it and visualize it. Although the focus of the MakerVis is not the implementation of a complex tool but more the exploration of the different challenges encountered in the process of visualization.

The work-flow provided by MakerVis is composed of six steps all displayed in the user interface seen on figure 2.4. First users need to upload a CSV file containing the data to visualize. After that users can select between several visualization styles. Once a visualization is selected the data the user can begin mapping the data to the visualization by selecting data variables. Further on users can manipulate the visualization's geometry through an array of sliders and controls. In order to setup fabrication parameters and selecting the machine users can make use of the lower right section where the visualization is deconstructed layer by layer. Finally the STL file of the model can be exported for fabrication. A helpful functionality the authors implemented was the specification of printing materials through a JSON file. It is worth mentioning that MakerVis does not provide true 3D visualizations. The produced designs are indeed physical objects but the final result is a pseudo 3D visualization. In order to achieve this the authors use principally 2D fabrication methods employing laser cutting and CNC machines, only basic 3D printing support is provided. The visualizations users can choose from are more directed to traditional charts and bar graphs and not so much geared towards more artistic representations. Due to the modular engineering of tool, the visualizations can be expanded. The available tools for data manipulation is also limited and advanced manipulation should be better performed in an external tool. MakerVis was build with modern web technologies based on the JavaScript programming language like Node.js[17], Three.js[6], D3.js[4] and jQuery[25]. As some of this technologies were also used in the Activity Sculpture Configurator they will be explained in depth in Chapter 4.

Although the authors conducted a relative small user study, the results provided valuable information about what areas can be further improved. The user study showed that users wanted more detailed control about the decorative aspects of visualization. Providing tools for personalize text labels and scales increases would allow users to further customize their visualization. Another challenge encountered was that of material representation. It was difficult for users to decide on which materials to use and expressed the desire to physically interact with the available materials. Also the correct scale representation of the object was estimated wrongly by most users. The need of the ability to save and load visualizations was also expressed to be needed. This findings might sound as failures but they only make clear the limitations of the screen as a medium to transmit haptic properties of materials and that unifying every tool needed for data visualization in a tool is an immense challenge.

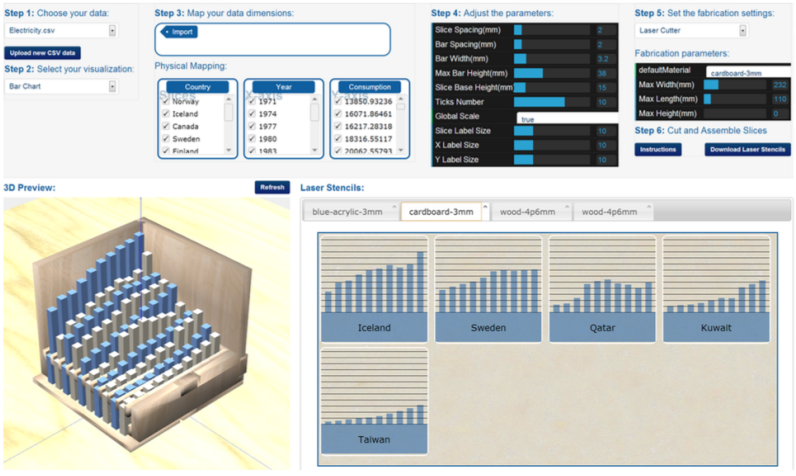

Figure 2.4: The MakerVis fabrication tool[41]

The MakerVis fabrication tool approximates closely the aim of the work discussed in this thesis. This work shares the same mission of building a tool were the whole process of visualizing a 3D object is contained. The MakerVis focuses more on data manipulation and fabrication as it basically dedicates two thirds of the whole screen to data filtering and fabrication parameters. None the less the interaction concepts and design layout served as a reference point for the activity sculpture configurator.

2.1.3 Twikit

The 3D printing market is a fast growing market estimated to reach US$16.2 billion dollars in value by 2018[39]. Many see the potential to offer services to facilitate the design and production of 3D printing goods. An interesting example is Twikit[45] a company located in Belgium that offers innovative software, fabrication and shipping solutions for brands and retailers looking to easily implement product customization to their product portfolio. The Twikit website[45] states that their goal is to "allow end-to-end 3D product customization, in the easiest way possible" and they see 3D product customization as "key in the future of products and experiences".

The range of services the belgian company offers covers every step in the development of a 3D configurable product. If needed Twikit is can aid brands in the development of their 3D product through collaboration with existing design teams. On the software side, Twikit offers a complex engine for 3D visualization, customization and fabrication called Twikbot. This engine allows companies to integrate customization tools into their current e-shop or application. Due to the modular nature of the engine, retailers can choose what kind of interface controls they need for the customization process and integrate them with the assurance that the design specifications and constraints will be met. The Twikbot also offers material configuration functionality for a variety of 3D printing techniques. Another integral component of the Twikbot is its Content-Management-System (CMS). The Twikbot CMS is a backend tool that manages and tracks currently configured and sold products and through an API cloud-based service it links to logistics and 3D print fulfillment providers.

The Twikit website showcases several study cases from small and large businesses that have integrated their software to sell appealing customizable products. As much as it would be interesting to know how Twikit performs in all areas of their services, for the purposes of this thesis, only the configurators showcased will be evaluated. One interesting case study in the website is the 3D Trophy Factory[45] which is owned and run by the same Twikit people. This e-shop sells a variety of trophy models were the text can be customized (see figure 2.5). It is a very simple configurator that allows customers to interact the trophy in 3D space through click and drag. Depending on the model customers can input up to three different text lines. The configurator offers the possibility to save and load configured trophies. If users have a custom 3D model they would like to print as a trophy, the e-shop supports uploading 3D model files. In some designs users can also change some text properties like randomize the positioning.

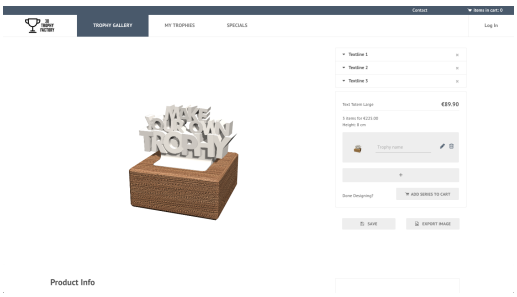

Figure 2.5: Twikit powered 3D Trophy Factory web configurator[5]

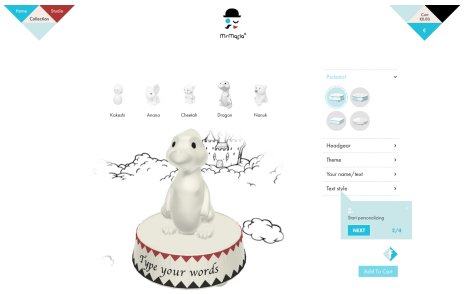

Figure 2.6: Twikit powered MrMaria Studio lamp web configurator[28]

The next Twitkit case study shows that the technology offered by Twickit can be easily used to enable brands no matter how big or small to start offering customizable products. Amsterdam based design studio Mr Maria[28] added a customizable toy lamp to their product line. The lamp configurator showcases the brand identity of the studio and allows customers to customize their lamp in a playful way. The lamp is composed by a model of an animal and a pedestal were a text is placed. Users can choose different animals to place over the pedestal and further customize it by adding different accessories like hats, different pedestal designs with different color themes and a text field for adding a custom text (see figure 2.6. The lamp is placed in a cartoon style background which can be changed to a dark view where the lamp glows simulating to be turned on.

The 3D Trophy Factory and the Mr Maria lamp configurator were both very appealing and fun to work with. Twikit does not say much about the technologies used in the framework but a view into both e-shop's source code showed that it makes use of the Three.js[6] graphics library. In summary, the toolkit offered by Twikit seems to make quality visualizations with good performance as the interaction with the products is always fluid. It would be interesting to see how much does Twickit charge customers for their service but the website only offers a contact form to get information.

2.2 Activity Sculptures

The advancements in digital fabrication technologies have allowed the development of new visualization metaphors transitioning from the screen to physical space. Activity sculptures or data sculptures are a fairly new concept in the data visualization field and its usefulness is still largely misunderstood. Much work has been done trying to give activity sculptures its place comparing them to other physical visualizations like ambient and casual information visualizations[22]. A understandable to differentiated activity sculptures from other visualizations by highlighting their perceived physical qualities[47, 54]. Data sculptures are per se, the embodiment of the data in a tangible and visible form[54]. This gives activity sculpture a more broader representation space making it difficult to find a metaphor were the influence of the data on the object's form can still be related producing, as Vande Moere called it, a metaphoric distance[47]. Activity sculptures can communicate also through the affordance of an object which is the perceived potential to perform an action through the object. This property calls users to interact with the sculpture in an explorative manner[22, 46], which could be take advantage of haptic qualities of objects and materials to communicate information through more sensory channels[3].

In the following sections current work on the use of activity sculptures to visualize physically different kinds of activity data will be presented.

2.2.1 Sweat Atoms

SweatAtoms is a visualization system developed in a research project by Koht et al.[26]. The authors aimed to better understand how the representation of physical activity data though material artifacts can be used to reflect on physical activity. In this work the authors concentrated in visualizing heart-rate data through 5 different sculptures each one emphasizing a different aspect of the data (see figure 2.7. For visualizing heartbeats per minute an extruded graph was used. Higher fluctuation in the heart-beat values were visualized as a flower mapping the heart-rate value and duration to the length and width of the petal. The amount of the performed activity in a day was mapped to the size of a frog. The time spent in each of the six different heart-rate zones (resting, recovery, aerobic, anaerobic, speed and alarming) was mapped to each side of a dice. And lastly a ring depicts through circles the number of active hours in a day, the diameter of these added circles is affected by the increment of the heart-rate.

The authors conducted a two week field study with 7 participants with different demographics and exercise habits. Each participant received a 3D printer, a heart-rate sensor and an iPod

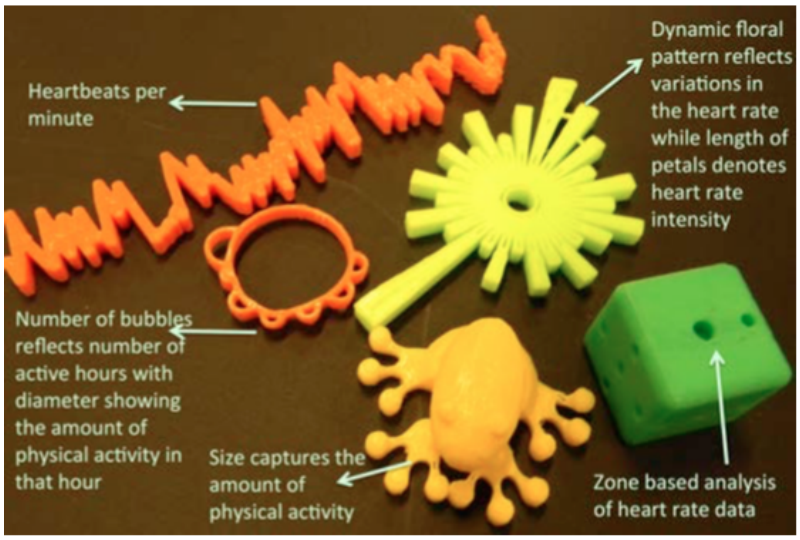

Figure 2.7: SweatAtmos activity sculptures[26]

touch. Participants were required to wear the hear-rate sensor every day. The sensor was paired via bluetooth to the iPod and automatically loaded the data to the SweatAtoms system when the monitoring stopped. SweatAtoms then generated the 5 sculptures from the data. The models were then send to the authors for STL export. Once converted the participants received the STL via email. Participants then proceeded to print the 5 sculptures with the provided 3D printers at home, a procedure that took around two hours. Users kept a diary reflecting on the sculptures and their activity every day.

The study showed the participants engaged differently with each sculpture. The favorite sculpture was the frog sculpture. The graph was described by a participant as “not very exciting as we can see the same on a virtual screen”. On the other hand a very active participant liked to see its graph sculpture as he could see how active he had been. For the flower participants expressed different ideas as they could interact with it. A female participant saw the flower suitable for wearing it as earrings. The utility of the rings was often questioned, and was regarded as the least appealing sculpture of the 5. Some users started grouping and assembling the sculptures to form a bigger sculpture. Some users expressed that the dice made them reflect on their lifestyle by analyzing the time they spent on each heart-rate area. The sculptures were also subject of conversations with work colleagues and friends. Users also stated that the value of their heart-rate had gained more significance as the sculptures provided allowed them to “touch and feel” their data, this made the sculptures more valuable to participants than screen based visualization. The uniqueness of the objects was repeatedly mentioned by users to be very appealing and the fact of being able to constantly reflect on their activity motivated them to exercise with more intensity.

The SweatAtoms study is a great example of how through activity sculptures motivated users to reflect more about their activity and made them take action. It is surprising to see how participants did not have any trouble at all with the fabrication of the sculptures at their home. The different technologies integrated seamlessly providing a solid set of tools to visualize and easily construct the sculptures. The metaphors utilized to map the data were varied and showed that visualizations that are useful in virtual space not are not necessarily appealing as objects. On the other hand sculptures that were not extremely abstract but rather communicated the data through a playful metaphor, like the frog, were the ones that users liked the most. Overall the SweatAtoms was a very successful project that produced interesting findings regarding activity sculptures and their influence on users.

2.2.2 Mental Fabrications

Mental Fabrications is an art project from artist Ion Popian[38] that aims to visualize brain activity produced in response to different types of stimuli in the form of a 3D printed landscape were the intensity of the activity creates valleys and hills (see figure 2.8). Popian states normally architects design spaces and buildings and study how these spaces are perceived by people. This motivated him to develop a concept were the design of environments is originated by the perception of people about a space. Through a NeuroSky MindWave Headset[31] electroencephalogram (EEG) Popian is able to meassure the brain activity while users are wandering through different environments for a prolonged time frame. In this way it is possible to study how users perceive their environment through their . By analyzing the way the brain reacts he attempts to design a space or environment that provokes a certain stimulation to users.

The Mental Fabrications project was produced in collaboration with programmers that developed a software in Max/Msp[1] that translated the EEG data from the headset to produce hills and valleys in a plane and exported for 3D printing. For a series of exhibitions of the work, Popian developed a film that was presented to visitors wearing the headset. The brain activity was then measured and visualized in the landscape. Visitors could then self reflect on how calm they were at certain scenes of the film or what sequences provoked hills in the landscape as a consequence of high brain activity. With the collaboration of enthusiastic participants the exhibit produced several landscape visualizations enabled by the usage of sound, textures and imagery in the film, showing visitors the process of generating visualizations from data. To expand the sculpture a second set of data was being generated in the exhibition, namely a camera was filming the movement and proximity of the visitors and was later visualized as a second landscape in a wire-frame style which was then interposed to the landscape generated by the brain activity of the viewers.

Even though this project is more art oriented it proposes interesting ideas of designing environments. Technology is at a point where even EEG devices are easily obtainable allowing designers, or architects in this case, to use data to create new design concepts. Among the flood of quantified self applications Mental Fabrications offers a fresh approach to activity data exploring brain activity which can be viewed as strongly linked to emotions and thoughts. The produced sculptures are really elaborated and as seen in other studies provoked participants to analyze how their brain reacted to the imagery. This work It will be interesting to see how technology enables the visualization of different forms of activity through new sensors.

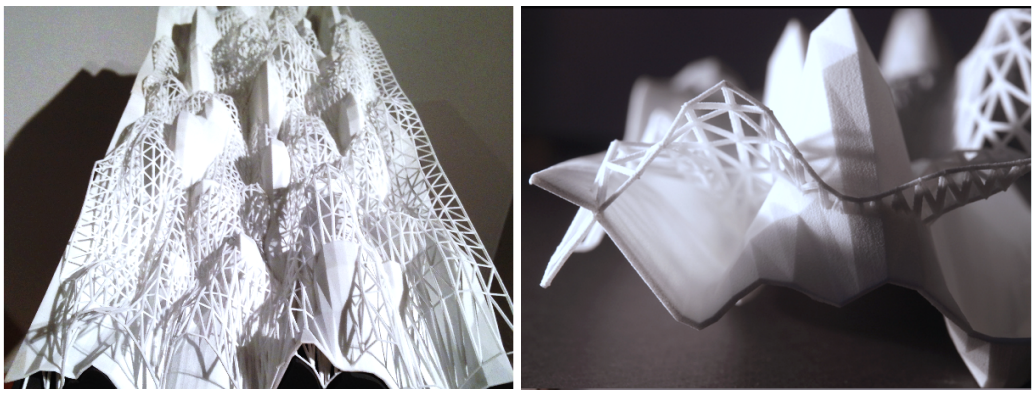

Figure 2.8: Mental Fabrication's brain activity landscapes[38]

2.3 Fitness Trackers

An integral part of the activity sculpture configurator developed in this work was the gathering of the activity data as it is basically the first step in the visualization pipeline. As shown in many

examples[26, 41, 38] through fitness trackers we have the possibility to gather information in an non obtrusive way, facilitating the task immensely. Added to these tracking devices many of the manufacturers also provide a set services for developers to encourage the development of third party applications that can take advantage of their fitness tracking product. In order to make the gathering and exporting of data as simple as possible for users, the author decided to use a wearable fitness tracker in the form of a wristband or clip and make the data available to the web configurator through a web Application Programing Interface (API). By doing this, the user does not need to export the data through USB sticks or handle CSV files. Working with web APIs ensures that the configurator will always read the data in the same format because of the standardization and organization an API provides. Further details of web API implementation and functionalities will be addressed in chapter 4. Even though there are many applications for smartphone the user experience design goals explained before narrowed the options down to dedicated fitness trackers. In the next section an overview of considered fitness trackers and their accompanying API will be presented.

Nike+ FuelBand SE

The Nike+ FuelBand SE[19] is a wristband equipped with sensors providing information for daily step count, burned calories and Nike Fuel, a unit introduced by Nike to measure daily activity. The wristband does not provide that much information by its own, but when used with the accompanying iPhone and Android applications which makes use of the device GPS sensor to provide positioning data and routes from running sessions. This product was first considered because of the author's previous experience with the Nike+ Running App[20]. Nike provides a web API and several Software Developer Kits (SDKs) for different platforms in their developer portal[18]. The web API provides only basic documentation and most of the features of the wristband and the app like GPS data and activity data are supported, although in comparison with the other APIs reviewed it is very limited. The major drawback of the Nike+ environment is that its only available to selected partners. A contact form is available but it is unknown what selection process has to be undergone and most importantly how long does it take to receive an answer from Nike. This was the main reason of why the Nike+ FuelBand SE was discarded to be used for this work.

Jawbone UP 3

The Jawbone UP 3[23] is a really well designed, both aesthetically and functionality wise, fitness tracker. It tracks steps, exercise, calories burned, sleep and heart-rate. Jawbone also provides a smartphone application where users can also track meals and set activity gaols. The Jawbone API[24] offers a great documentation with example code and detailed explanations. It provides developers access to users information about any measure the tracker and the app can perform. It even offers information about marketing strategies for developers seeking to develop a third party product for Jawbone products. The API is available to the public in general. The only point of consideration about using the UP 3 for this work was the high price tag of around €180.

Misfit Shine

The flagship product of Misfit is the Shine tracker[49]. The tracking possibilities is limited to steps, calories and distance but the Shine compensates this with extreme robust materials, up to 50m waterproof and it does not need to be charged. The Misfit API[48] had not been released at the time of researching available options which was the main reason for discarding the tracker. As of today, the API provides a short and concise documentation and is openly available.

Fitbit Flex

The Flex fitness tracker from Fitbit[16] measures steps, distance, calories burned, active minutes and sleep monitoring. All in all the flex is a very complete tracker with an affordable price tag. At the time of performing the research Fitbit had announced two new trackers with heart-rate and GPS support which are now both available. The API offered to developers[15] would serve the purposes of the activity sculpture configurator well as it provided access to all tracked data and it was well documented. One aspect that caused interactivity about its usefulness was that at the time of researching available options it did not support heart-rate data. The API is also available to everyone with a Fitbit account.

Withings Pulse Ox

Thw Withings Pulse Ox[51] is a compact tracker that enables users to keep track of steps, distance, elevation, calories burned, activity time, sleep, heart-rate and saturation of peripheral oxigen (SPO2). Out of all available trackers in the price range of €100 to €150 the Pulse Ox tracks the most types of activity data. This was a very attractive feature as the budget for this work was limited and having many variables for visualization was highly sought after. Withings provides also an app for smartphones that offers an overview of all the activity tracked by the device. The Withings API[50] has decent documentation, but just enough to get started but all the tracked information is available. Because of the affordable price of the device and the openly available API the Pulse Ox was chosen to gather the activity data for this work.

Figure 2.9: Fitness Tracker Wristbands. From left to right: Nike+ Fuel Band SE[19], Misfit Shine[49], Jawbone UP 3[23], Fitbit Flex[16] and the Withings Pulse Ox[51]

Summary

In general all available fitness trackers in the market offer good functionality for monitoring daily activity and would serve well any quantified self enthusiast. For more advanced users that are looking to develop their own tools the provided APIs depend in large to the functionality offered by the sensor and the mobile app. For the purposes of this work the decision was narrowed down to the Wihtings Pulse Ox, the Fitbit Flex and the Jawbone UP 3 as these brands showed more presence in tech and quantified self blogs. The Withings Pulse Ox was chosen because it offers a wide range of activity data, its affordability and well supported API. The authors experience actually working with the fitness tracker and the API will be further discussed in chapter 4.

3 Prototype Design

This chapter presents the process of developing the designs for the activity sculpture and the web configurator. In the first section the requirements for the activity sculpture are presented and four different designs that attempt to fulfill the requirements are presented. Finally the validation process for the sculpture to be designed will be discussed. The second section is devoted to the design process of the customization system. This comprehends not only the user interface but also the user experience while operating the system. After a process where three different concepts were ideated, through the validation of the design the final prototype is chosen.

3.1 Activity Sculpture Design

The activity sculpture and the configurator are strongly interconnected as depending on the design, the sculpture will influence the quantity of controls to be taken into consideration for the design of the configurator giving users greater or lesser freedom for manipulating the the sculpture. As we discussed in section 2.2, activity sculptures portray different attributes inherit from their physical nature. This why a different approach for designing physical data visualizations is needed. For this purpose the design taxonomy proposed by Vande Moere et al.[47] was used as a guide to better categorize the qualities of the developed designs. This taxonomy is has two dimensions which describe the design space of activity sculptures: *representational fidelity* and *narrative formulation*.

The representational fidelity attempts to explain the decision made for the embodiment of the data in form. This includes the chosen metaphor for mapping the data to the object and the resulting metaphorical distance, this is the level of abstraction used to represent the data through the metaphor. In order to better explain the abstraction level Vande Moere's taxonomy uses concepts from semiotic studies. According to C.K. Ogden et al.[34] semiotic signs can be explained through their three major concepts: the signified, the signifier and the sense. The signified is an object that represents a physical thing or and idea. The signified is represented by the signifier who tries to bring the same experience an observer would have with the signified. The sense is the experience brought by the signified. Furthermore signs can be categorized into iconic, indexical and symbolic. Iconic representation occurs when the signifier resembles the signified, like a picture or a diagram. Activity sculptures are iconic when they resemble the metaphor they are interpreting. Examples of this could be the heart-beat extruded graph sculpture in discussed in section 2.2.1 or the MakerVis visualizations in 2.4. An indexical sign has a sensory feature that correlates directly to the signified. The signifier points to the signified through an actual connection, like dark clouds point to a forthcoming rain or smoke points to fire. Activity sculptures can be classified as indexical when through the use of a property directly related to the data. An example of such a sculpture would be the SweatAtoms frog in section 2.2.1 or the . The most complex kind of sing is the symbol, as it does not bear any resemblance to the signified. The relationship between the signified and the signifier has to be taught by convention in order to be understood. Activity sculptures making use of symbolic representation are the hardest to understand as the relationship to the data has to be learned as it is not apparently displayed. Example of symbolic sculptures would be the landscapes in the Mental Fabrications project discussed in section 2.2.2. Through the definition of iconic, indexical and symbolic representation we can derive their metaphorical distance resulting in indexical having the closest distance, symbolic the furthest and iconic a medium distance[41].

The narrative formulation of activity sculptures is a product of the physical form and the affordance of the object which influences the user's ability to discover information through interaction and perception. This quality is strongly interconnected to the representational fidelity as the level of abstraction in which the data is presented will form the properties in which the sculpture communicates. As discussed in section 2.2 the affordance of an object describes to the viewer the object's potential to perform an action. The level of abstraction of the sculpture will influence how

inviting the object is to the viewer depending on the user's level of familiarity with the metaphor used.

Computer aided design systems offer almost endless possibilities in the design of activity sculptures, allowing designers to create complex structure designs that with manual methods it would be almost impossible to conceive. Even though this might be the case in the digital realm, translating the virtual object into a physical object may be still a challenge. An important aspect to be considered while developing activity sculptures is the manufacturability of the sculpture[41]. 3D printing machines still are challenged by certain types of structures depending on the technology that is being used to manufacture (granular vs extrusion methods). Therefore it is important to take into account how challenging the manufacturability of the sculpture will be.

The the aforementioned design considerations of activity sculptures the requirements for the activity sculpture were formulated as follows.

- The sculpture has to be aesthetically appealing to users
- Motivate users to self reflection
- Because of the wide range of activity data types obtained through the fitness tracker, the sculpture has to be able to visualize as many variables as possible
- In order to provide users a relatively high level of freedom while customizing the sculpture, the sculpture has to offer multiple configuration options
- The sculpture has to be extended to new interaction forms
- The sculpture has to be 3D printable by current 3D printing technologies

With the defined requirements the author formulated four designs exploring different possible approaches. Due to space and layout considerations, the sketches drawn for the prototypes will not be displayed in this chapter. Due to the large sizes of the sketches all prototype sketches were placed in their entirety in the appendix of this work. For the sculpture prototypes sketches please refer to section A.1, for configurator prototypes sketches refer to section A.2.

3.1.1 3D Graph

The first prototype is based on a line chart but augmented to describe more data variables. The idea was inspired by multiple exposure images of Olympic athletes in the middle of their performance. The multi exposure technique allows photographers to take a snapshot of the athlete at a specific point in time. The resulting image shows a group of athletes in different positions completing a cycle of a movement (see figure 3.1). The concept of presenting snapshots of the athlete's position over time is actually a parallel concept to standard charts and charts where the value of a variable is presented at a specific point in time. Only transferring the line-chart to a physical space would have been not appealing enough and very limited as it would have been only possible to visualize one variable over time. The first modification made in order to improve the aesthetic of the sculpture was to give the chart-line volume and a triangulated or low polygon count (lowpoly) aesthetic, two properties that can be explored thanks to physical space. With this modification the sculpture gained the ability to visualize one more variable. The first variable influences the hight changes in the Y axis of the chart-line over time and by adding the volume to the line we can change the radius of the line according to the value changes of the variable over time.

Up until this point the 3D graph would look as shown in figure 3.2. It visualizes up 2 variables over time. Even though the data is being visualized as an abstract triangulated body with hight and radius changes the sculpture could take advantage of the depth dimension not only to display volume but to steer the body also in this dimension. Through this realization, the 3D graph now

Figure 3.1: Athlete's movements captured in a multiple exposure image[9]

can map 3 variables. To further enhance the aesthetic of the sculpture the concept of the athlete's snapshot in specific points of time was explored. For this a set of avatars performing different sports were developed. These avatars would intersect the graph body in specified intervals by the user. By adding different avatars performing a variety of sports users can chose the avatar that represents best the sport or activity the user did to generate the data. The sculpture could be expanded to support different decoration styles. For example apart from the triangulated look of the graph body, other visualization like a wire-frame option or a smoothed look could be offered. As shown in figure 3.2, the whole structure looks as if it would float in the air with the help of a support structure, which could be manufactured separately from transparent acrylic so that they fade away centering the attention in the sculpture. This support structure would be inserted into a wooden or acrylic plate. The author explored the idea of engraving a summary of the data the sculpture represents. In this way users have both the abstract visualization and the actual data in the same place close enough to analyze. This might be useful while showing it to others, as it can help them better grasp how the sculpture was generated. By adding a plate to the sculpture we open a new set of configuration possibilities for users to edit in the configurator.

The 3D graph embodies activity data through iconic and indexical representations. Indexical because as stated before, the concept emerged from an expanded line-chart an the graph body points to the path line-chart would have but abstracted and stylized and with the avatars in different positions point to movement in activity. The avatars are a strong icon of a human body in motion. The 3D graph shows a somewhat short metaphorical distance as the sculpture points strongly to the a line-chart metaphor used to embody the data. In the narrative formulation of the sculpture again the chart-graph resemblance and the plate tell the user this object is to be analyzed or at least admired as the plate does not allow grabbing the sculpture. Self reflection is highly encouraged as the metaphor motivates comparison of values over time.

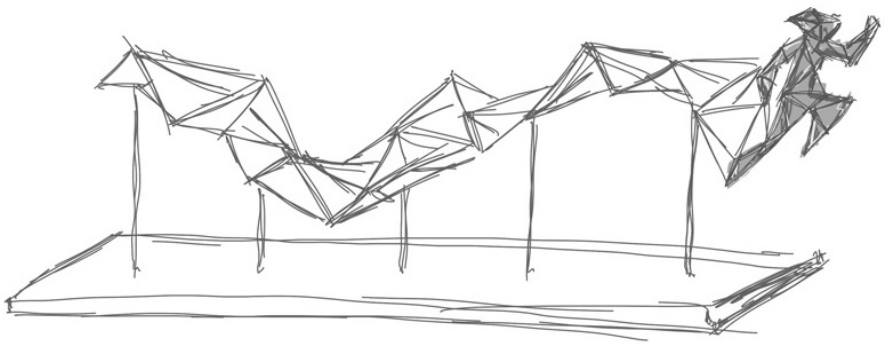

Figure 3.2: 3D Graph sketch

3.1.2 Activity Landscape

Figure 3.3: Procedurally generated landscape [35]

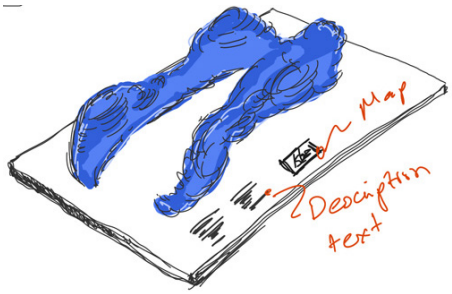

Figure 3.4: Activity Landscape sketch

3.1.3 Activity Flora

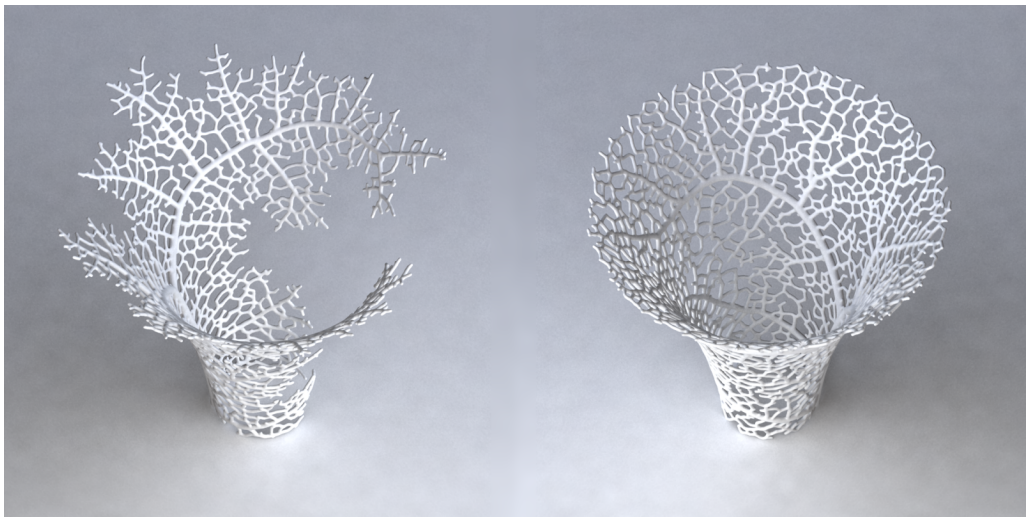

Figure 3.5: Sculptures made with generative algorithms based on hyphae growth as seen on leave and coral structures[21]

3.1.4 Activity Vase

3.1.5 Prototype Validation

3.2 Configurator Design

[2] [27] [40]

3.2.1 Ideation Process

3.2.2 Prototype Validation

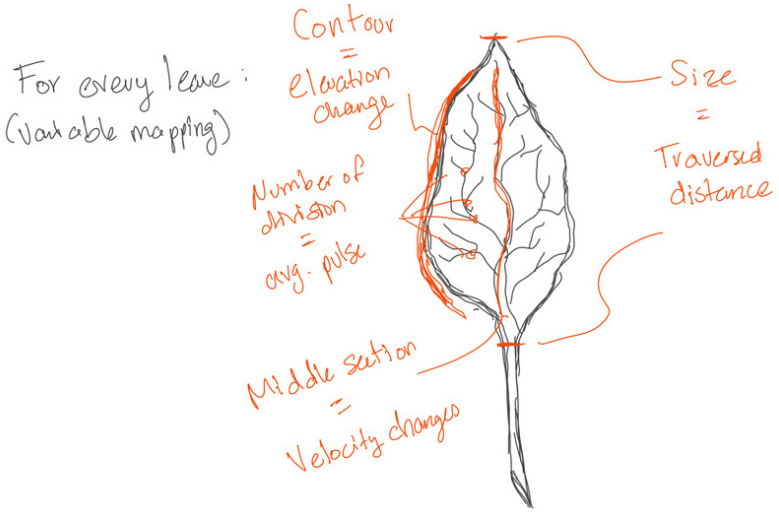

Figure 3.6: Activity Flora sketch

Figure 3.7: Fhaz: Procedurally generated vase based on facial profiles[32]

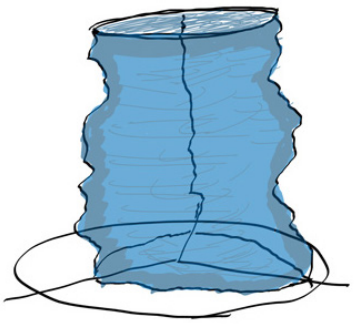

Figure 3.8: Activity Vase sketch

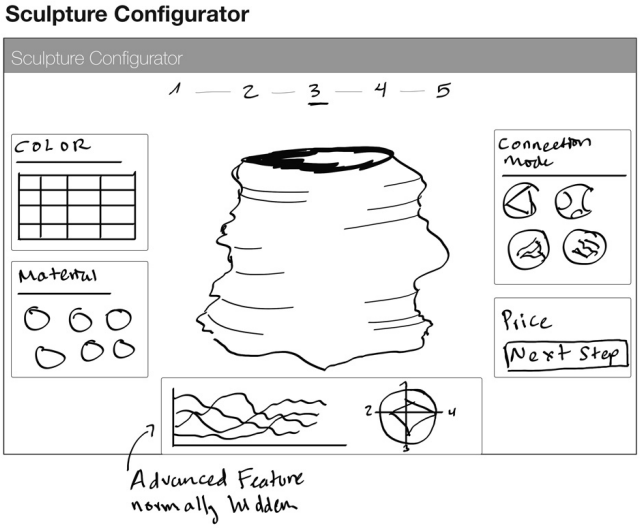

Figure 3.9: Sketch of step based configurator prototype

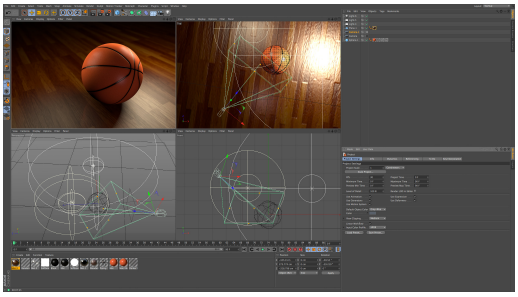

Figure 3.10: 3D modeling software Cinema 4D graphical user interface[8]

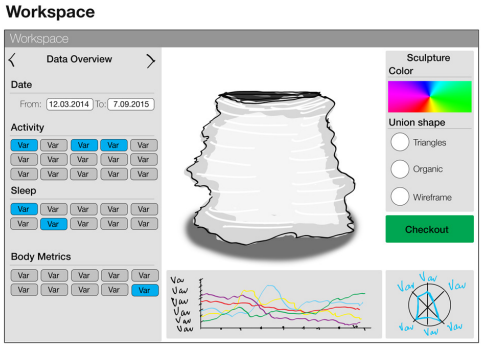

Figure 3.11: Sketch of 3D modeling software inspired configurator prototype

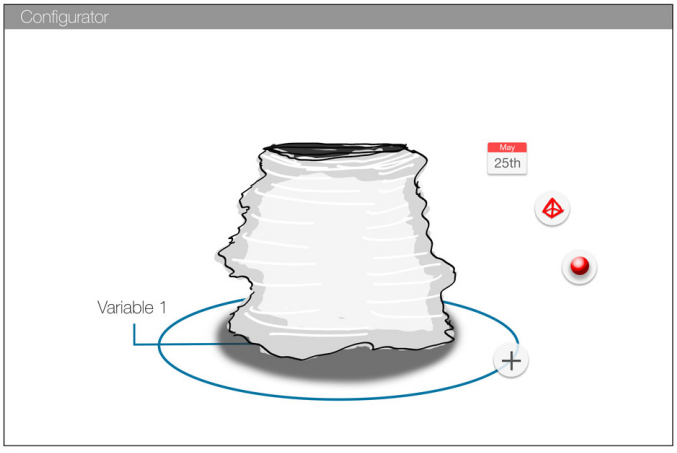

Figure 3.12: Sketch of “freestyle” configurator prototype

4 Implementation

4.1 Requirements

4.2 Technology

4.3 Architecture

4.4 Configurator

4.4.1 Sculpture Manipulation

4.4.2 Sculpture Generation & Rendering

4.5 Backend

4.5.1 Withings API Integration

4.5.2 Data Processing

4.6 Challenges

5 User Study

5.1 Study Design

5.2 Questionnaire

5.3 Participants

5.4 Procedure

5.5 Results

5.6 Limitations

6 Conclusion

7 Future Work

List of Figures

LIST OF FIGURES

References

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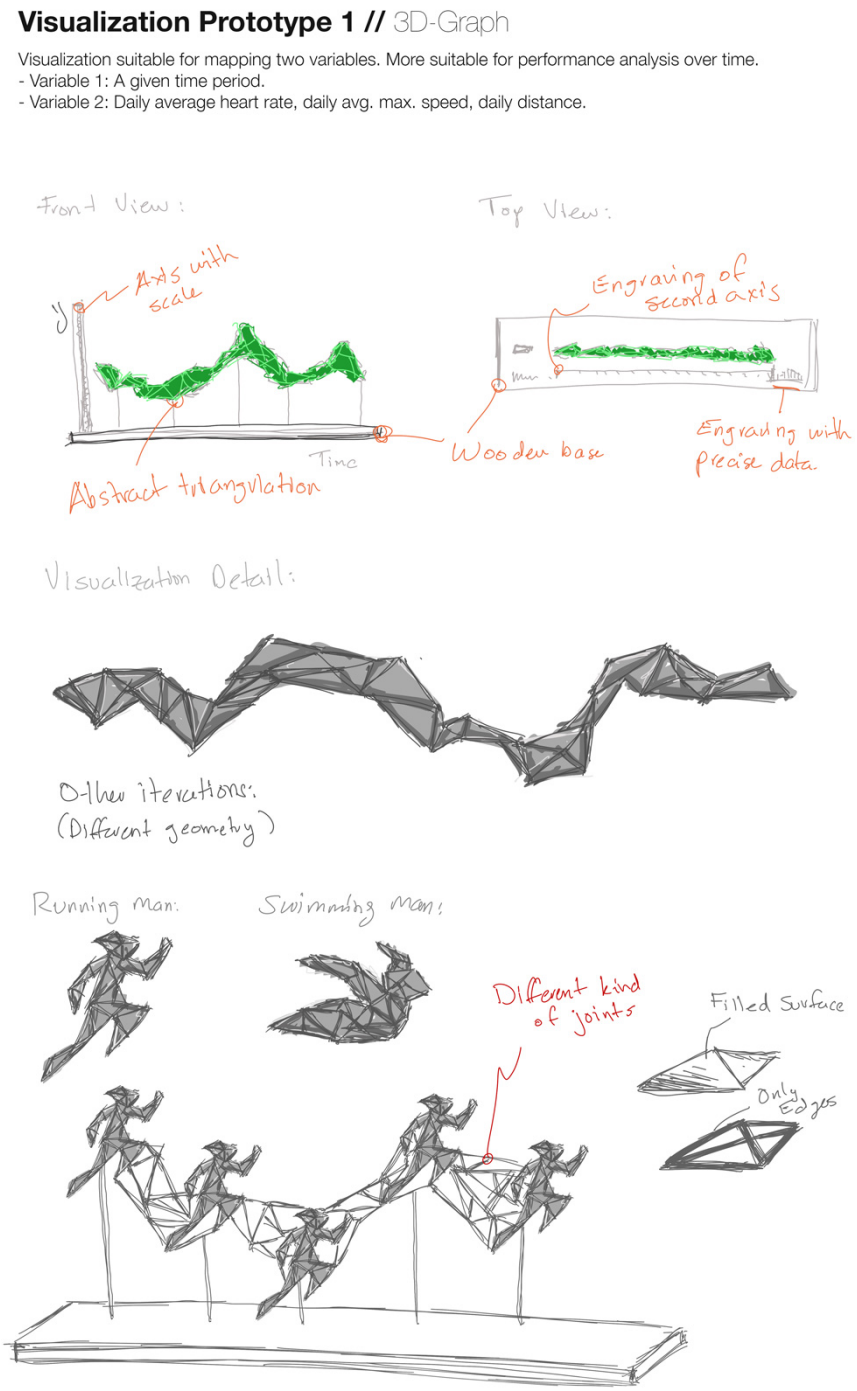
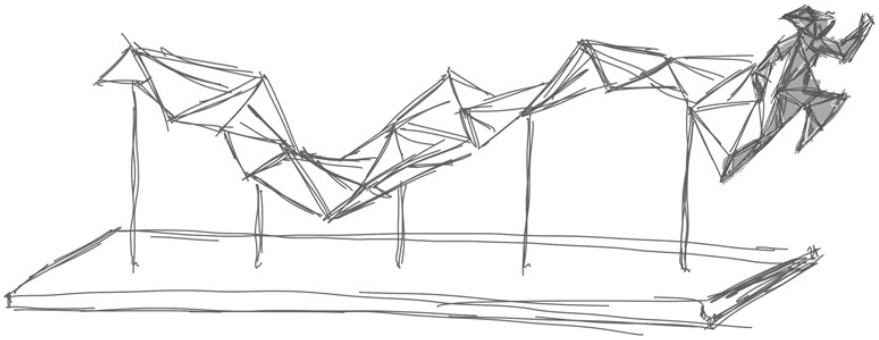
Appendix

A Prototype Sketches

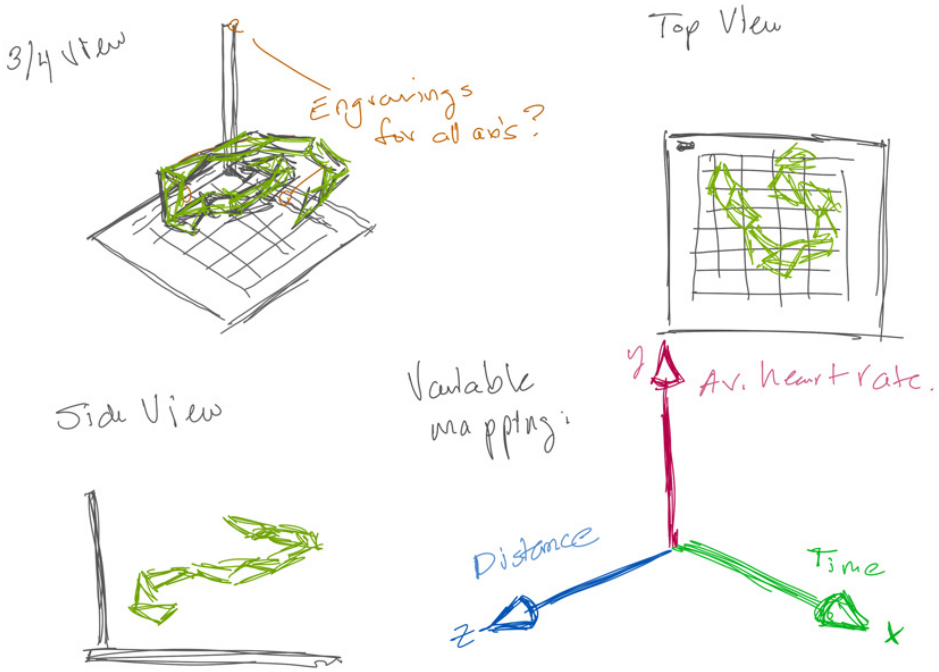
A.1 Sculpture Prototypes

3D Graph Sculpture Prototype (continues in next page)





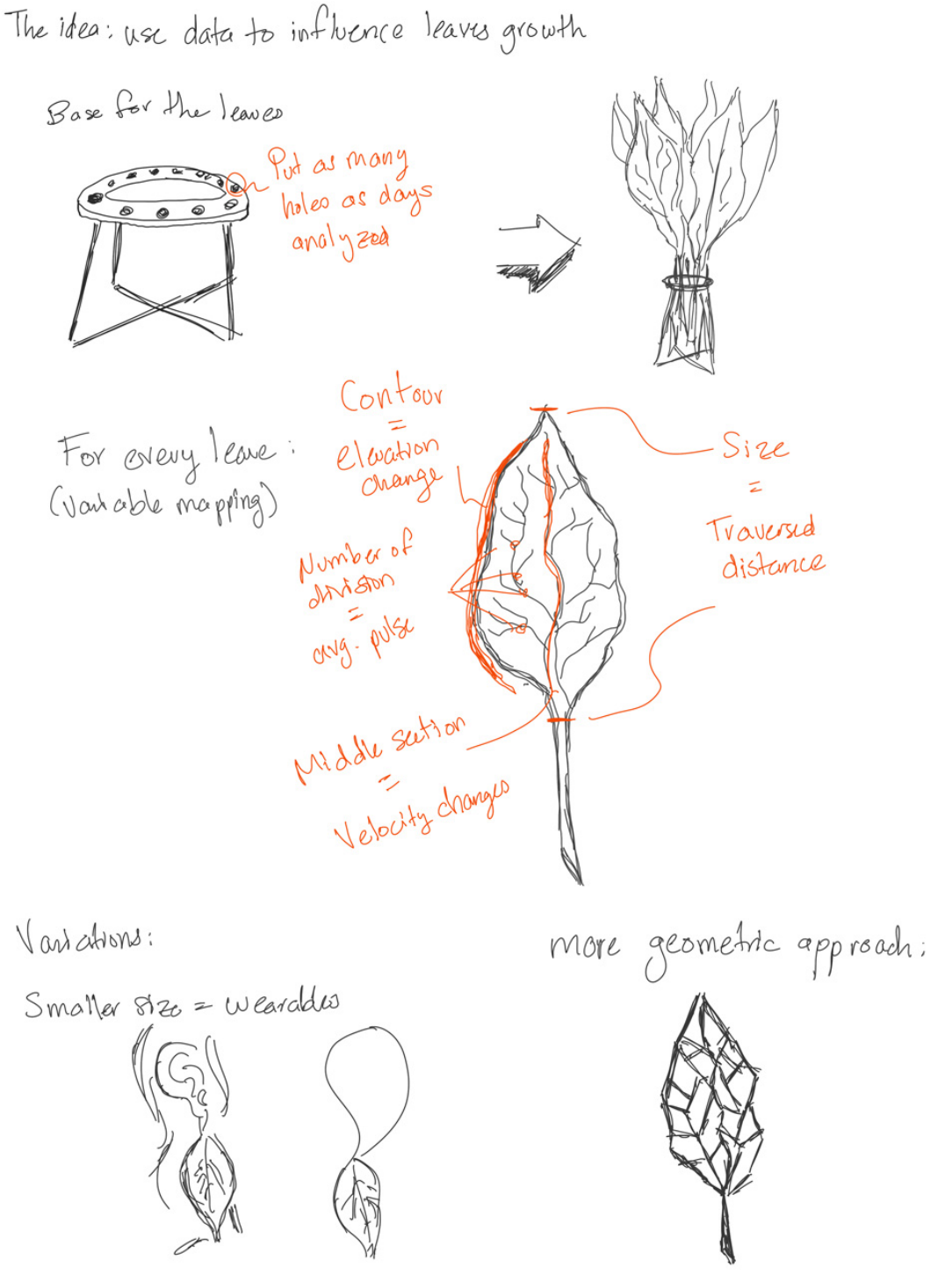
Variation for 3 mapping variables



Activity Flora

Visualization Prototype 3 // Activity Flora

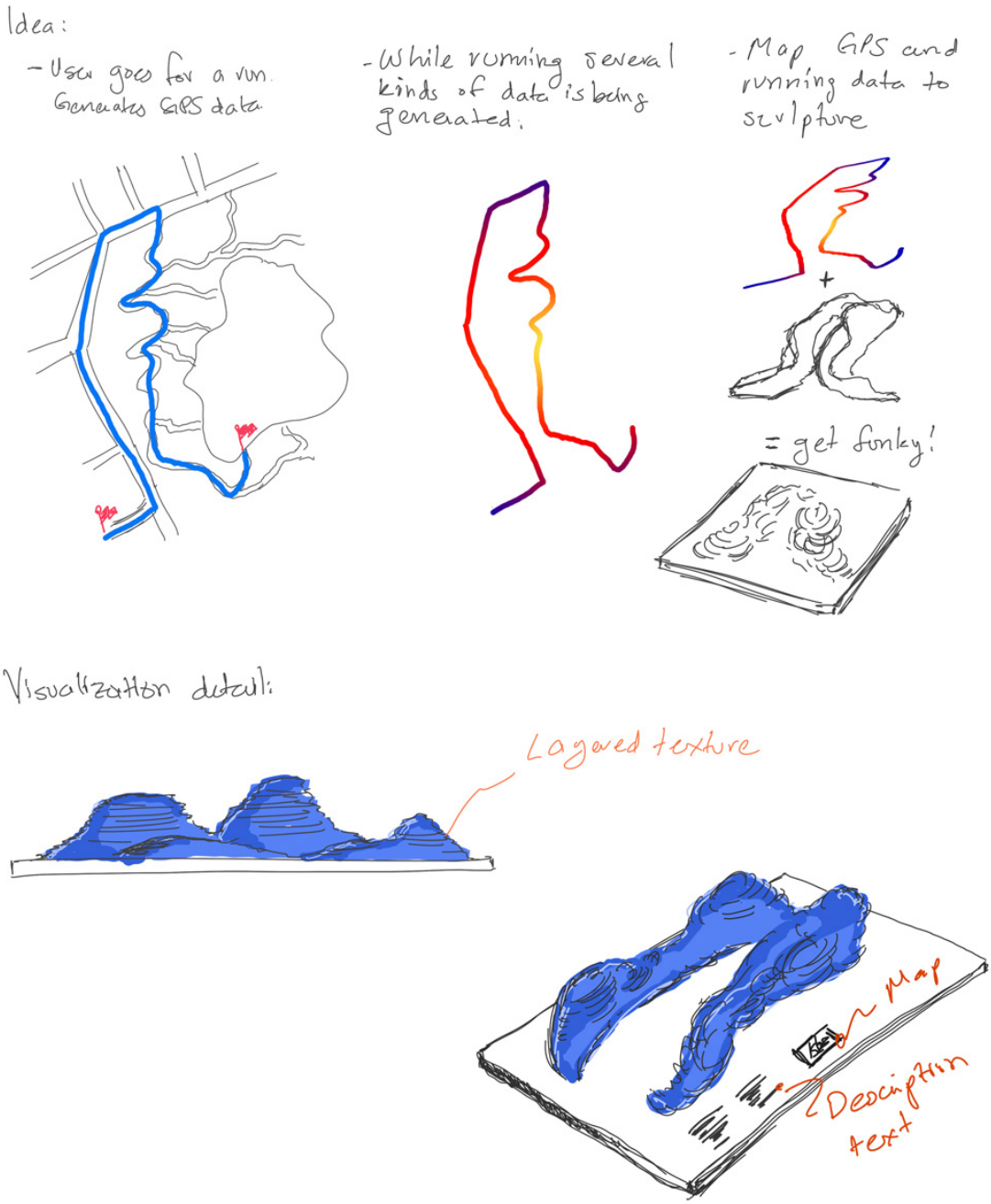
Visualization suitable for several variables. More suitable for short to mid term performance analysis.



Activity Landscape

Visualization Prototype 2 // Activity Landscape

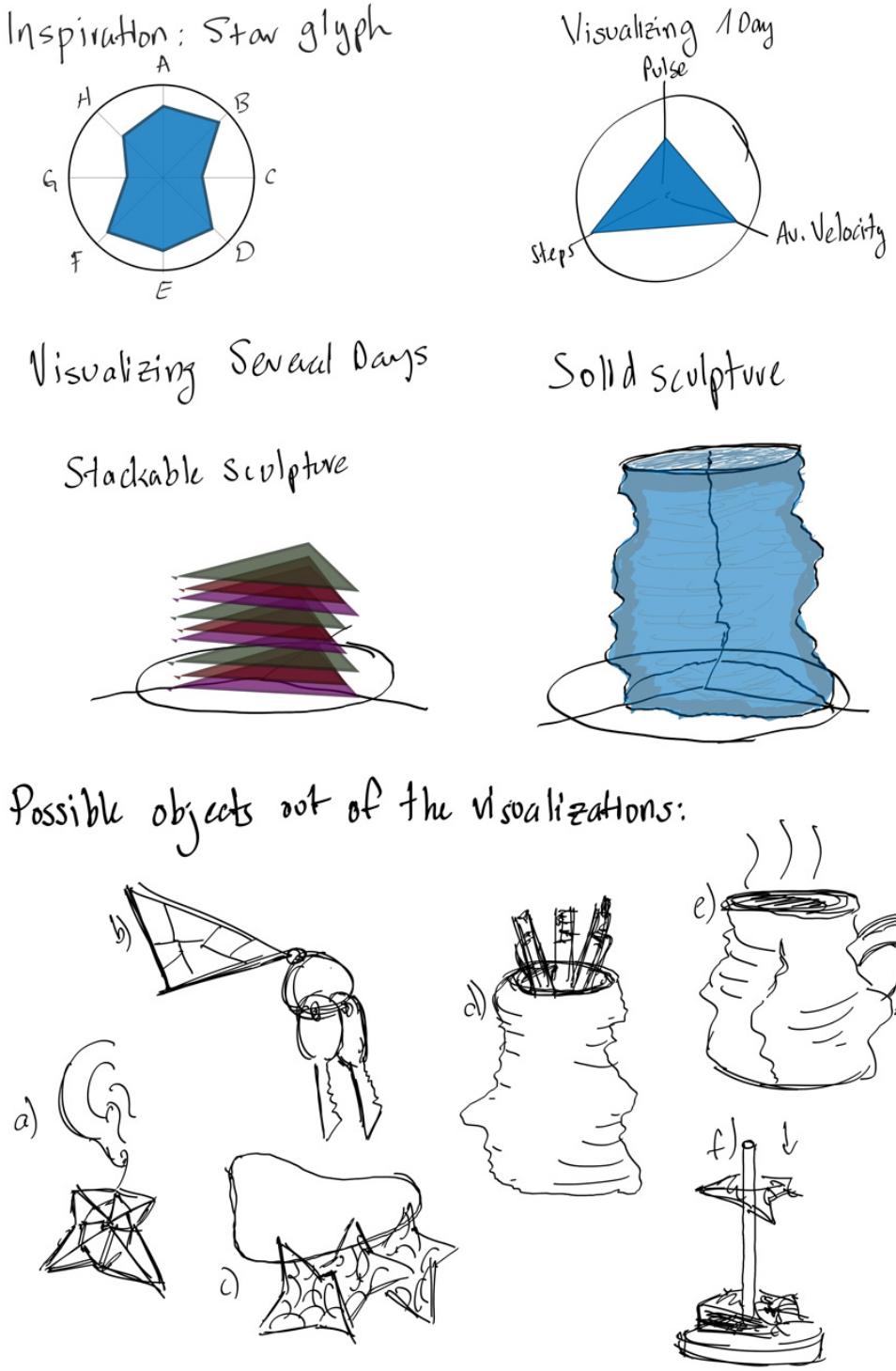
Visualization suitable for mapping two variables. More suitable for performance analysis using localization
- Variable 1: GPS Localization points.
- Variable 2: hear trate, speed, altitude.

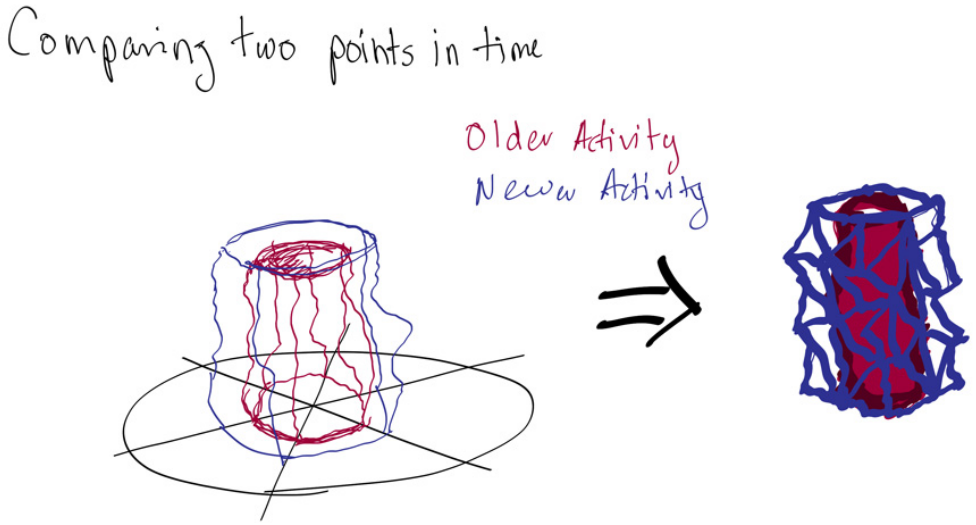


Activity Vase (continues in next page)

Visualization Prototype 4 // Activity Vase

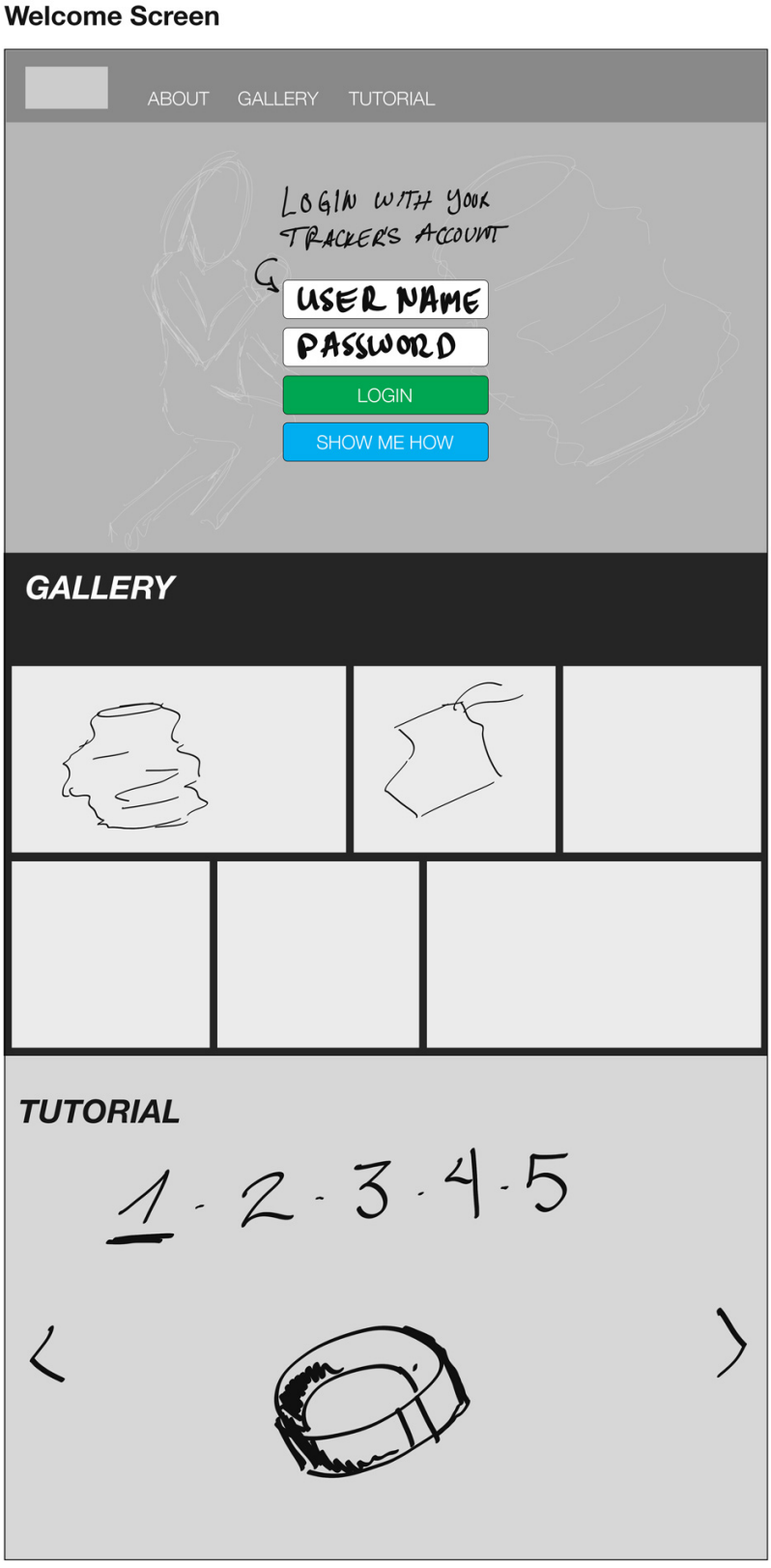
Visualization suitable for several variables. Suitable for visualizing activity data from one day or from longer time spans: a week or a month.



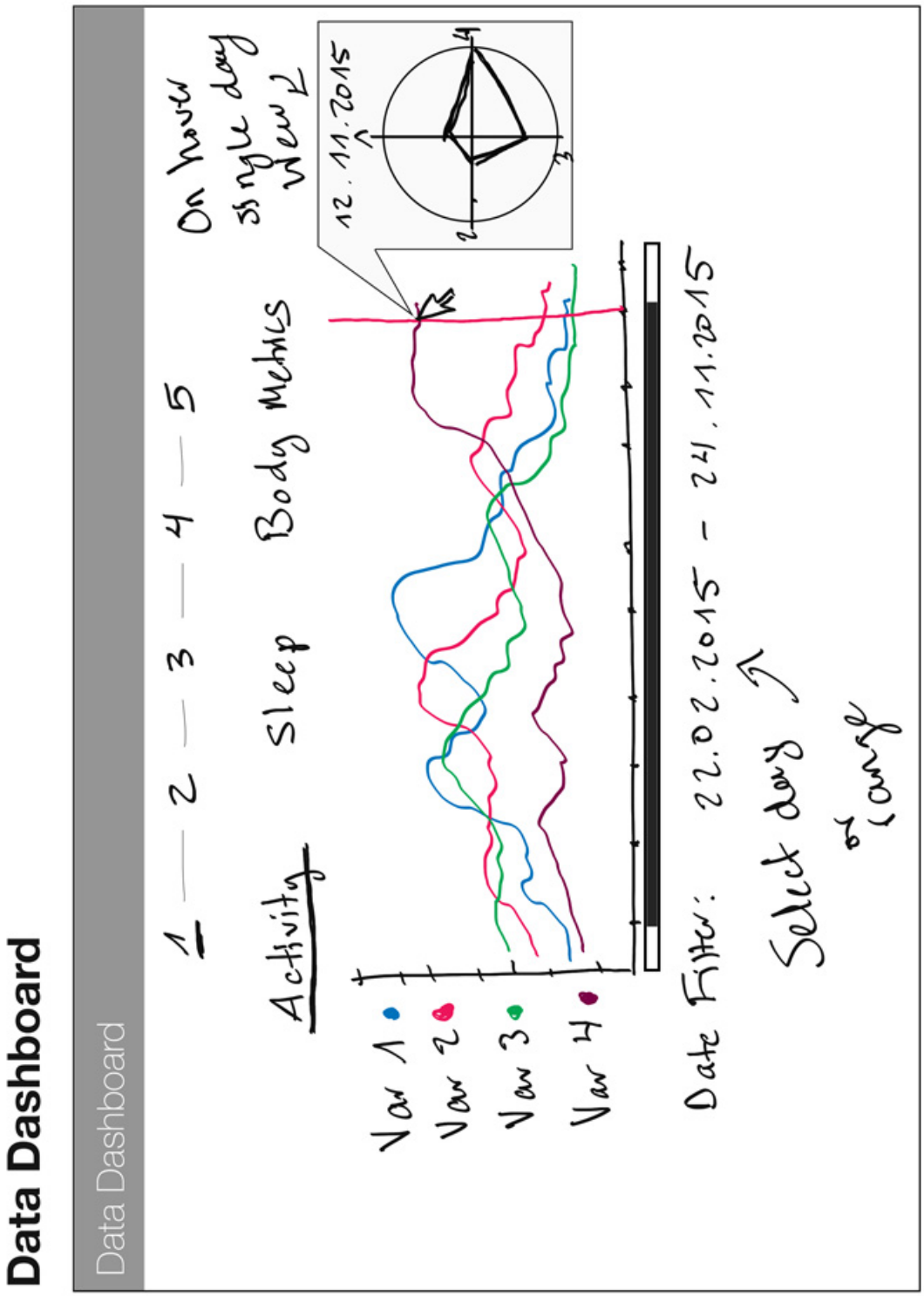

Comparing two points in time
Older Activity
Newer Activity

A.2 Web Configurator Prototypes

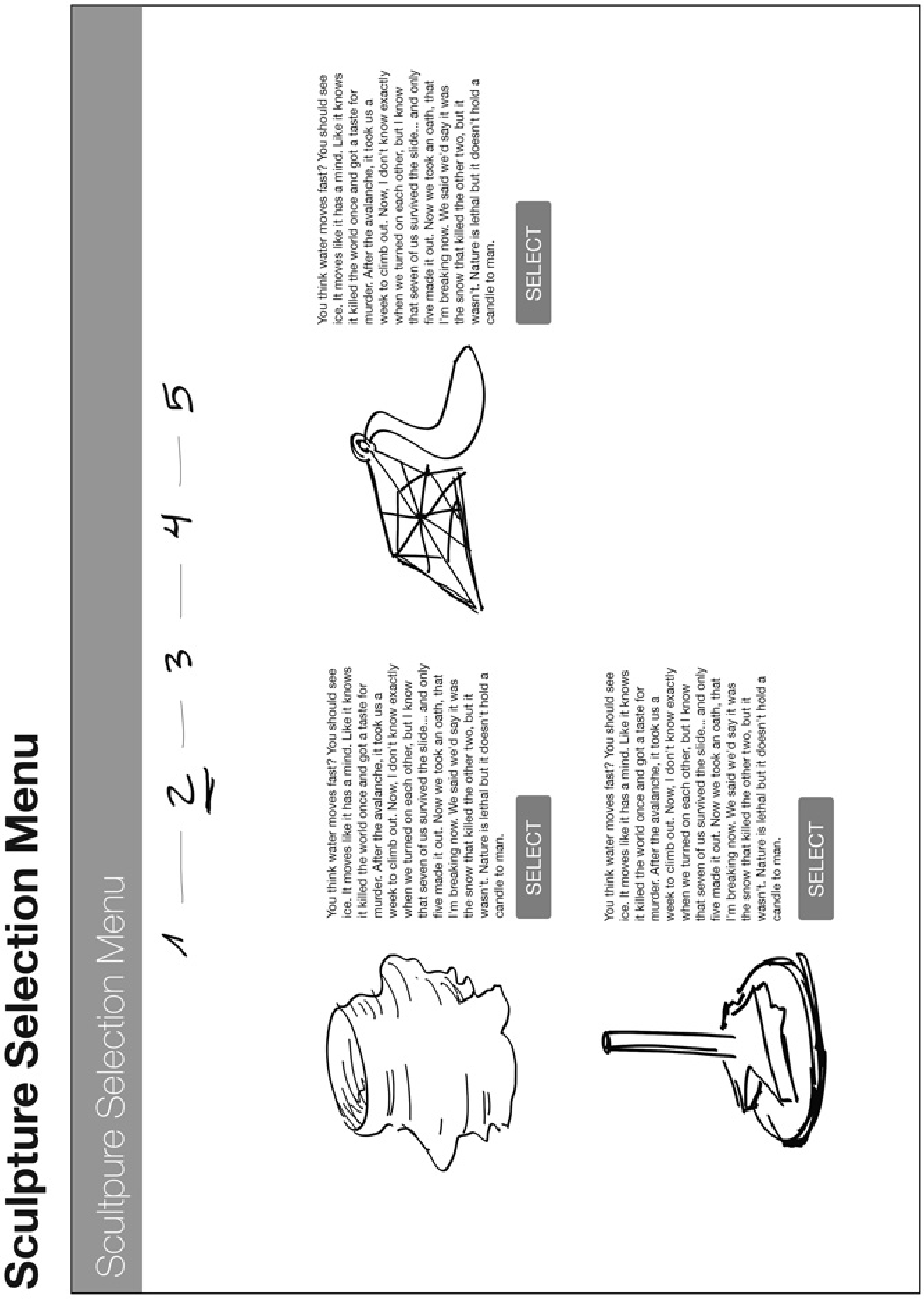
Configurator Protype No.1 Welcome Screen



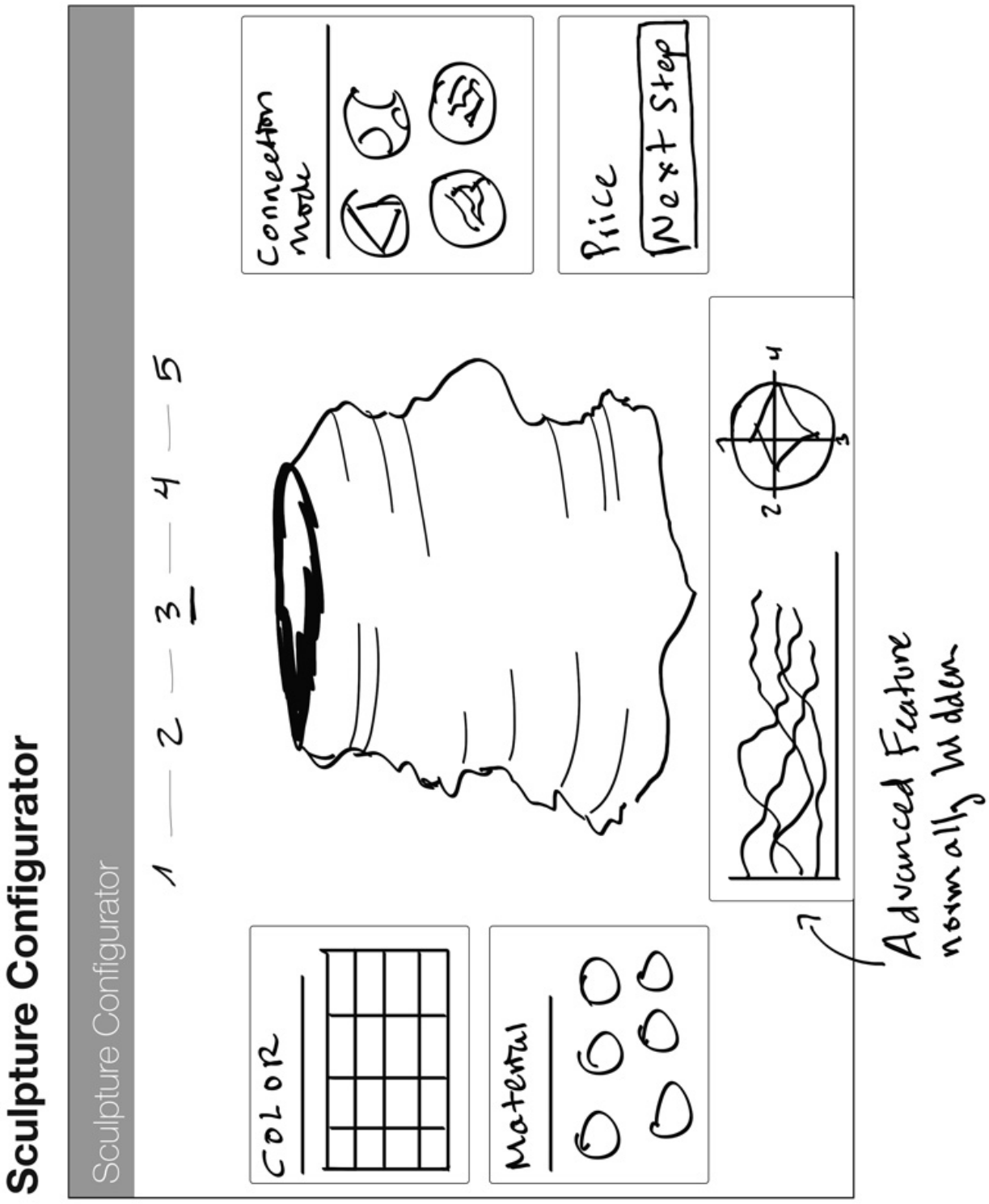
Configurator Protype No.1 Dashboard View



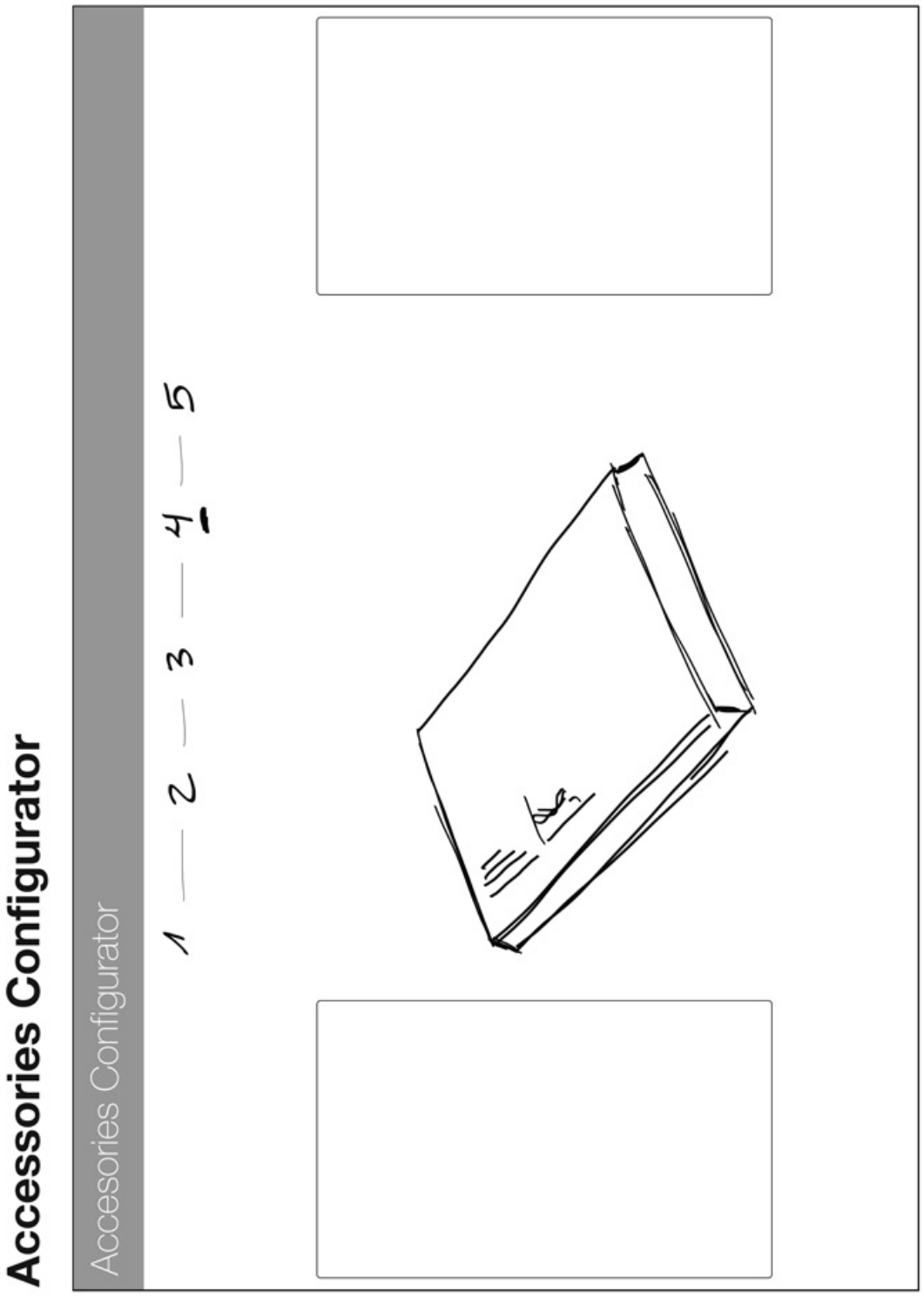
Configurator Protype No.1 Sculpture Selection View



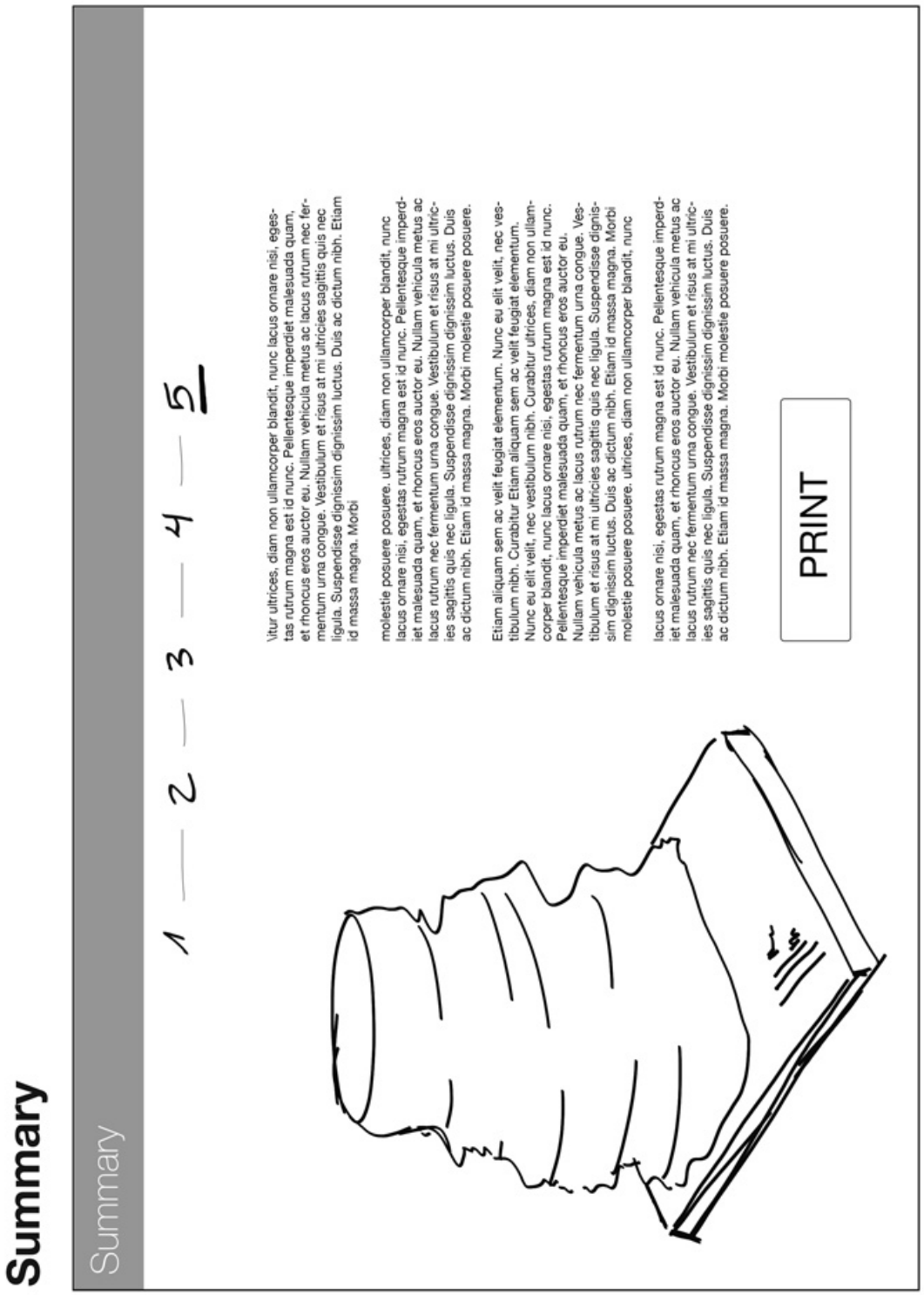
Configurator Protype No.1 Scultpure Configurator View



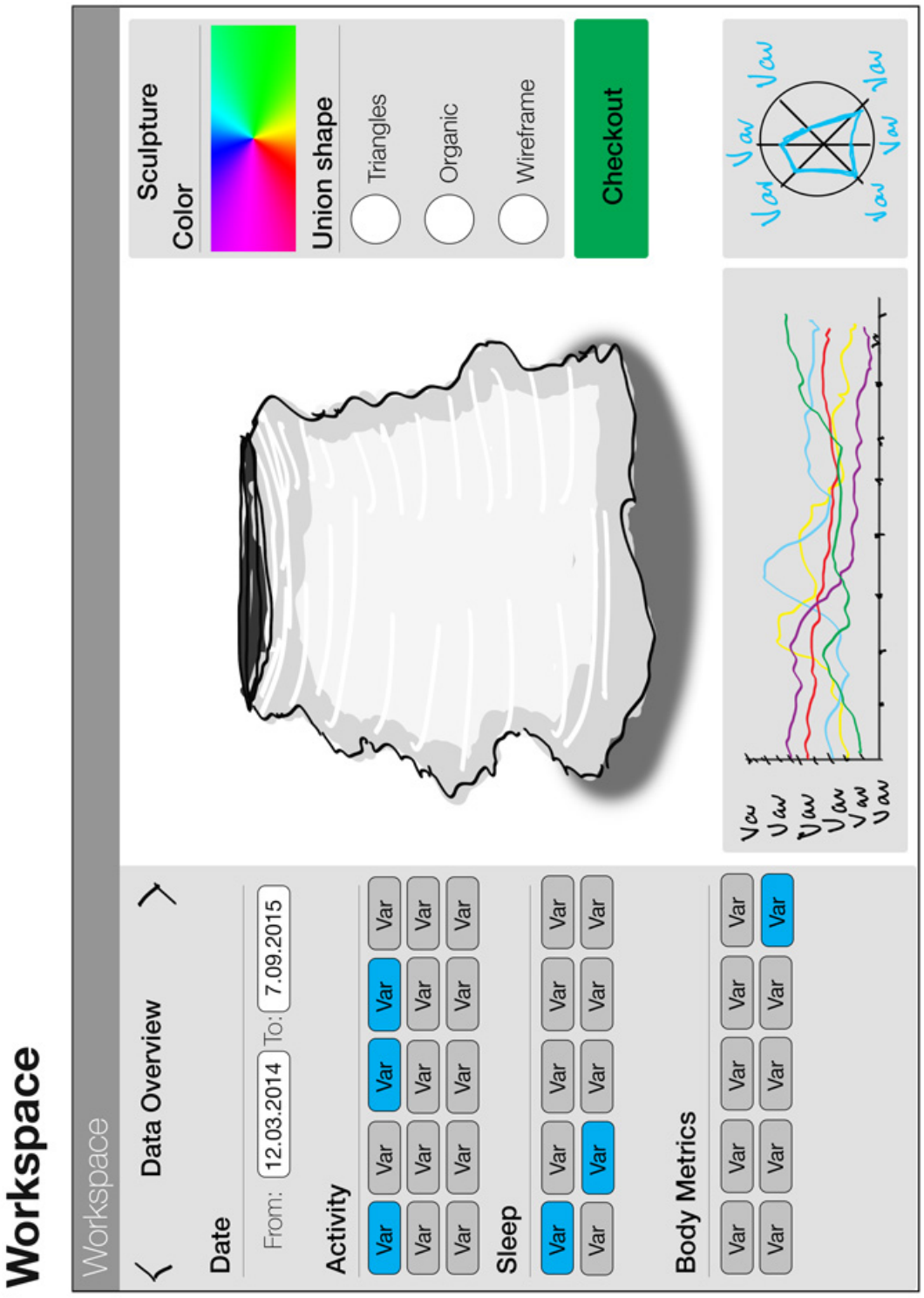
Configurator Protype No.1 Accessories View



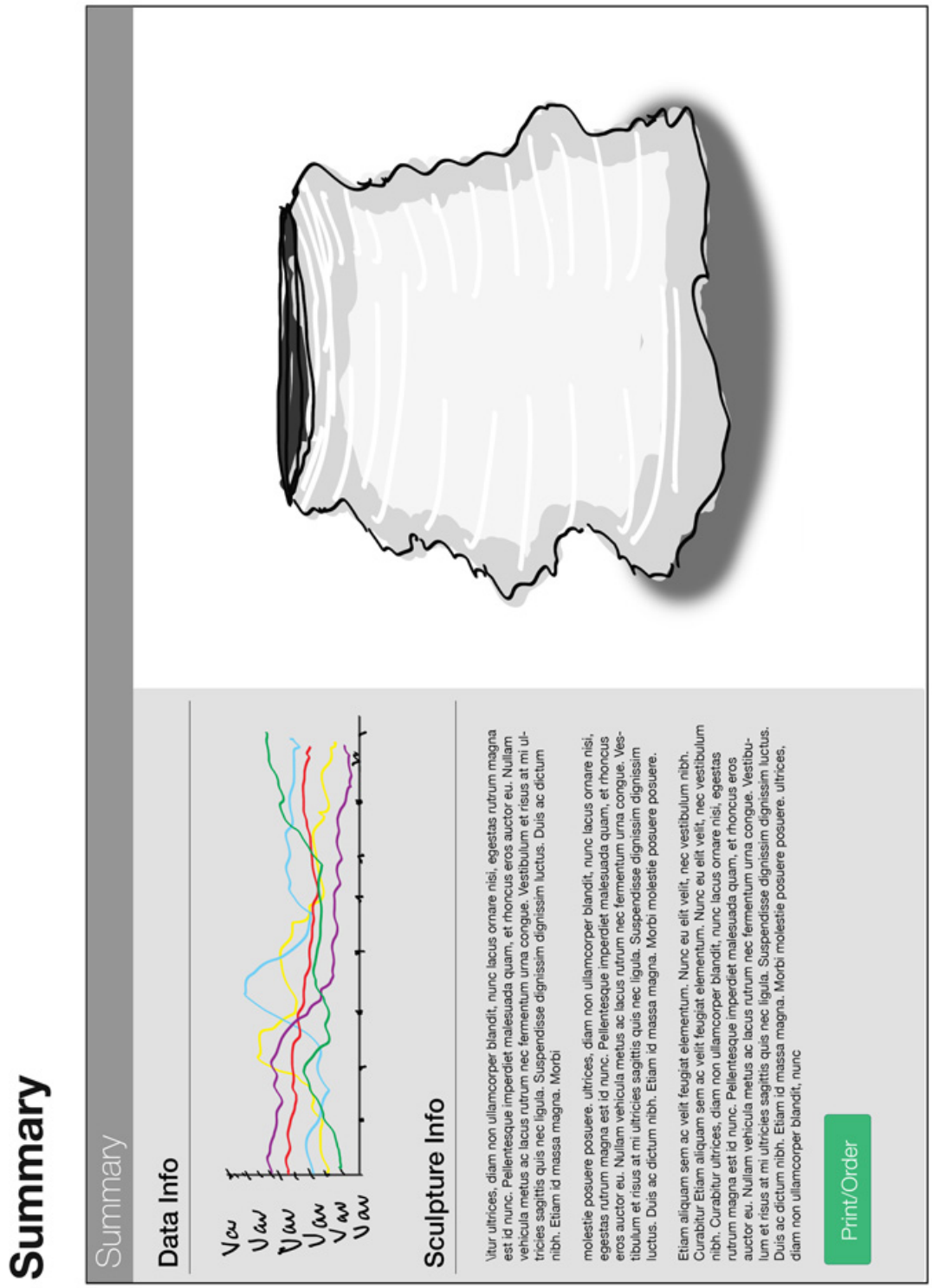
Configurator Protype No.1 Summary View



Configurator Protype No.2 Configurator View

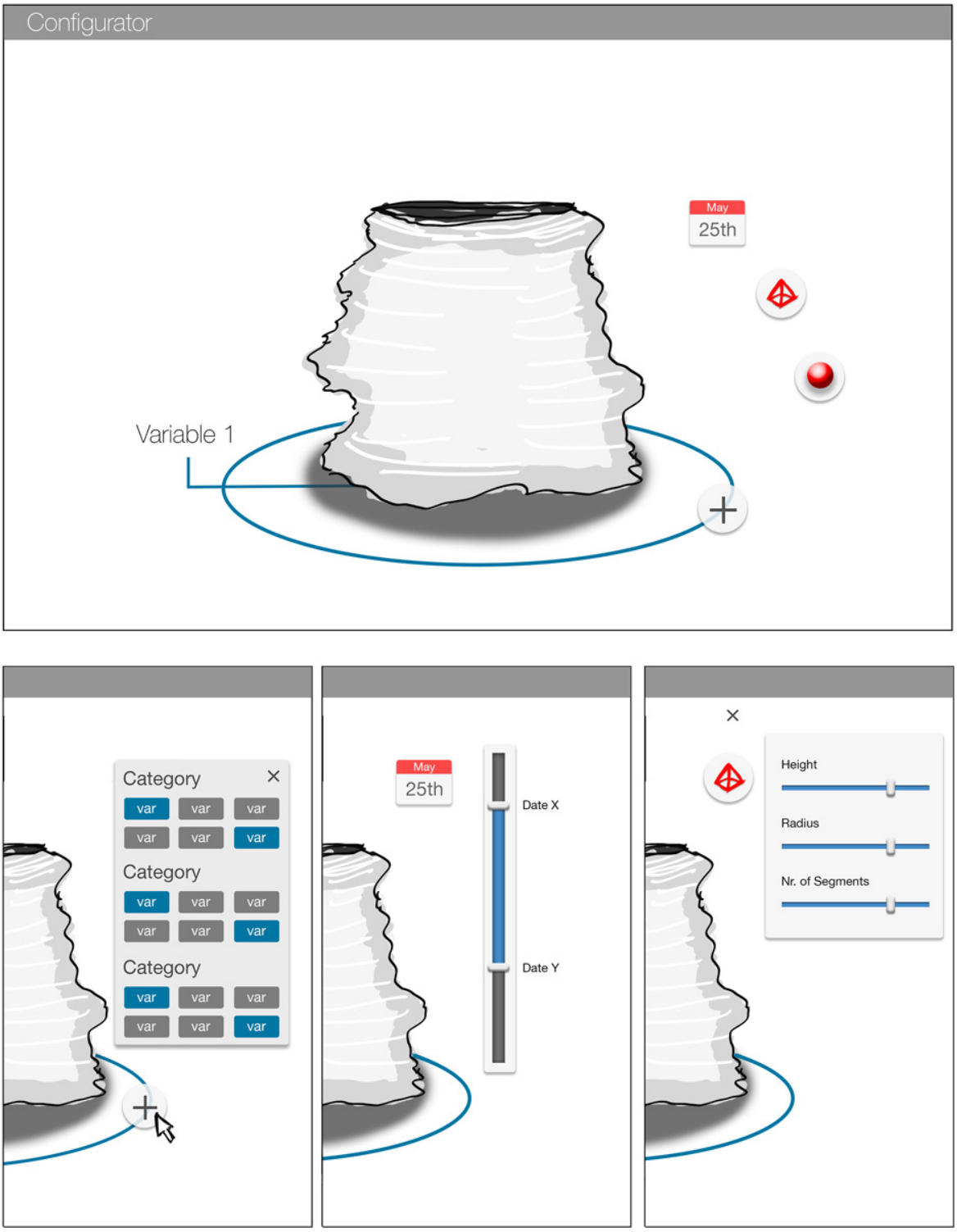


Configurator Protype No.2 Summary View



Summary

Configurator Protype No.3



B User Study & Questionnaire

B.1 Questionnaire

Activity Sculpture Web-Configurator

This questionnaire helps us to better understand your experience while using the configurator.

* Erforderlich

1. **Gender** *
   Markieren Sie nur ein Oval.
   - ◯ Male
   - ◯ Female

2. **Age** *
   .....

Web Configurators

3. **Describe the type of experience you have with 3D modelling software** *
   Markieren Sie nur ein Oval.
   - ◯ None
   - ◯ Low
   - ◯ Intermediate
   - ◯ Advanced
   - ◯ Pro

4. **Have you ever used a web configurator before?** *
   Markieren Sie nur ein Oval.
   - ◯ Yes *Weiter mit Frage 5*
   - ◯ No *Weiter mit Frage 6*

Weiter mit Frage 6

Configurators in E-shops

5. **What describes best your experience while using web configurators?** *
   Markieren Sie nur ein Oval.
   - ◯ Frustrating
   - ◯ Complicated
   - ◯ Neutral
   - ◯ Interesting
   - ◯ Enjoyable

Product Value

6. **Do you think customising your product adds more value to it?**
Markieren Sie nur ein Oval.

- ◯ Yes
- ◯ No

7. **Do you think products that can be customised tend to be more expensive?** *
Markieren Sie nur ein Oval.

- ◯ Yes
- ◯ No

Tracking Devices

8. **Are you mindful/aware of your daily activity, i.e. have exercise goals like the recommended 10000 daily steps** *
Markieren Sie nur ein Oval.

- ◯ I've never thought about it
- ◯ From time to time, and try to do some excersie
- ◯ Yes, I exercise a few times a week
- ◯ It is really important to me, I exercise daily

9. **Do you use a tracking device?** *
Markieren Sie nur ein Oval.

- ◯ Yes *Weiter mit Frage 10*
- ◯ No *Weiter mit Frage 12*

10. **What tracking device do you use?** *
Markieren Sie nur ein Oval.

- ◯ Jawbone Up-2/3/4
- ◯ Fitbit Flex/Cahrge
- ◯ Withings Pulse X/Activité
- ◯ Polar A3000
- ◯ Sonstiges: .....

11. **Has the tracking device influenced your activity** *
Markieren Sie nur ein Oval.

- ◯ Yes
- ◯ No

Weiter mit Frage 13

12. **Have you considered using a tracking device** *
Markieren Sie nur ein Oval.

- ◯ Yes
- ◯ No

Activity Sculptures

13. **Which style did you find the most attractive?** *
Markieren Sie nur ein Oval.

- ◯ Normal
- ◯ Interpolated
- ◯ Wire-frame
- ◯ Wire-frame + Interpolated

14. **The sculpture was aesthetically appealing** *
Markieren Sie nur ein Oval.

	1	2	3	4	5	
I strongly agree	◯	◯	◯	◯	◯	I strongly desagree

15. **I felt attached to the sculpture in some way** *
Markieren Sie nur ein Oval.

	1	2	3	4	5	
I strongly agree	◯	◯	◯	◯	◯	I strongly disagree

16. **It was interesting to see my activity data visualized in a sculpture** *
Markieren Sie nur ein Oval.

	1	2	3	4	5	
I strongly agree	◯	◯	◯	◯	◯	I strongly disagree

17. **I would use it regularly to visualize my data** *
Markieren Sie nur ein Oval.

	1	2	3	4	5	
I strongly agree	◯	◯	◯	◯	◯	I strongly disagree

18. **If available, I would order a 3D printed sculpture of my activity** *
Markieren Sie nur ein Oval.

	1	2	3	4	5	
I strongly agree	◯	◯	◯	◯	◯	I strongly disagree

19. **I would wear my sculpture if it could be adapted to earrings, necklaces, rings, smart-phone cases, key chains,** *
Markieren Sie nur ein Oval.

	1	2	3	4	5	
I strongly agree	◯	◯	◯	◯	◯	I strongly disagree

20. **I would show my sculpture to friends and relatives**
Markieren Sie nur ein Oval.

	1	2	3	4	5	
I strongly agree	◯	◯	◯	◯	◯	I strongly disagree

Configurator Usability

21. **The configurator's interface was aesthetically appealing** *
Markieren Sie nur ein Oval.

	1	2	3	4	5	
I strongly agree	◯	◯	◯	◯	◯	I strongly disagree

22. **The configurator was easy to use** *
Markieren Sie nur ein Oval.

	1	2	3	4	5	
I strongly agree	◯	◯	◯	◯	◯	I strongly disagree

23. **The configurator was easy to learn** *
Markieren Sie nur ein Oval.

	1	2	3	4	5	
I strongly agree	◯	◯	◯	◯	◯	I strongly disagree

24. **I found it helpful to see a summary of all my activity in the dashboard** *
Markieren Sie nur ein Oval.

	1	2	3	4	5	
I strongly agree	◯	◯	◯	◯	◯	I strongly desagree

25. **A gallery of my sculptures is helpful as it allows me to collect my sculptures over time** *
Markieren Sie nur ein Oval.

	1	2	3	4	5	
I strongly agree	◯	◯	◯	◯	◯	I strongly disagree

26. **Each label clearly described the functionality of the slider or toggle control** *
Markieren Sie nur ein Oval.

	1	2	3	4	5	
I strongly agree	◯	◯	◯	◯	◯	I strongly disagree

27. **It was always clear how each slider and toggle button manipulated the sculpture** *
Markieren Sie nur ein Oval.

	1	2	3	4	5	
I strongly agree	◯	◯	◯	◯	◯	I strongly disagree

28. **The available configuration options were enough for me** *
Markieren Sie nur ein Oval.

	1	2	3	4	5	
I strongly agree	◯	◯	◯	◯	◯	I strongly disagree

29. **It was helpful to see the sculpture update instantly after changing a slider or toggle value** *
Markieren Sie nur ein Oval.

	1	2	3	4	5	
I strongly agree	◯	◯	◯	◯	◯	I strongly disagree

30. **I would have liked to see a visualization that represented the data more acurately** *
Markieren Sie nur ein Oval.

	1	2	3	4	5	
I strongly agree	◯	◯	◯	◯	◯	I strongly disagree

31. **I would have liked to have different sculptures to choose from** *
Markieren Sie nur ein Oval.

	1	2	3	4	5	
I strongly agree	◯	◯	◯	◯	◯	I strongly disagree

Final Remarks

32. **I find the configurator's functionality useful** *
Markieren Sie nur ein Oval.

	1	2	3	4	5	
I strongly agree	◯	◯	◯	◯	◯	I strongly disagree

33. **I would use a configurator like this again** *
Markieren Sie nur ein Oval.

	1	2	3	4	5	
I strongly agree	◯	◯	◯	◯	◯	I strongly disagree

34. **I am pleased with the sculpture I configured** *
Markieren Sie nur ein Oval.

	1	2	3	4	5	
I strongly agree	◯	◯	◯	◯	◯	I strongly disagree

35. **Any final thoughts you want to share?**

.....

.....

.....

.....

.....

B.2 Questionnaire Results

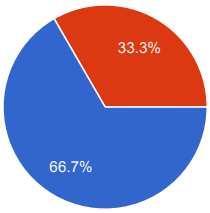
w.rempeningd@gmail.com
Dieses Formular bearbeiten

9 Antworten

Alle Antworten ansehen Analytics veröffentlichen

Zusammenfassung

Gender



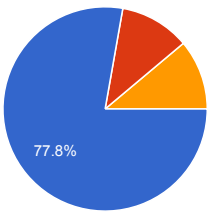
Male	**6**	66.7 %
Female	**3**	33.3 %

Age

35
22
23
24
26
28
19

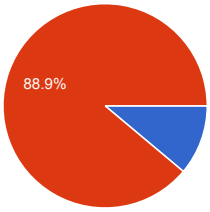
Web Configurators

Describe the type of experience you have with 3D modelling software



None	7	77.8 %
Low	1	11.1 %
Intermediate	1	11.1 %
Advanced	0	0 %
Pro	0	0 %

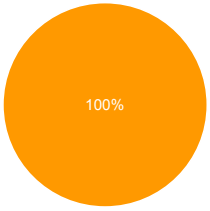
Have you ever used a web configurator before?



Yes	1	11.1 %
No	8	88.9 %

Configurators in E-shops

What describes best your experience while using web configurators?



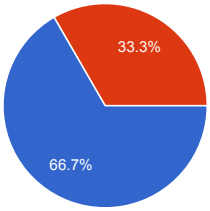
Frustrating	0	0 %
Complicated	0	0 %
Neutral	1	100 %
Interesting	0	0 %
Enjoyable	0	0 %

Product Value

Do you think customising your product adds more value to it?

Yes	**9**	100 %
No	**0**	0 %

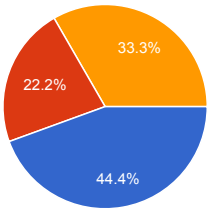
Do you think products that can be customised tend to be more expensive?



Yes	**6**	66.7 %
No	**3**	33.3 %

Tracking Devices

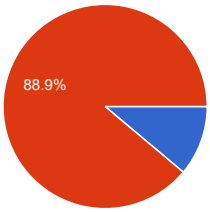
Are you mindful/aware of your daily activity, i.e. have exercise goals like the recommended 10000 daily steps



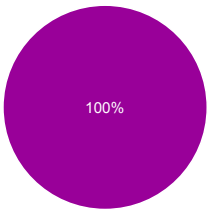
I've never thought about it	**4**	44.4 %
From time to time, and try to do some excersie	**2**	22.2 %
Yes, I exercise a few times a week	**3**	33.3 %
It is really important to me, I exercise daily	**0**	0 %

Do you use a tracking device?

Yes	**1**	11.1 %
No	**8**	88.9 %



What tracking device do you use?



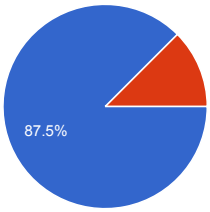
Jawbone Up-2/3/4	**0**	0 %
Fitbit Flex/Cahrge	**0**	0 %
Withings Pulse X/Activité	**0**	0 %
Polar A3000	**0**	0 %
Sonstige	**1**	100 %

Has the tracking device influenced your activity

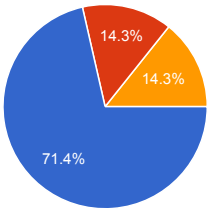
Yes	**1**	100 %
No	**0**	0 %

Have you considered using a tracking device

Yes	**7**	87.5 %
No	**1**	12.5 %

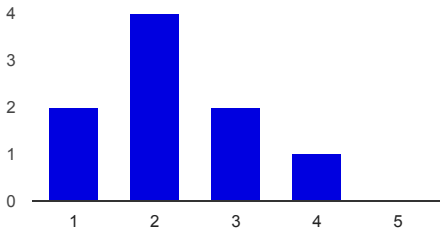


Which style did you find the most attractive?



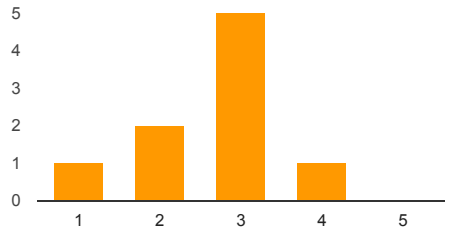
Normal	**5**	55.6 %
Interpolated	**1**	11.1 %
Wire-frame	**1**	11.1 %
Wire-frame + Interpolated	**0**	0 %

The sculpture was aesthetically appealing



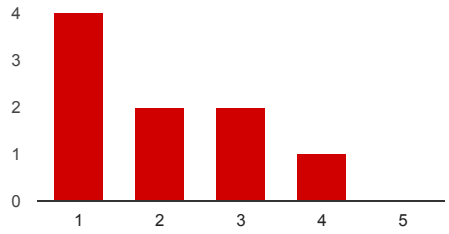
I strongly agree: 1	**2**	22.2 %
2	**4**	44.4 %
3	**2**	22.2 %
4	**1**	11.1 %
I strongly desagree: 5	**0**	0 %

I felt attached to the sculpture in some way



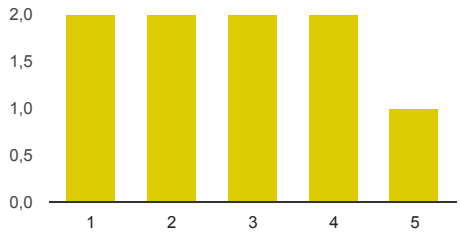
I strongly agree:	1	**1**	11.1 %
	2	**2**	22.2 %
	3	**5**	55.6 %
	4	**1**	11.1 %
I strongly disagree:	5	**0**	0 %

It was interesting to see my activity data visualized in a sculpture



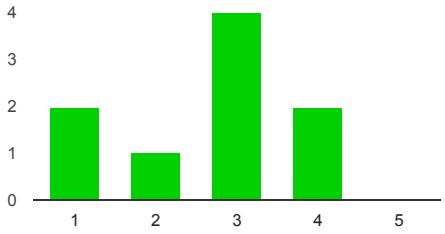
I strongly agree:	1	**4**	44.4 %
	2	**2**	22.2 %
	3	**2**	22.2 %
	4	**1**	11.1 %
I strongly disagree:	5	**0**	0 %

I would use it regularly to visualize my data



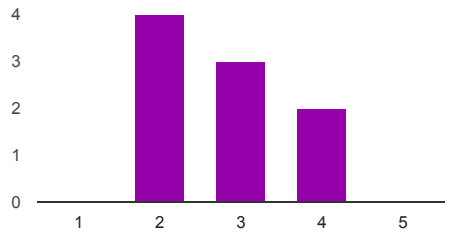
2	**2**	22.2 %
3	**2**	22.2 %
4	**2**	22.2 %
I strongly disagree: 5	**1**	11.1 %

If available, I would order a 3D printed sculpture of my activity



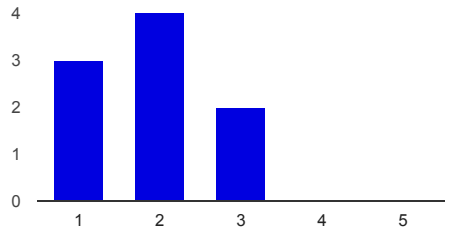
I strongly agree: 1	**2**	22.2 %
2	**1**	11.1 %
3	**4**	44.4 %
4	**2**	22.2 %
I strongly disagree: 5	**0**	0 %

I would wear my sculpture if it could be adapted to earrings, necklaces, rings, smart-phone cases, key chains,



I strongly disagree: 5 **0** 0 %

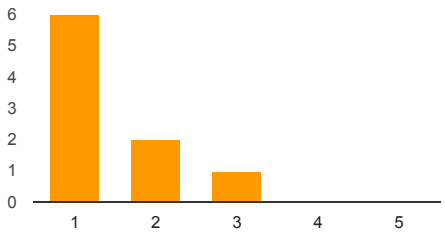
I would show my sculpture to friends and relatives



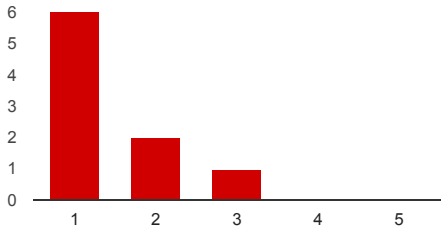
I strongly agree: 1	**3**	33.3 %
2	**4**	44.4 %
3	**2**	22.2 %
4	**0**	0 %
I strongly disagree: 5	**0**	0 %

Configurator Usability

The configurator's interface was aesthetically appealing

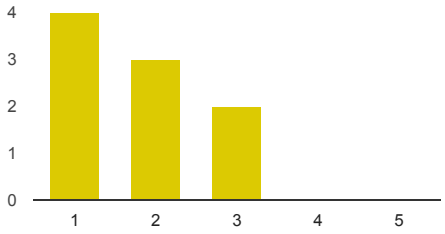


The configurator was easy to use



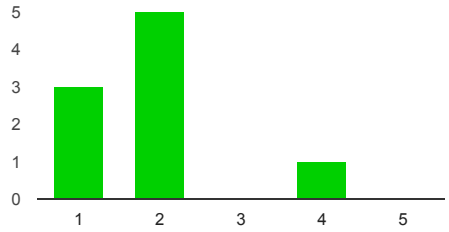
I strongly agree:	1	**6**	66.7 %
	2	**2**	22.2 %
	3	**1**	11.1 %
	4	**0**	0 %
I strongly disagree:	5	**0**	0 %

The configurator was easy to learn



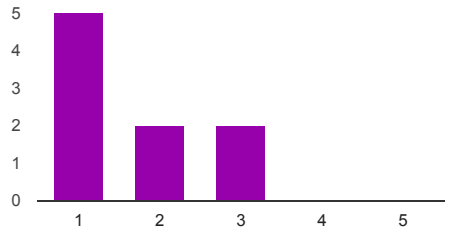
I strongly agree: 1	**4**	44.4 %
2	**3**	33.3 %
3	**2**	22.2 %
4	**0**	0 %
I strongly disagree: 5	**0**	0 %

I found it helpful to see a summary of all my activity in the dashboard



I strongly agree: 1	**3**	33.3 %
2	**5**	55.6 %
3	**0**	0 %
4	**1**	11.1 %
I strongly desagree: 5	**0**	0 %

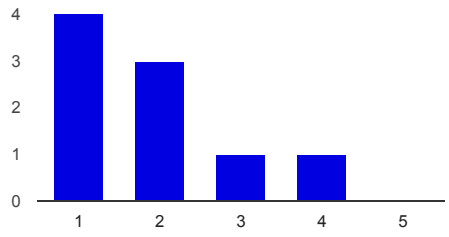
A gallery of my sculptures is helpful as it allows me to collect my sculptures over time



I strongly agree: 1	**5**	55.6 %
2	**2**	22.2 %
3	**2**	22.2 %

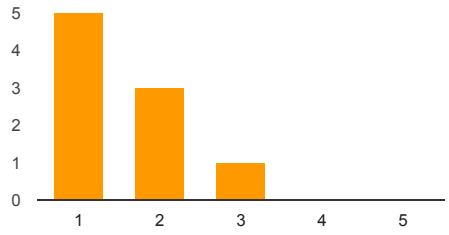
4	**0**	0 %
I strongly disagree: 5	**0**	0 %

Each label clearly described the functionality of the slider or toggle control



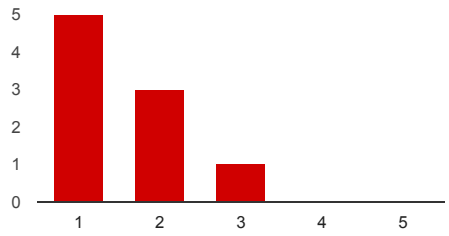
I strongly agree: 1	**4**	44.4 %
2	**3**	33.3 %
3	**1**	11.1 %
4	**1**	11.1 %
I strongly disagree: 5	**0**	0 %

It was always clear how each slider and toggle button manipulated the sculpture



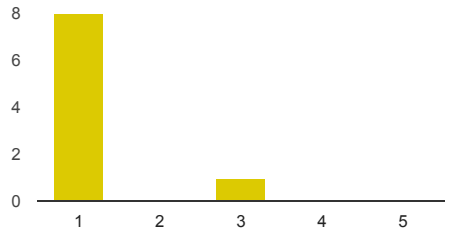
I strongly agree: 1	**5**	55.6 %
2	**3**	33.3 %
3	**1**	11.1 %
4	**0**	0 %
I strongly disagree: 5	**0**	0 %

The available configuration options were enough for me



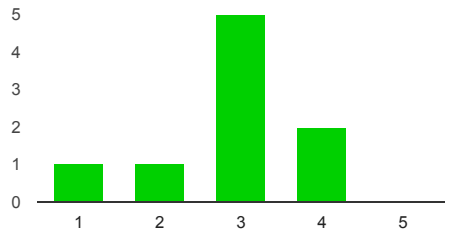
I strongly agree:	1	**5**	55.6 %
	2	**3**	33.3 %
	3	**1**	11.1 %
	4	**0**	0 %
I strongly disagree:	5	**0**	0 %

It was helpful to see the sculpture update instantly after changing a slider or toggle value



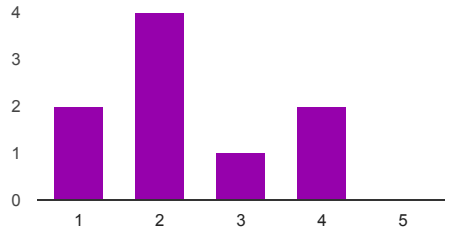
I strongly agree:	1	**8**	88.9 %
	2	**0**	0 %
	3	**1**	11.1 %
	4	**0**	0 %
I strongly disagree:	5	**0**	0 %

I would have liked to see a visualization that represented the data more acurately



I strongly agree: 1	**1**	11.1 %
2	**1**	11.1 %
3	**5**	55.6 %
4	**2**	22.2 %
I strongly disagree: 5	**0**	0 %

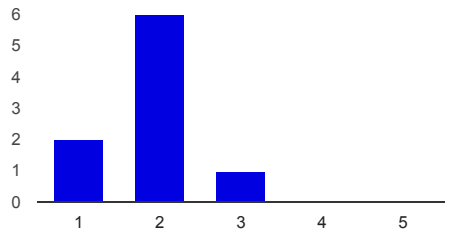
I would have liked to have different sculptures to choose from



I strongly agree: 1	**2**	22.2 %
2	**4**	44.4 %
3	**1**	11.1 %
4	**2**	22.2 %
I strongly disagree: 5	**0**	0 %

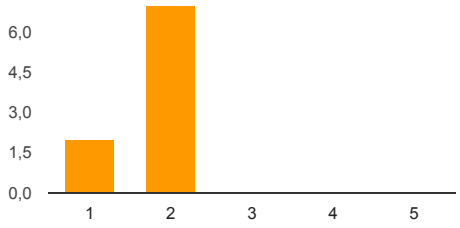
Final Remarks

I find the configurator's functionality useful



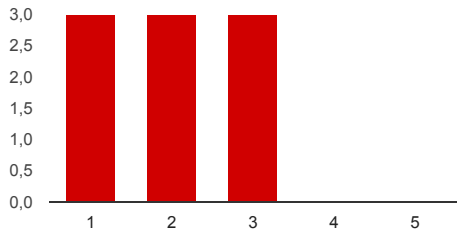
I strongly agree: 1	**2**	22.2 %
2	**6**	66.7 %
3	**1**	11.1 %
4	**0**	0 %
I strongly disagree: 5	**0**	0 %

I would use a configurator like this again



I strongly agree: 1	**2**	22.2 %
2	**7**	77.8 %
3	**0**	0 %
4	**0**	0 %
I strongly disagree: 5	**0**	0 %

I am pleased with the sculpture I configured

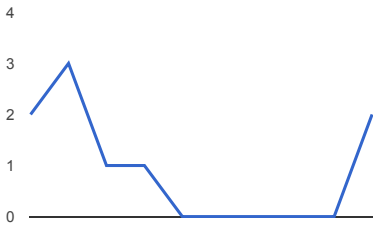


I strongly disagree: 5 **0** 0 %

Any final thoughts you want to share?

In ther diagramm you should not show the intensity on the same level as the burned calories.

Anzahl der täglichen Antworten

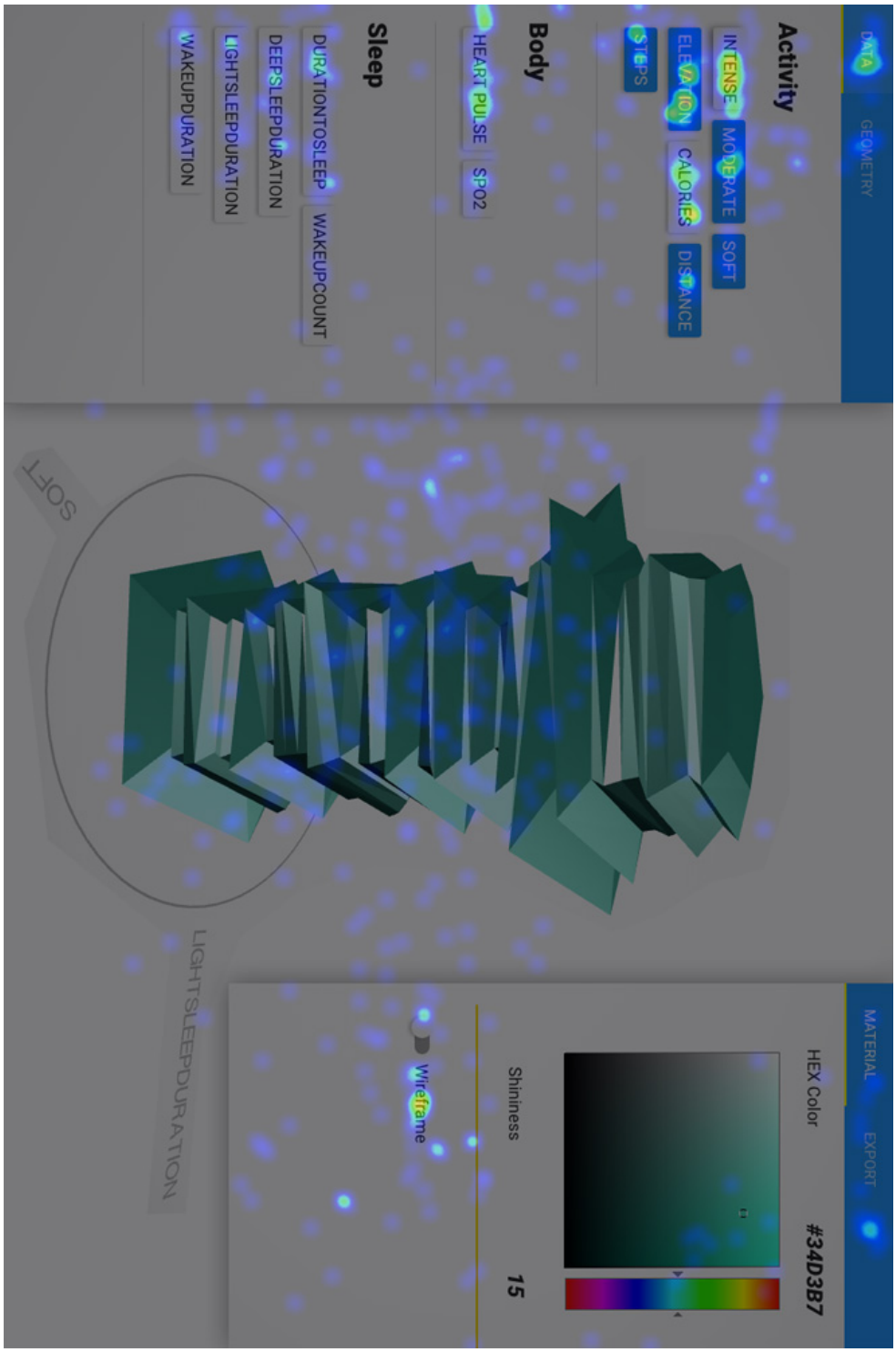


B.3 User Study Results

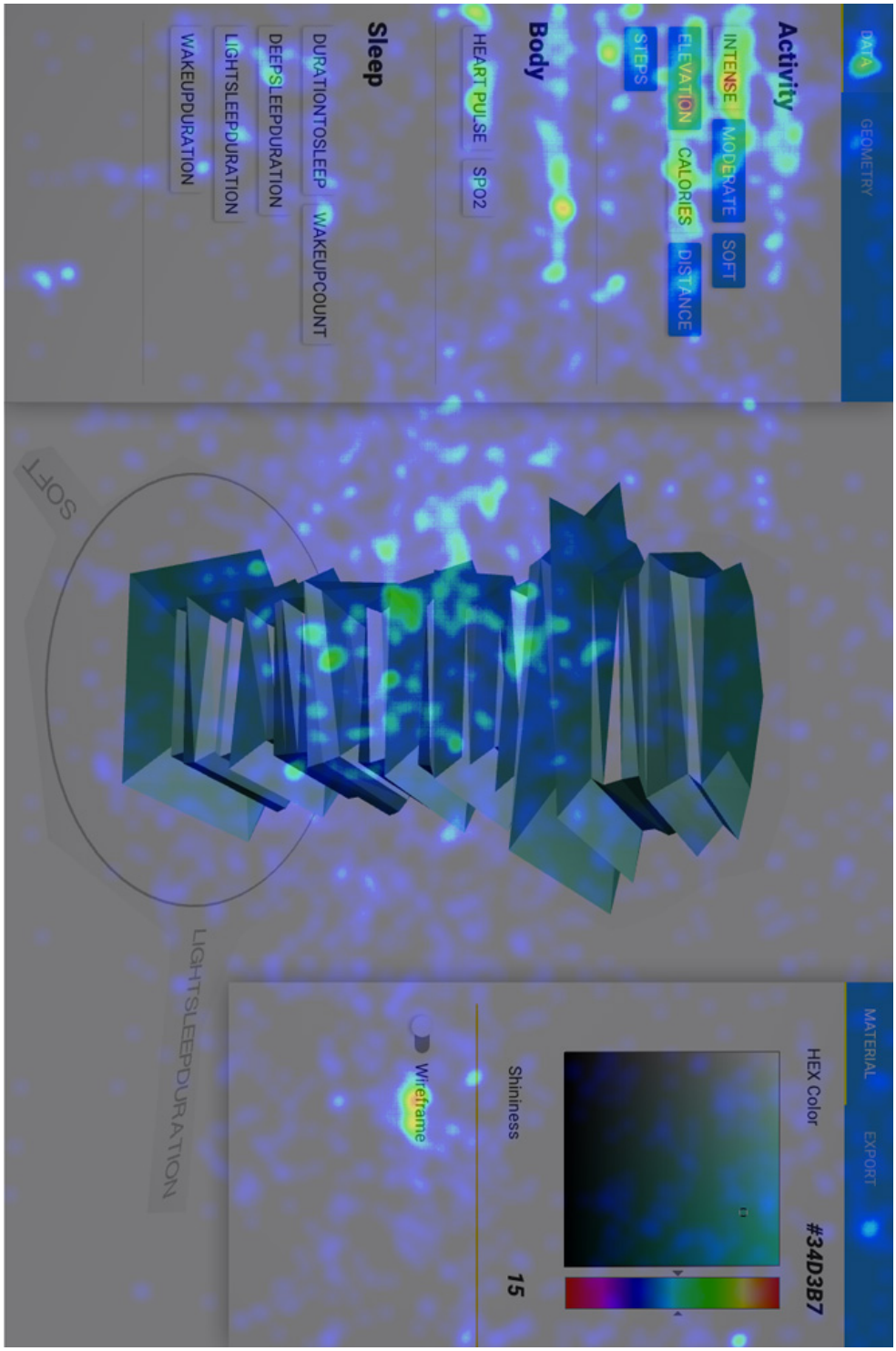
User Nr.	Missed Features	Widgets Problems	Remarks	Comments
1	Geometry Tab, Wireframe, turn off labels	Couldn't operate toggle button, tryed to slide it as if it would be a touch gesture	-Intuitively navigatet the sculpture -Not many comments about the dashboard	-Obvius to make a new sculpture with the button -Dashbaord Activity Graph wasn't logically grouped, remove calories -Interesting for comparing the relationship between variables -Found the normalization of the values illogical -Its ilogical that values equaly increse or decrease evenly -What tangible benefit has the sculpture? Dataviz should be precise -Didn't like the interpolation visualization
2	Turn off labels	Couldn't operate toggle button, tryed to slide it as if it would be a touch gesture	-Didn'd understand SPO2 -Intuitively navigatet the sculpture -Understood the idea of the stacked radar chart -Not many comments about the dashboard	
3	Interpolated view with several variables, turn off labels		-Wanted to enter values, didn't quite get the idea of viewing data from your tracker -Not many comments about the dashboard	-What is this shape supposed to tell me? -Understood that the data is visualized over time
4	turn off labels		-Navigation in space was later discvored -Not many comments about the dashboard	-I can add an achsis to the sculpture -Don't quite understand the interpolated mode -For the date range slider day 1 is the first day
5	Wireframe toggle		-Kind of made a story out of the data, "this day I made a lot of intense activity" -Found the interpolation slider step bug	-Surprised of how much data one can gather about one self -Don't get the difference of adding more variables to the achsis -I don't know what my heart rate is -I add the values to the sculpture -My data was already tracked and it is visualized differently -With many variables it is difficult to see what difference it made -Really liked to see the different days -Don't understand what interpolated does

B.4 Heat Map Images

Click Heatmap



Eye-tracking Heatmap



Contents of the enclosed CD

Thesis

- LaTeX Document
- PDF File

Presentations

- Initial presentation
- Final presentation

Activity Sculpture Web Configurator

- Prototype sketches
- Source code
- Gitlab and Github mirrors
- Instructions for deployment
- Login Data

Sculptures

- Prototype sketches
- .stl 3D print ready example files

User Study

- Questionnaire
- Results
- Heat map images