PRODUCT DESIGN ALGORITHM

A proposition to empower laymen users of 3D printing to create unique design files

Graduation thesis
Michiel Spaapen

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Student

Michiel Alexander Spaapen
Design for Interaction

Supervisory team

Chair: Hoftijzer, J.W. Msc. - *Human Information Communication Design*
Mentor: Dr. ir. Sonneveld, M.H. - *Design Aesthetics*

Faculty of Industrial Design Engineering
Delft University of Technology

Executive summary

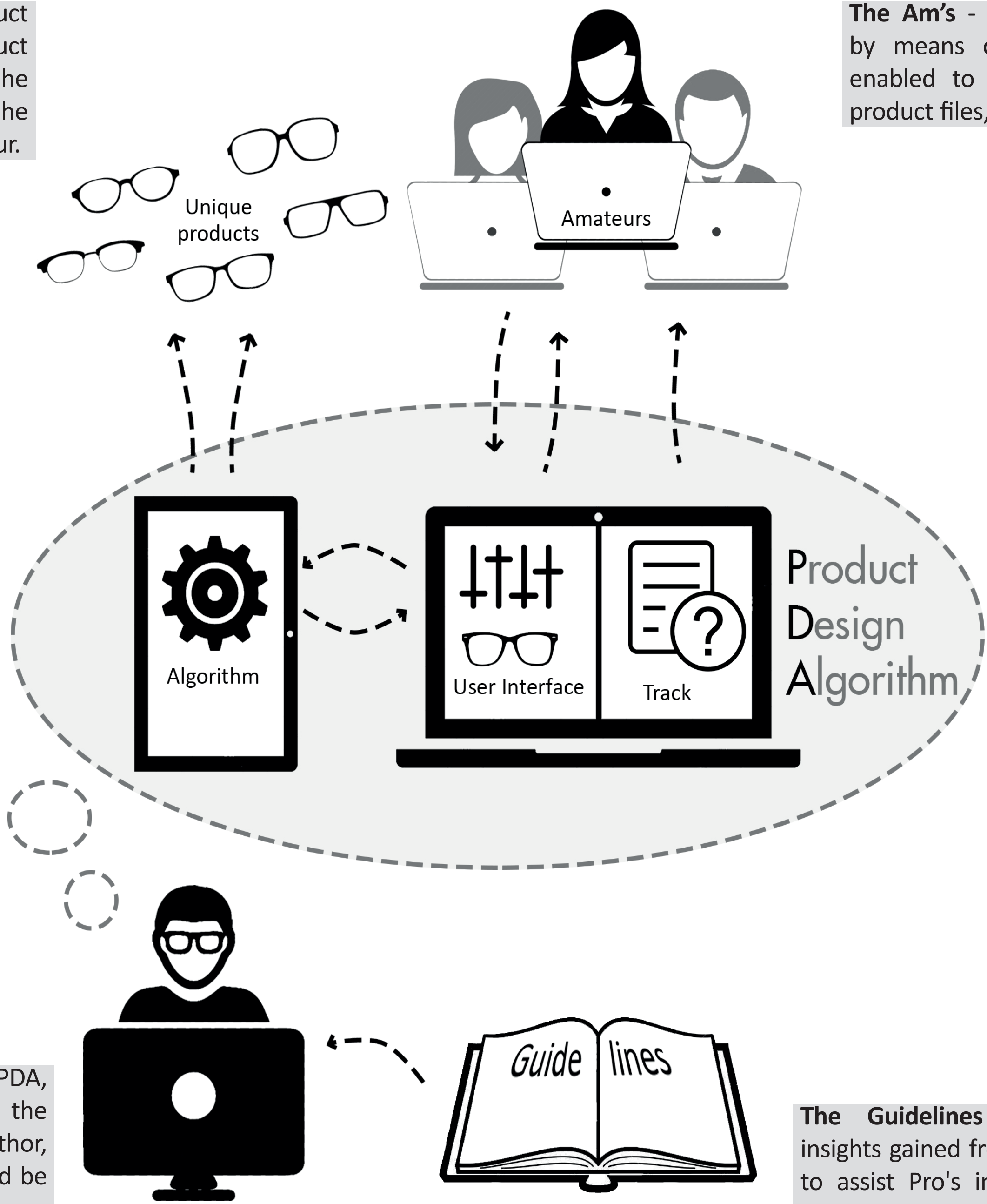
For many years 3D printing has been one of the most exciting promises in future technologies. Because the seemingly endless possibilities spark the imagination so much, it had no shortage of media attention. A lot of news sources proclaim that soon everybody will own a printer and continue on how that will revolutionise people's daily routine. However, in spite of the propagation of this utopian imagery, real penetration in people's life has yet to occur. There are many reasons why this tantalising future seems forever out of reach, many of which have to do with the lacking technical innovation. However, this graduation thesis explores a different hurdle to be had. One of the issues with the penetration of 3D printing technology is the required proficiency with creation software; and the lack of experience in design. This report describes the exploration into a novel means to empower users to create unique design files to 3D-print and in doing so aspires to increase the technology's audience.

The current users of the technology are mainly people with technical backgrounds or highly invested autodidact amateurs. The audience that is targeted with this project consist of creative, tech savvy early adopters; people who lack the skills but not the inclination. There are some solutions that try to achieve the same goal of simplifying the creation process, but these have some disadvantages. They tend to either fail in really simplifying the process or oversimplify by making the design interventions trivial or non-specific. The idea proposed by this project was to find a compromise between freedom and ease of use, while maximising the perceived freedom and sense of authorship.
The approach to achieve this goal is by the means of formalising a digital design process through an algorithm. By offering a set of instructions and options the user would be guided through the process. The consequence of this choice is that the creation of such a tool is productgroup-specific. This means that an example of an implementation of this approach could be a tool that facilitates the design of coffee cups, but nothing else. The challenge is to make it such that the users have the freedom to create any coffee cup they want. The objective is that the user experiences a successful DIY-type cycle with sense of genuine authorship over the outcome. It does so by combining several types of tools into a specific combination setting up a framework for other people to use for specific product types.

It proves to be a multi-faceted problem consisting of: the algorithm; a user interface; a way to guide the user through the process called the Track; and guidelines to create an implementation of the framework, on a meta-level. Each of the facets is explored and combined to create the concept. After thorough analysis and ideation the concept proposal is the PDA (Product Design Algorithm)-framework. It consists of various agents:

The Product - A unique product variation within the product species generated by the algorithm on the bases of the chosen input from the amateur.

The Am's - The user who, by means of a PDA are enabled to design unique product files, ready to print.



The Pro's - The creator of a PDA, in the cases in this project the role was fulfilled by the author, but in the framework it would be professional product designers

The Guidelines - Important insights gained from this project to assist Pro's in making their own PDA's

By making a couple of prototype cases and reviewing them, through quick user tests, a lot of insight was gained. This iterative process proved to be a productive means to get comprehension in the implementation of the proposal. This led to the creation of the final design case; Spectacle.
Spectacle showcases the implementation of the framework with a full track, algorithm and user interface. It facilitates the creation of glasses and guides the user in specific steps through the process. By manipulating things like sliders, points and curves, the user forms the design of the glasses. It provides real-time feedback by displaying a representation both in 2D and 3D according to the specific step in the process. In some instances parameters are controlled directly and singularly and in others they form group for a more subjective feeling of control. It made use of augmented reality to combine map the model on the users face via a web-cam.

The Spectacle was tested with group representing the target. Through observation; vocalising the thought process; and post use-interviews new insights were gained that were either implemented immediately wherever that was possible and otherwise included in the guidelines. These guidelines were an organic list throughout the process and were eventually condensed into their final form.
This report suffices as an exploration into the world of creating specific algorithmic design tools. However this context is on the forefront of innovation and therefore constantly changing. While this project tries to make its recommendations as fundamental as possible it is likely that some things will change over time.

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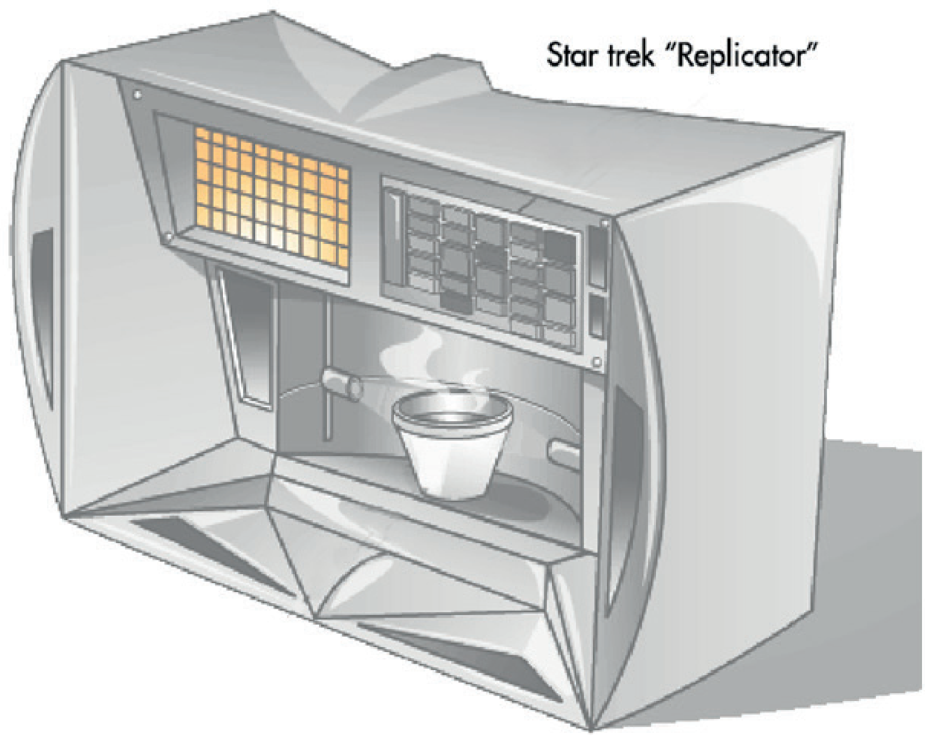
Introduction

History

The rise of 3D printing is sometimes referred to as the third Industrial revolution because of the potential for changing manufacturing[1]. The first industrial revolution was started by the mechanisation of the industry, the first being the textile weaving industry of England in the late 18th century[2]. The second industrial revolution came in the early 20th century, when Henry Ford mastered the moving assembly line and ushered in the age of mass production[3]. Mass production was responsible for a substantial increase in overall wealth but it had consequences. One consequence is that mass production lead to uniformity. Anyone that grew up in the 20th century knows that products might come in a couple of colours but are otherwise standardised and consistent in shape, a stark contrast with the artisan-driven manufacturing ways of the age preceding it. Apart from the wealth, scientific and technological gain achieved by the industrial revolution, it also caused an unintended, increasingly prevalent loss in the form of environmental damage[4].

Revolution

3D printing has the potential to disrupt this paradigm. By producing locally and on demand it negates the necessity for transport and storage, two major contributors to the emission of green house gasses. The fact that domestic 3D printing is done inside the home has demanded that no toxins are emitted and because of the additive nature there is hardly any waste[5]. Multiple companies/organisations are innovating on making the material increasingly more recycled and/or recyclable. It also allows for more form freedom, reminiscent of the artisan ways of before.



Star trek "Replicator"

Introduction

Democratisation

Where the first two industrial ages led to increasingly enormous factories that are centralised and have uniformity as output, the 3D printer provides minute “home-factories”, decentralised and customisable. This trend of decentralisation didn’t start with 3D printing and it probably won’t end with it but it definitely could play a significant role in it. Other industries that preceded it include the music industry, photography and the paper printer. They all made sharing, making or editing their media available for domestic use where it was previously reserved for professionals[6].

Paradox

These are the reasons why for the last fifteen years several news media outlets have been covering the story of 3D printing. Soon, they say, everybody will own a 3D printer and it would become the principal means of product fabrication. With examples like the “Replicator” from science fiction series Star Trek, a machine that materialises objects from thin air, implanted in the collective consciousness it is not hard to see why many people are excited about this. Although consumer 3D printer sales have been rising since their introduction we are still far-removed from actual penetration in daily life. This raises the question; why aren’t more people engaged in this technology? It seems that most people in the western world are aware of the technology, but it is just a minute percentage that actually interacts with it. If this technology is to live up to expectations is imperative that it reaches a wider active audience.

Problem exploration

There are many technical reasons for why this technology has yet to be implemented at a greater scale. These include but, aren’t limited to, problems with material, production quality and integration of for example electrical functionality[8]. Innovation within these categories is occurring all the time and while the current state of affairs has its shortcomings the current user group is still using the technology despite of it. It could be possible that these flaws are responsible for holding back the expansion. That would mean that the current user group is inherently more forgiving then the potential group. While this might be true there is arguably a more important thing that sets these two groups apart; the access to one of the technology’s most defining aspects.

Goal introduction

When someone wants to 3D-print something they need, apart from the hardware and software, a file instructing the machine what to make. One of the unique perks of using additive manufacturing is its almost unlimited freedom of form and the fact that uniqueness has the same cost as uniformity. The

Introduction

making of this file however is a time-consuming effort that requires skill, which takes even more time to develop. Without this skill or the time-investment, users are denied unique files and must rely on downloading existing files thereby negating one of the strongest properties of 3D printing. Another benefit gained from designing the files oneself is the psychological joy of creating. Especially in a society that values creativity[10]. It is arguably a great feeling to make something and that feeling could really benefit the relation one has to a product. This project conjectures that 3D printing could improve its outreach if more users were able to create unique designs to print. This would be bringing the suggested fantasy a little closer to reality. This conjecture led to the introduction of the following goal:

Provide a way to facilitate the creation of unique designs for 3D printing, by users that lack the necessary skills required for CAD-software.

Report structure

Analysis

The analysis explores the problem. It maps the stakeholders by creating persona's; and the context by comparing existing solutions; and tries to reveal what factors play a role to successfully reach the goals.

Concept synthesis

This is where the framework is explored and proposed as a solutions to the stated problem. The different aspects of the theoretic solution are explored.

Practical synthesis

To properly test and develop the framework prototype cases are presented as well as the final incarnation of the framework. The final design (Spectacle) will be thoroughly dissected as an example of the framework in practice.

Evaluation

Insights are given about the effectiveness of the solution through a series of user tests both on the prototypes as well as the final design. It concludes with the finalisation of the theory in the form of guidelines to create more PDA's.

Discussion

The project's merits and flaws are discussed as well as the future potential for the solution-space on different levels, both in this incarnation and beyond.

1 Analysis

Analysis

Scope

In order to contextualise the focus of this project some insights are necessary about 3D printing in general. Despite of the attention the technology receives it is important to acknowledge that, although the technology has been around for a while, it is just coming out of its infancy[11].

PC example

To illustrate how the 3D printing world could be understood it can be compared to the personal computer. Both technologies were patented by large corporations who didn't see a potential for domestic use and were picked up by devotees who could see that potential. It took 30 years for PC's to truly penetrate the market and start to make an actual impact on daily life and the lion's share of the penetration came in the last 10 years of that era. The similarities are abundant, as the PC also started as a do-it-yourself kit, not being able to do more than simple tasks but embraced by engineers and makers. Much like current 3D printers, the early PC's where stricken by flaws and sub-optimal performance[12]. It is even hard to imagine why anyone would even consider acquiring for example a PC from the 80s when it is compared to today's machines. Over time, they where incrementally improved for, and by, their small but enthusiastic community. If this adoption by amateur enthusiasts is viewed as the rebirth of the technology then the acceptance by the general public is arguably like reaching puberty. Everything goes faster after that. For the PC, penetration in the household market followed after the introduction of innovative software, namely Windows, Mac OS; and programs like Word and Photoshop. These examples helped to expand the potential user group by giving them the inclination and the capabilities to increasingly embrace the computer as a valued household item[13]. This ushered in a new era where users could get something out of the machine without all the technicalities holding them back.

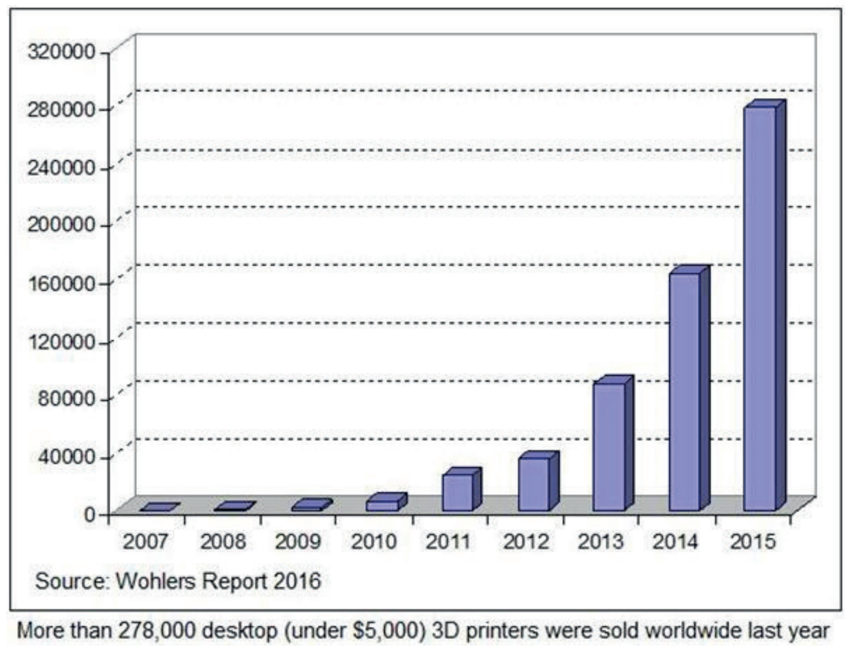


Figure 1.1: Annual sales of desktop 3D printers

Introducing Apple II.™
The home computer that's ready to work, play and grow with you.
Clear the kitchen table. Bring in the color T.V. Plug in your new Apple II,* and connect any standard cassette recorder/player. Now you're ready for an evening of discovery in the new world of personal computers.
Only Apple II makes it that easy. It's a complete, ready to use computer—not a kit. At $1298, it includes features you won't find on other personal computers costing twice as much.
Features such as video graphics in 15 colors. And a built-in memory capacity of 8K bytes ROM and 4K bytes RAM—with room for lots more. But you don't even need to know a RAM from a ROM to use and enjoy Apple II. It's the first personal computer with a fast version of BASIC—the English-like programming language—permanently built in. That means you can begin running your Apple II the first evening, entering your own instructions and watching them work, even if you've had no previous computer experience.
The familiar typewriter-style keyboard makes communication easy. And your programs and data can be stored on (and retrieved from) audio cassettes, using the built-in cassette interface, so you can swap with other Apple II users. This and other peripherals—optional equipment on most personal computers, at hundreds of dollars extra cost—are built into Apple II. And it's designed to keep up with changing technology, to expand easily whenever you need it to.
As an educational tool, Apple II is a sound investment. You can program it to tutor your children in most any subject, such as spelling, history or math. But the biggest benefit—no matter how you use Apple II—is that you and your family increase your familiarity with the computer itself. The more you experiment with it, the more you discover about its potential.
Start by playing PONG. Then invent your own games using the input keyboard, game paddles and built-in speaker. As you experiment you'll acquire new programming skills which will open up new ways to use your Apple II. You'll learn to "paint" dazzling color displays using the unique color graphics commands in Apple BASIC, and write programs to create beautiful kaleidoscopic designs. As you master Apple BASIC, you'll be able to organize, index and store data on household finances, income tax, recipes, and record collections. You can learn to chart your biorhythms, balance your checking account, even control your home environment. Apple II will go as far as your imagination can take it.
Best of all, Apple II is designed to grow with you. As your skill and experience with computing increase, you may want to add new Apple peripherals. For example, a refined, more sophisticated BASIC language is being developed for advanced scientific and mathematical applications. And in addition to the built-in audio, video and game interfaces, there's room for eight plug-in options such as a prototyping board for experimenting with interfaces to other equipment; a serial board for connecting teletype, printer and other terminals; a parallel interface for communicating with a printer or another computer; an EPROM board for storing programs permanently; and a modem board communications interface. A floppy disk interface with software and complete operating systems will be available at the end of 1977. And there are many more options to come, because Apple II was designed from the beginning to accommodate increased power and capability as your requirements change.
If you'd like to see for yourself how easy it is to use and enjoy Apple II, visit your local dealer for a demonstration and a copy of our detailed brochure. Or write Apple Computer Inc., 20863 Stevens Creek Blvd., Cupertino, California 95014.
Apple II™ is a completely self-contained computer system with BASIC in ROM, color graphics, ASCII keyboard, lightweight, efficient switching power supply and molded case. It is supplied with BASIC in ROM, up to 48K bytes of RAM, and with cassette tape, video and game I/O interfaces built-in. Also included are two game paddles and a demonstration cassette.
SPECIFICATIONS
• Microprocessor: 6502 (1 MHz).
• Video Display: Memory mapped, 5 modes—all Software-selectable:
· Text—40 characters/line, 24 lines upper case.
· Color graphics—40h x 48v, 15 colors
· High-resolution graphics—280h x 192v; black, white, violet, green (16K RAM minimum required)
· Both graphics modes can be selected to include 4 lines of text at the bottom of the display area.
· Completely transparent memory access. All color generation done digitally.
• Memory: up to 48K bytes on-board RAM (4K supplied)
· Uses either 4K or new 16K dynamic memory chips
· Up to 12K ROM (8K supplied)
• Software
· Fast extended Integer BASIC in ROM with color graphics commands
· Extensive monitor in ROM
• I/O
· 1500 bps cassette interface
· 8-slot motherboard
· Apple game I/O connector
· ASCII keyboard port
· Speaker
· Composite video output
Apple II is also available in board-only form for the do-it-yourself hobbyist. Has all of the features of the Apple II system, but does not include case, keyboard, power supply or game paddles. $598.
PONG is a trademark of Atari Inc.
*Apple II plugs into any standard TV using an inexpensive modulator (not supplied).
apple computer inc.™

Analysis

Market driven innovation

This reveals a part of the reason why this project chose to focus on making the technology valuable for a new user group by attempting to expand access to it. That is not to say the incremental technical innovation isn't necessary or important, on the contrary, they are vital for the success of the technology in the long run. However, it could arguably be claimed that an expansion of the user audience is vital to keep the motor of innovation running; and even speed it up if the comparison to the PC is preserved. While the magnitude of household penetration is far removed from significantly present, with only around 300.000 domestic printers sold worldwide, the rate of annual sales is increasing exponential. If this rate is to be kept there has to be an expansion of potential users. To achieve this, the functionality has to be accessible to these new users.

User focused project

The focus is therefore on the interaction between the device and the user, considering the machines will get better over time. To better understand the opportunities, over the next chapters, this interaction is analysed. In addition, the current user is described and juxtaposed to the potential user to see what opportunities arise what hurdles need to be circumvented.

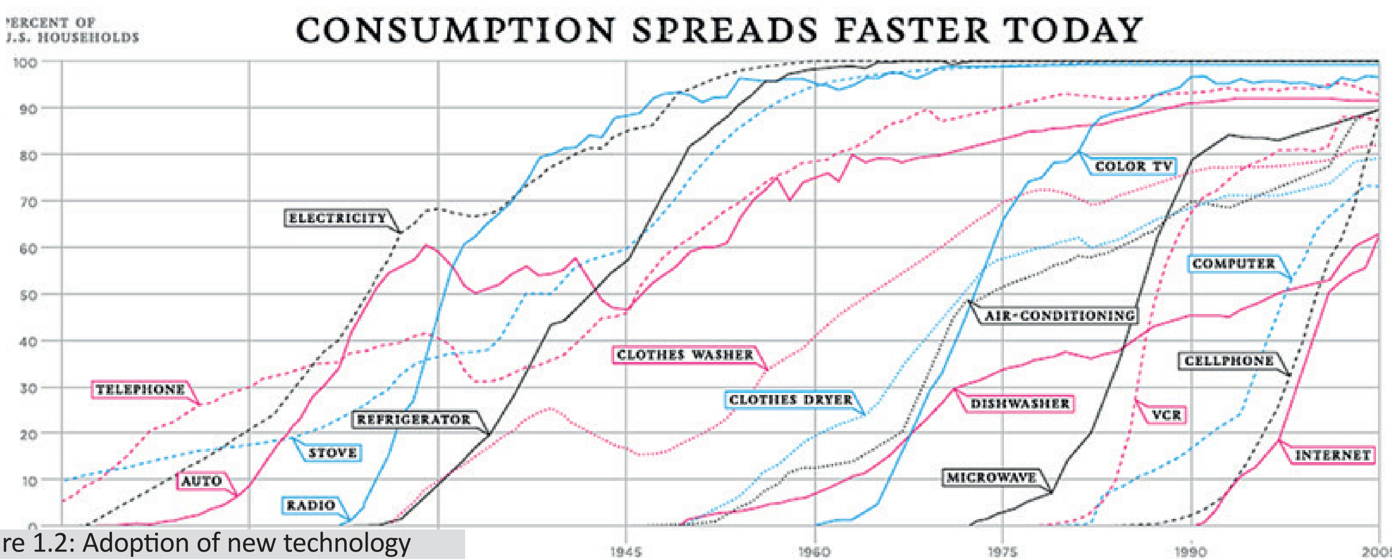


Figure 1.2: Adoption of new technology

Analysis

Interaction

The 3D printing work-flow can be simplified to three steps as can be seen in Figure 1.3. Each of the three phases provide difficulties specifically for that phase. Since the production phase is completely dependent on the effectiveness of the machine, and that was already excluded from the scope, this phase is neglected. The third phase is actually mostly comprised of actions related to the limitations of the process. For example, the removal of support material or application of a surface finish could be made redundant with the innovation of the 3D printers of the future. For these reasons the project was only focused on what happens during the preparation phase.

The preparation phase can in turn be divided into two segments; the acquisition of the file and the preparation of that file to make it ready for manufacturing. The latter of the two is factually a necessary evil. Because the current users are adapt enough to tweak the parameters of the printing process to optimise the print this is still an active step in the process. However, it doesn't have to be. Upon improvements on the printers in general this conversion could be automated as well.

To say that most difficulties with 3D printing will subside with technical improvements is putting it a bit bluntly but it is not without merit. This however does not include the acquisition of the file. It is therefore arguably the most promising topic as it is most likely the most innate to the technology. To explain how the acquisition of the file is done now and what options users have it is important to define exactly who the users are.

Preparation phase	Production phase	Postproduction phase
Idea - Have an idea for a print job.	**Material** - Choosing one or more materials to print with.	**Removal** - removing any excess material from the print i.e. support material
Design - Make a design, from scratch or by downloading (parts) from a digital library.	**Setup** - Setting the printer to the needs for the job i.e. speed vs. resolution	**Finishing** - Chemically or manually applying finishing methods
Digitalise - Formalise the design in a STL-file, through one of the many posibilties using CAD-software.	**Printing** - Wait for the printer to conclude the printing process	**Assembly** - Putting together the parts to acquire the final product
Slice - Slice the STL-file into layers which in turn are translated to machine movement for the 3D-printer.		

Figure 1.3: 3D Printing full function cycle

Analysis

Users

In order to expand the audience for 3D printing it's imperative to get an idea where the current expansion is coming from in order to predict where it is going. In the case of this project this means understanding the characteristics of the current users.

Early adopters

As aforementioned the technology had a previous life and found a rebirth. The start of 3D printing was in the 1980s with the patenting of several different principles of production in this manner. It did not receive much media exposure at the time nor was it impactful on a large scale in product manufacturing, remaining a niche market. It was with the expiration of these patents that 3D printing arguably had its rebirth, at least in the public's eye and definitely for consumer purposes. In the early 2000s researchers from MIT started a project using this technology, which had just appeared in the public domain, with the ambition to create a low-cost 3D printer making it much more accessible[14]. This project, dubbed RepRap, made a technology that was previously unaffordable and unobtainable into an open source and reasonably priced do-it-yourself kit. This kit consisted of readily available parts at the local hardware store laying its foundation in the maker movement.

After being introduced as affordable technology by the researchers from MIT and because of their decision to open-source the project, it quickly spread amongst academia, engineers and designers who saw use for it in their daily activities, primarily making parts for prototypes. This is why the technology was known for a while as Rapid Prototyping. However, as the finished products increased in quality it became apparent that the technology had potential for end-products as well, especially in cases where it concerned small quantities. Where mass production has a high investment but an increasingly lower cost per product as the batch size increases, 3D printing has a low investment and a relatively high consistent cost per product[15]. Figure 1.4 shows that cost per product are significantly cheaper with small batch sizes. This meant the technology bled into the artist/design community where low quantity and low investment are eagerly welcomed. Another benefit which made this group enticed to use the technology was the freedom in form.

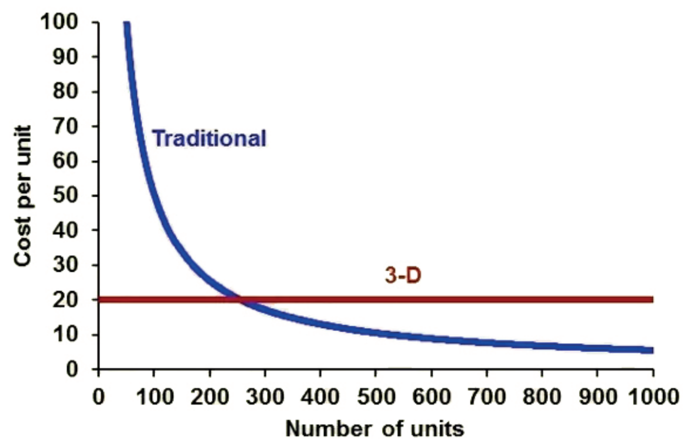


Figure 1.4: Cost per unit 3D printing

Analysis

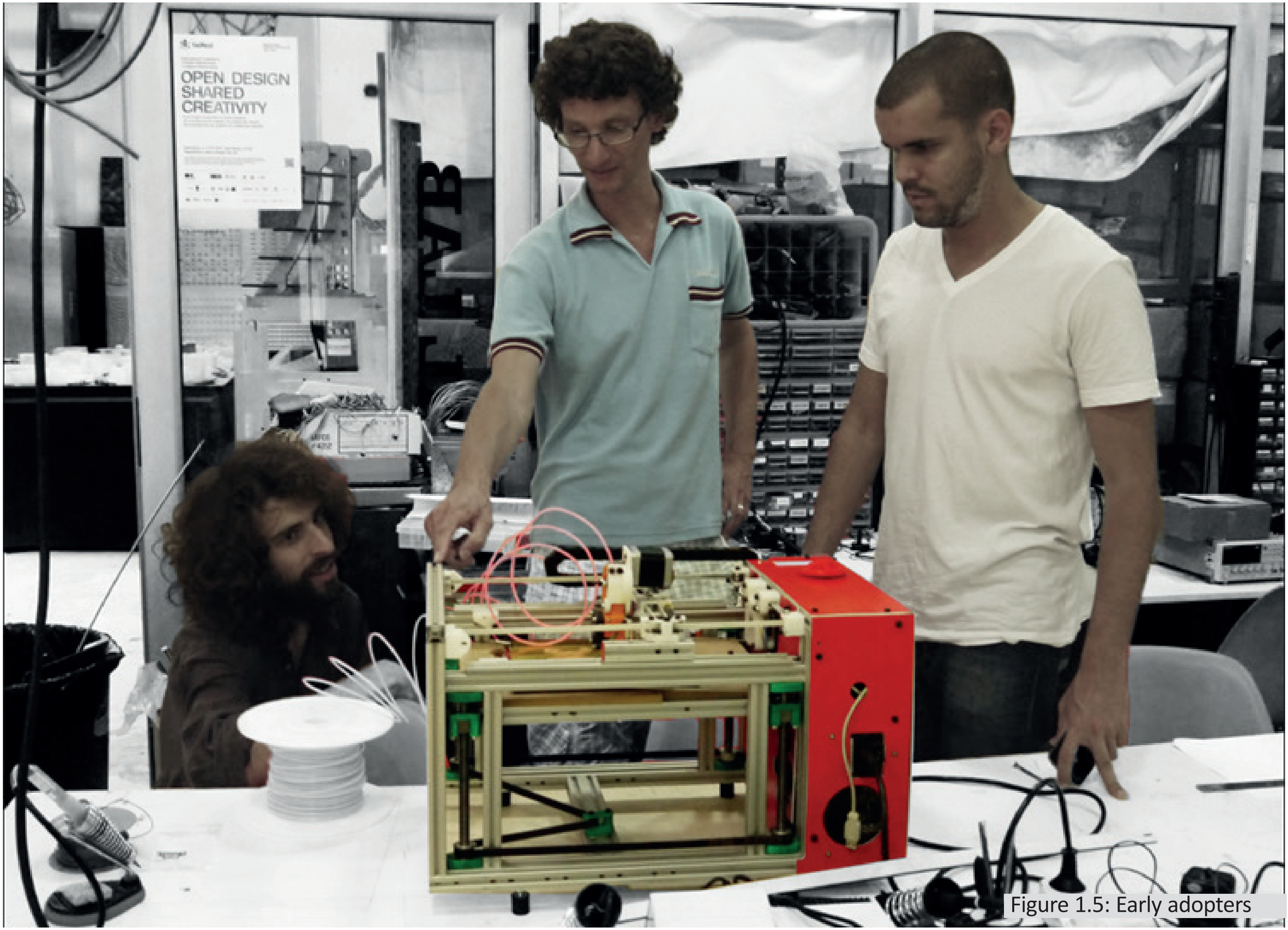


Figure 1.5: Early adopters

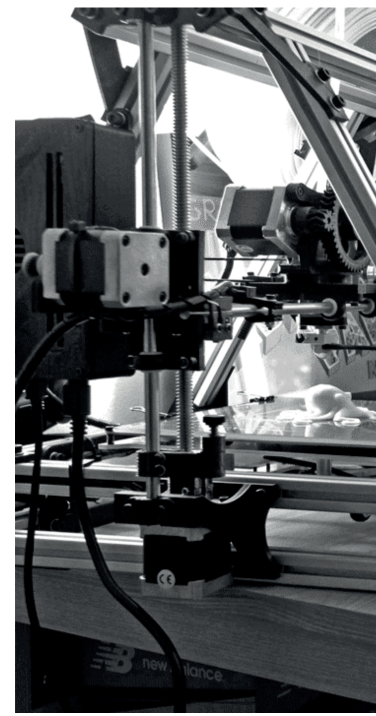
Analysis

Current audience

3D printing as a technology is arguably deeply interwoven with their audience. Like mentioned before, it may not have even survived, or at least not in this form. This special relationship is definitely felt by the earliest of users and is amplified by the adoption of the technology into the maker movement. To summarise, the current user group consists of two general domains; the qualified (Fig. 1.6) and the adepts (Fig 1.7).

The qualified are introduced to 3D printing through their work and include engineers, academia, designers and artists. The adepts have found their way to 3D printing through the maker movement or are completely self taught, they include hobbyists, makers and devotees. The qualified innately have a more technical background and are more than often proficient with things like CAD-software. While the adepts lack that advantage they make up for it with enthusiasm, dedication and communal support.

Figure 1.6: Qualified



It is important to note that most people fall on the spectrum between the qualified and adepts and are mostly a bit of both. To elaborate, it can be used as a way to illustrate differences within the group but it shouldn't be seen as an actual split dividing the group. However, what really unites this group is the willingness to invest the necessary time for the limited output in an emerging technology.

The new user group

The currents user group's most distinctive trait is their absolute immersion in the technology and the effortlessness of their time-investment. The new user group lacks this trait. They share in the enthusiasm but not in the absolute devotion. To illustrate what kind of people the target audience would consist of, three persona's were created. There is one persona extra that represents the current users of 3D printing to highlight the differences and because they could play a role in the overall scheme of the concept, which will be discussed in a later stage.

Figure 1.8: New User

Analysis

Persona's

Rick "current user"

Rick represents the current demographic, with a technical background and an insatiable drive when it comes to the exploration of new technology. They have been 3D printing for years and often combine it with other efforts in the maker movement.

Figure 1.9: Rick

Celia "potential user"

Celia is a member of the first senior group having new technology constantly introduced over their entire lifespan. When she was young it was the TV, a little older the computer, then the Smartphone and now this. They are truly used to adapting and dismiss the notion of opting out.

Figure 1.10: Celia

Analysis

Randy "potential user"

Randy is the kind of person who takes pride in being the skilful one in the family. It is people like him that get asked to help with devices or minor technical difficulties by their loved ones.

Rose "potential user"

Rose represents the creative natives. They are full of creative ideas, but would normally for example turn to paper, textile, glue and scissors to manifest them.

Figure 1.9: Randy

Figure 1.9: Rose

Analysis

Context in creation

In the last few chapters the scope of the project was narrowed down to the acquisition of STL-files. That marks the objective for the new audience, which was previously defined as well. The reason for choosing this scope was, in addition to all the reason presented in the previous chapters, due to the fact that this step is fundamentally innate to the process as a whole. Even if a perfect 3D printer is imagined, one that automatically produces anything in perfect form, users would still need to provide it with a description of what they want. In the current situation there are two basic ways to acquire a STL-file, either by creating or downloading. Downloading it is definitely the least time-consuming and can be done either from a commercial source or a free library. This would make the process much like picking products from a shelf or online store, with the exception that it would be materialised at home. For some products this is perfectly fine but this doesn't provide many benefits over buying a finished product.

Form freedom

One of the unique perks of using additive manufacturing is its almost unlimited freedom of form and the fact uniqueness has the same cost as uniformity. The making of this file however is a time-consuming effort that requires skill, which takes even more time to develop. Without this skill or the time-investment, users are denied unique files and must rely on downloading existing files thereby negating one of the strongest properties of 3D printing. Another benefit gained from designing the files oneself is the psychological joy of creating. Especially in a society that values creativity. It is arguably a great feeling to make something and that feeling could really benefit the relation one has to a product.

Creativity

People seem to have an innate urge to be creative[16]. It is even conjectured that it is this characteristic that set our species apart and allowed it to thrive. This urge is something that could be tapped into with 3D printing. Historically, to make products, tools or art someone would need manual skills to exert their creativity. With CAD, this shifts the skill from the manual plane to the digital and leaves the actual production up to automation. When skills become digital it is much easier to facilitate them. For example, photo editing manually in a darkroom takes years of study and practice. With the introduction of Adobe Photoshop many of the complicated processes can be digitally replicated with very little effort. This exemplifies ease through aid.
Digital editing or design can only replace its manual counterpart when the fabrication is also digital, i.e. printing an edited image. 3D printing has these characteristics and is therefore a excellent medium to exert creativity.

Analysis

Benefits of Self-design

Schreier describes four benefits of self-designed products[17]. (1) to be better tailored to his individual needs (functional benefit) and (2) to be more unique (perceived uniqueness). In addition, there might also be some 'do-it-yourself effects' (as the user actively engages in problem-solving instead of rather passively picking a product off the shelf). (3) First, the process of using a mass customization tool-kit itself might imply additional costs but also additional benefits to the user, which may influence the perceived value created (process benefit). (4) Second, as the users themselves act as designers, they will also be likely to value the output of the self-design process more highly: They might experience strong feelings of pride, which in turn could increase the value created ('Pride of authorship' effect).

Sense of Authorship

It is the last benefit that is arguably the strongest. If the objective is to facilitate the exertion of creativity it is important to maintain the sense of authorship. With too much facilitation users might lose the sense of authorship and with too little they might never reach a satisfactory result. It is therefore important to balance them out.

Relationships

Both the ease of use (influenced by facilitation) and sense of authorship have a relation with the amount of freedom given to the user (Fig. 1.13). Sense of authorship has a positive dependency relationship while ease of use has a inverse relationship. If the objective is facilitating self-design a designer has to find a point on the graph that fit the target user's desire.

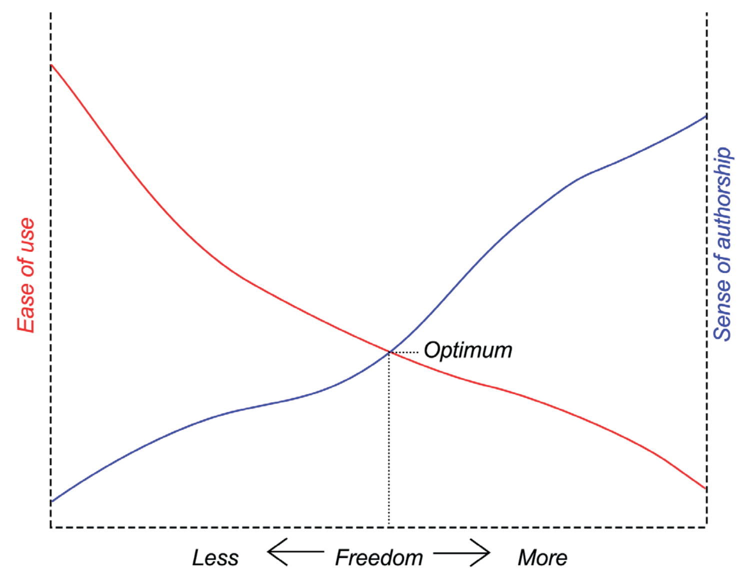


Figure 1.13: Freedom vs. Usability vs. Authorship

Analysis

Perception versus reality

Apart from the relationship with the amount of freedom they are also dependant on the user. What is simple and straightforward for one might be complicated for another. This is also true for the sense of authorship as one might have it after a few minor design choices and another would need a lot. In addition to this, is the subjective nature of freedom. Therefore its better to talk about perceived freedom. Manipulating these three subjective parameters allows the designer to find a even better optimum, where a user might perceive more freedom while objectively having less (Fig. 1.14).

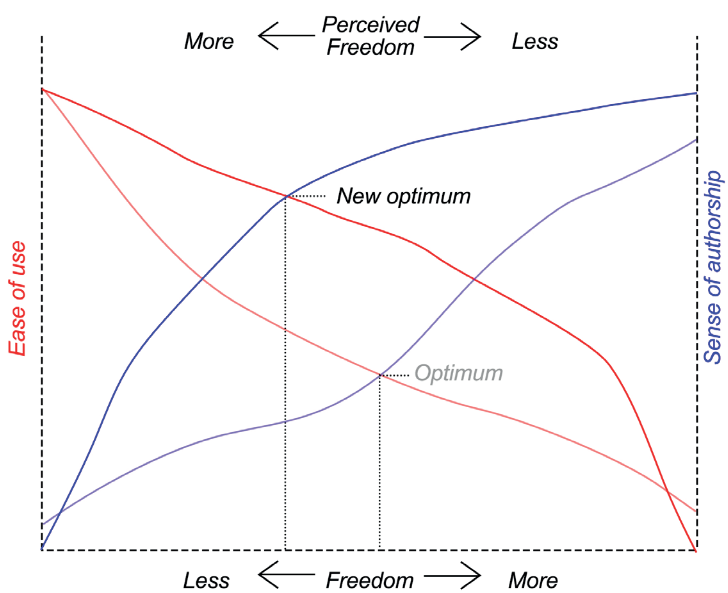


Figure 1.14: “Freedom vs. Usability vs. Authorship” manipulated

Criteria

This triad of interconnected relationships should also be the most important criteria for evaluating the concept. Any concept should be easy enough to be used by the target group, while making them feel the pride of authorship. Theoretical support for the ‘pride of authorship’ effect can be drawn from literature. For this project the definition of pride is drawn from the works of Weiner. He states: “Pride is associated with achievement and depends on a favourable outcome attributed to one’s own efforts”[18]. Ownership is defined by users satisfaction with the results and their connection with the final product. Any concepts should try to maximise the perceived freedom to optimise the potential sense of authorship.

Analysis

State of the art

There are several ways in which different parties facilitate the creation of STL-files and differ from each other in a couple of interesting ways that are significant to address. The more traditional solutions are mostly targeted at the current users, but more recently there have been some attempts in creating new types of tools with the same goal as in this project; simplifying in order to attract more people. To understand the differences and similarities between these attempts, it is important to get a sense of what is offered and how they relate to each other.

This was done by collecting the examples of tools, categorising and comparing them. Two attributes are important when comparing the categories; the amount of freedom they offer and the effort it takes to get a result. The effort aspect also encapsulates the investment of skill acquisition.

Mesh-Mix

These applications allow the user to combine existing files. It makes use of the numerous available libraries. Users can make a 3D collage by merging different objects into new ones. This process is straightforward and uncomplicated, but highly dependent on availability amongst the libraries. The speed by which unique files are created goes hand in hand with the lack of freedom. It can be argued that tools like this, whilst able to create some entertaining results, are not actual creation tools as such. It is however another explanation how design-freedom is exchanged for usability.

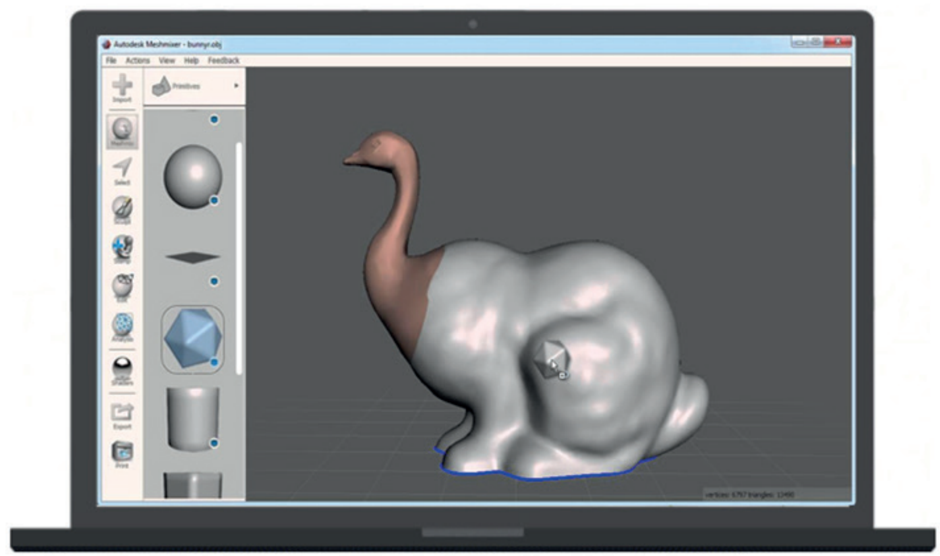


Figure 1.15: Example of a mesh-mix application

Analysis

CAD-software

The common way to create unique digital files is using CAD software. Different providers offer different software packages that focus on various applications. What unites them is their sandbox-design. Users start with a blank canvas where they can build their models through a series of operations. These programs usually originate from the professional practice and that fact shows in their functionality. However, more recently companies have introduced some software more directed at the consumer market, without much loss of the functionality of their professional counterparts.

Traditional CAD-software offers the most freedom out of all the categories but is also the one the new target audience is most likely to fail to grasp. A great deal of time goes into the use of these modellers and even more time goes into acquiring the skill to operate them. In addition to this drawback, the sandbox nature of the apparatus demands a lot of knowledge and creativity from the user. Even if users are proficient with it, they would still have to have some insight in how products can be designed to successfully serve their purpose. The risk of printing product that are mechanically or aesthetically inadequate, or wont print at all is increasingly present when users without a design background use CAD.

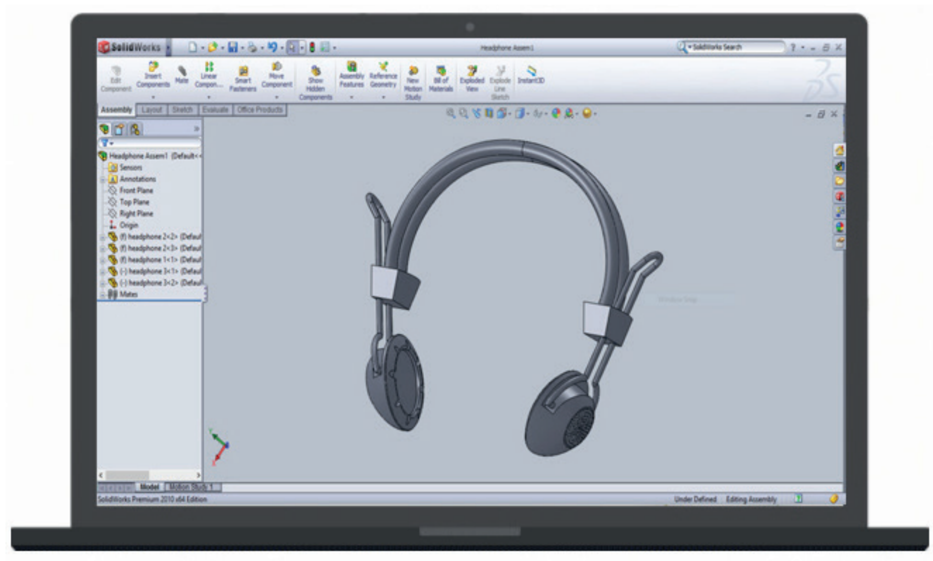


Figure 1.16: Example of a CAD-software

Analysis

SimpleCAD

More recently, companies have made efforts to create simpler versions of CAD software that have less functions and are intended to be more comprehensible for starting users. This is generally done by removing many operations from the pallet and leaving only those that are essential and understandable. While it is true that the daunting nature of the amount of available functionality in traditional CAD-software can be a hindrance to new users, it is obviously in there for a reason and removing some comes with consequences. The consequences could be seen as a trade-off. Reduced possibilities provide quickness to learn, while simultaneously reducing the potential for specific outcomes.

However, what is more important is that it doesn't address the blank canvas problem. Users might be able to create something where they were previously unable, but if their creation is insufficient or downright faulty that still poses a problem. The most important lessons that can be drawn from these simpleCAD solutions are how to address these users who are new to the paradigm of 3D creation. It is interesting to consider how these companies approached this and what choices of simplification they made.

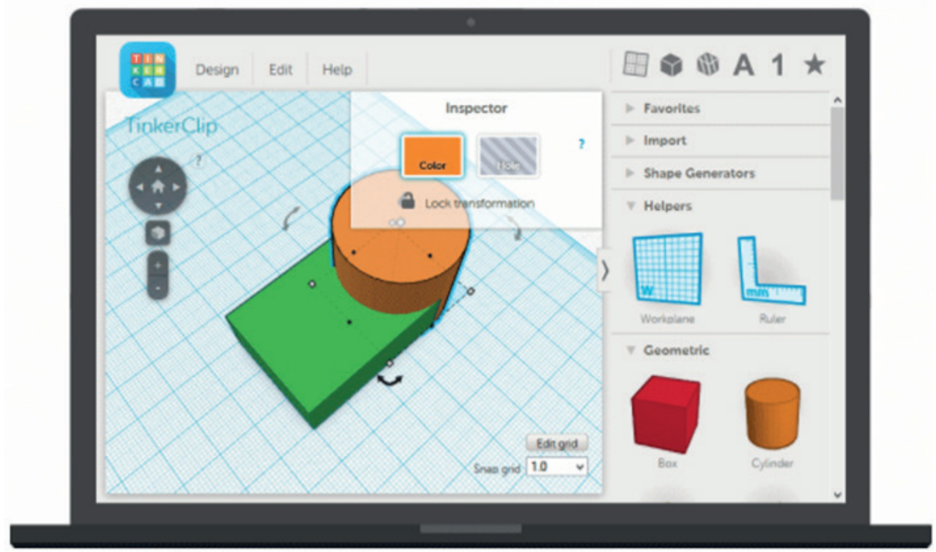


Figure 1.17: Example of a simple CAD-software

Analysis

2D to 3D

These are applications that give an extra dimension to 2D drawings, effectively turning them 3D. Much like the Meshmix applications, these offer a faux sense of creative freedom. Simply adding thickness to a 2D drawing might make it 3D in the technical sense but it can hardly touches on the actual freedom which derive from an extra dimension. In addition to this, it merely shifts the problem over, as users are still required to make a 2D rendering. The creation or otherwise acquiring of the 2D images poses the same problems that occurred before, including the blank canvas problem.

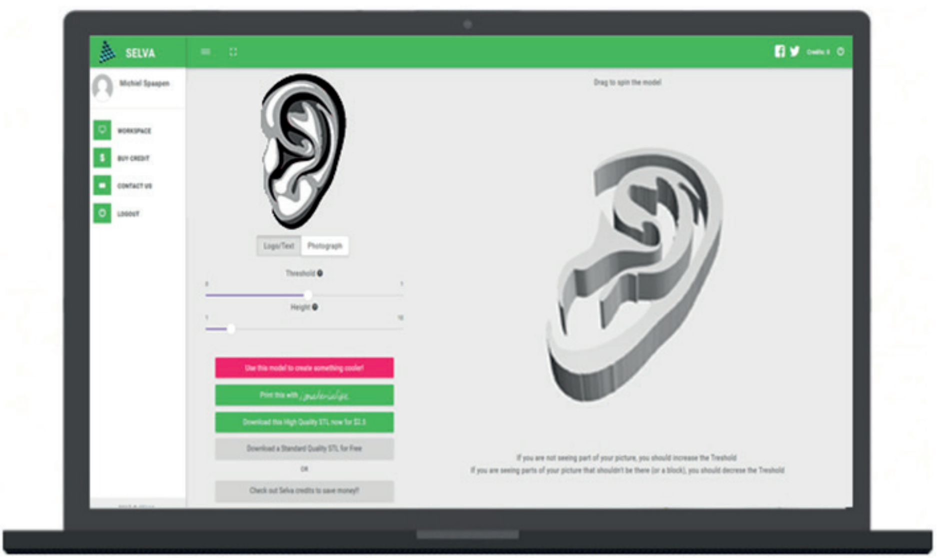


Figure 1.18: Example of a 2D-3D application

Parametric customisers

Parametric customisers are applications that give some kind of control over the parameters in a design or allow a user to add simple elements like text. This is a fairly new approach to the repertoire of creation tools and is found in two forms; either for products that live within a parametric family innately or by companies that give some end-result options for their product.

An example of the first group is the parametric screw, with one model it allows to create all sizes of standard screw. While this is a great way to save on design time it can hardly be seen as a creation tool for end-users. The latter is more interesting for the purpose of this project. A few examples were found where companies made their products customisable by the user, but what was striking was that they were mostly sculptural pieces. To be more precise it was mainly jewellery. The second thing which stands out is that the freedom only manifests in arbitrary choices, not fundamentally changing the design. An example of this is the necklace by Kinematics like in figure 1.20. Where a user can add triangles and manipulate the shape but the archetype of the necklace is arguable already set.

Another is the encode ring, that generates a unique ring based on an audio message. It arguably makes it personal; however the user will most likely not feel like the designer as the input interaction is so far removed from the changes in the design.

Analysis

Figure 1.19: Example of a parametric customiser

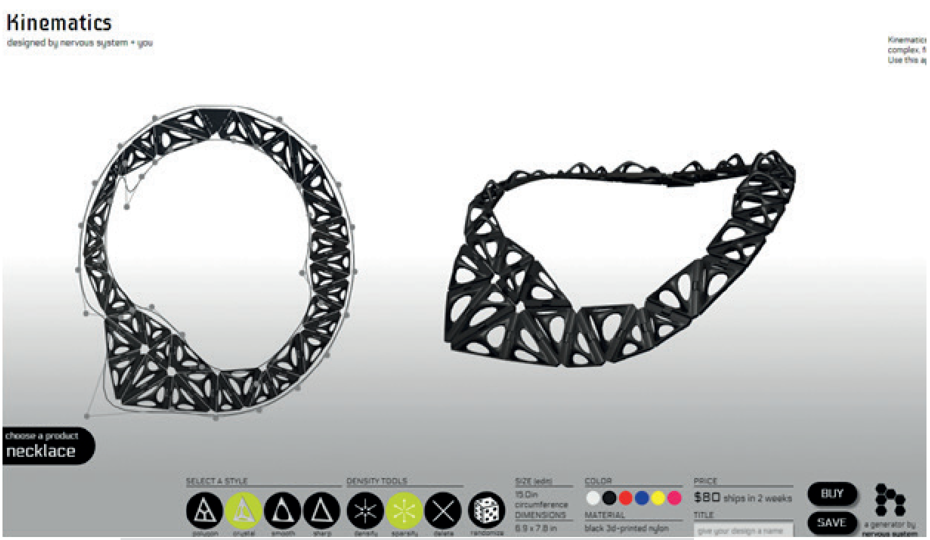


Figure 1.20: Example of a parametric customiser

Conclusions

Several things are compelling about the mapping of existing solutions. The first is the emergence of the recent additions to the collection if creation software, namely the SimpleCAD and the parametric customisers. The fact that the industry acknowledges the difficulties inherent to current solutions, by trying to create new ones that address this, is proof of its validity.

Another thing is the relation between creative freedom and the required skills to operate a tool, which seems to be proportionally related. To put differently, a tool that lowers the required skill by reducing options inadvertently reduces the amount of freedom user have with it.

The third observation is that, while these solutions lie on a spectrum, it is mostly the ends of the solution spectrum are saturated whilst the middle is neglected. They try to hide this fact by proclaiming that; the solutions that offer a lot of freedom are easy to use; and the solutions that are easy to use offer a lot of freedom, when in fact they arguably choose one over the other.

Analysis

Conclusions Analysis

The problem that arises is a consequence of the combination of a few assertions; the idea that simply downloading a file doesn't utilise the full potential of 3D printing; the idea that creating a file is either hard and time-consuming, or lacks actual freedom; and the idea that the target audience lacks the devotion to invest as much as the current user group. These things combined lead to the conclusion that the target audience will find it difficult to get invested in 3D printing with the current solutions. This conclusion is naturally followed by the conjecture that 3D printing could improve its outreach if the target users we able to create unique designs to print.

Unique approach

The objective to exceed the existing solutions. This thesis argues that the existing solutions miss a necessary profound paradigm shift in their approach. They either disguise their traditional CAD-software with a more user-friendly interface or present simple tricks posing as freedom; instead of offering a novel means to reach this end. This means the solutions on the one end of the spectrum are likely to require too much of investment to succeed, while the solutions on the other end will deliver results. However, the suspicion is that the arbitrary nature of the design due to a lack of actual freedom will cause the user to lack a sense of authorship. The conjecture is that this is a vital part of the success; else it would be similar to downloading a file. The solution should try to incorporate the ease of use of one end of the spectrum with the perceived freedom of the other end.

To get a fresh perspective on the problem it was necessary to abstract the problem and look at it from a completely different angle. This resulted in the following interaction vision:

Analysis

Interaction vision

If a user needs to do something but is unable due to a lack of knowledge or skill, he asks an expert for help. Therefore, if a user needs help with designing he should ask a designer for help. A designer can assist users in designing something for themselves. For example an interior designer knows which questions to ask and which examples to present in order to generate a unique design; that hopefully, delivers what the user desires. In this way the designer bridges the knowledge gap; provides inspiration; and streamlines the process. This alleviates the user from most of the burdens and pitfalls otherwise holding him/her back. The designer would have to anticipate the user's wishes but in theory this could provide a way to reach the goal set by the project.

Figure 1.21: Designer helping with creation process

Vision

One of the aforementioned problems with traditional CAD-software is the blank canvas problem. If somehow it could be like a designer was present in some form to guide the user through the process this could alleviate it. It could bring the discouragement of total freedom down while maintaining the sense of authorship. The decentralised and autonomous nature of 3D-printing juxtaposed to this personal and intensive guidance creates a paradox. Not every 3D-printer can come with a personal designer. However, much like the parametric customisers a designer could formalise his actions in this guiding role in a step-by-step process and automate the outcome. This would lead to step-by-step program for the user to design unique products within a product family. Where CAD-software is a sandbox, this would be more like an instructional.

The consequence is that for each type of product a new formalisation is necessary, but it can be much more specialised thereby reducing its complexity. It is important to note that the end output of this design aid would have to be a digital file in order for the 3D-printer to properly output the final product. It is therefore convenient for this formalisation to manifest in the digital realm as well. A digital manifestation of a step-by-step program is generally referred to as an algorithm. Hence, the solution space explored in this project shall be addressed as Product Design Algorithms (PDA).

Analysis

Product Design Algorithm

A PDA works in the following framework. A professional designer, hereafter called Pro (professional), develops the application (PDA) for the user, hereafter called Am (amateur). The Am uses the PDA to design products to 3D print.

To illustrate the intended interaction between a potential member of the new audience and the concept, a scenario was created. It includes a member of the adept 3D printer in the form of an uncle as the provider of information to the main character. This role is included because the PDA-concept doesn't include assistance with the actual printing itself. To emphasise this hiatus and offer a likely scenario to cover it is the reason for including him.

Something that stands out in the storyboard is the magnitude of discouragement users can feel when they have such an exciting technology at their finger tips only to find out what hurdle prevents them from reaching their goals. This hurdle, the CAD-environment, is precisely what the PDA hopes to omit or replace for these users.

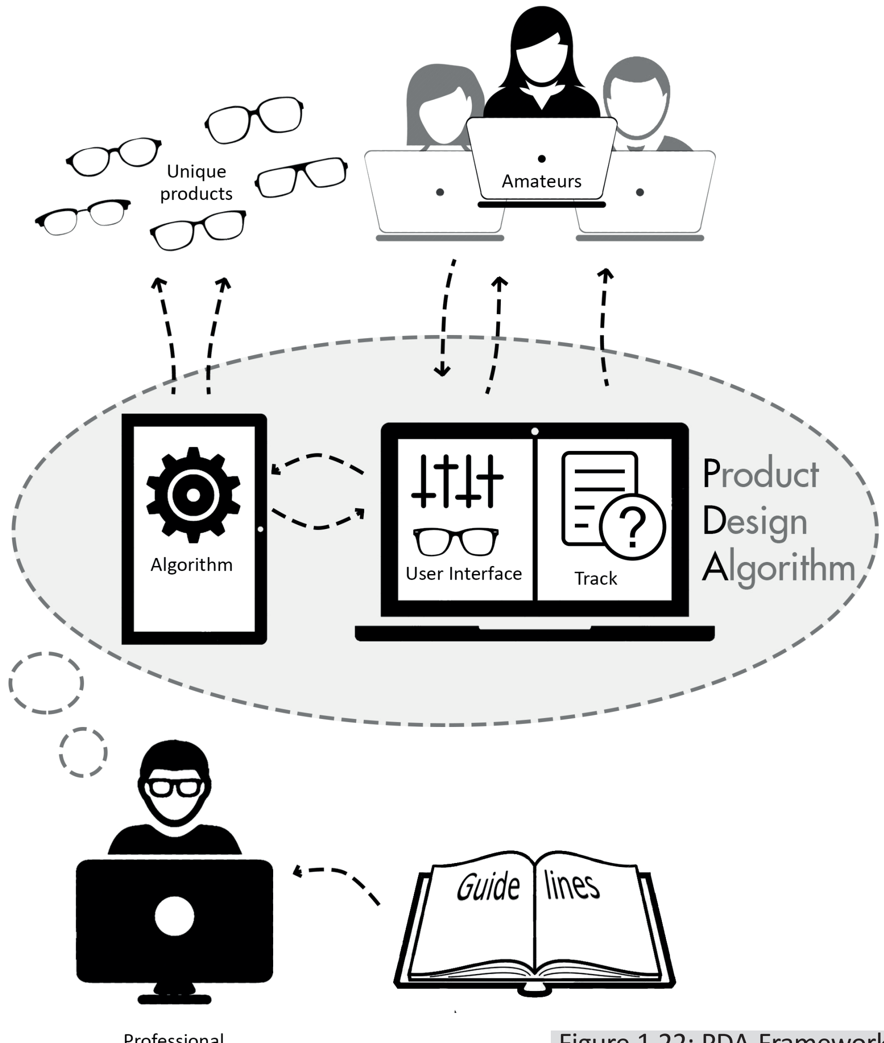
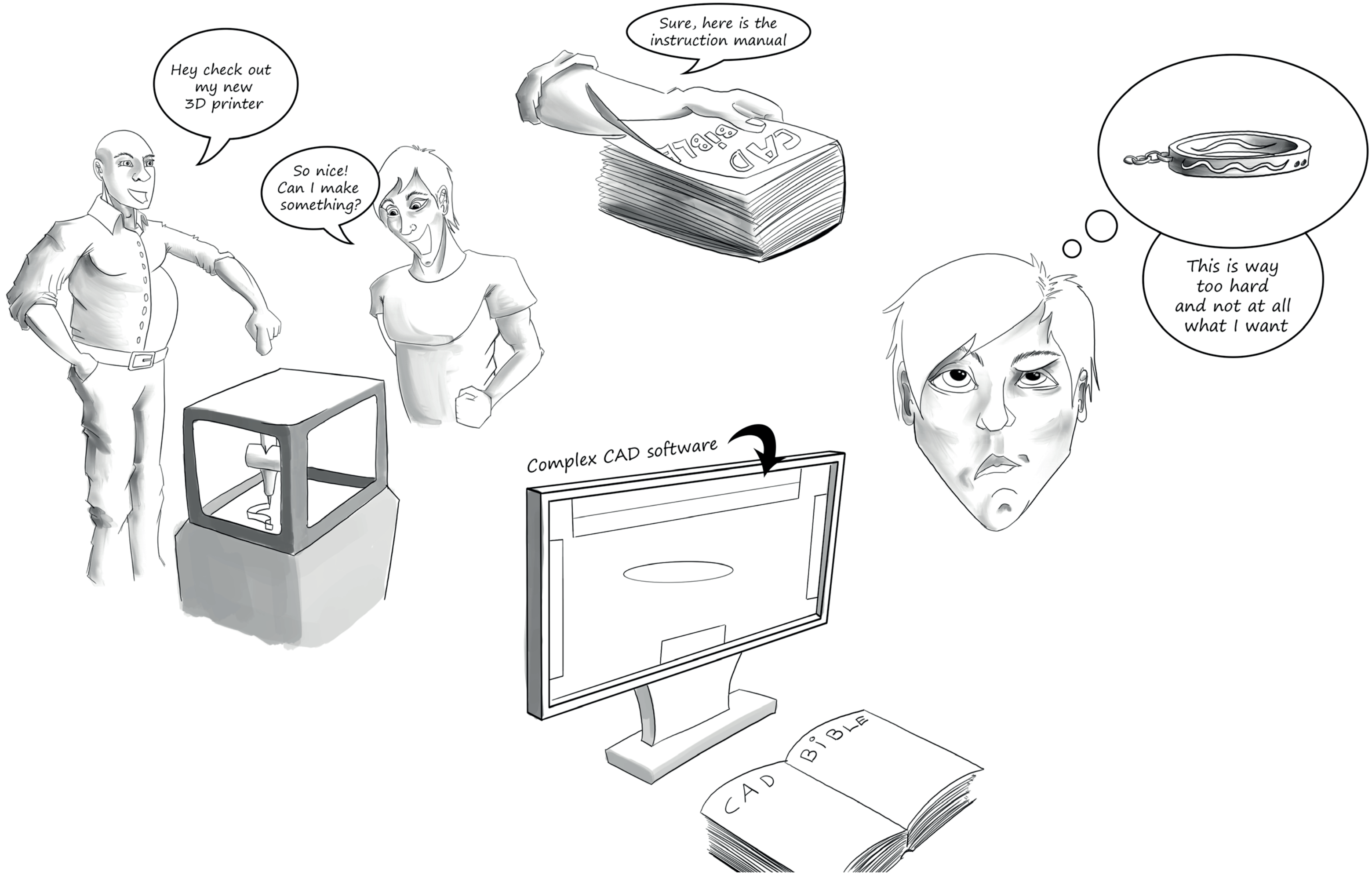


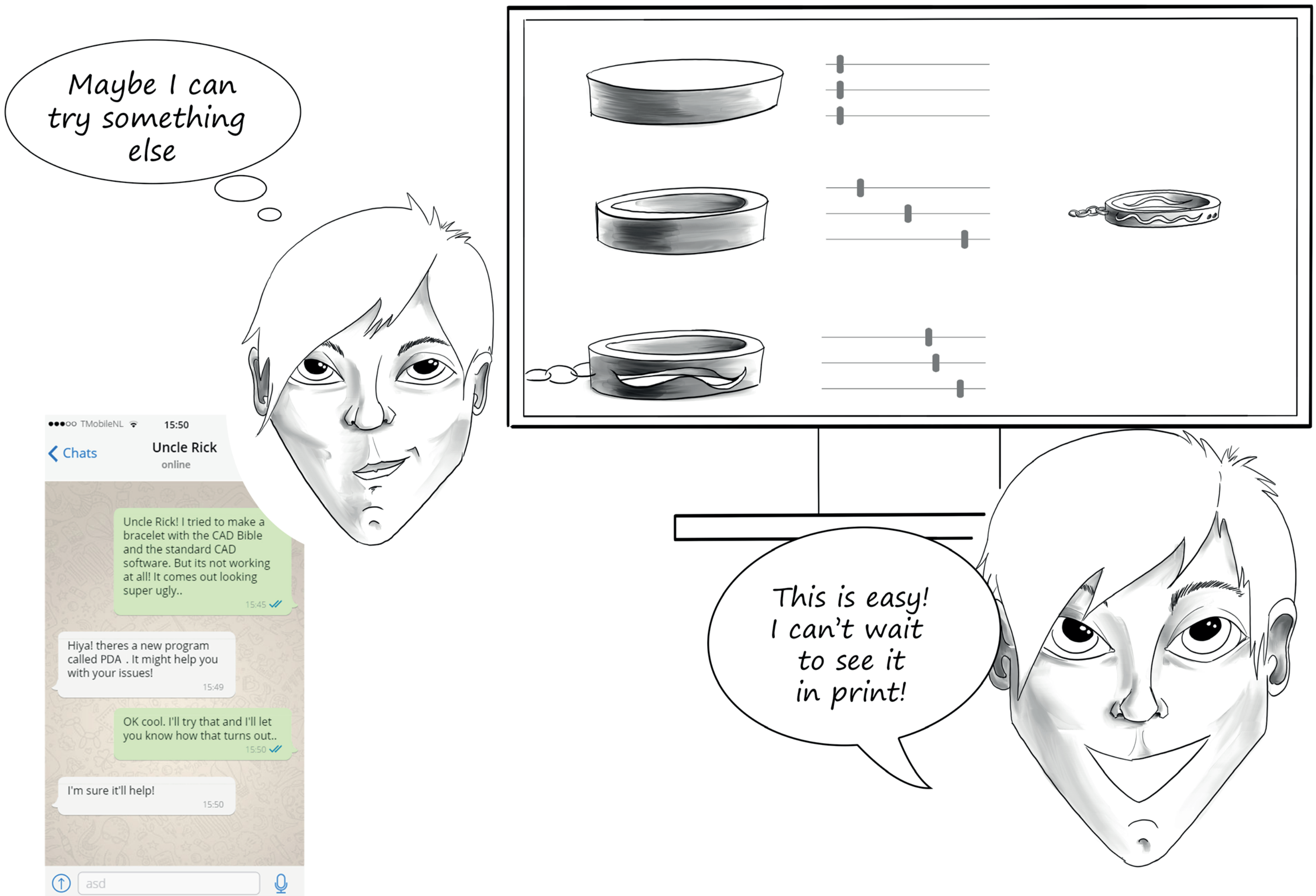
Figure 1.22: PDA-Framework

Analysis

Scenario



Analysis


Maybe I can try something else
TMobileNL 15:50
Chats
Uncle Rick
online
Uncle Rick! I tried to make a bracelet with the CAD Bible and the standard CAD software. But its not working at all! It comes out looking super ugly..
15:45
Hiya! theres a new program called PDA . It might help you with your issues!
15:49
OK cool. I'll try that and I'll let you know how that turns out..
15:50
I'm sure it'll help!
15:50
asd
This is easy! I can't wait to see it in print!

2 Concept synthesis

Concept Synthesis

Assignment

The assignment is to support end-users in creating their own designs for 3D-printing, by creating Product Design Algorithms and to reflect on how the choices made during its creation impact the user's experience and the final products created with it.

Definition

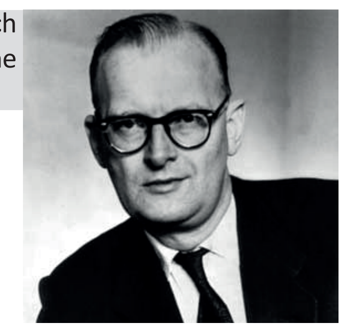
A Product Design Algorithm in this project is defined quite straightforwardly as such; an algorithm that "designs" products. More formally the definition will be: A process or set of rules automating the generation of a digital drawing for an artefact before it is made, depending on the input provided. The entomology and construction of this definition through combining the definitions of the parts making up the abbreviation can be found in the appendix.

Concept

A PDA's results are similar to a product line or product family, but different enough to justify a distinction. A PDA, analogously, produces variations by following the recipe but changing the measures. Another analogy is evolution. Individuals of a species are fundamentally quite similar but superficially different due to the genes inherited. A product species is what the PDA provides and an individual product is conceived by the user tweaking the genes. It should not be made to facilitate the creation of just one product or even multiple copies of the same design; rather its purpose is to facilitate the creation of endless combinations, preferably by numerous Am's, within the boundaries set by the creator of the PDA. The Am is unaware of what goes on inside the PDA and shouldn't be concerned as it should feel as a facilitator for their creativity.

"Any sufficiently advanced technology is indistinguishable from magic".

Quote by Arthur C. Clarke which describes the moonshot goal for the project



Concept Synthesis

PDA schematic

The interaction is illustrated schematically in figure 2.1 and consists of the following agents: The user, the track, the PDA, the display, inputs and outputs. The relation between the agents in the PDA can be seen as well. The Am enters the track with the ambition to create a product file to materialise via the printer. The track leads the Am along providing clear direction and hierarchy in decision making. They visit the different points to provide input to the PDA. The PDA processes the input and communicates the progress back to the Am.

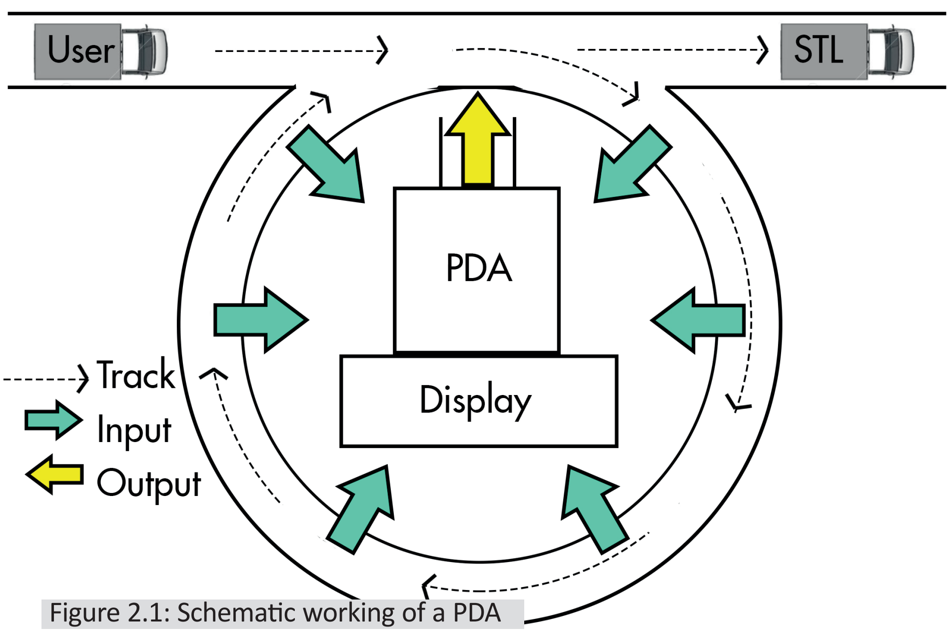


Figure 2.1: Schematic working of a PDA

They can visit points once or repeatedly depending on the design of the track and the wishes of the Am. Once the Am is content with their result they can collect their output and precede to the next phase, which is primarily 3D-printing the file, but this lays beyond the scope for this project. The design of the PDA-model is multi-layered, much like an onion. The deep inner layer is where the algorithm resides and is hidden from the Am; basically a black box. The second layer is the interaction layer. This is where the Am and the PDA work together to create the product. It consists of the various input opportunities and the feedback information communicated back to them. The third layer is dubbed the track. It guides the Am through the design process and encompasses the complete design journey, whether it is linear or otherwise. Each of the layers must be well designed for the complete model to work.

By making the PDA like this, the expectation is that it should be able to increase the ease of use and the perceived freedom. The hidden layer should ensure that users are unaware of all the extra help they get and therefore retain their sense of authorship.

Concept Synthesis

Choices

After having discussed the concept of the PDA and having explored the intended new audience it is important to understand where and how the two should connect. Every choice has its consequence and for the concept of the PDA it is not different. The intent to set the bar low in regards to the required skill level will reduce the amount of design freedom. A challenge for this project is to form ideas about how to balance these two variables and more importantly the perceived experience of these two. Choices can be offered at specific points in the design cycle and in various ways. The expectation is that it matters how a choice is presented and when.

To further illustrate this, the following example is used. In a normal design process designers have an idea what they want to design, for example; a seating solution for a single person (chair). They are then confronted with choices determining the final design of that solution. In this example, the design cycle is simplified to include only four moments in which the designer makes a decisive choice. The choices are: number of legs; height of the chair; shape of the back; and whether the chair looks rounded or jagged. A maker of a PDA that produces the same products would be confronted with the challenge of which choices to present to the user and how. He could, in this simplified example, choose to exclude the choice for the look of the chair and decide that it will only produce rounded looking chairs. The other three choices however, are decided to be included and create a 3-dimensional solution space (figure 2.2). The Pro then has to decide how to offer the Am control to finalise a design. The height of the chair could be a parameter that follows the specific user's own height, making it a passive variable. The number of legs could be an integer between one and four, and would change other things about the design, making it an example of indirect control. The shape of the back could be manipulated by the user through an input option, making it an example of a directly controlled parameter.

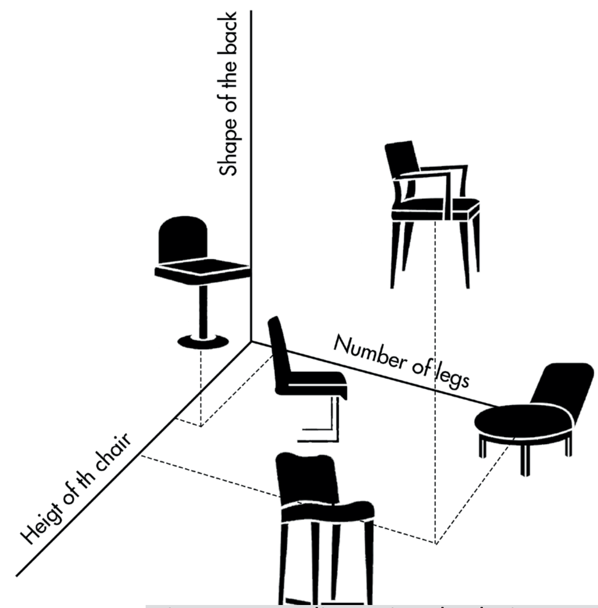


Figure 2.2: 3-dimensional solution-space

Concept Synthesis

Categorisation

Apart from the things previously mentioned regarding what choices and when, there is also the effect. Decision moments can be understood as micro interventions on parameters changing the design of the product. To better understand what kinds of interventions are possible, they can be divided in the following categories.

Direct control - The user directly controls one parameter. For example: the height of a coffee cup.

Indirect control - The user controls multiple parameters at the same time combined into a subjective parameter, while they interact to ensure a correct design solution. For example: the "roundness" of the ear on a coffee cup.

Passive parameter - This is a parameter that is specific to a user and results from innate attributes. For example: left- or right-handedness for the orientation of the ear on the cup.

The maker of the PDA has to decide where the transition of control benefits the experience (ease of use, perceived freedom and sense of authorship) and where it benefits to withhold design decisions. In addition to this there is the question of how much control and how to give that control.

Experience

The three-layered onion model reveals two layers that directly influence the user experience and one that does so indirectly. To discuss the user experience it is sometimes convenient to regard them individually; however it must be stated that they are experienced holistically by the user. In other words, if one of them fails to provide a satisfactory experience the whole is regarded as such.

Black-box inner layer	Interaction layer	Track layer
Choice of product	Types of input	Design story
Attributes to control	Types of feedback	Guide user
Exclusion of control	Direct vs. Indirect contro	Provide insight in choices
Ensure validity	Depth of control	Combine sub-tasks
Magnitude of control		

The attributes of the first two layers have mostly been covered in the previous chapters. Little insight has been given however into the last layer. The Track might be the distinctive part in this concept, because elements of the other two can be found in other customisers, though not as extensively as in the PDA. For this reason it is essential that this layer gets a more extensive explanation.

Concept Synthesis

Track

The Track is the first thing users encounter, introducing them to the jaunt they are about to embark on, metaphorically acting as a guide until the destination is reached. The track is where the creator of the PDA communicates hierarchy and order to the users by offering certain choices before others and letting the user easily return to some while discouraging this for others. The grouping of decisions is an aspect expected to influence the experience. To illustrate this take the example of the chair. A creator might want to make sure a user commits to an amount of legs before detailing them further, much like a traditional design process. This works very similarly to when designers define the design process for their own work. This is where they normally document and plan the structure. Instead, when working on a PDA, they would have to define the design process for the user. It can be compared to LEGO instructions (Fig 2.3) where the designer has left the user with a clear guidance; tasks and subtasks; and a suggested work-flow.

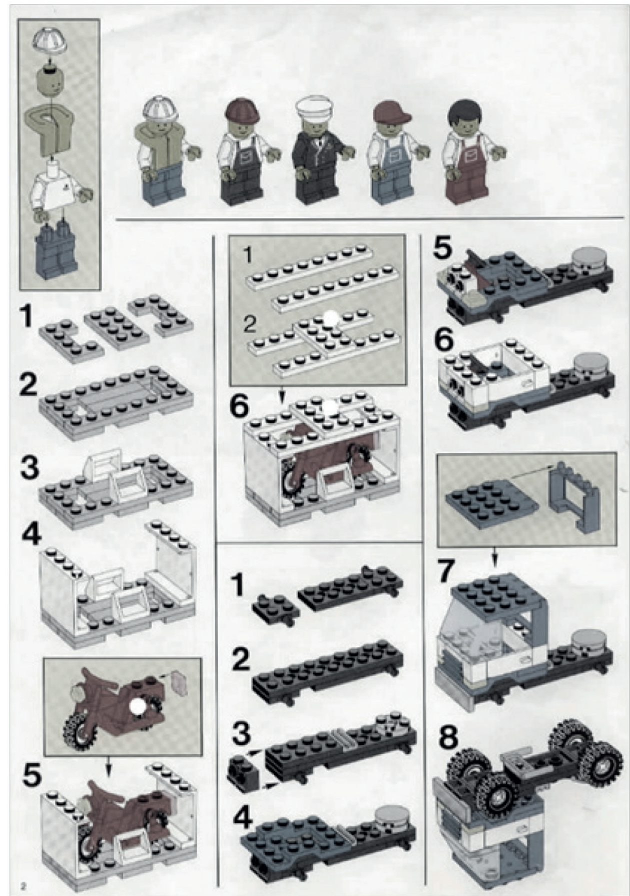


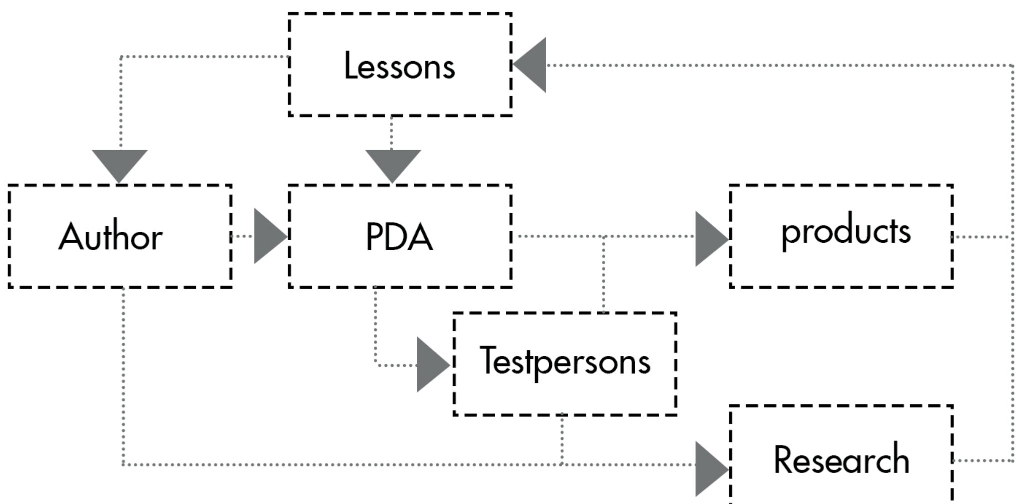
Figure 2.3: Lego instruction manual

Concept Synthesis

Development

This project's aspiration is to iteratively gain insight on how to design the PDA's well, by prototyping and testing. The author of the project will perform the role of designer as well as researcher. This poses a dilemma, as it would be ideal to include designers as a test group. To simplify the project and reduce the run time it was decided to limit the scope to only include the users as a test group. The consequences will be increased focus on the effectiveness of the PDA's themselves instead of the difficulties creating them. However it might give results that are specific to the one designer in particular.

The end-result of the project, which includes a framework for other designers to use when creating PDA's, shall remain untested. However, due to the novelty of the concept and focus on it, rather than the meta-implications, this is justified. The research on the prototypes is done by letting Am's interact with it; studying their behaviour; and interviewing them afterwards about their experience. The expectation is that the PDA-framework should be used like this in the future as well.



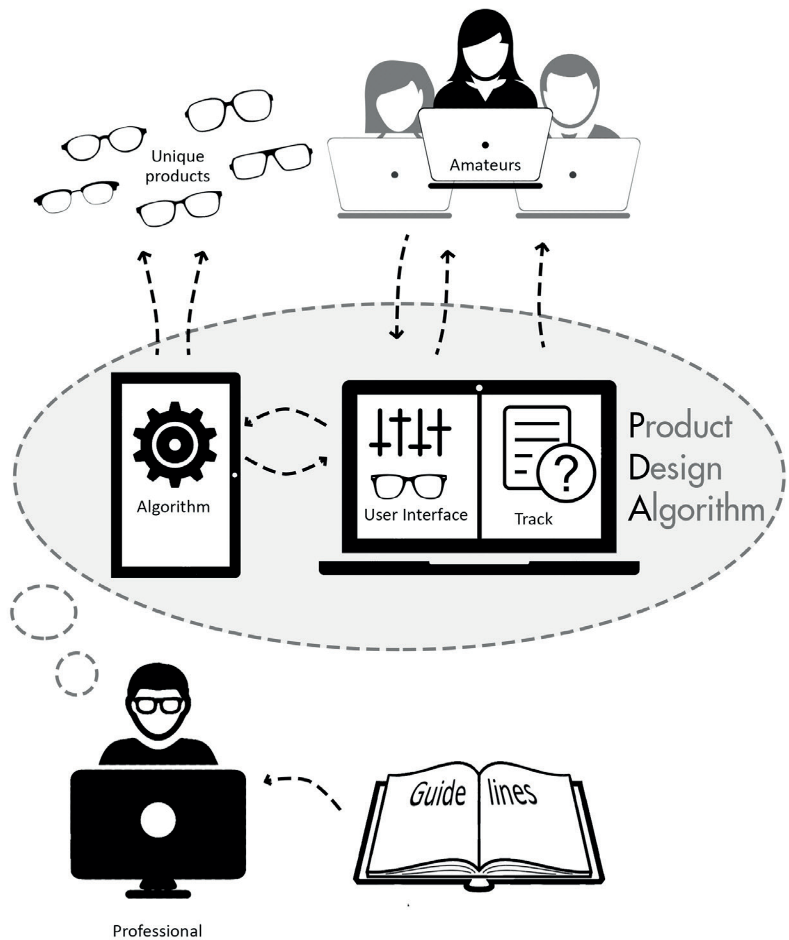
Concept Synthesis

Unique Selling points

The basic function of the concept is the same as its competitors, facilitating a user to get from idea to digital file. It distinguishes itself by trying to combine two benefits from the ends of the spectrum of competitors while ridding itself of their disadvantages as much as possible. In particular, the two competitors it aspires to combine are the sandbox-type CAD environment and the customisers.

From the sandbox-type CAD environment it differs because it tries to omit the blank canvas problem by starting at a specific product-type, whilst trying to retain as much freedom from there on. This means there is a lot less strain on the software because its not designed for total freedom. However, the expectation is that the user will have a lot of perceived freedom, because from the starting point onwards they will be able to make whatever kind of that specific product they want.

From the customiser it differentiates mostly in ambition and scope. Where most customisers allow the user to make slight adjustments or make a selection from pre-set choices, the PDA tries to give enough control to manifest original ideas the user has beforehand. It however retains the translation from technical transformations into a comprehensible format.



3 Practical synthesis

Practical synthesis

Introduction

Simultaneously with the development of the conceptual framework, there was an iterative design process for the practical application. Both developments worked together feeding into the concept as a whole. The prototypes therefore worked both as presentations of the theory as well as research subject improving it. This chapter will explain how the prototypes where build, what influence they had on the PDA-framework and it will conclude with the final practical implementation. This final design serves as test subject for the evaluation of the framework as well as an example of the framework in practical use.

Interface level. This is what the amateur will interact with when using the PDA. Plug-in running in Grasshopper

Parametric modeller that facilitates the script building by the professional that generates the geometry. Runs on the Rhinoceros engine

CAD-environment that actually runs all the operations called for by the Grasshopper script.

Platform

There are numerous methods for creating PDA's. Programming languages like Processing, JavaScript or C# are more than capable of reaching the level of functionality and interaction achieved in this process. However there were some reasons why Grasshopper was used during this project and why this thesis could recommend it for future endeavours as well. The fact that this programming language exists within a CAD-environment and can address the operations present within it offers a serious benefit. By tapping into these operations designers can prevent themselves from having to reinvent the wheel, reducing the development time. Combine this fact with the visual nature of the language and the learning curve for new users drops dramatically. These reasons are responsible for an endemic spread among students and professionals in the architectural world. The Grasshopper environment provides an intuitive way to explore designs without having to learn to script, but learning the fundamentals of scripting subconsciously along the way.

Grasshopper explained

All the implementation of the PDA-framework was done in Grasshopper. Grasshopper is a visual programming language and environment developed by David Rutten at Robert McNeel & Associates that runs within the Rhinoceros 3D (CAD) application. Programs are created by dragging components onto a canvas. The outputs to these components are then

Practical synthesis

connected to the inputs of subsequent components. Grasshopper is primarily used to build generative algorithms, such as for generative art or architecture. It is used as a means to an end, by a designer and has of yet few applications for amateur end-users. In this project however, the goal was to have an amateur interact with a design. The software is open-source and this has led to a lot of third party plug-ins, one of which was used during this project.
There are of course drawbacks as well. One of its major strengths is also weakness, as being confined to the CAD-environment also limits the options. Much like the PDA-concept there is a trade-off, where freedom is exchanged for usability.

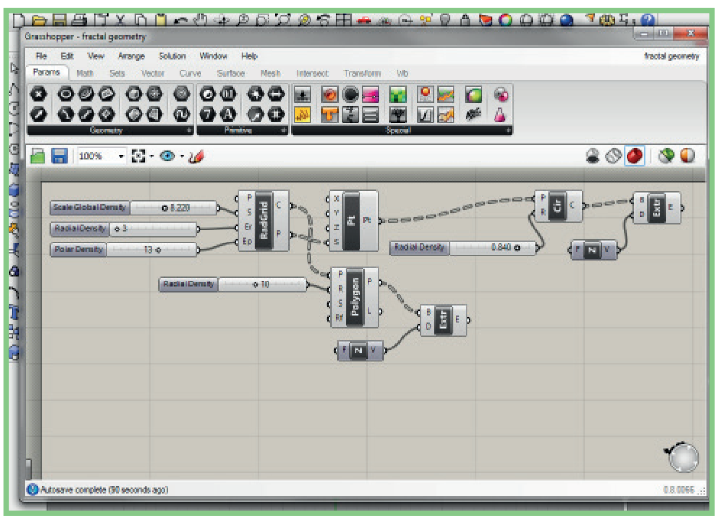


Fig 3.1: Example of a generative script using Grasshopper.

Human UI

The Human UI plug-in was created by a third party for its own use and later shared with the community because of the open-source nature of the platform. This add-on proved to be extremely beneficial as the natural Grasshopper environment is a prototyping tool, and looks like that as well. This add-on allowed for an extra layer on top of the algorithm for the Am's to interact with. It could be compared to the CSS component of a website. It allows the Pro to hide the algorithm and create a stylised user interface for the use of the PDA. The drawback of this plug-in is that it doesn't offer many possibilities it offers, nor is it as user friendly as Grasshopper itself. This a drawback that can be found in many open-source solutions, but this may improve in the future if more people where invested in its use. For the scope of this project it proved adequate when it was pushed to its limits. This plug-in is called Human UI and was made by Andrew Heumann from NJJB, an American global architecture, planning and design firm with offices across the globe.

Practical synthesis

Method of creating the PDA

The prototypes and the final design are created in similar ways and always start with a blank canvas and an idea. By explaining the method with the prototypes used as an example it becomes apparent what the creation process is like. However firstly, it is important to show a quick overview of the process before delving into the details.

1. The Grasshopper environment, running within the rhino environment, starts off with a blank canvas. The blank canvas is where the script is made and will contain both the components for creating the product and the user interface.

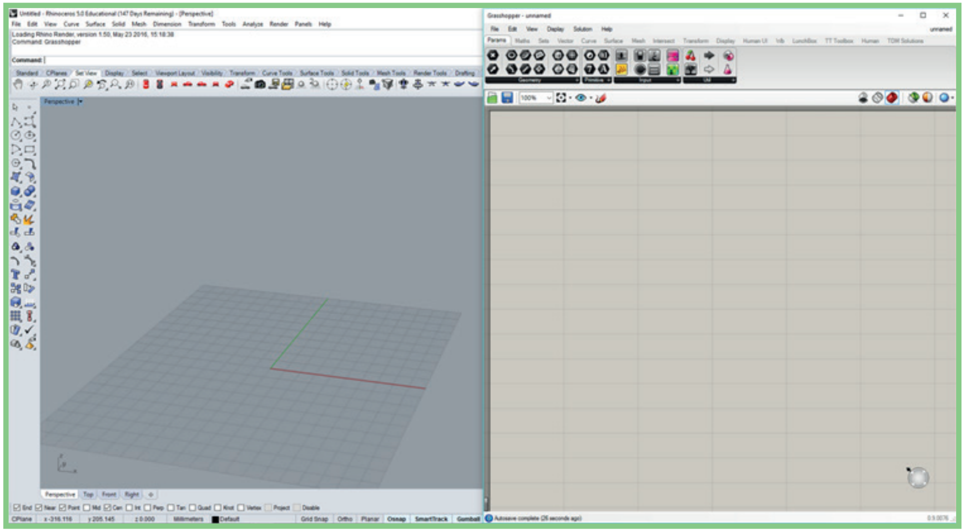
2. The first step in the process is creating the foundation for the product. This is done similarly to creating a model in with CAD with the exception that all the steps are formalised and their inputs are kept as variables. A lot of thought goes in to deciding which variables drive other parameters.

3. The second step is checking whether the model still delivers geometry when the input is changed. This is actually one of the most difficult aspects of the creation of a script, as it should work with all possible combinations of input. This will almost certainly cause the creator to re-evaluate and change the design. When the Pro is content with the algorithm, he can move on to the user interface. This is scripted as well and connects on several places to the design of the product. Where it connects is determined by the Pro and results from the options they want to give the Am when using it.
4. The next step is creating the Track. Naturally, the foundation for it has been laid with the choices in control over input and architecture of the product.
5. As a final step, the pro should test his model with Am's to see if the PDA reaches desired results. This will most likely cause the Pro to go back a few steps; make adjustments; and test again.

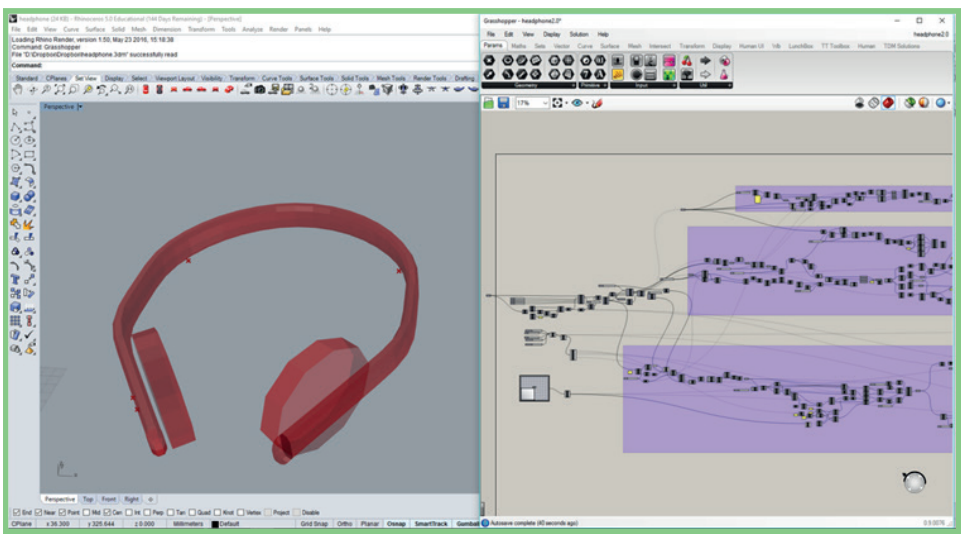
It's important to note that while this is presented in a linear fashion it is much more iterative in nature in practice. A pro starts with an idea on all the steps but will be forced to start with the first few steps and most likely have to go back to them after testing it. To illustrate this further one of the prototypes used in this project will be discussed.

Practical synthesis

Headphone prototype



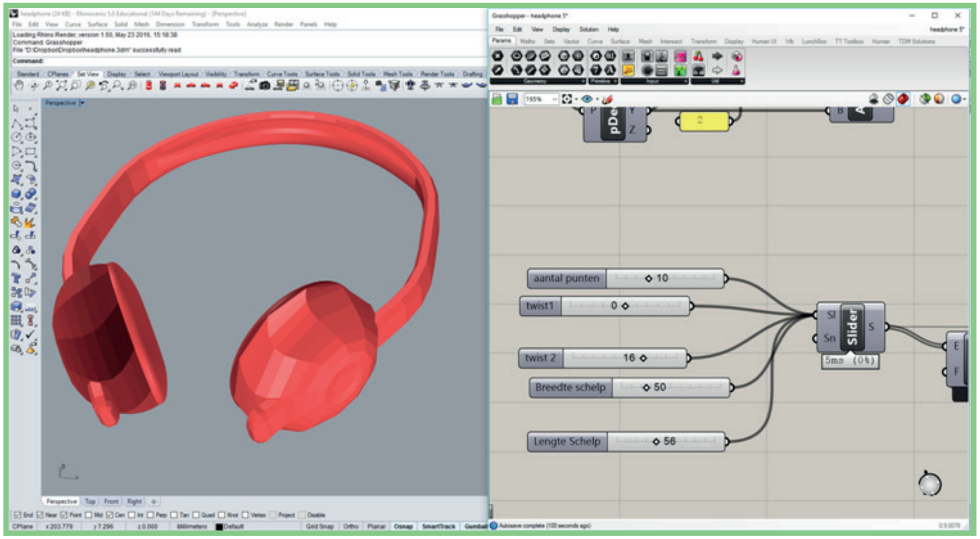
This is the blank canvas. On the left is the rhino environment with all the functions visible in the toolbars. None of these will actually be used, but what is being use is the preview window where the geometry created in the Grasshopper script will appear. On the right is the Grasshopper canvas.



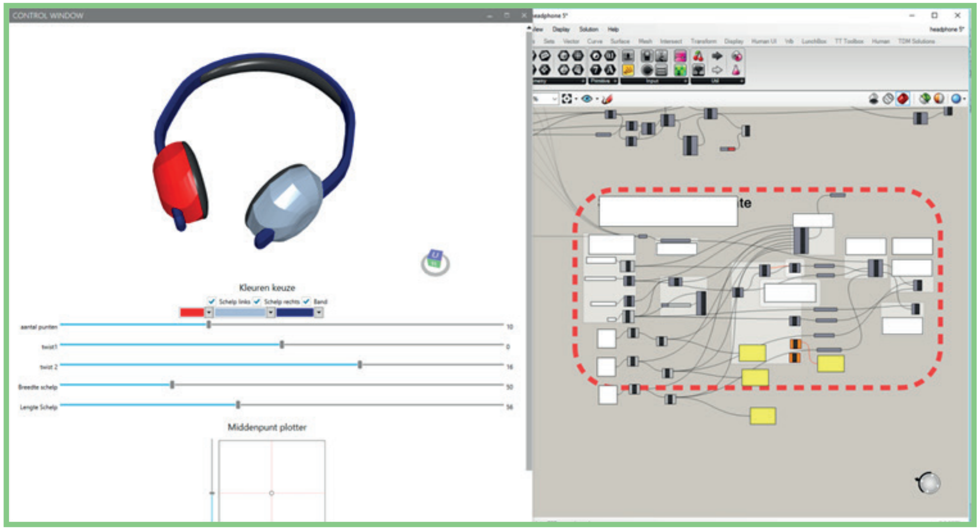
The goal for this prototype was to generate headphones. On the left is the preview of the generated geometry at this stage. On the right are the connected components that create the headphone. In order to have a nice overview, groups of components are clustered that form a specific step in the design process.

Practical synthesis

After having thoroughly tested different input combinations a sufficiently finished headphone is generated. On the right is a zoomed shot of the code. The sliders in the middle of the screen are some parameters that drive the design of the model. By changing these, the appearance of the headphones change accordingly.



This is where the user interface is introduced. This new window is what the Am's will eventually use to create their unique products. While this is being designed, the Pro is continuously switching between the UI-, the Rhino-, and the Grasshopper window. When the Am will use it this will be the only thing it interacts with.



Practical synthesis

Prototyping

The project as a whole can roughly be split in two parts. Both parts where heavily filled with a continuous interchanging repetition of the following steps; research, building prototypes, testing the prototypes, draw insights to include in the next prototype. The first part was filled with the aforementioned quick prototypes. They were short endeavours taking only a couple of days to create. Each time, they were completed completely from sketch and usually to try a limited number of design ideas. This was done to keep them from becoming cumbersome as often happens when writing large scripts. The testing on them was informal and quick for the same reason. The intention was to gain as much insight as was possible in the shortest amount of time.

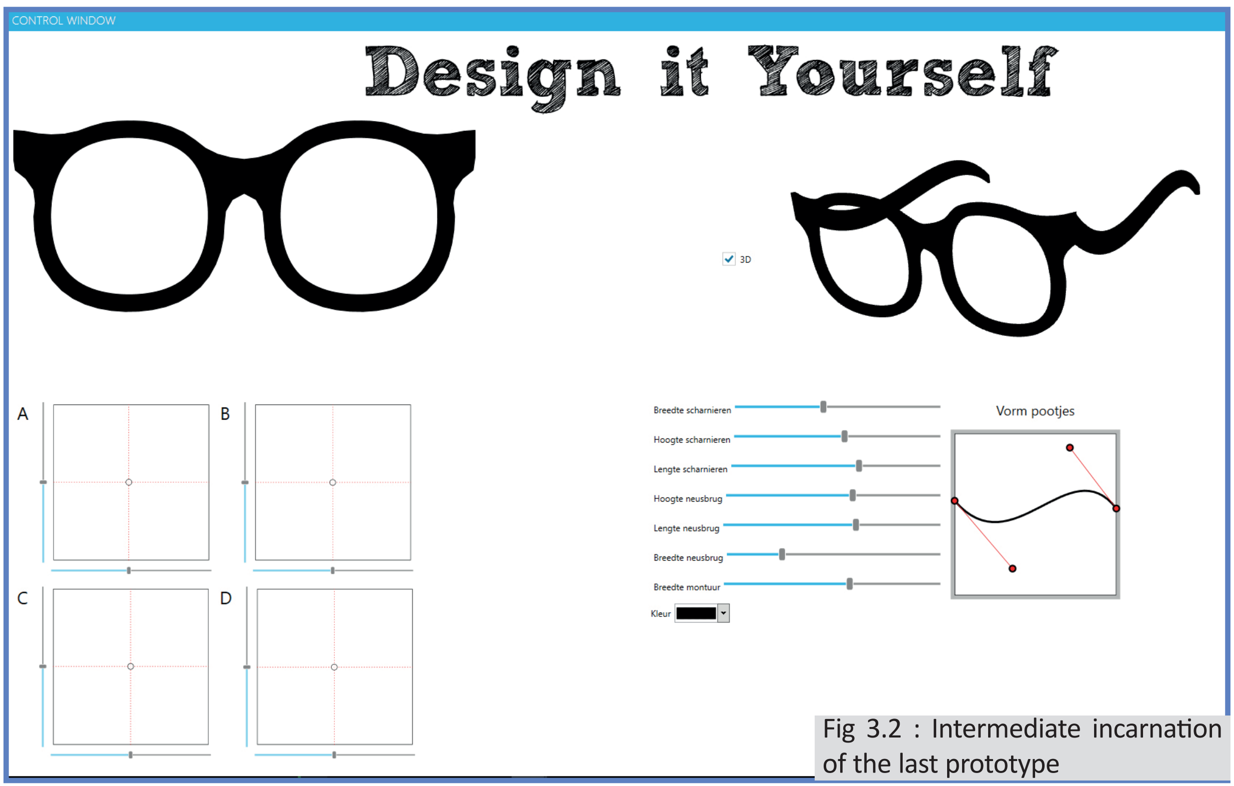


Fig 3.2 : Intermediate incarnation of the last prototype

Practical synthesis

Introduction to Spectacle

At around the midway point another focus was chosen. Rather than continuing with this fast messy method of prototyping several products, it became the continuous improvement of one model. The Spectacle concept was made to: build the theory; test the theory; and show the theory. This model, its final form presented in the next chapter. The tests with new user were conducted in a more formal manner and were focused on iteratively improving the model

Reasons for choosing glasses

Before presenting the final design case it is interesting to explain why the glasses were chosen as a good medium to test with. There are several reasons glasses make an excellent product for a PDA.

3D printing reason

The first reason is from a 3D printing perspective, as glasses are valuable, relatively small and highly personal. While 3D printing still endures a high production cost and small build platform these are qualities that validate using this technology. When the mechanical and aesthetic quality of the technology progresses this only becomes more important. It has recently even become possible to print optic lenses[19]. Being able to print the glasses in their “closed” position reduces the space it takes up in the printer and further reduces the cost. There are no electrical components and the product is not strained during use.

Topological reason

The second reason is from a topology perspective. Glasses arguably come in a wide variety and communicate a lot about who wears them. Most people immediately know what a pair of pilot (aviator) glasses or cat glasses are. However from a topological perspective there is hardly any difference, as almost all glasses have two legs, two lenses, a frame which connects the two and a bridge to find support on the nose. This lends it itself very well for any parametric design tool as minor differences in the parameters lead to a large perceived difference in products.

Figure 3.3: Topological difference between glasses and vases

Practical synthesis

To illustrate this further consider a vase (Fig. 3.3). A vase is personal and comes in a lot of variety, but it is much harder to find topological consistencies. The only actual consistency is that it needs to have room for flowers and water but there are many ways to facilitate this. This makes is much harder to make a tool capable of creating the examples of vases in the image. With glasses however, it is actually attainable to get good approximations of most archetypical models. The conjecture is that this will benefit the perceived freedom experienced by the Am.

Figure 3.4: Not all glasses fit all people

Fit for people reason

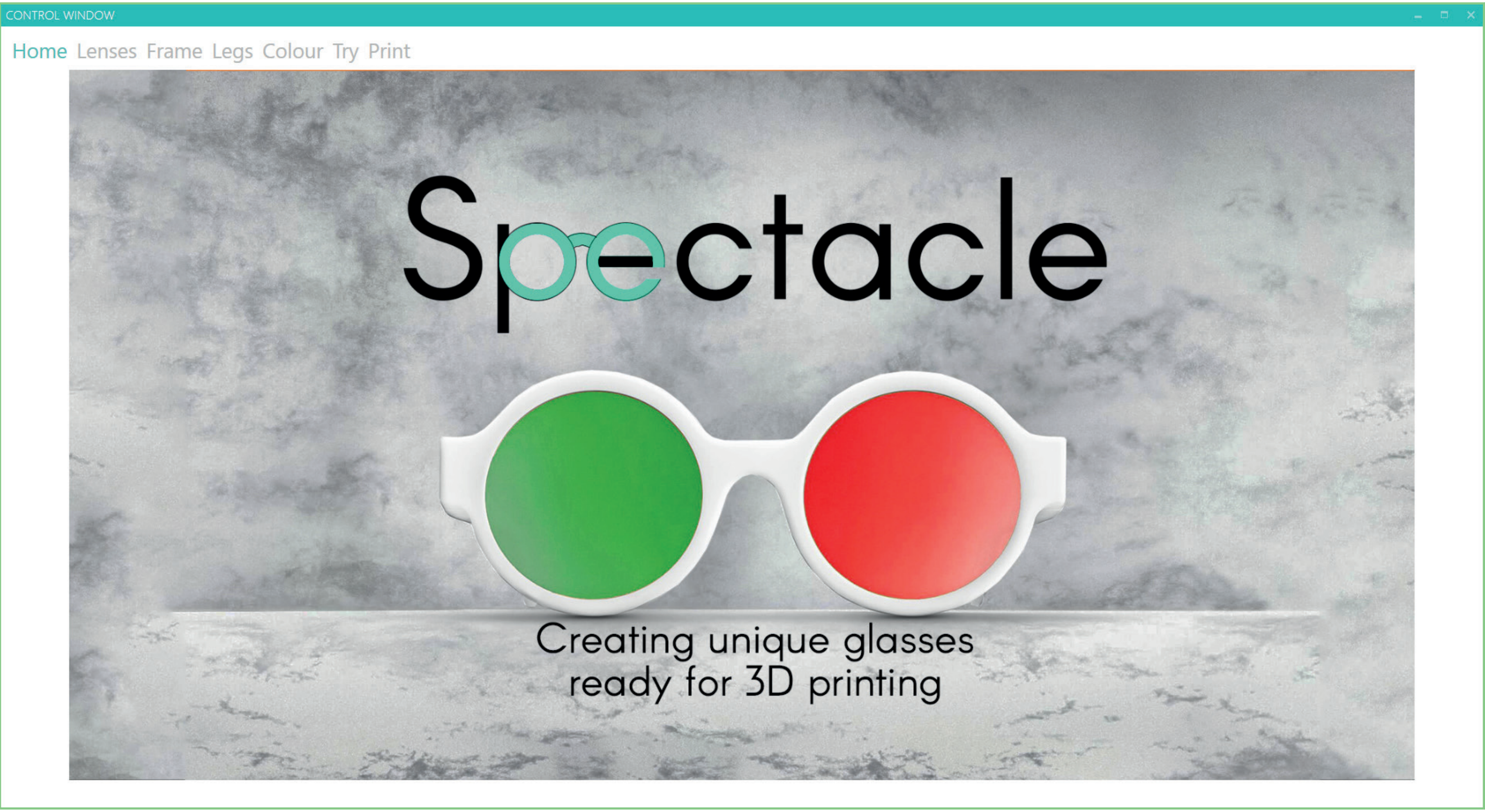
A third reason is that glasses are products that somewhat need to fit a body. No person is the same and therefore glasses need slight variations to fit the individual in question (Fig 3.4). A PDA could integrate parameters that are defined by measurements taken from the face structure for example. They could be measured by the individual, taken from a database or read from an input device like web-cam.

For the final design this type of human driven-parameters were excluded. This was done to keep the focus on the design aspect of the prototype but it is something that could easily be implemented if it would benefit the experience.

Suitability

It is good to realise that, especially considering 3D printing technology is still having teething problems, that not every type of product lends itself as good as some for this kind of applications. Any designer that wants to build a PDA should consider how the characteristics of a product match with those of the technologies in question.

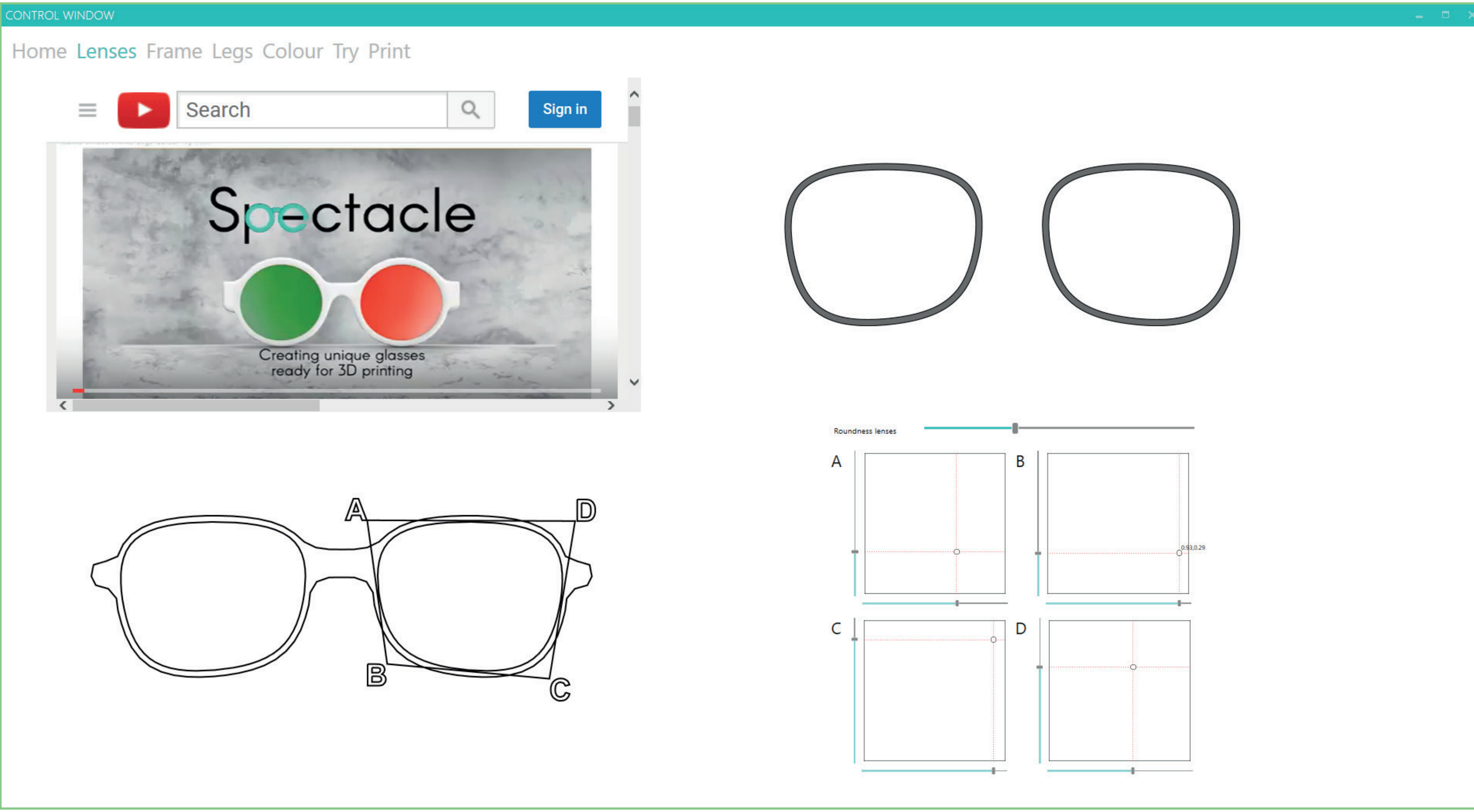
Spectacle



This is the home screen welcoming the users to the application. Like aforementioned this app, called spectacle, allows users to design their own pair of glasses. The process is cut up into different steps to prevent the user being overwhelmed by functionality as well as make sure that users follow a certain logical path through the design process. Although they are free to choose their own path. On the top-bar are tabs to navigate through the different steps.

The glasses in the welcome screen have the distinctive red and green glasses seen in 3D-glasses, this was done as a wink to the manufacturing process.

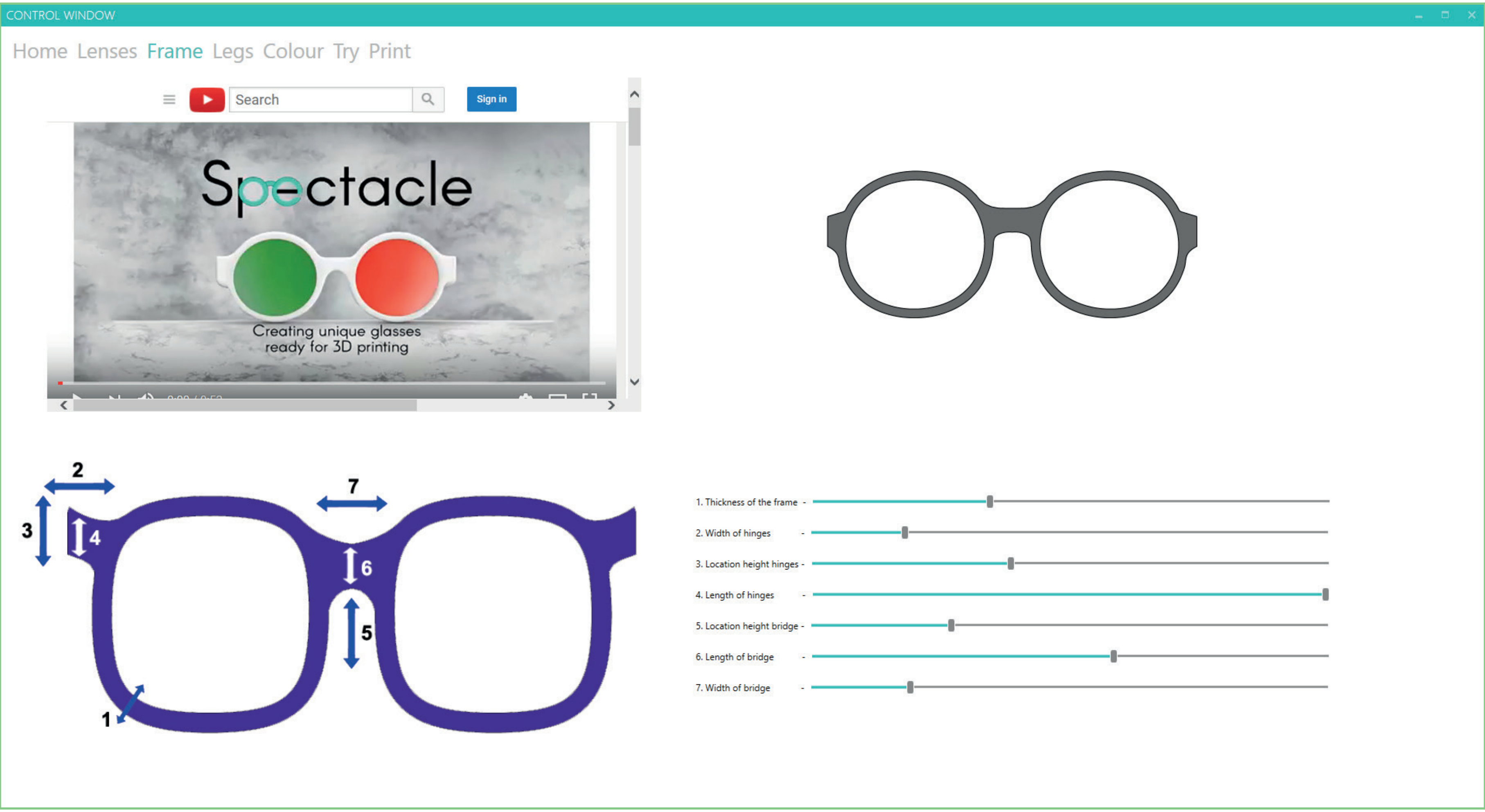
Spectacle



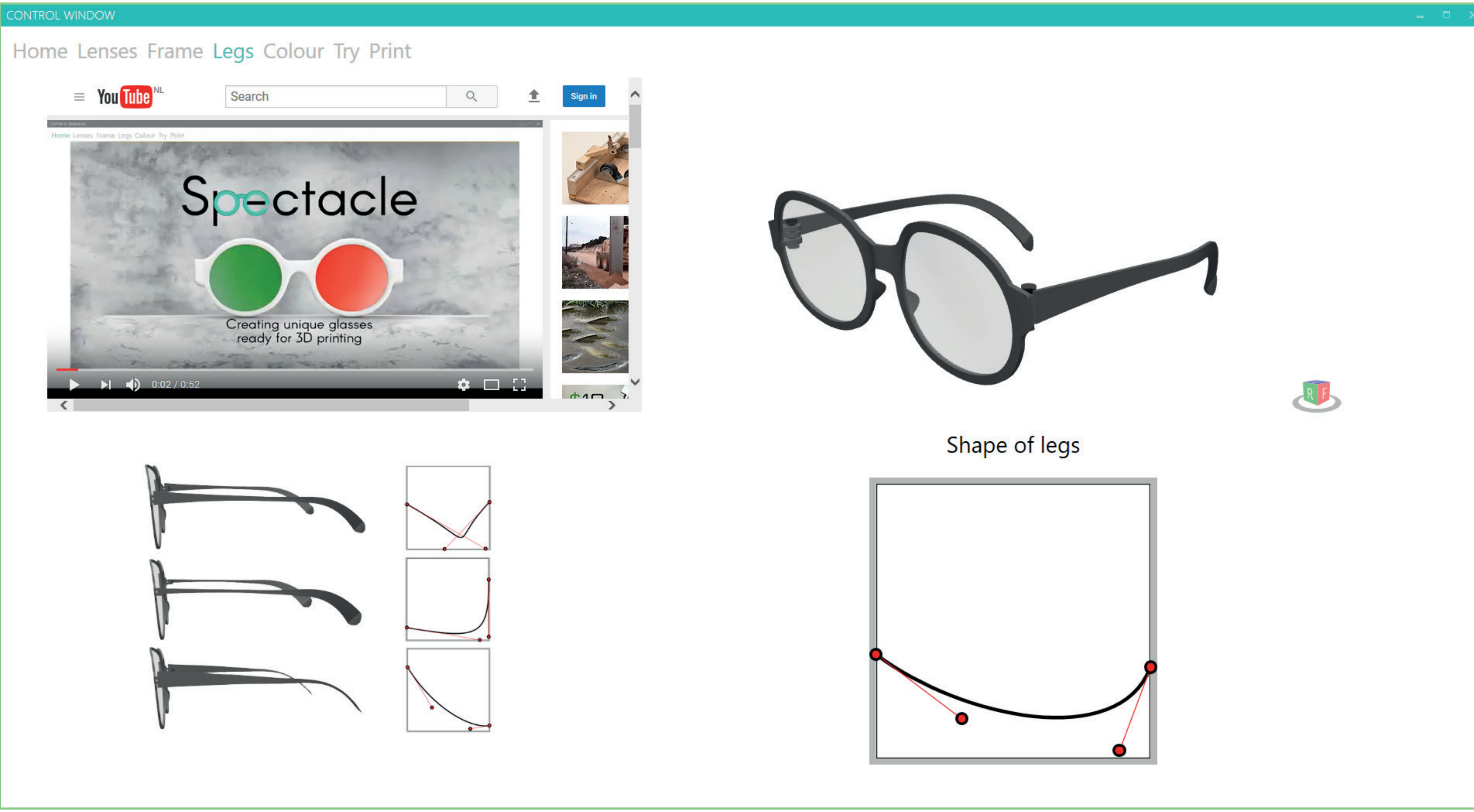
The first step is the creation of the lenses. A short introduction to the goal of this step as well as an explanation is on the ways the user is expected to provide input is stated on the right in a video (Digital Appendix) .

There are two different ways the user is allowed control over the design here. The first is direct control over a subjective parameter through the slide; this determines the “roundness” of the glasses. The second way is through manipulating four imaginary points with 2-dimensional sliders indirectly altering the overall shape of the lenses. The result is dynamically returned through the 2D shape image display.

Spectacle

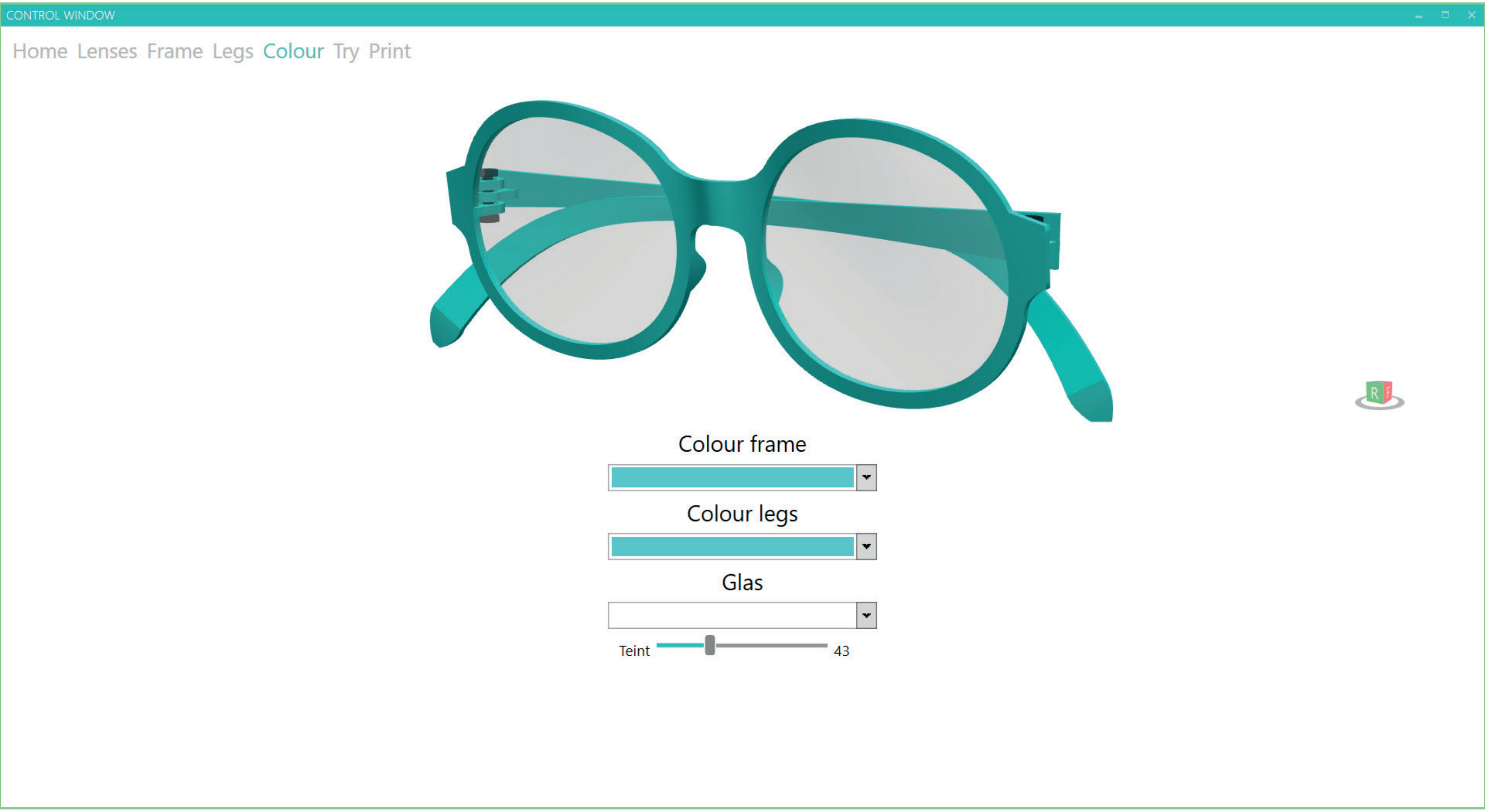


The seconds step is building the frame around the lenses. This step is similar to last one, although there are more variables here. They are all controlled through 1-dimensional sliders. Where the last parameters where subjective and indirect, these are the opposite. They each control one clearly labelled variable. Changing these might make the user want to return to the first tab to adjust the lenses according to the changes made to the frame. All the tabs update backwardly as well so any changes made further in the progress are saved and updated when the user takes a step back. This is to ensure the user feels comfortable with a more cyclical design process. A video explains the process (Digital Appendix).



The third step, shaping the legs, is a profound one. This is the first step where the user sees a 3D representation of their design. This model can be moved and rotated en allows the user to look at it from all angles while manipulating the input controls. Another video explains the process (Digital Appendix)

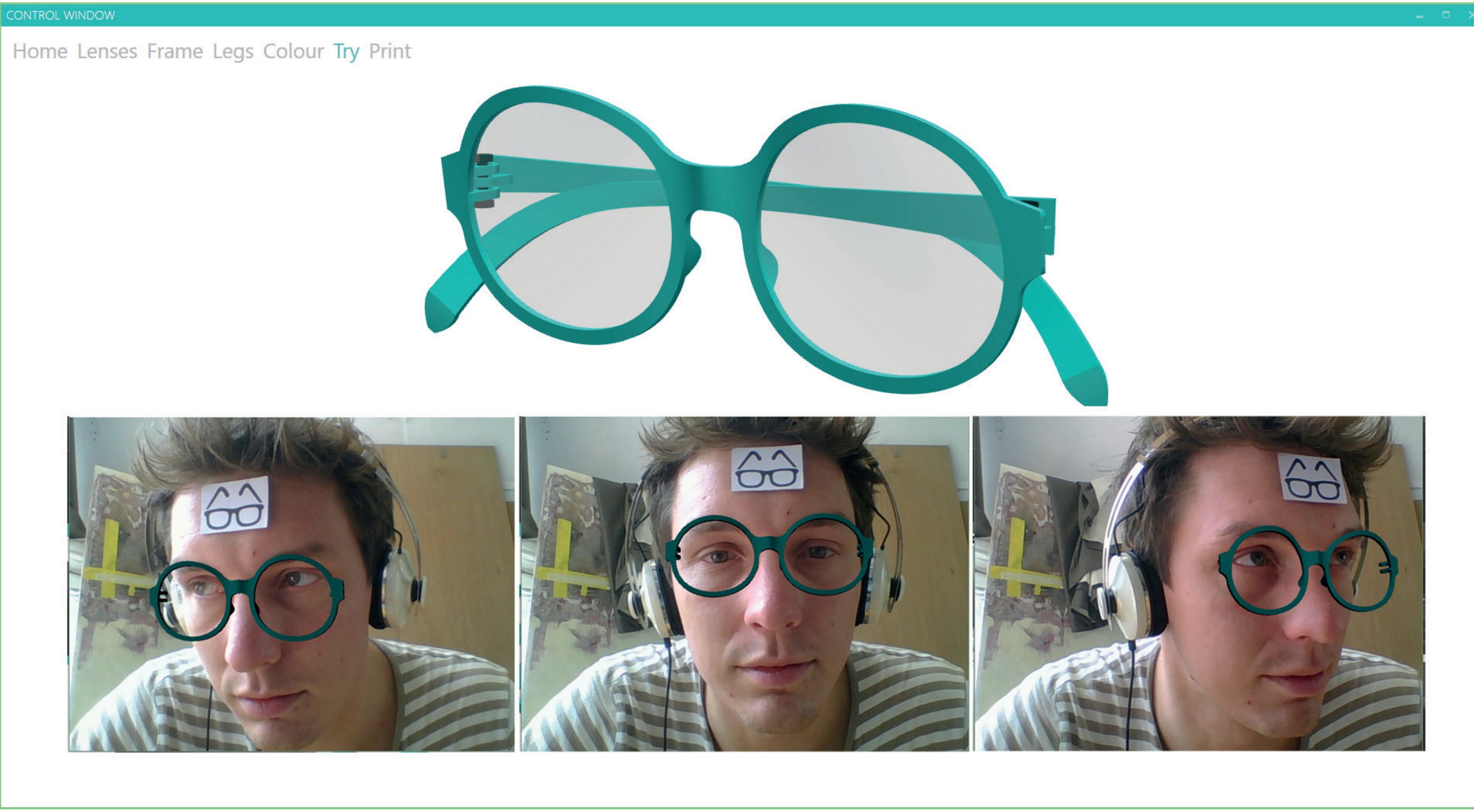
The parameter controlling the weight of the legs along their length are controlled via a Bezier-curve. This mathematical way of describing a distribution of material could be a bit confusing at first but because it is the only parameter in this step and it works kind of intuitively the user should fine.



The fourth step is choosing a colour. This is done by either selecting a standard colour from a set or by picking a specific colour from a hue wheel. The glasses have a neutral colour up to this point because it can't be shown without. Having this choice at this stage in the design process helps "claiming" the glasses as their own creation.

Off course, 3D printers are dependent on which colour material the users feeds them for the colour the product becomes, but this might change in the future. The actual glass can be varying degrees of translucent, which is mostly there for the trial phase. The next step where the user sees the glasses on their face.

Spectacle



The fifth step is not a step where users can provide input but they can make decisions. Mainly whether they are content with their design or whether they want to reject it and make adjustments. This is done by using a web-cam and a script in Processing, which takes the design and uses augmented reality to put it on the user.

If a comparison is made with a traditional design phase this would be the evaluation or testing phase right before going to production. This step will also nudge the user to approach design from a more cyclical perspective as they are forced to reflect.

Spectacle

The final step in the program would be to compile the file to be sent off to the printer. This isn't possible as of yet. Instead the user is given a nice render of their creation to help them imagine the materialisation. Other functions could include a cost calculation or a redirection to a lens-supplier for the custom lenses to fit the glasses.

4 Evaluation

Evaluation

Intermediate evaluation

The tests during the first phase of the project were quite unstructured and quickly performed. For the most time this consisted of getting a few test people from the direct surroundings. However, they provided a lot of insight and played a vital role in the development of the concept. For this reason an attempt will be made to put some structure where there was few and explain roughly what the test where about and what their consequences where. They will be discussed in a generalised fashion for this reason.

Research goals

There are two questions that sum up what these tests wanted to find out; how successful is this prototype in facilitating the design process and does the user feel authorship over there creation? In a more specific way it examined whether the functions were properly understood and in what form they were impactful on the design process as a whole. The first objective was to get people inexperienced with the 3D environment to reach a result but as most prototypes provided a result regardless of the input this quickly moved on. Some prototypes were aimed at testing certain input ways and others were targeted more at the cosmetic experience and the design instructions.

Figure 4.1: User using the application

Evaluation

Set-up

This was done through making function-specific prototypes. This means that none of them represented a fully operational PDA; rather a prototype was build around that aspect of the theoretical model that needed exploration. Users were asked to interact with the model and to vocalise their thought process, while being observed. When they finished the task they were asked specific questions regarding parts of the functionality and the experience as a whole.

Results

As aforementioned the goal of the test was primarily to gain insight in whether the prototypes performed as they were designed. There is little to say about this except that sometimes it did and other times it didn't. Where it didn't, new solutions resulted. What was more unexpected and valuable were all the results that surfaced that were never expected to be found. Aspects of the PDA-framework like the track layer only entered into the model after these test showed its importance.

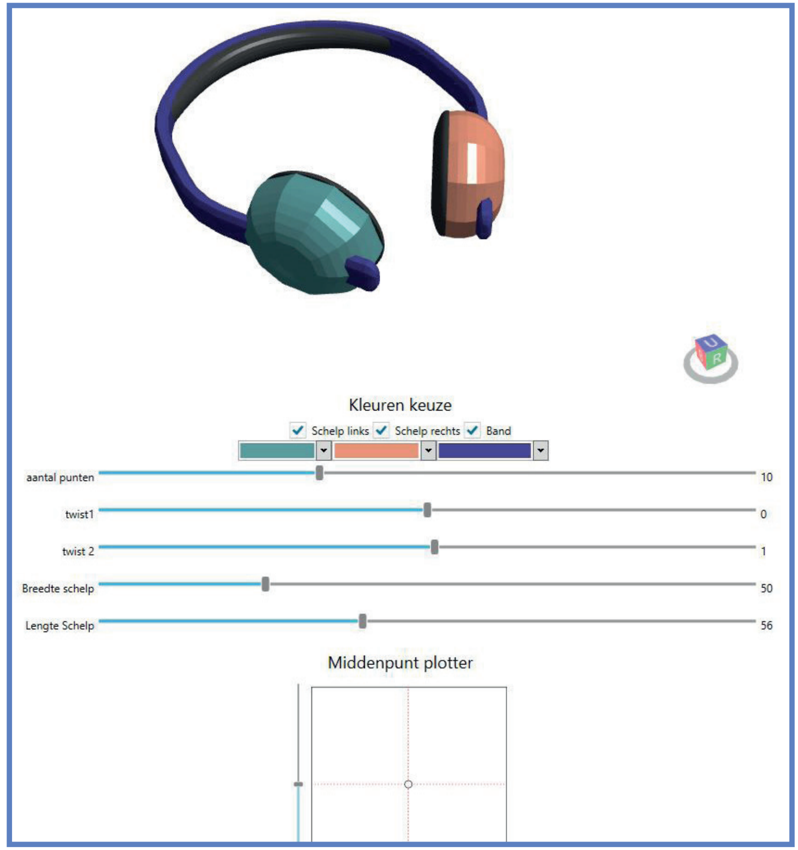


Figure 4.2: Intermediate prototype

Evaluation

User test Spectacle

The final concept, Spectacle, had three iterations which were tested with several people and the results were implemented to create the next iteration.
The first round of testing was much like the tests for the intermediate prototype. They were without a formal structure and served primarily as a way to quickly improve the concept and Beta-test for any bugs or faulty results.
The second round had a formal structure (Appendix 2.1) and can be viewed as the last opportunity to find problems and opportunities to make meaningful improvements. The third round was with a smaller group for logistical reasons and serves as the final test to evaluate and validate the concepts part and as a whole. To give as much insight in the process of improvement a summary of the three tests will be included in consecutive order. They implications of the results will be discussed together at the end.

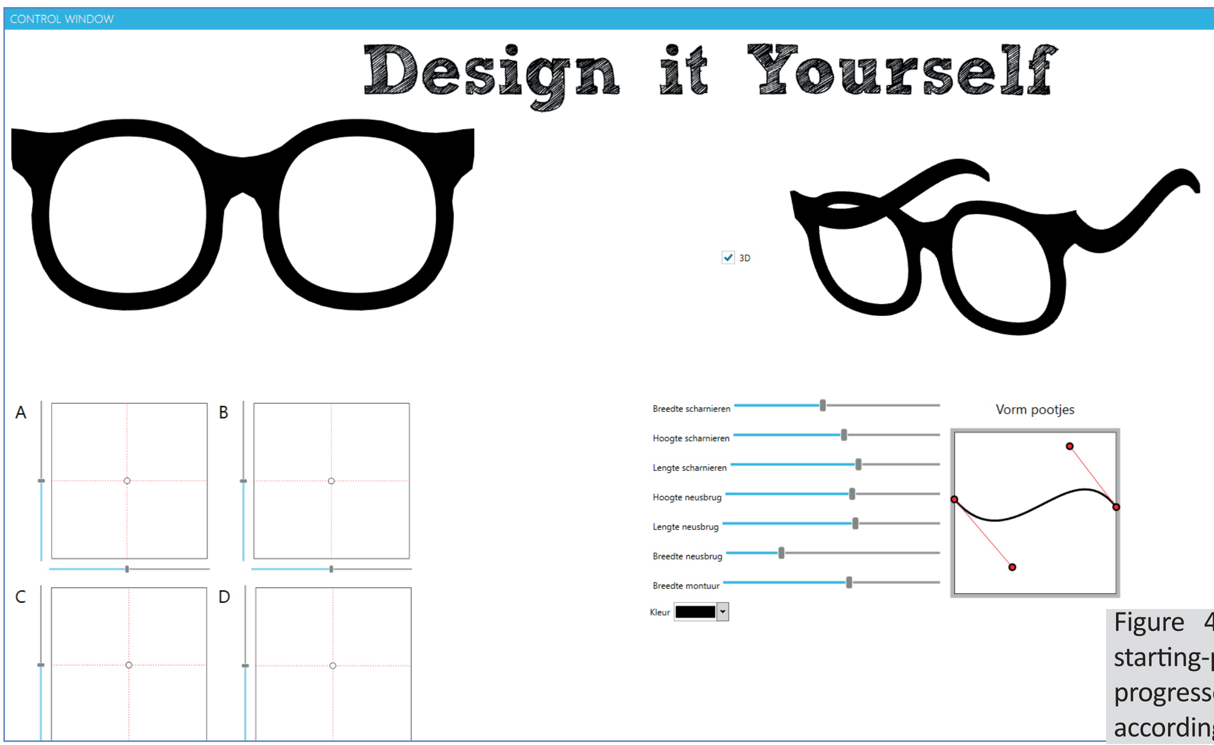


Figure 4.4: Beta test model starting-point. As the iteration progressed the model changed according to the results.

Evaluation

The Beta-test

Research goals

The goals for this test where for the most part technical but there where some indirect usability aspects as well. The goals included; finding bugs, deciding on different input ways, tweaking the limits for the parameters, improving on display ways and streamlining the algorithm.

Set-up

The set-up was comparable to the intermediate tests. A potential user was asked to execute the program and follow the steps while vocalising their thought-process and being observed by the author. Afterwards there was a reflective talk about the process as a whole. The test model was updated in between session where possible and there was no formal structure.

Results

The technical results regarding errors, bugs or balance tweaks will be left out because they are not as interesting for the development from a conceptual perspective; however it is important to note that fixing these was one of the main objectives for the tests. Any of these can be seen to be removed, improved or replaced in the next iteration. One of the most critical findings was that users felt overwhelmed by the lack of hierarchy in this iteration. The where not only lost on where to start but didn't experience the build up of a design process. Since the model was there when they started they felt they were merely tempering with- and tweaking a pre-designed model. This greatly diminished the impact of the perceived design freedom and sense of authorship.

"But...The model is already there, do I need to change it?"

"I find the controls confusing, is there no explanation?"

"How can I interact with the 3D-model?"

Quotes from the research

Evaluation

The 1.0 version test

Research goals

In contrast to the intermediate studies, which were aimed at testing the various functionality parts and how they played a role in the holistic experience, this study is primarily interested in the holistic experience. The goal is to test the Spectacle design proposal and try to find results that evaluate the theoretical model as well as this example of it in practice. Investigating what aspects influenced the sense of authorship, perceived freedom and ease of use was the primary objective. The aims to find out whether the test persons find Spectacle simple to use; how much freedom they experience; if, and how much authorship they hold over the result; and how this will affect their position on 3D-printing. It will also review the new functionality introduced after the beta prototype and how they impact the experience.

“I would like to try them on now..”

“...is like in a video game and I have the controller”

“Instructions...?”

Quotes from the research

Set-up

To achieve the goals set for this study the test persons are asked to interact with the application after having been given an introduction. They will be observed as well as asked to vocalise their thought process. The researcher will write down as many interesting observations and quotations as possible but will otherwise not interfere in the process. When the test persons reach the end and consider themselves finished they will be interviewed on the experience. Most questions have been prepared in advance but they can be expanded by any questions sparked by the observation.

Results

Part of the results from this text was taken into the final evaluation of the concept and part was used to improve the model for the final design. The latter will be discussed here. What became apparent is that the instructions that were added since the last iteration completely missed the mark. Users either didn’t read them or did so reluctantly. Another complaint was the lack of the model in context. It did however significantly helped the sense of authorship that the application was build up into steps. Starting with a 2D design and working towards 3D was a big help in this. An example of one of the interviews used during this test can be found in Appendix x.

Evaluation

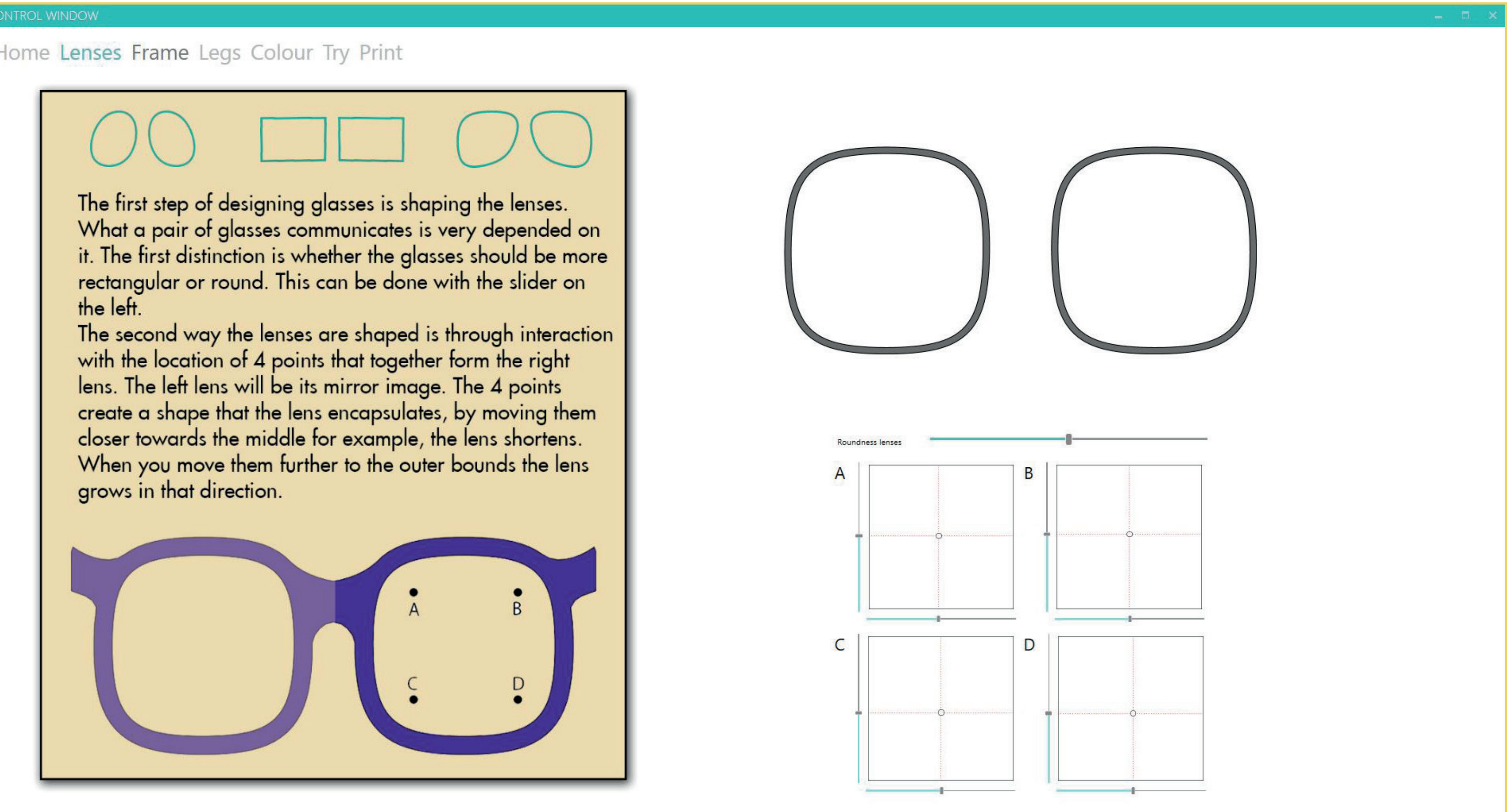


Figure 4.5: One of the tabs of the 1.0 version. With clearly separated steps and written instructions.

Evaluation

The Final concept test

Research goals

In contrast to the previous tests there would be no new iteration afterwards in this project. This did not mean the objective of finding points of possible improvement was negligible, on the contrary, points of improvement were now unhindered by technical limitations inherent to this project. This expanded the scope of the research to a more abstract level and focused in more on the purpose of the design rather than its technicalities. To really test the fullest interaction of this design the test-persons actually had their model 3D printed after the design process. The primary reason to do this was to find out the impact of the actual materialisation of their design opposed to having simply a digital rendering of the product. The aspect most important in that goal was the sense of authorship.

Set-up

For this test the final design was used as described in chapter 3. The set-up test was the same as in the last test with a few exceptions. To incorporate the augmented reality part of the design process there had to be an intervention by the researcher as that part of the process couldn't be successfully integrated at the time of the tests. Another difference is the added part of the actual printing. The test subjects came in after a week, when the prints had finished, to receive them and to have a follow-up interview. The reason for keeping the rest the same was to be able to transfer any results for the last test by comparing the differences the printing of the products had made.

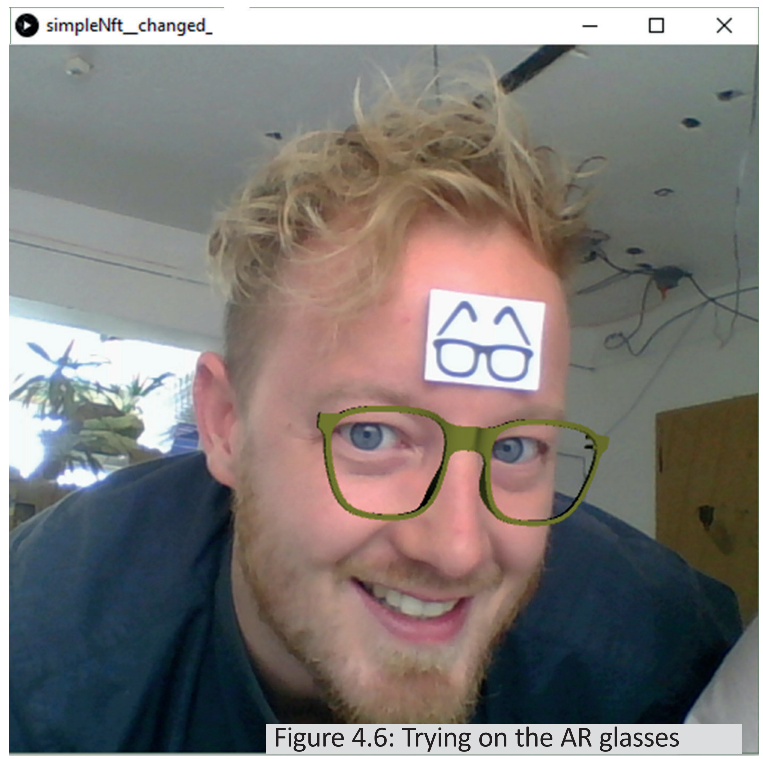


Figure 4.6: Trying on the AR glasses

Evaluation

Results

The result where very positive. The changes made especially to the Track in the form of adding video's really connected with the test-people. In addition to that was the success of the introduction of augmented reality, which worked much smoother than the solution in the last iteration where the model was displayed in a flat manner and the user needed to actively position their head. However the real impact really came when people had the actual 3D printed object in their hands or on their face. There were some surprises surrounding the difference between the digital model and the physical model. A difference like quality can be explained due to the nature of the type of 3D printing but is something that might be reduced with extra optimisation steps.

Other differences were more innate to the application. For example both test people found their glasses to be much thinner and more fragile than they expected.

Both participants wore each others glasses as well and claimed that it made them realise how much they felt authorship over the glasses. One of the participants told that he normally has difficulty buying off-the-shelves glasses because his head was quite narrow. The fact that his own design took this into regard furthermore increased the sense of authorship. The quality of the print was considered a reducing factor in sense of authorship. The option to design it yourself was seen as adding value, but the frailty reduced that.


Figure 4.7: Trying on the printed glasses

Evaluation

Research conclusions

The research served a threefold purpose. The first purpose was to continually improve the consecutive iterations of the designs and this has been discussed in the previous sub-chapters. The second purpose is to reflect on effectiveness of the solutions to the problem as defined in the analysis. That is to say, how well does Spectacle perform in reaching the goals set as an example of an incarnation of the theoretical model. The third purpose is to validate the choices made and to generalise them into best practices. The lessons learned from both the research and the design of the practical concepts are formalised in guidelines as part of the final result of this project. These guidelines are presented at the end of this chapter as they contain the practical application of the insights from this evaluation. Before this is presented in that form, the most significant or surprising lessons that sprang from the research and design are discussed below.

Track

One of the key insights was the necessity to provide extra attention to guiding the user through the design process. Early test showed that users were kind of lost with a simple customizer and without a clear process had a severe loss in sense of authorship. This is actually where most of the theoretical emphasis on guidance in design process came from which consolidated in the Track layer. The test that were done after the track layer was added, explored different forms and eventually settled on a combination of graphic and moving images and a step-by-step program for the Spectacle PDA. It became apparent that this became one of the aspects that really set the PDA-framework apart from parametric customizers.

Figure 4.8: Test set up of application

Evaluation

Testing

Another key finding from the test was the absolute indispensability of testing the prototypes. Much more than in a traditional design project, where you test for a few concepts or a final design, there are many tests necessary with a PDA. This is mainly due to the almost infinite combinations possible when a number of variables are left undefined. This goes both for the usability as well as the algorithm itself. Sometimes a certain combination of parameters can result in very unexpected and undesirable outcomes. Without thorough testing it is very hard to predict these “bugs”.

Authorship

The sense of authorship was a difficult thing to test for even with the physical products present. The fact that the prints were send in the mail from a factory that facilitated the 3D printing didn’t help. This undermined the experience of moving from file to physical in one go. One test person noted that it would have helped to see the machine do its work right after the design was done and by outsourcing this process another black-box was introduced. Because another agent was involved it was harder to claim pride over the complete process. Another peculiar thing is that the test people noted that they had designed something completely different from what they would normally pick out at a shop. It is hard to say what the implications are of that, but this could be something to explore in the future.

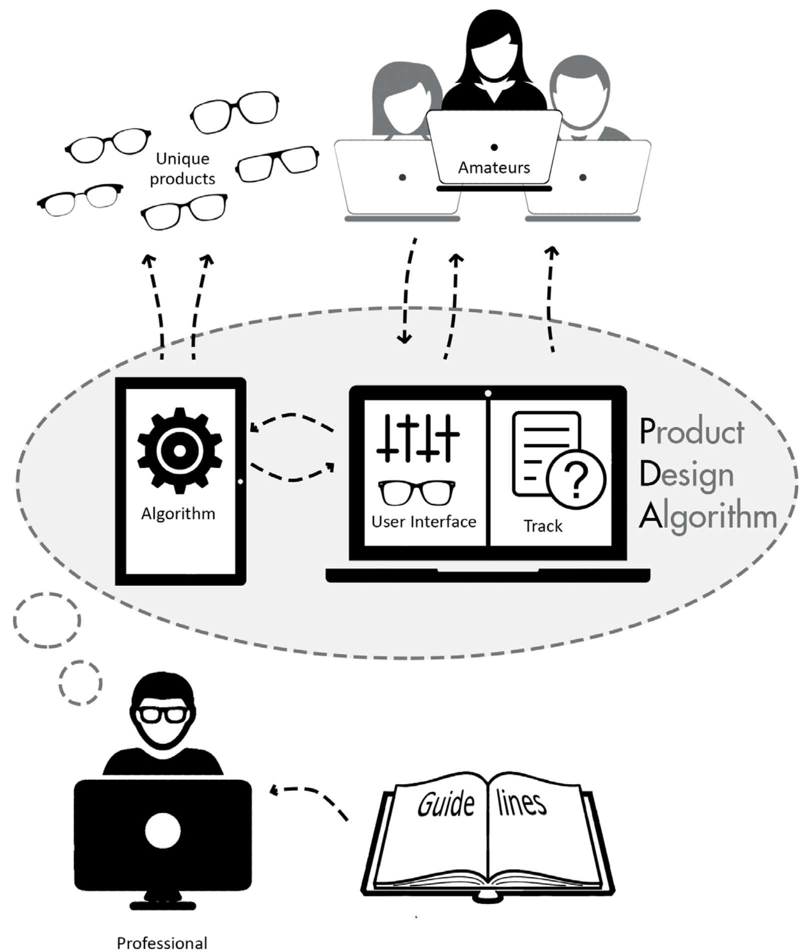
Figure 4.9: User enjoying the fruits of his labour

Evaluation

PDA Design Guidelines

Preface

Before the Design Guidelines are presented there are a couple of things that need to be clarified in advance. Firstly the purpose of the guidelines is that they are followed by designers who want to venture into the domain of parametric design. The reason why its necessary to state this explicitly is because it assumes know-how of product design and the skills associated with that. That having said, everyone is free to use it whatever background they might have, but it is something to keep in mind. Secondly, the guidelines have been made with an ever changing context in mind, specifically regarding software, and an effort has been made to make them as universal as possible to prevent it from becoming obsolete with the introduction of new techniques. However it is inescapable that some signs of the authors preferences or the state of the art of the software from the time of when the guidelines are written will leave some traces. Again, feel free to use the software described but remember that alternatives exist. The software used in the guideline is Rhinoceros 5 as a CAD environment and Grasshopper 0.9 as the parametric script modeller. The user-interface was created using HumanUI, a plug-in for Grasshopper.



Evaluation

What is a PDA?

A PDA is a new way of looking at product design. Automated production allows for mass-customisation and that is what a PDA facilitates. PDA stands for Product Design Algorithm. By encapsulating a design process in an algorithm, formalising the steps and defining where to leave room for the user to interact, it's possible to create applications that enable users to create unique products otherwise unobtainable for them. The idea is to define the relations that make up a product in variable left for the user to define effectively making them have the final say in the design of the product.

Why use a PDA

The PDA is a versatile concept. Its application ranges from simply including third parties in your design process to making full-fledged customiser software. It was originally conceived to help designers facilitate consumers to make design files for 3D printing but has a potential to be used for other applications as well. The goal for using it should always to provide options in a way that a user feels facilitated in making the decisions that generate the product-file, because the lack the necessary skills to design it using conventional CAD-software

What are the parts of a PDA?

A PDA consists of three parts: the algorithm, the user interface and the track. The algorithm is where the product design possibilities are defined. This is where the proverbial magic happens and is hidden from the end-user. Similar to creating CAD-files in a traditional design process, the algorithm is where designers are forced to formalise their decisions, with the exception that instead of defining everything with constants they define it with variables, parameters and relationships. The user-interface is where the end-user gets to interact with the algorithm. Where, how and how much are things that need to be defined by the designer. All three of the parts need attention and how to address that is best shown in an example, which will follow below.

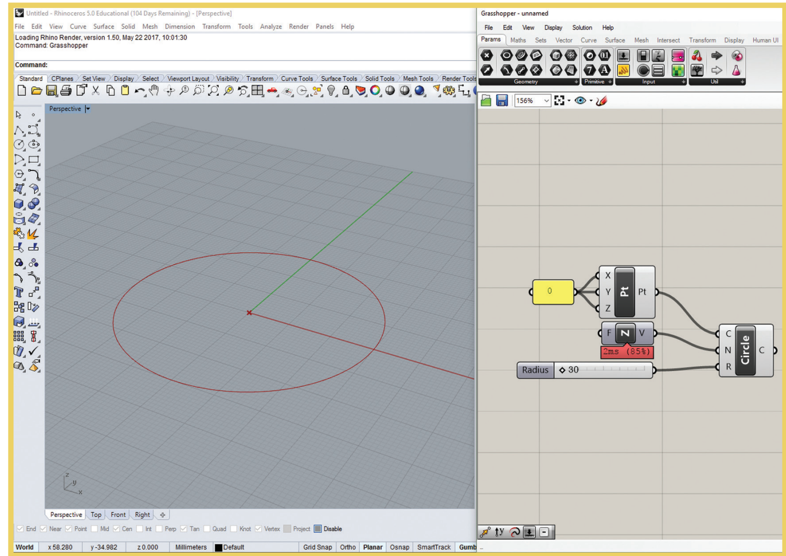
Example design process

To explain the process the following example is used. This example is presented to provide insight in the technical aspect of a basic PDA. It is important to realise that the PDA is like any traditional product design methodology, in the fact that this example should be viewed like a rough guide and never as a definitive set of rules. Every project demands unique questions with unique answers and anyone using this structure should realise this.

Evaluation

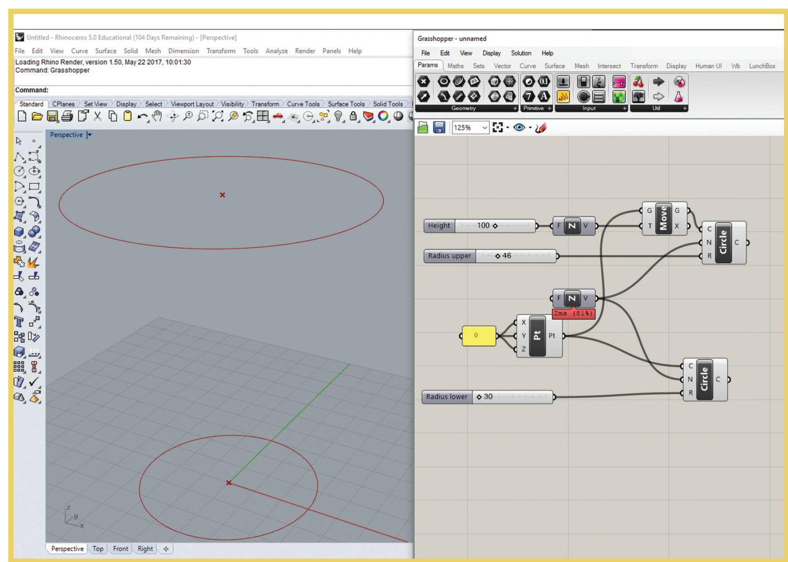
Example PDA project

In this example the goal is to make a simple application that facilitates the creation of coffee-cups. Its goal is to make a family of significantly different but not extremely unorthodox products. The planning of the steps is skipped because the reasons for doing things can be explained on the way. The start is always the algorithm, when that is sufficiently done you can move on to the other two part, although in actual practice there will be much more switching between parts.



Step 1. Starting point

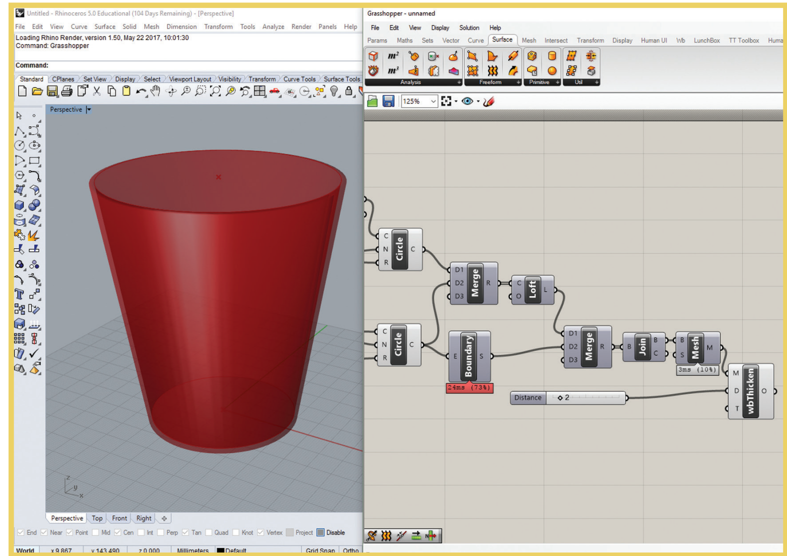
You start by defining the centre of the circle that is going to make the base for the coffee-cup. In this example the origin point is taken (0,0,0). Then a circle is drawn with a normal vector in the Z-direction and a variable radius (now on 30mm).



Step 2. Making the basis

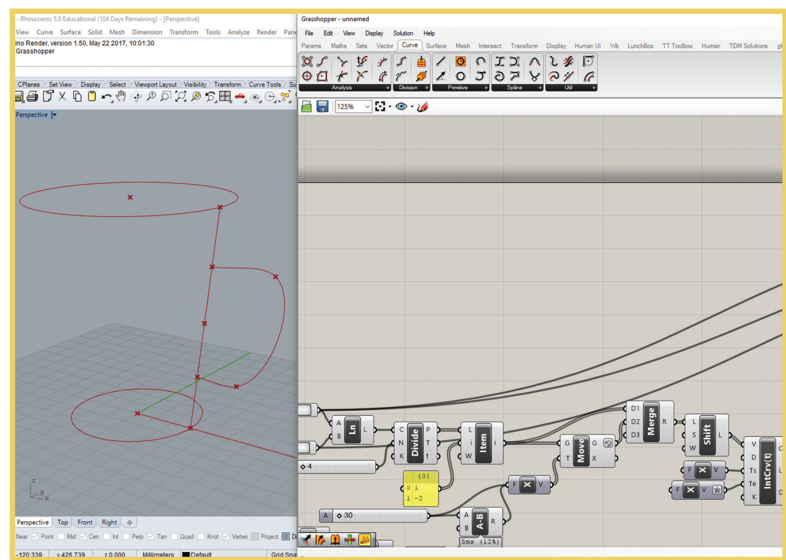
You continue by moving a copy of the first point in the z direction. The amount is defined again in a slider and will determine the height of the coffee-cup and is named as such. Then, a second circle is drawn, parallel to the first but with a different centre (the new point) and with a different radius. This circle is the top of the cup.

Evaluation



Step 3. Creating the main shape

From the bottom circle you create a surface. This means the curve describing the circle is now a flat circular surface. This is the bottom of the cup. The walls of the cup are made by creating a lofted surface between the two circles. The bottom and the walls are then joined together to what is starting to look like a cup. However it may start to look like a cup it lacks something vital and that is thickness. This cup is still made out of infinitely flat surfaces. Before you move on to the ear you need to fix this. We do this with the thicken feature, which takes in the flat geometry and a thickness variable from a slider (now at 2mm).



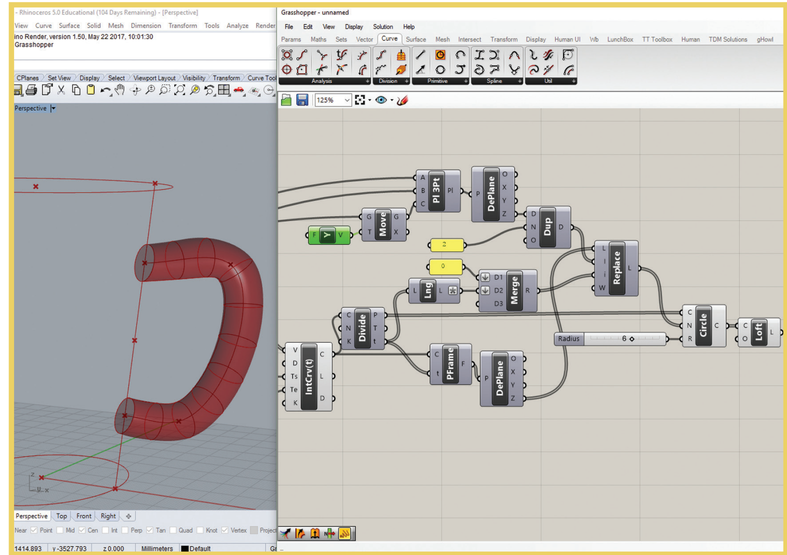
Step 4. Setting up the details

You turn of the thickness for a better view and start on the ear by first drawing a line between the top and the bottom. That is than divided and the second and second to last points are taken as the points where the ear will meet the cup. By moving these to in the x direction you find 2 new points. We interpolate all 4 points to get the curve that describes the ear. The distances the points have to each other are kept in variables

Evaluation

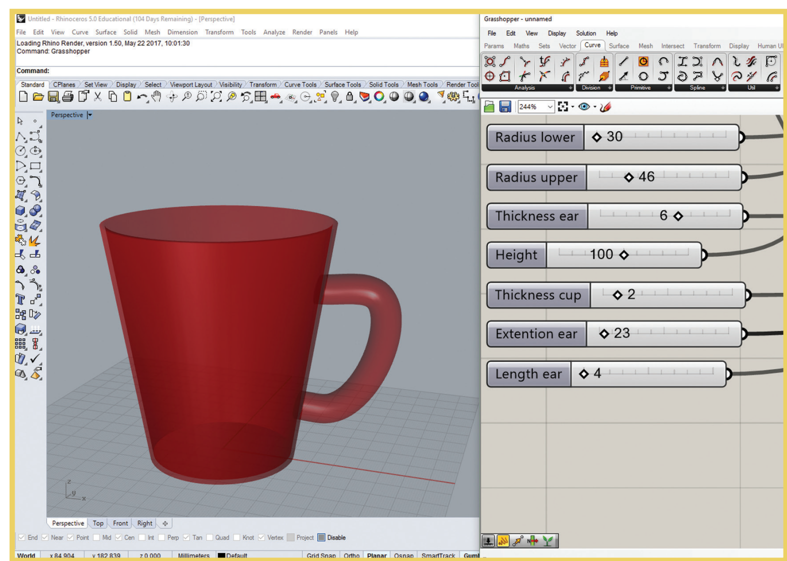
Step 5. Creating the details

To make sure the ear connects nicely to the rest of the cup you need to make 2 circles that are tangent to the line connecting the top and the bottom. After that you divide the curve that makes the shape of the ear into a number of points where you draw circles that will make up the cross-sections of the ear. Use the division points as centres and evaluate the curve to find the normal vectors. The first and last of these vectors are replaced by the vectors that ensure that those circles are tangent.



Step 6. Finishing the algorithm

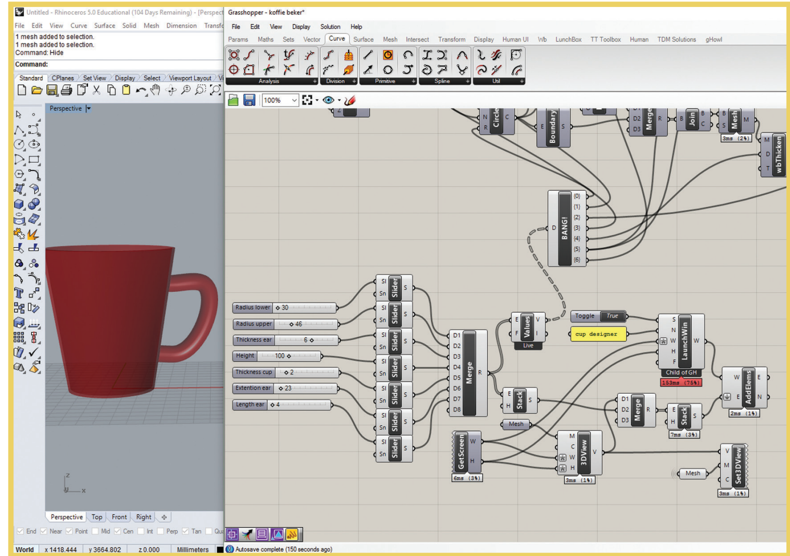
You bring back the cup and join it to the ear. The model is now finished. The variables are isolated and brought forward. Now is the time to decide which to include in the user interface and which to leave hidden in the algorithm. Since this is such a simple example, all the variables are included. In the next step you will create the user interface using the HumanUI plug-in.



Evaluation

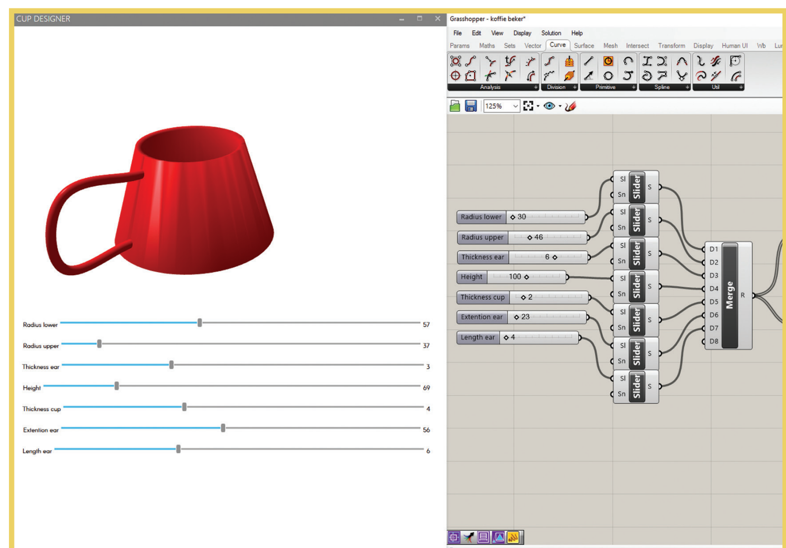
Step 6. Setting up the user interface

To start you take the isolated variables and make them into UI elements that have a value-listener that feeds back into the algorithm. Then you create a 3D-display which takes in the final shape. This ensures that the input gathered in the UI gets run through the algorithm and displays the result. These elements are then added to a UI window to finish of the first user interface.



Step 7. Trial and error

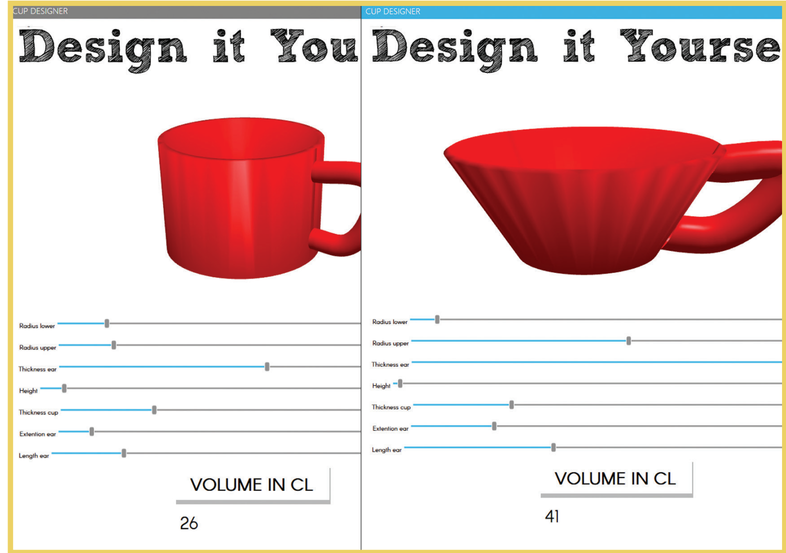
To find hidden errors in the model, mistakes in the algorithm and to check whether the variables are set to the correct limits you have to try it out. Usually, this phase takes as long as the original synthesis of the algorithm and there is no simple way around it. This simple model has only 7 variables which together can form endless combinations, each of which can potentially pose problems. The best way to do this is to look for the extremes and as experience grows you get an feeling for potential area's of concern.



Evaluation

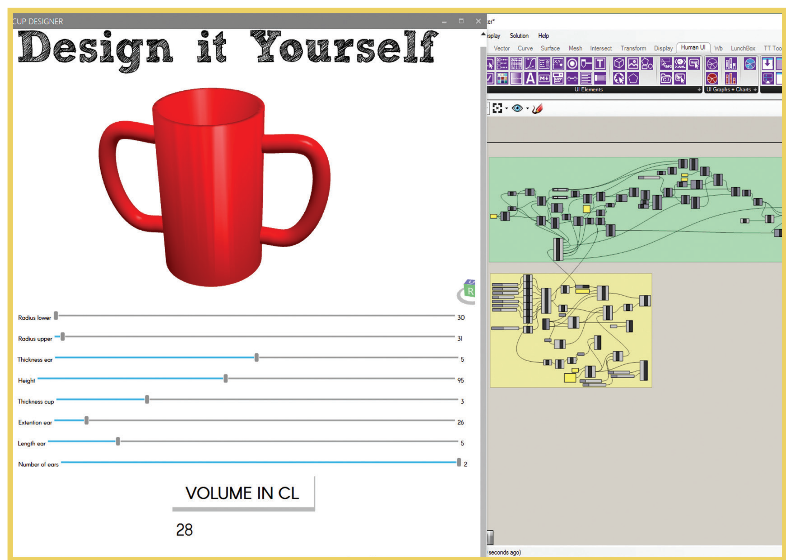
Step 8. The Track

When you feel comfortable about the model and it provides satisfactory results it is time to include the elements that will guide the user trough the process. Since this is such a simple model it might not even need much explanation but when the models become more complex and functional it becomes increasingly more important. For this example you just add an header and include a feedback system that provides the volume of the cup.



Step 9. Test

A vital step which will probably force you to revisit al the other steps is the test-phase. You need to find out whether your ideas work and whether you missed any desires the potential user might have that need to be included. In this example, after testing, there was an option added to have 0, 1 or 2 ears instead of just one. The complete model is divided into the green group making responsible for the algorithm and the yellow group responsible for the user interface. Cleaning up the code is important if you want to come back to it after a while



Evaluation

PDA Ten commandments

Less is more, more or less

Most often, a PDA tries to facilitate as much freedom as possible. If users feel like they are held back by the options in the UI, the perceived freedom suffers. However this doesn't mean adding more options is better, as this can make the process complicated or tedious. Some parameters can be combined into a single replacing parameter when they work together towards a specific design aspect.

Know the user

Like any traditional product, a PDA has a specific target group. A PDA to make a toy will have a different look, feel and difficulty as a PDA for a phone case. When designing a PDA it is imperative that the prospected user is taken into regard when making decisions regarding the user-interface and the track. The might also have a different sense of authorship or perceived freedom.

Test often

A PDA is a piece of software and like all software testing it can take up almost as much time as developing it. This means the time between the start of the development and the first time it runs, is about as much time as there is between its first run and the finish. This detailing phase takes much longer than in a traditional design project and should be taken into account when planning a project.

Embrace the cyclical nature

One of the perks of having an algorithm do all the work is that a designer can change something in the beginning and everything should adjust accordingly. This makes these kinds of projects especially suited for a high level of iteration.

Code light

When you design an algorithm the amount of data quickly tends to spiral out of control, because a simple factor of 10 somewhere could result in exponentially more calculations down the line. Awareness of this is vital, not only to keep it from crashing but because it influences the user experience as well. It is similar to resolution in images; there is no point in putting a poster sized image on a post-stamp. The same goes for a PDA as there is no point in making a model outperform the 3D printer it will be materialised on.

Guide the user

The value of a good instruction manual to raise the capabilities of the user is undeniable. While some steps might not need explanation, others might not reach their potential without it. A good track will affect both the ease of use and the perceived freedom. Beware of spelling everything out and leave some aspects to be discovered to ensure there is no loss of a sense of authorship.

Evaluation

Don’t be judgemental

Beauty is in the eye of the beholder and a designer making a PDA should accept that it won’t find all the products made with the PDA to be aesthetically pleasing. When considering the fact that the purpose is to provide freedom, there is always the potential consequence that it is used differently than the designer would have hoped.

Provide steps and hierarchy

An algorithm is always built according to a certain hierarchy, similar to traditional CAD. This natural hierarchy might be a sensible start when deciding on the design steps that will be presented to the user. It could however be the case that a totally different hierarchy in steps works better for a user. Breaking up a complex design process in logical steps is important for the PDA.

Freedom is perception

It can be hard to predict what users will want in a design process. Some design aspects included in the PDA might not be missed when they are removed. The amount of options won’t predict how much freedom a user perceives it is all about the ones that matter. Testing is the only way to find out what options are missing and which aren’t missed when they are removed.

Write notes and comments

When an algorithm is created it is important to include notes and clear descriptions of what is happening at that point in the script. Especially when the algorithm is made by a team rather than a single person but it also becomes important when a designer revisits the code after a while. It takes a lot of time to figure out what the code was doing without notes and that will increase the time it takes to mend or adjust it.

5 Discussion

Discussion

Discussion introduction

The discussion is divided into three parts, which naturally follow each other. Firstly, the final design Spectacle is discussed as an implementation of the theoretical concept. Secondly the theoretical framework-concept (PDA) is discussed and valued. Thirdly and lastly, the project as a whole is reviewed and recommendations for the future are made. This is because the implementation validates the model and the both sum up the project. Each part will reflect on the goals set and the matter of success it has had on achieving them, where it can be improved and what the future could look bring.

Figure 5.1: Satisfied user of the Spectacle concept

Discussion

Discussion Spectacle

Three goals where set for the creation of the final design. The unifying factor for them was that they are supportive to the theory. The Spectacle concept was made to: build the theory; test the theory; and show the theory. All three goals were fully achieved in one sense and could never be completed in another sense. However as the first "complete" implementation of the theory it performed better at some goals than others.

Building the theory

The Spectacle concept was definitely the major contributor to the insight gained that helped form the theory. The necessity or desirability of the Track for example, one of the three pillars of the theory was found while testing one of the first iterations. Because the theory and the concept, despite being presented sequentially, were constructed simultaneously one can hardly be seen without the other. Its impact on successfully building the theory will be assumed until a second PDA is completed.

Testing the theory

The downside to the iterative nature of the project was that the final design in its last form was only fully tested with two people. This was mostly due to the costs and logistics of acquiring the 3D printed products. On the other hand, the same iterative nature led to many test and a continuous process of improving the theory. It also allowed trying the ideas that were improbable to be successful, either to rule them out or to be taken by surprise and include them in the theory.

Testing the theory

The problem with building the Spectacle concept is that a lot of ideas were difficult to make. This had two major reasons, one of possibilities and one of capabilities. Both have to do with the fact that the design was build using four layers of software. Starting off, Rhinoceros (CAD-software) was completely fine and provided no obstacles, as it is a widespread commercially used piece of software. Grasshopper running in Rhino, however, is a free, work in progress, open-source software, which means that a lot of functions aren't working properly as of yet. Human UI is a free plug-in for Grasshopper that was made by one person and is therefore severely limited in options. The augmented reality part was made using Processing and here is became a problem of capabilities. This project was done by an industrial designer and not a computer programmer. Having more skill or options when it comes down to the tools would have made a positive impact on the implementation of the theory as more ideas could have been tested. However within the limited options almost everything was tried therefore at least the possibilities within this paradigm have been explored.

Discussion

Discussion PDA

Provide ways to facilitate the creation of unique designs by users for 3D printing that lack the necessary skill and/or inclination to create it using existing tools.

This was the design goal to which the PDA-framework was the solution. From the analysis it was found that three aspects and their relationship to each other played a vital role in the reachability of this goal; sense of authorship, perceived freedom and ease of use. The tests from the final design indicated that all three were achieved in a way that is sufficient to reach the goal. This means the PDA-framework has worked at least once. To properly test the framework it will be necessary to have a designer do a project from scratch using the framework to see if the results are repeatable. During the project it became apparent that even the test-subjects with experience using CAD-software noted that the PDA was doing something that they couldn't do themselves. It was outperforming the traditional CAD-software used by skilled people. This was a unexpected, but welcome side-result

Drawbacks

There are two main things that could provide problems for the PDA-framework. The first is the suitability of other product groups. As aforementioned, glasses are really suited to be used in a PDA for 3D printing due to printability, topology and the innate characteristic of uniqueness in human faces. There are many similar products but even more that miss one or even all three of these perks. The PDA might not be able to reach satisfying results for these products, but more testing would be necessary to find that out. The second thing is the necessary programming skills designers need to have when they make a PDA. While it is arguably a manageable feat to acquire them, it is also definitely one of the major snags in the concept.

Context

The PDA is in essence a structured an improved version of the parametric customizer with the greatest difference in the level of depth. Where a parametric customizer wants to customise, the PDA wants to design. Since the two are closely related, it could also be seen that both lie on a spectrum. On the one end are customisers that allow the user to change a colour and on the other end are the most extensive examples of a PDA, where the user's end result varies in all kinds of ways. It seems to separate itself from other solutions like the simple CAD software, as they intend a user to acquire skill over time. Figure 5.2 indicates this by stating "...learn to create your first 3D print”, admitting both a repeated use and a learning process. PDA’s can be as successful the first time as after repeated use and should at least deliver good results on the first try. During this project there was an example of a new application that went further down the spectrum towards PDA than any customizer in the analysis. Tylko (Fig 5.3) provides users with a simple app that allows them to customise a cupboard and see it in their house with the help of augmented reality. This example of Zeitgeist is encouraging that the PDA concept has some merits.

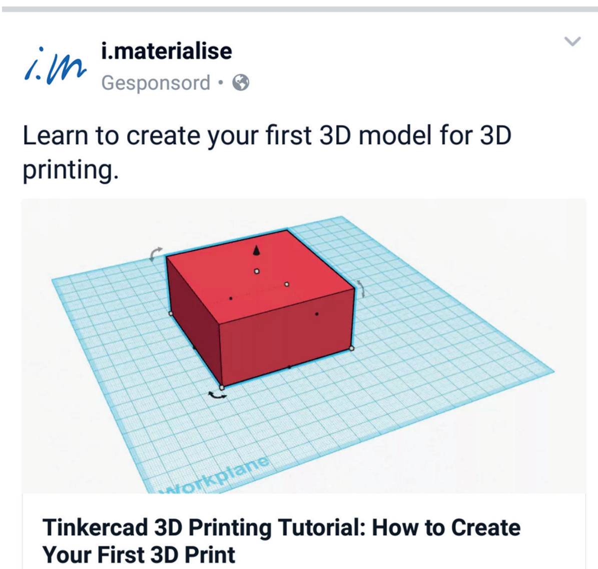


Figure 5.2: Advertisement for Simple CAD

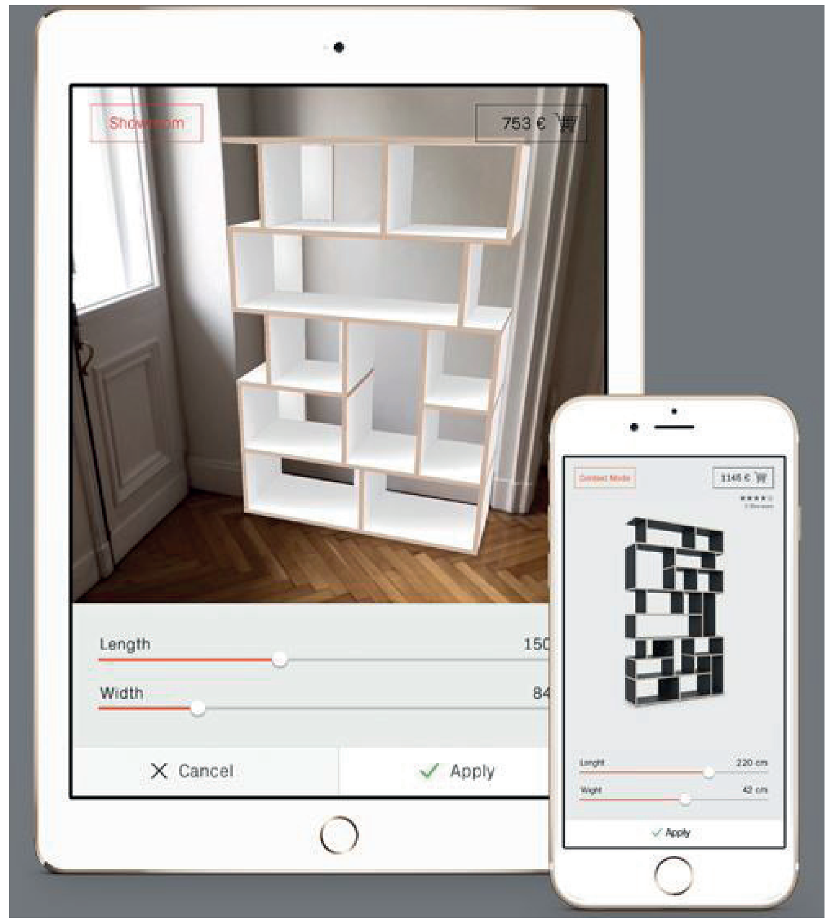


Figure 5.3: Tylko, example of a second generation parametric customizer.

Discussion

Discussion Project

This project started with some simple pondering about the discrepancy between the attention given to 3D printing and the actual use. After mapping the aspects of the technology that cause it, the project found a problem that is ignored much more than the other more technical shortcomings. That was the problem of creating unique design files without extensive skill and time investment. It was conjectured that if 3D printing is to achieve acceptance by a wider audience, it can't rely on inherent traits unique to the current user group, which are absent in others. More specifically, it can't count on them to learn CAD-software and design practices. The PDA-framework could be one of the solutions that attract more people to the medium, but is certainly has to progress a lot more before it could reach its full potential.

Future

Once again, a comparison can be made with the personal computer, where the PDA could be seen as one of the first games. Like the computer games of early days, which had only one person making it and was held back by the context of its situation (limited memory and display options), the PDA is limited by the possibilities of the software it relies on. It took a long time for computer games to come from something like Space invaders to a Fall Out 4 (Fig 5.5). In the latter, more than 100 people participated in its creation, each developer with their own specialty and purpose within the team. It is almost comedic to make the comparison but at the time people forgave the old game its shortcomings because it was new and fun. The same might be said about PDA's in their current form. There is a lot of room for improvement but overall that is to be expected from an exploratory design project.

Figure 5.5: From Space invaders to Fall out 4

Discussion

Recommendations

The aspect that needs improving the most is the graphic interface. This was hardly designed visually because the software didn't facilitate it and it provided limited options for user interaction. One course of action would be to make a completely new plug-in specifically for this purpose or to try to convert the PDA to a platform with inbuilt functionality. Consequential, it was hard to properly explore this aspect in the project and it therefore has fewer meaningful insights specifically on this aspect.

Another recommendation, stemming from something this project hardly touched on, is to explore a marketing model. Who and how is this going to be implemented in such a way that it makes economical sense. If everyone could make their glasses themselves with the help of one application this would seriously disrupt the glasses industry, if not completely destroy it in its current form. But this of course is a very distant future.

This project was done to improve the accessibility of 3D printing but there is no inherent reason why the PDA-framework couldn't be used for other production ways too. There is only one important aspect that is necessary and that is that the production is automated. It could be very interesting to explore the potential application of the framework on for example products made with an automated milling machine or laser cutter.

3D printing has a potential to be disruptive to the way products are made, but like any disruptive technology it is hard to predict what the future has to offer. If the PDA-framework is to have a future alongside the future of 3D printing it is important to realise that this will probably demand the solution to adept. What kinds of innovation will happen in the 3D printing world is hard to say, but it cant afford to be stagnant and the same goes for PDA's.

Apart from the 3D printing world itself it could be interesting to combine it with other technologies. It is not hard to imagine virtual reality finding a home within the PDA-framework, instead of- or besides augmented reality. A possibility for including economical and juristic aspect could be found in Block-chain technology, which has the same decentralised nature as 3D printing. Another good match would be voice recognition technology or even artificial intelligent assistance in designing.


FIN....

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Appendix

Appendix 1.1 example interview 1.0 version

Introduction:

The aim of this model is to allow you to design a pair of glasses. The final result will be a pair of glasses you could send to a 3D-printer to be made. Take a minute to think about what kind of glasses you would like to design; what is something that would suit you? When you have a rough idea of what you want to make start the app. Please vocalise your thought process and there will be questions at the end.

Carlo Den Dekker 27 years old

Q Was this the first time you made a 3D model (if so how experienced are you?)? Did you enjoy this experience?

A *No, pretty inexperienced, yes pleasurable, I would like to put in numerical values in the sliders though*

Q How easy/hard was it to use and to figure out the app?

A *Relatively easy, wrong sequence in my opinion though, that has to do with the wording of the tabs, frame/lenses is misleading. I wanted to start with the frame because I expected to shape the frame there which turned out to happen at the lenses stage*

Q Can you elaborate on something you've found to be easy and something that was hard?

A *I thought it was nice that it was quick and dirty. It was really easy and fast to get to a conceptual result, I missed some underlying processes though i.e. that there was linked data between the hinges and legs, that they were at the same height*

Q What was your aim with making these glasses?

A *I went for provocative and extreme.*

Q Does it match up with that aim? If not, why?

A *A bit, but there was one thing that I couldn't do that bothered me.*

Q Are you content with what you made? And explain why

A *Sure, not many people could pull this off, from the experience I have I know that it is difficult to make such a complicated model, and it liked doing it.*

Q Do you consider yourself the designer of these glasses? Why (not)?

A *Yes and no, I still felt a bit limited in freedom but making the steps while being aided along the way is like in a video game and gives me the sense I have the controller.*

Q Did you go back a step to change something? Why (not)?

A *Yes between lenses and frame. Because frame should be first in my opinion.*

Q Did this app offer you enough freedom or did you need more?

A *Not for the first try but probably for the second try yes. The first time I was testing its limits more than making what I would wear.*

Q In what part of the design process would you like to have more (or less) freedom?

A *Depth thickness of the frame would be a nice addition.*

Q Would you like to design more products like this?

A *Yes, it is fun. But I can also see the advantage of professionally designed products*

Q What did you think about the feedback of the model (2D,3D)

A *That was good, although it would be nice if the response time was a bit better*

Q Can you say something about the clarity or helpfulness of the instructions

A *Didn't read the first, a video would be way better*

Q Does this make 3D printing closer to something you would use?

A *If it was as easy as pressing the print button when I was one with this application, then yes*

Q Anything you want to add?

A *It would be so much better to hold the result in my hand*

Q Working on it, thanks for your time

Appendix 1.2 example interview Final version

Introduction:

The aim of this model is to allow you to design a pair of glasses. The final result will be a pair of glasses you could send to a 3D-printer to be made. Take a minute to think about what kind of glasses you would like to design; what is something that would suit you? When you have a rough idea of what you want to make start the app. Please vocalise your thought process and there will be questions at the end.

Sander Oude Veldhuis 28 years old

Q Was this the first time you made a 3D model (if so how experienced are you?)? Did you enjoy this experience?

A *No, I am somewhat experienced but I really liked the experience, it went so quickly.*

Q How easy/hard was it to use and to figure out the app?

A *Quite easy actually. There was a lot of trial and error. I tried a lot of things.*

Q Can you elaborate on something you've found to be easy and something that was hard?

A *For me the coming up with the initial idea was hard. I needed some time to figure out what kind of glasses I wanted to make. The roundness feature was cool and really impacted the look of the glasses. Designing the legs with manipulating the curve was hard. It didn't naturally make sense to me.*

Q What was your aim with making these glasses?

A *I wanted a pair of glasses that was remarkable, impressive unique and out there. I didn't have a particular shape in mind when I started.*

Q Does it match up with that aim? If not, why?

A *yes, but I was hoping it to be even more impressive, maybe on my next try.*

Q Are you content with what you made? And explain why

A *Yes, because I really feel like I could wear this.*

Q Do you consider yourself the designer of these glasses? Why (not)?

A *Absolutely, Its is unique and I changed the almost all of the input.*

Q Did you go back a step to change something? Why (not)?

A *Yes, I thought it was too round and when I went back a step to change it, I found other parameters I overlooked at first glance.*

Q Did this app offer you enough freedom or did you need more?

A *Yes and no. If you want to make a "normal" pair of glasses there was enough freedom but if you wanted to create something extreme you needed more.*

Q In what part of the design process would you like to have more (or less) freedom?

A *Depth thickness of the frame and maybe some more options for the legs.*

Appendix

Q Would you like to design more products like this?
A *Yes I could see myself designing shoes or something.*
Q What did you think about the feedback of the model (2D,3D)
A *The 3D rendering, I found very nice. The fact that it is build up in steps is really good.*
Q Can you say something about the clarity or helpfulness of the instructions
A *The images were helpful but the text not so much. I didn't read some of them*
Q Does this make 3D printing closer to something you would use?
A *Yes especially after seeing it in 3D, it makes you want to hold it in real life.*
Q Was digitally trying it on helpful?
A *Yeah! Cool to see that the glasses moved when I moved my head. Reminded me of Snapchat filters*
Q Anything you want to add?
A *no*
Q Thanks for your time and see you in 5 days.

Post-print Interview

This interview started with a recap of the design made, because a significant amount of time (almost a week) had past between the design phase and the delivery of the printed model.

Q What are the first things going through your mind, now that your holding the printed glasses?
A *It is really nice, The colour is very cool. It is much more fragile than I expected.*
Q Do you recognise your model from the digital rendition and are there things that surprise you?
A *I totally recognise it. It is really strange to see something from the digital realm in real life. It is thinner than I expected and the quality feels a bit crappy.*
Q Would you like to try it on and see how it looks in the mirror? What do you think about how it looks on you?
A *Wow, this is really weird, but it looks good. (He also tries another printed glasses belonging to someone else). It remarkable how much more I like the one I made myself, I think it really suits me.*
Q Are there things you would like to change now that you see it materialised?
A *Its too light and I don't really like the finishing but I am happy with the design. Having made it myself implies a certain level of quality. It should be like the cheap Chinese models.*

Appendix

Q Would you say having it materialised changed how you judge the experience

A *Hell yes, I have an urge to design more now.*

Q Anything you would like to add?

A *Yes, I am pretty sure that I would have never picked up this glasses in a store, but I really like it now so that must have something to do with designing it myself.*

Dedicated to my mum