LOCALLY GO FROM DIGITAL TO GARMENTS

GRADUATION THESIS CEES JAN STAM

EXPLORATION OF DIGITALLY MANUFACTURED GARMENTS

"LOCALLY GO FROM DIGITAL TO GARMENTS"

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PREFACE

You are about to read my graduation thesis, Locally go from digital to garment. It is the result of a long graduation track. During this period I have investigated many of the aspects related to the new industrial revolution. The smart industry is upon us and how do we as designers cope with this? This is one of the questions I will be answering in the pages in front of you. But before continuing I would like to express my sincere appreciation to some of the people involved in the project in their own way.

First, my graduation team, Han Brezet and Jouke Verlinden. They have both been instrumental to the project. Not just in their normal roles but also in providing motivation and inspiration along the way. Offering critique and an experienced eye to make sure I would not become complacent. But also appreciating my research by including it into other projects, courses or talks. For this I am very thankful. I hope that I might be fortunate enough to work with them in the future.

Next we have Natasha van der Velden, it was her research that started this assignment. And she has remained closely connected to the project throughout. Offering guidance and suggestions in all stages of the project. And also facilitating the trips that where undertaken during the project. With the ICAT convention in Vienna a fitting end to a great project. Thank you for all the support.

During my graduation research I traveled throughout Europe to gather information and work with inspiring people, as was the case when visiting Aalto university, or when visiting Openknit. As such I would like to thank Jussi Mikkonen for his help and support during my visit to Aalto, and off course the students at Aalto for their great enthusiasm during our session. And I would like to thank Gerard Rubio for allowing me to come in and work with him on redesigning his amazing machine the Openknit, without him this thesis research would not have been possible.

Furthermore I would like to thank my friends and family for supporting me throughout my studies and graduation. Without your support it would not have been the amazing time it has been. You have each in your own way been part of my student life and have helped shape me into the person I am today.

Lastly I would like to thank Stefanie. It has been a long and sometimes difficult journey, but you have always been supportive of my decisions. Offering guidance and help when ever needed, or pushing me to continue when I would loose steam. Your keen eye for detail has helped take this graduation to a higher level then I would have ever reached on my own and for this I am forever thankful.

SUMMARY

The maker culture has created a dynamic in which designers are less responsible for the design and quality of the final product, but instead for the tools the consumer uses to create their own.

While additive manufacturing (AM) is gaining acceptance among the general public, it is still seen as a prototyping tool instead of a high quality production technology. This limits its acceptance within co-design and maker culture. The research question is: How to create greater acceptance among the general public regarding the AM technology and its products? In order to achieve this a product category needs to be selected that can benefit greatly from the capabilities of digital design and manufacturing. For this clothing was selected as it hold both great design and cosmetic possibilities for personalisation.

One way to create greater acceptance of digital design and manufacturing is to apply co-design principles on a local scale. By this means the public will be exposed and included in the design and production process, which will ensure the end product is has value to the consumer. In time this could help spark a maker movement within the community. To validate these assumptions a test case was developed in which local design and production of simple wearables played a major role. This took place in a local urban context.

In order to facilitate this a digital design tool combined with a mobile digital knitting machine was developed to allow for a rapid co-design track. The wearables would be produced by the consumer themselves. The final design of the garment depends on the consumer's choice of material, shape and pattern. A mobile set-up provides the means to test the principle at different locations and allows the consumer to be intensively involved in the making of their own product. In the future this might take place in the maker movement in their own neighbourhood. A small and low-cost knitting machine was developed, the Wally 120, and tested outdoors in a local park in Barcelona. By making bespoke hats/ beanies, the response of the park visitors to the technology could be gauged and their perception of it positively altered.

The results of the test case can be summarized as: increased engagement in the production process, greater acceptance of digital design and increased exposure of the technology. The public present during the test was engaged in the exposition of the technology. While some only observed, others actively engaged in conversation about the machine and its possibilities. The actual test garments where well received, even tough the machine did not perform without flaw. As such it can be concluded that local exposure would help create greater acceptance of AM technology.

Concluding, even though the maker culture changes the role of the designer, their importance to the design process will remain. Not as a creator of designs but as a guide to the making of consumer products.

CONTENT

Figure 1. Designs by Iris van Herpen

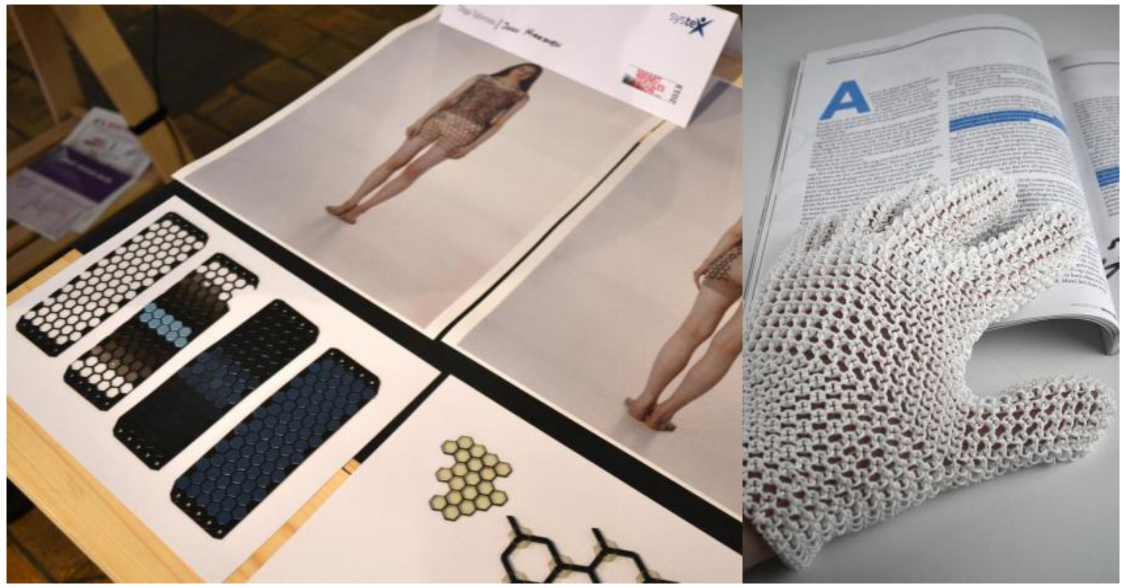


Figure 2. Soft/mesh (left), fresh fibre (right).

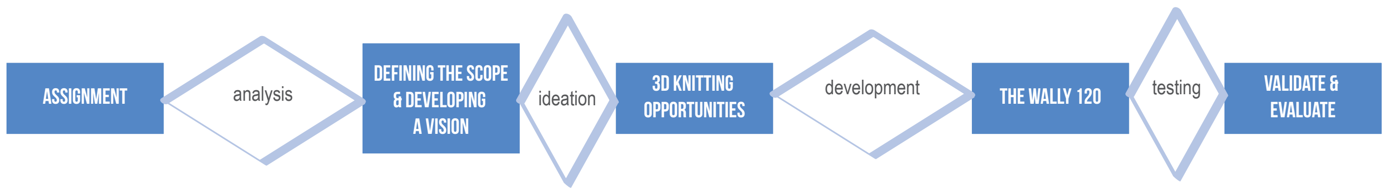


Figure 3. Project outline

INTRODUCTION

This graduation assignment is carried out on behalf of the Technical University Delft. This graduation assignment focusses on 3d printed garments and researches its possible potential for the consumer market. This chapter contains its outlines.

CONTEXT

The world of 3d printing is gathering momentum and is being integrated into more design fields as it grows. What do we think of when the words 3d printing and clothing are mentioned in the same sentence? Most of us will imagine pictures of very artistic inflexible garments seen in some of the fashion shows over the last couple of years, like the designs of Dutch Design Award winner Iris van Herpen (see Figure 1.). These garments explore the creative freedom resulting from using additive manufacturing, giving the designers a new medium to work with. But comfort and everyday use are not the main drivers in these designs. However this doesn't mean it is ignored, for example we have Soft/ mesh and fresh fibers latest developments (see Figure 2.) here they have strived to achieve greater comfort.

And while digital design has made big leaps in the last years, most consumers and designers alike are still very much unaware of its potential. This is limiting the development as more users and cases within the field will help mature the technology. In order to facilitate a greater awareness and eventually acceptance it is imperative to look outside the current scope of the exposure of the technology.

How to create greater acceptance among the general public regarding additive manufacturing technology and its products, in this case garments? This will be the main question addressed in this thesis.

The chosen product group, wearables and more specifically garments, was selected for it duality. While on one hand garments and other body orientated products are used as an expression of personal style and preference. Yet at the same time it also follows mass consumer behaviour. These two seem to be in direct conflict with each other.

ASSIGNMENT

The following assignment was formulated:

"To develop a methodology which bridges the gap between the **3d print technology** and **the end user**. This means looking for ways to create **greater acceptance** and understanding regarding **additive manufacturing of wearable's**, while also looking at the role of the designer in this **new dynamic design interaction**."

Within this assignment the main drivers can be identified as being the following; 3d print technology, end user, greater acceptance, additive manufacturing of wearables and new dynamic design interaction. In order to design within this context we will need to identify the main aspects of these drivers and how they will interact with the design space.

APPROACH

To achieve this the following activities were undertaken to test the public's receptiveness to AM produced clothing. First of all a more detailed overview of the developments in local design & manufacturing will be given, as it defines the scope of the research. This also includes the current dynamic within the clothing industry and how this will be redefined. How do designers perceive this new dynamic? This will be the goal of the initial research.

This is followed by selecting a method of creating this acceptance, it will need to fit the context of not just creating acceptance but also instigating a maker spark in the consumer. This will then be applied to an interaction design to create the desired outcome. This interaction will be tested within a public area to validate its effect on the public. After which it will be evaluated and suggestions for adaptations to further improve the concept's effectiveness are given. a visual representation of the approach can be seen in Figure 3.

METHODOLOGY

The research will be framed within the reflection in action method. This method works with 4 phases; Naming, framing, moving & reflection. These steps generate a constant cycle of evaluation and reflection during the process. As stated by Reymen (2003) "Reflection-in-action can be defined as thinking about doing while doing it, in such a way as to influence further doing" [1]. This method ensures that the process is never just going somewhere but decisions are made based on reflecting on the previous work and findings. This is done on a small scale and focuses above all on the design activities.

ANALYSIS


POLITICS + DESIGN
PRINTING PEACE
Printing Guns
I WONDER IF MY PONY CAN FLY.
TERRORISM
DEMOCRATISATION - OPEN ACCESS
OPEN SOURCE
CULT OF THE AMATEUR
BECOMING MORE AFFORDABLE
GENERATING DIY MOVEMENTS
DEMOCRATISATION
PEOPLE PRODUCE SHIT
Too many choice of what can be printed
I CAN DO EVERYTHING! BUT THEN I'M ALWAYS ON THE INTERNET...
WHAT ABOUT THE MEANINGS OF THINGS?
COPYRIGHT ISSUES
REPURCUSSIONS OF DEMOCRATI
PLAYING GOD!
Body parts
PRINT SKIN, FUR. PLASTIC SURGERY
NEW IDENTITIES
CYBORGS.
PRINTING LIVING TISSUES
FUTURE FUNCTIONS
3D SCANNING + 3D PRINTING
PRINT HOUSES
RECYCLING MATERIALS
EXPLORATION OF NEW FORMS
DAMN! I DON'T KNOW HOW TO 3D MODEL!
COMPLEX FORMS
IT WORKS LIKE MAGIC!
BURGER
EASY LIKE STAR TREK REPLICATOR
Fix broken things

CURRENT SITUATION CLOTHING INDUSTRY

What are the key words we as a society think of when looking at clothing products? Most of us will probably struggle to even figure out where their clothing actually comes from. The clothing industry is one of the worlds largest industries, but it is also one of the most obscure. It took the 2013 Savar building collapse for the main public to start seeing the issues that plague the clothing industry. This internationally shared event, exposed the dark underbelly of the fashion industry. The incident in question relates to a Bangladeshi clothing factory that collapsed killing 1.129 people. So what else is going on?

GLOBALIZATION

The clothing industry is one of large quantities, we want clothes and we want them cheaply. This results in a need for cheap labour and materials in order to still turn a profit in this cut-throat industry. This results in a very localized industry, where global demand is met by a relatively small geographical region. This off course has the advantage of centralized organization and optimization of the production process. [2]

Accompanying this is a global distribution system, this consists of international shipping, distribution hubs both national and local and then retail locations/systems (digital and physical). This entire system is needed to get the products from the factories to their end users. As such shipping and its limitations are also very influential in the overall process. The same is true for the raw materials/ components, for example fabrics, yarn, wool and/or cotton. These also require extensive transport to reach the production facilities.

This global shifting of materials and products puts a strain on both land and water transportation routes. And as with all long supply chains minor infractions can have big consequences down the line.

Within a global industry standardization is an important tool in optimizing production. It allows for a clear product range that can be measured, controlled and optimised for production in terms of material, and production steps needed.

Something related to this giant industry, that is currently growing, is the demand of the consumers to know the origins of their clothing. With several very public incidents taking centre stage in the global news the consumers are becoming more aware of the impact of their clothing demands. This unfortunately Companies are slowly starting to accept this and share information about their production facilities and product origins.

SUSTAINABILITY

Looking at the sustainability of the current clothing industry we see several practices that are lacking. The clothing industry is an industrial giant, the processes are streamlined and efficient and provide much of the world with cheap clothing. The downside is that it is done at great cost, both environmental and humanitarian [3]. The working conditions are appalling, not to say there is no variation. But there are production facilities, like the Savar building, in many countries around the world.
The facilities and working conditions for the workers are not the only problems. The environmental strain related to the bulk production of clothing results in water shortage, mono culture and land quality depletion. This has a direct impact on the local population in the raw material generating regions. Within the production regions we encounter pollution caused by the improper disposal of industrial waste and by product.

So, is it only bad? No it also creates employment. Which helps to support local economies. However they also helps keep the communities from thriving, with the community members needing to work from a young age to keep their families afloat financially. Preventing education and future development. This is not to say all people that work in the industry suffer from these social sustainability problems, towards the end of the supply chain we see shop keeps, managers, truck drivers making a living within the comforts of the western society. But the start of the chain needs to be able to share in equal measure.

These issues are hot topics within the industry, as several companies have started to fix these issues. However in doing so they are exposing more and more of the industry changing the public's perception. But non the less positive steps are being taken.

CONCLUSION

We see an industry struggling with a past that has been or is still being tainted by the problems of the Industrial Age. The general public is slowly becoming aware of these issues as they get more interested in the origin of their products.

This means that producers have to start taking more responsibility for the entirety of the supply chain they use, and where possible choose the more sustainable option. As a failure to do so will have a negative impact on their brand [4]. And it is the customers responsibility to be an informed consumer, and if possible choose a more sustainable option [5].

Within the social context of individualism another relevant aspect in regards to clothing is product fit, this is strong driver when looking at customised clothing [6]. While no two people are exactly alike the consumers have to cope with standardized sizes. This in stark contrast to the fact that a correctly fitted product can greatly increase the product satisfaction. As such it is an area well suited to the possibilities of digital design and production, as it could allow the users to design and wear “made to measure” or even bespoke tailored garments. This could result in the co-creation of value [7]. Which in turn should result in a greater product attachment which carries value in the field of emotional sustainability.

This alternative take on product design will also create opportunities to actively alter the supply chain we use [6]. Cutting out several steps and placing the process in a more local context. In a sense design globally but produce locally. This could help elevate the pressure on both social, humanitarian and environmental resources and also make us more aware of the effort required behind our clothing.

EMOTIONAL SUSTAINABILITY

Looking at sustainability one of the fields that is becoming more popular is emotional sustainability. Within this field we look at more engagement from the user/consumer of products. This is achieved by creating an emotional attachment to the product. This helps to ensure a sense of responsibility for the product, which can lengthen its product life. While also making sure it is properly disposed of the product at the end of product life.

In a sense we want to give, even the lowest priced goods, value to the end user [8]. Think of it as a picture a child drew for you. This drawing might not carry a large monetary value. Yet we can have great emotional attachment to it. While a similar drawing might be in an art gallery as part of an artists collection. Here the monetary value might be significant but without the emotional connection could be perceived as worthless.

So how can digital design provide additional value to clothing? As stated before product fit is an important aspect of the comfort of clothing. As such making bespoke clothing could help with creating value by means of great product fit. While local manufacturing can also allow for greater user input in regards to its specific design and look. All these things can create a greater emotional attachment to the product [9]. This could potentially create an extended product life, in comparison to of the shelf clothing. This would offer a competitive edge in comparison to the current clothing industry.

LOCALISED MANUFACTURING

A development that has been gathering momentum is localised manufacturing. Taking industrial processes back to their basics and placing them within a local context [10]. This is starting to take back some of the production power to the locals as well. While local practices have a focus on analogue means, several digital production means are also showing up in the local context. These are either supporting or replacing some of these analogue steps. Most of these new options use digital models as the bases for their actions. Examples are 3d printing, Laser cutting and digital milling or CNC machining. Allowing for the production of more complex and products within a local setting. However this does require a level of knowledge in regards to digital design and models.

Looking back at the assignment, the main focus here is 3d printing. The machine has undergone a lot of development. This has resulted in several self-build or basic models for the explorative user to experiment with. The most prolific machine is the filament printer, also know as Fused Deposition Modelling (FDM) machines. This machine using a filament feed to print and is relatively cheap and easy to use. Other print systems are the Stereo Lithography (SLA) a system that use UV curable resins to print, and Selective Laser Sintering (SLS) which uses a powder base and selectively fuses the grains together. For a more complete overview see Appendix A.

Due to the accessibility of FDM or filament printers these are the main focus of the general public. As these machines are easy to build, run and maintain. These machine are being used in education, prototyping and production roles. They focus mainly on hard shape products, fabric like products are still proving difficult to make. So opportunities for improvements in this regard are present.

DESIGN CULTURE AND 3DPRINTED GARMENTS

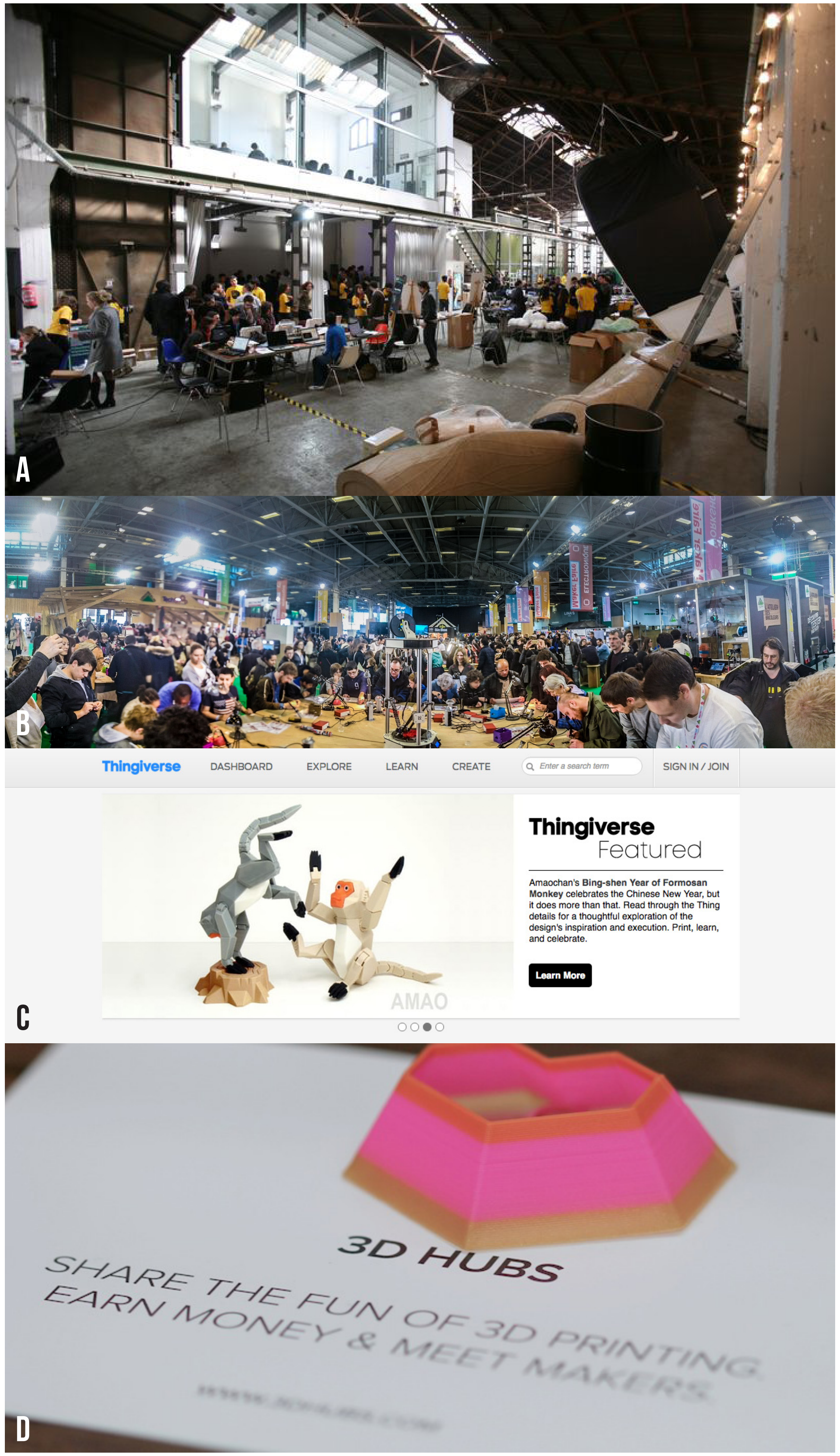


Figure 4. Overview of maker culture.

The goal of the assignment is to bridge the gap between 3d printed technology and the end user. 3d Technology or AM requires a certain skill set in order to achieve the results desired, therefore there is a threshold when wanting to use these production methods.

3d Printed technology/AM are methods that are suited for local implementation or local manufacturing. This will bring the technology closer to the end user and therefore partially close the gap between these. Localized manufacturing is a movement that can be observed in general culture today.

One of the main drivers behind localized manufacturing, and a redefining one for designers, is the rise of the maker culture. This cultural shift from mass produced to home-/self-made products is driving a new wave of development in localized manufacturing and design tools and methodology [10]. The maker culture manifest itself in several ways (also see Figure 4.):

A) Fablab
The fablab principle is something that fits into the maker culture, as it allows makers to build more complex products for which they do not own the tools or have the expertise to build. These workplaces are stocked with digital manufacturing tools like; 3d printers, CNC machine and laser cutters. These are supplemented by the more common tools like; drills, laves and band saws. These spaces are either open to the general public or are linked to educational or artistic institutes. While most major cities around the world have a fablab facility, most are hidden from public view due to location or lack of recognizable markings. This results in a lack of public knowledge about the facilities and possibilities, and as such is not noticed by the general public (http://fablab.org).

B) Maker fairs
These events are generally held in public areas/ buildings and generate more public awareness and attention. While still visited mainly by makers, they also attract people generally interested but not (yet) participating in maker culture. These event help to showcase, educate and create appeal for the results of maker culture. This has a great benefit in helping the movement to grow and develop. As fellow makers can meet and exchange ideas. This is augmented by the physical nature of the event in that the products and tools are there and can be used/touched and explored. Still most of the visitors are already interested in or connected to the movement, creating a new wave of makers from yet unengaged people is not the aim of these events. (http://makerfaire.com/)

C) Digital Maker Culture
One of the effects of the digital design is the ability to share it using digital media, through open sourced platforms or paid services.. This does not exclude other non-digital designs as tutorials are also wide spread. This helps to create exposure for the products that can be made. While most users of digital and social media will come into contact with maker culture the effect of seeing a picture or movie is not the same as holding the actual product. This gap between exposure and contact is a limiting factor in creating attraction in regards to the final product [11].

D) Maker Service
Within the maker culture, the service industry has been working hard on providing means for the general public to access it. Even if they themselves do not posses the expertise or materials needed. An interesting example is 3d Hubs. This network company provides users with a means to create 3d printed products without buying a machine or going to the bigger Fablabs. Instead it provides a platform with which 3d print owners can create return on their investment. The owner can register their printer and after a successful trail test they are accepted into the 3D HUBS network. Once this is done he/she can start taking on print jobs from the users of the 3D HUBS. The current network has over five thousand registered printers all over the world.

This new local network is thereby also connected to a global network, which enables greater knowledge transfer regarding applied knowledge. As the platform also creates interaction between hub owners and local clients, the work flow generates a face to face meeting on product pick up, which helps tie the maker community members together. While also creating a local and global network of maker enthusiasts.

The service design enables the hub owners to host their mini fablabs on the website, they also help the costumers by checking the digital models they upload, making sure the designs are feasible. As failed projects due to a design error would create negative feedback and backlash to both 3D HUBS and the hub owner. Yet this service still relies on user generated content or designs from online databases like thingiverse. Creating a connection between designers and costumers prior to the fabrication might enable a co-design/ co-creation track to be initiated.

CONCLUSION

Too conclude, the maker culture and AM results in a positive movement for early adapters and other creatives that already possess the skill to deal with the challenges of the digital additive manufacturing technology. However, the gap between this technology and the every day users results in a high threshold and therefore a lack of acceptance within the public at large. In the context of LDM and AM the future of the designer might lie in creating means for design instead of creating finished products.

The developments in the fields of local design & manufacturing (LDM) and the rise in maker culture are both means to help redefine the roll of designers in realizing greater exposure for AM.

CO-DESIGN

In order to test the new dynamic between designer and end user it is important to redefine their relation [12]. The freedom created by LDM also creates a larger design space, for example aspects like shipping and regulations are very different in a local context in comparison to a global system. In order to help guide the end user in this process designers have an opportunity to lend their expertise by means of for example Co Design.

Within this design method designers are moving away from translating the needs of the end user into a product. Instead they are facilitating the creation of this product by the end user [13]. This shift not only redefines the role of the designer but does the same for the role of the end user. As they will have a greater influence on the front end of the design process, and as such on the final product (see Figure 5.).

This coincided with the change in dynamic envisioned for the application of LDM as the method allows for local influences to guide the design process. It is not just limited to the local users but also local materials and cultural heritage. This could be used in combination with the design of wearables, were a correct fit and integration of personal style is valuable.

In short it allows for greater user integration and as such could connect to the strengths of digital design, within a local setting.

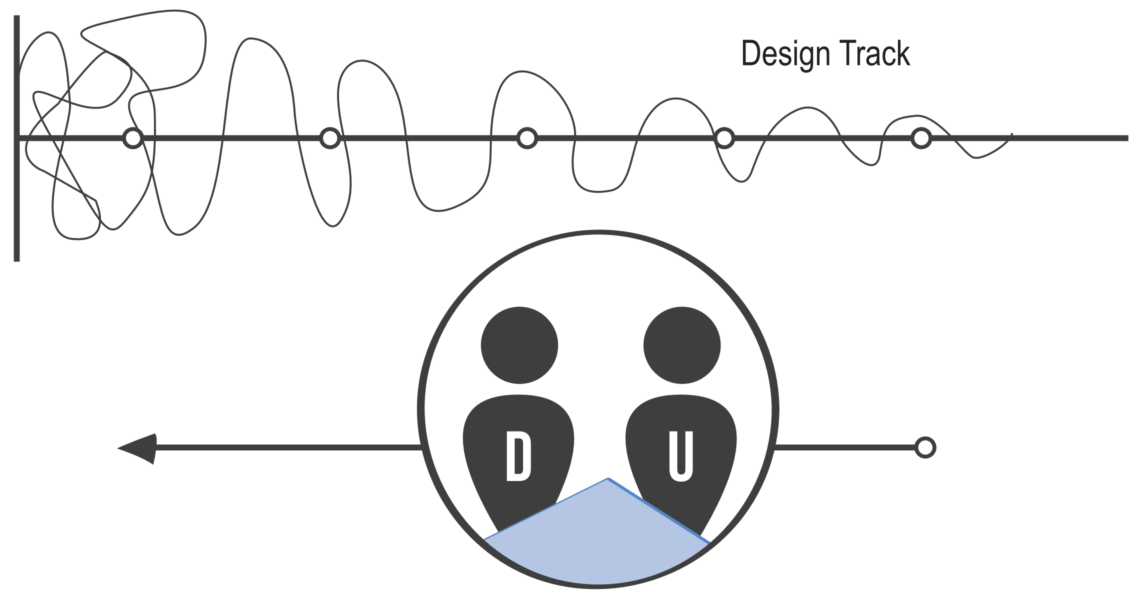


Figure 5. The the main driver behind Co-Design is the early integration of user input.

DEFINING THE NEW ROLE OF DESIGNERS

In order to define or redefine the role of designers within LDM it is imperative to look at the current state of affairs within the clothing industry in regards to the interaction of designer and end user.

Within the current wearables market the interaction is based on the industrial production of clothing. This results in a gap between designer and end user, with producer, wholesalers and retailers as the stakeholders (Figure 6.) [2]. This system has benefits, since each stakeholder has a clear task which can be optimized and perfected. However it also results in a lot of global shipping and a gap between designer and end user. The process also relies on large production numbers in order to function creating the need for standardization. This standardization is creating both effective means to produce but also leaves a lot of the users in discomfort. Their specific body types or styles not fitting this industry mould. Which creates friction between their needs and the products that are available. This leaves room for improvement for future clothing solutions.

When looking at the new dynamic that is created though local design & manufacturing we see that the number of stakeholders changes and that they take on new roles. This contrasting dynamic creates new opportunities and benefits. The close proximity both physically and structurally allows for different design methods and interactions. It creates room for personal/ one off designs as well as small locally influenced series of products. This new dynamic however does ask for different design tools and methods. As such redefining the role of a designer in this context will be important. Localized manufacturing has other benefits regarding sustainability, when looking at shipping and emotional sustainability. As the users involvement with the creation of the product grows so will their attachment to the product. These will all be influencing the outcome of the research.

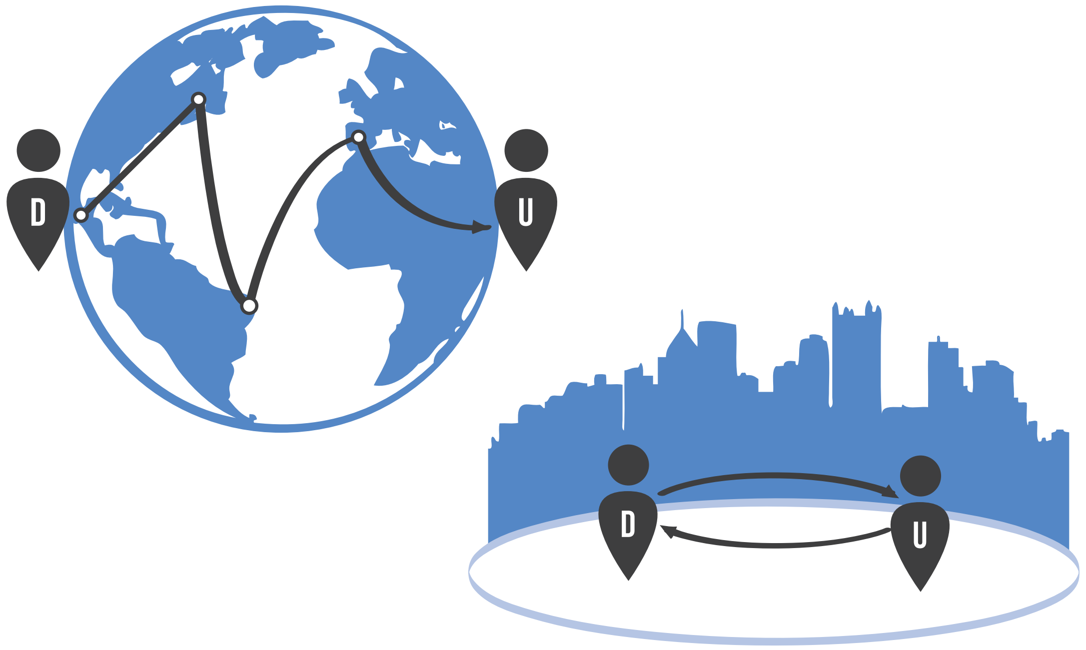


Figure 6. Current interaction (left) and the envisioned interaction (right) between designer and consumer, from global to local.

IMPLEMENTATION OF 3D PRINTED GARMENTS

As also mentioned in the introduction the university of Aalto has worked on 3d printed fabrics. During the initial research into the subject of AM of clothing additional links between the subject matter and the Aalto university were encountered. Several projects and initiatives surrounding additive manufacturing techniques and fabrics had taken place at the Aalto faculty for design. This suggested that this would be a suited location to further discuss the LDM of clothing. The objective of this discussion was to see how 3d printed fabrics could be used within a local design and manufacturing context. What advantages and opportunities are there but also important are the possible limitations or problems.

In order to establish this a creative session with the local students was realized. As the facilities and organisation within the faculty creates an interesting mix. The close relation between industrial design and fashion departments should hold great value in relation to 3d printed fabrics and their use. An example of this was the Soft/ Mesh project this is of great interests from a creative and implementation stand point [14].

As such being able to talk to Jussi Mikkonen(associated professor Soft/Mesh) and his students regarding this project and their current work in the field would be useful in defining the scope of the thesis research.

THE AALTO SESSION

During the session the students (see Figure 7.) were asked to give their insights into several aspects of AM technology and clothing. By using a creative session platform their insight have generated several mind maps and scenarios, which helped to identify how the new generation of designers looks at the possibilities of using 3d printing as a means to produce clothing. For the students this meant they had to work at the edge of their knowledge, as not all of them are fully aware of the current possibilities. Yet this gap between their ideas and the current state of the technology is valuable to this research as it might expose other opportunities.

DESIGN OF THE SESSION

During the session 11 students participated in several exercises designed to test their knowledge and define their expectations as designers and more importantly human beings. The session consisted of several consecutive steps that helped to sensitize them to the material and then test their ability to apply their design thinking to different scenarios. By using these steps they had personal attachments to the issues and solutions they uncovered.

The group was first asked to draw their favourite piece of clothing/wearable. This step ensured a personal attachment with the session subject. The object was draw and their unique attributes identified. These objects where then converted into persona, where the unique attribute of the garments where translated to personalities. These personality traits where then grouped to see if overlap existed between the several garment personalities. This would serve as the baseline to which I could reflect the final results of the session, and possibly identify conflicting or shared traits.

Figure 7. The participants of the session at Aalto University

Figure 8. Overview of the Aalto sessions.

RESULTS

The main focus of the results of the session seems to be one the following aspects of 3d design (also see Figure 8.). For a complete overview of the results see Appendix B.

Local production: as seen in the travel kit and Day designer ideas, both consider the technology mobile enough to take with you and print new cloths either over night or on demand. Location is not seen as a limitation but as an opportunity.

Speed: most ideas still revolve around a magic button concept of speed. They expect garments to me done extremely fast ranging from an 8 hour overnight period to +/- 30 minutes in the on demand concepts. This is not to say that they are not aware of the current printing speeds but they expect this to be further developed and increased in the near future.

Design input: the concept of having a large amount of input on the garment design is deemed as important by most participants. As well as great product fit using 3d scanning/mapping technology. This seems to suggest that the technology should be open or accessible enough for direct user input from a consumer perspective.

Design freedom: The premise of complete design freedom was very strongly engrained. The believe that 3d printing can basically make any shape without issue was shared by most. This was manly founded on the concept of digital design. It is possible to make a digital model of basically any user product. As such they feel that it can be build with 3d printing as that can generate a physical product from a digital model. The fact that there are some technical limitations to this currently does not seem to prevent this notion. The main issue that remained was the material properties related to the technology.

The design space, as desired by the students, for the digital manufacturing of garments only partially lies within the current capacity of 3d printing. However, the desire for digital manufacturing is very much present as it offers great creative and conceptual freedom.

DEFINING THE CORE VALUES OF 3D PRINTED GARMENTS

The main points that came to light after the Aalto sessions is that while the design community is aware of the strengths of the Additive Manufacturing process in regards to clothing; made to measure, one of designs and freedom to mix materials, they are also experiencing several issues in regards to the speed and product finish. Even within this group of young designers who are exposed to a lot of research projects regarding AM of fabric like materials the general perception it only produces plastics and not fabrics. This results in a limited design frame work as this limitation seemed a deep-rooted believe. They were eventually able to work around and ignore it in the final stages of the session.

While 3d printing clothing is being considered within the design community as a replacement of the traditional material and production techniques. As 3d Printing allows for great freedom in shape and construction. It is however seen more as a haute couture fashion technique. An example of this are the earlier mentioned works of Iris van Herpen. This combined with the long production time makes it unsuited for this research, as the aim is to create more acceptance amongst the general public through the creation of ready to wear garment. Therefore a more intermediate step is needed.

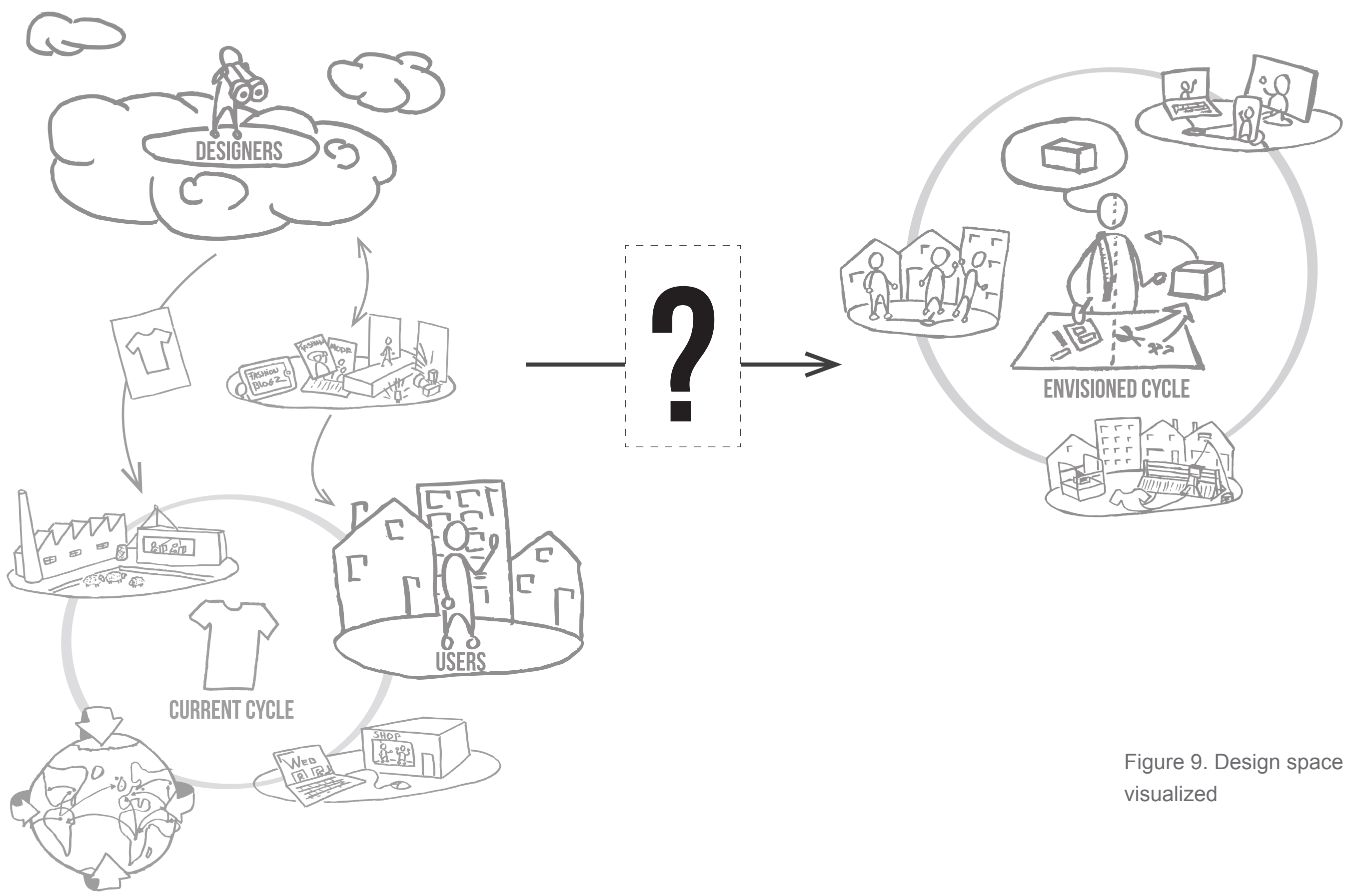


Figure 9. Design space visualized

DESIGN SPACE

The design space is defined by my vision on the subject as will be explained under Future vision and takes into account the core values that have been defined (see Figure 9.). Furthermore the current state of the garment industry will define the starting point and defines the other side of the design gap/ opportunity.

Within the vision we see the following; on the left the current stakeholders, influencing culture, technological developments and on the right the future vision. These two sides of the vision will be further defined in the following sections.

CURRENT SITUATION

Currently we still see a large detachment of the design practices in relation to its intended consumers (see Figure 10.). The production is causing several negative effects on society at large. The sustainability of this industry is lacking in several areas and as such alternatives should be developed. We also have a gap between our users and the digital production methods/ tools currently available. There is an opportunity for us as designers to close this gap and design designing for a broader audience. The maker culture and renewed interest in local manufacturing offer opportunities to rethink and relocate the production processes needed to realize products.

FUTURE VISION

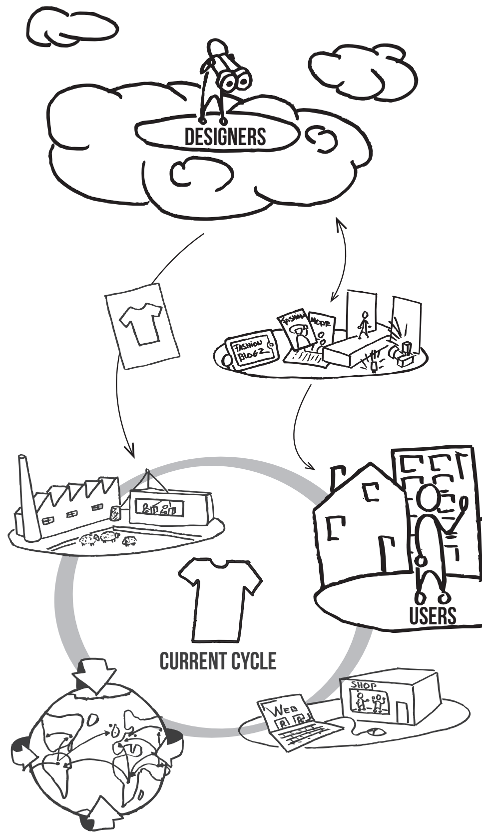
The vision I have for the future user, as based on the prior research, is a user that is able to use AM technology to their fullest potential within a supportive local context (see Figure 11.). This support comes from both a supportive community that shares a similar interest and local manufacturing initiatives/ facilities. These facilities are likely to originated from maker culture initiatives or perhaps are shaped into production shops. How this will take shape is one of the design opportunity.

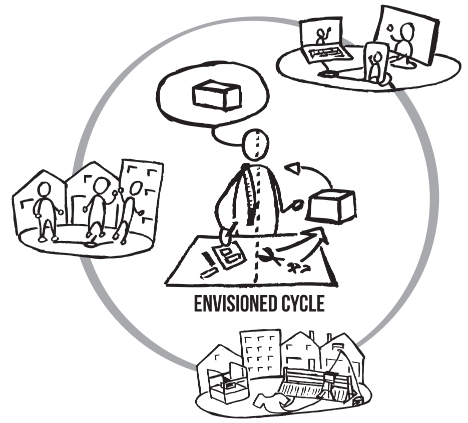
A supportive community requires public awareness, and perhaps local initiatives to guide this process. This could come from the maker culture, as well as neighbourhood initiatives.

The users would be able to design and create there own products or garments within this context. The skills required will need to be acquired or provided. This will result in a need for either close linked cooperation between users and designers, or perhaps by new tool concepts that allow the user to do this themselves.

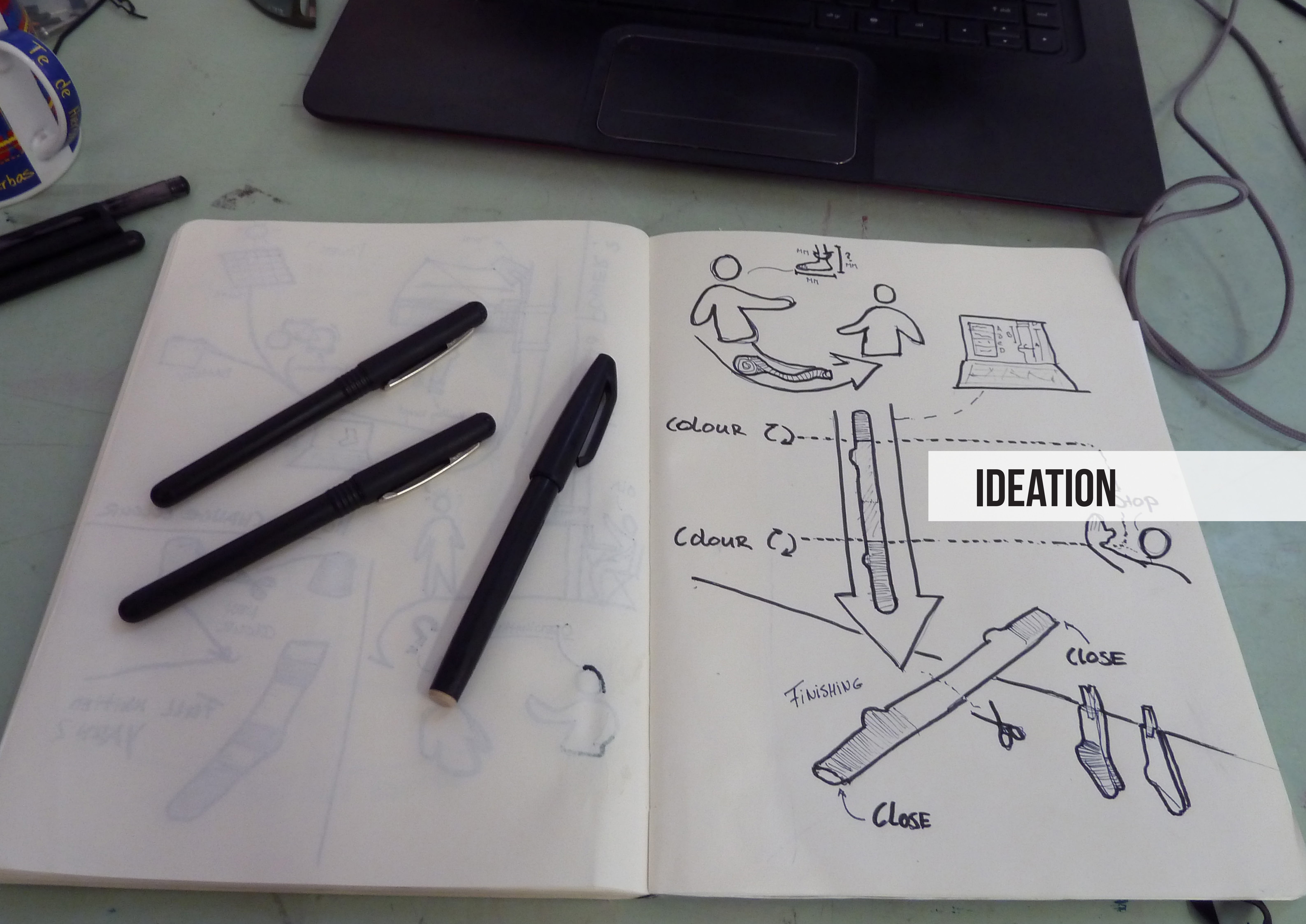
Figure 10. On the left side of this page, a visualization of the present day situation

Figure 11. On the right side of this page, a visualization of the envisioned situation





IDEATION



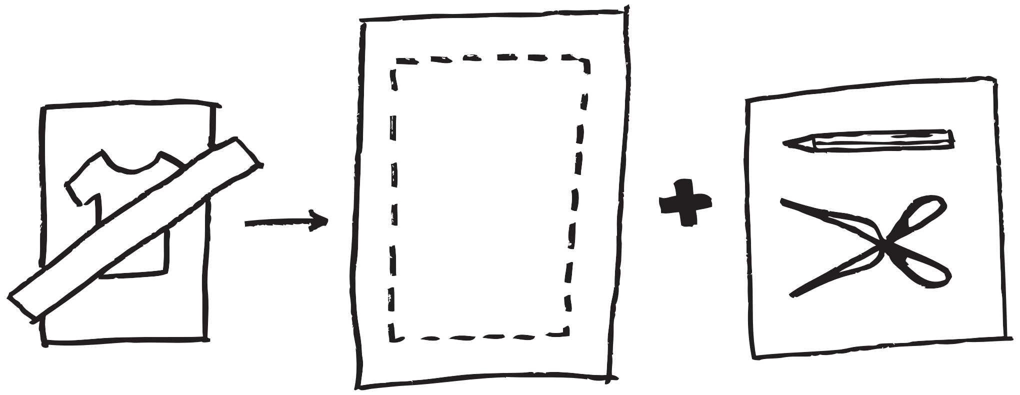


Figure 12. Visualization digital sewing kit.

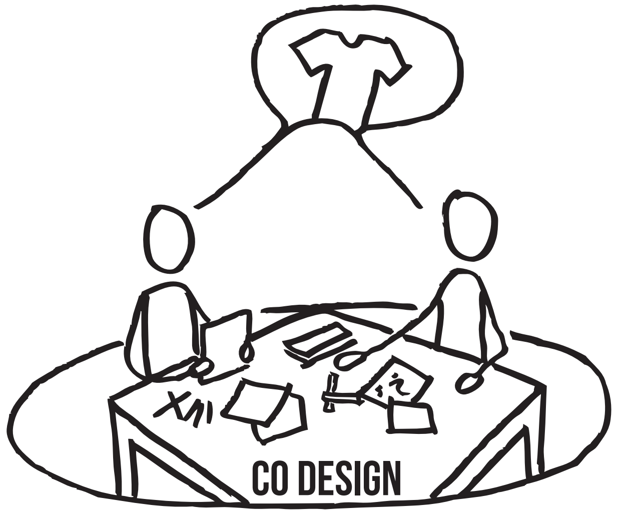


Figure 13. Visualization “Oploskoffie”

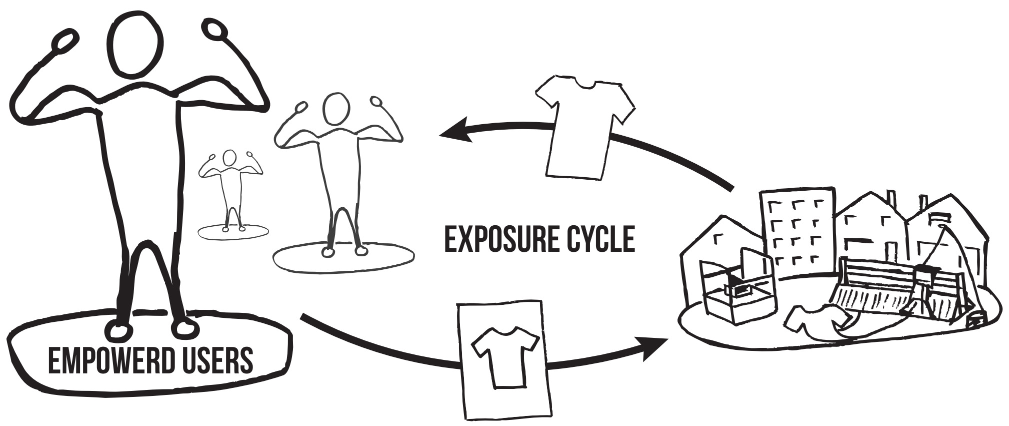


Figure 14. Visualization “Buurt sok”

DESIGN OPPORTUNITIES

Within the ideation phase several design opportunities will be identified for further development. These opportunities focus on bridging the gap between additive manufacturing technology and the end-user. Looking for ways of increasing acceptance and understanding in regards to this technology and defining the role of the designer in this new dynamic interaction.

The design space will help guide this phase, by defining the edges of our solution space. The ideation will look into solutions on several levels and a selection of one opportunity for further developed will be made.

CREATING A NEW DIGITAL SEWING KIT

The focus of the digital sewing kit lies on solving the design problem related to clothing by developing new software to generate digital clothing designs based on measurements or 3d scans (see Figure 12.). This would revolve around creating a full design tool allowing full customization of the garments based on body measurements and preferences. However an important aspect is the degree of freedom, how much input is needed to create a sense of personalization? This is the main aspect to be determined as to make sure the final interaction is one of satisfaction not frustration, it should be an effortless process. The actions needed to create a personalized piece should make sense and feel logical. Here the tool and not the garment is the final result.

In short the opportunity in further developing the tool kit lies in removing the need for external advice or help in the design process and as such provide a means for users to design for themselves. Helping the users to become their own tailors, and as such help close the gap.

“The designer of the future has to become a database designer, a meta-designer, not designing objects, but shaping a design space in which unskilled users can access user friendly environments in which they can design their own objects. “ - Prof.dr. Jos de Mul

DESIGNERS IN THE LOCAL DESIGN CYCLE

The focus of “Oploskoffie” lies on solving the design problems related to clothing by reintegrating the design community into the local design cycle. A local Co-Design track should be the goal here, creating an interaction/ service to facilitate this (see Figure 13.). The main drivers for this interaction should be:

- Local solution driven design
- Social input
- Circular economy
- 3d hub business model

These elements will ensure the system allows for face to face interaction and help create designs that really speak to the consumer. This will not only help them appreciate their products, it also helps a longer product attachment, partially based on emotional sustainability. It will also enable the local design community to directly affect their community. The focus here is on guiding the design process. But the production is left up to the user. They retain the freedom to decide how and where to do this.

This opportunity revolves around redefining the designers role and how this can be placed within a local context. It creates a strong tie between design, local culture and user needs. While still allowing the designer to use his expertise to guide the process.

“Designers are becoming entrepreneurs. By telling them to create their own way to make money, we relate to their sense of entrepreneurship. However, the concept of finding their own innovative ways to earn a profit has not yet been developed. This is a real challenge; they really have to make that mental shift towards entrepreneurial design.” - Renny Ramakers, Droog Design

THE NEIGHBOURHOOD SOCK

The “Buurt sok” focuses on solving the gap issues that currently exist between designers & technology and the end user (see Figure 14.). This is not Co-Design but Co-Creation were the products are made with the customers, on the spot, ready to wear items are the main outcome. The interaction should facilitate a smooth and creative process in which a user can quickly adapt and fit a piece of clothing to his/her specifications. Depending on the user the designer can facilitate this process

The main focus here lies with creating relevant exposure of the technological possibilities, in a sense create a technological teaser, to the public. This is needed in order to create a strong community. As awareness is needed in order to create desire and/or action.

DESIGN OPPORTUNITY PLACEMENT

When looking at the identified design opportunities they can roughly be placed in the overall design vision as seen in Figure 15. The digital sewing kit is a means to create a tool that indirectly allows the designers to facilitate the users design processes. The “Oploskoffie”, direction focuses on the more direct guidance of designers while counting on the users initiative to get their designs made within the local context. The “Buurt sok”, focuses on actively co creating with the users, making sure the entire process is completed from start to finished product.

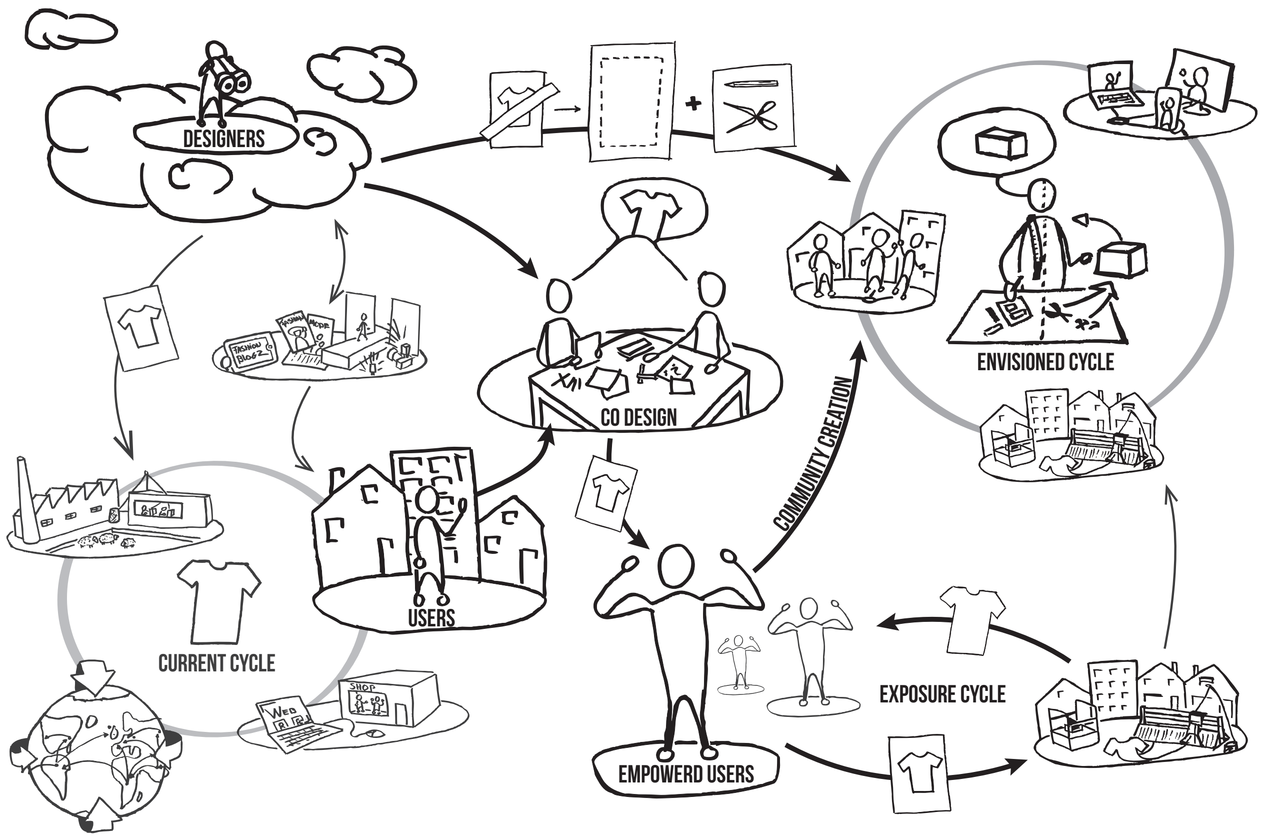


Figure 15. Opportunity placement in overall vision.

DESIGN OPPORTUNITY SELECTION

When looking at the three main opportunities the “buurt sok” stands out for its completeness (see Figure 16.). It has both physical as non physical design elements. It also helps in creating the community base for the envisioned future user. Its seemed to hold the most potential and opportunity for face-to-face user research and interesting product/service development. Moreover, it directly helps to close the gap while also providing a renewed design angle for the design community.

The other two opportunities also have merit however they are fields which have been researched or are being researched by other institutes and design agencies. As such opportunity for greater innovation seemed less likely.

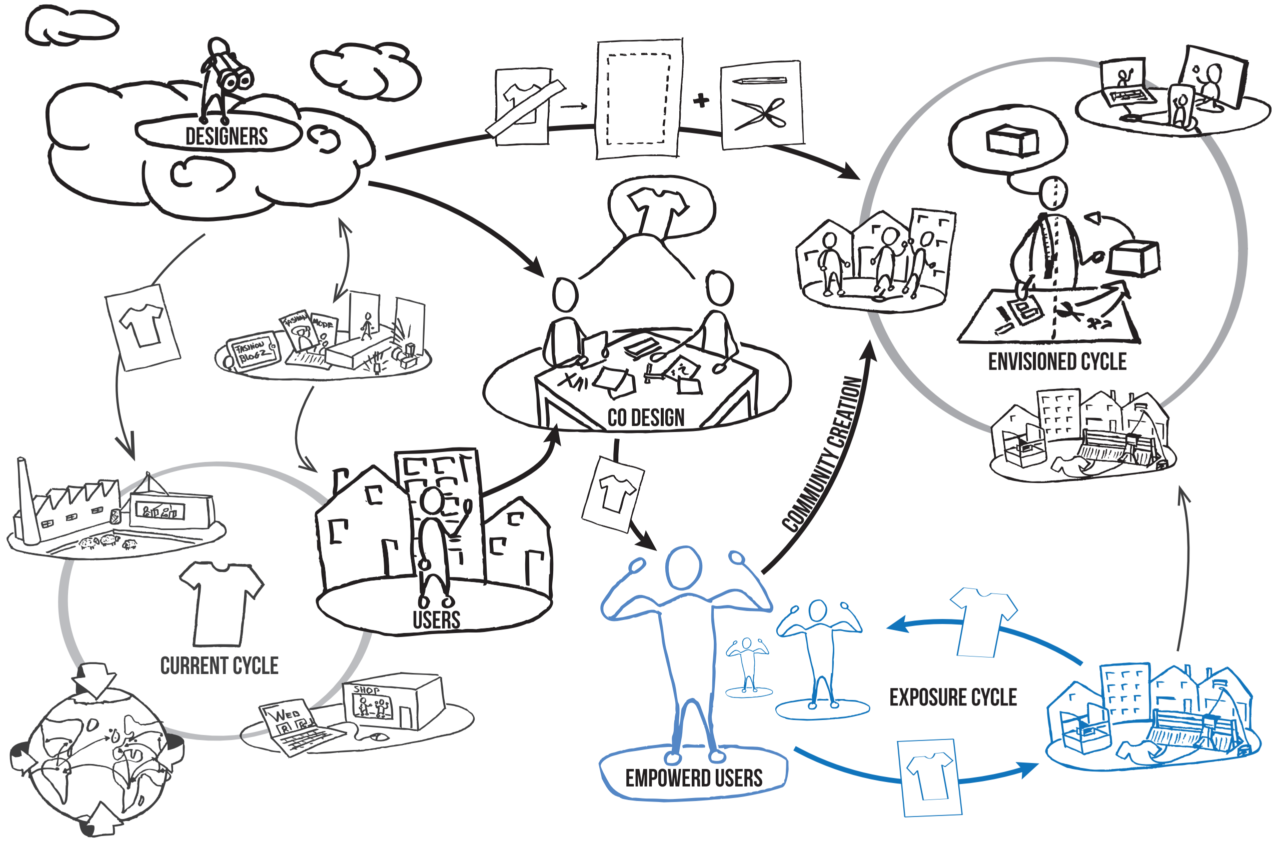


Figure 16. Opportunity selection for further development.

EMBODIMENT

DEVELOPING A LOCAL MANUFACTURING TOOL

The “buurt sok” proposes a solution for the gap as described in the assignment of this graduation. As described before the “buurt sok” has both physical and non physical elements. In order to validate the opportunity a digital manufacturing tool for wearables had to be developed, this tool could then be used to evaluate the response of a community in regards to digital manufacturing.

DESIGN CRITERIA

In order to facilitate the localized manufacturing aspect, a mobile digital manufacturing tool was needed. In order to use the tool within the local context several criteria where listed:

- It needs to be mobile, or light enough to be moved by a single person (less than 10 kg.)
- Big enough to create small garments; socks, scarfs, hats.
- Self-sustained when in use, no external power needed at the production location.
- Allow for a made to measure approach, allowing the user to take his or her own measurements by adapting an existing template.
- It needs to be reliable, as a minor error will ruin a garment.
- The product coming out of the machine should require little to no extra actions, as close to ready to wear as possible.

As such the following possibilities were taken into consideration. Each will be shortly addressed and checked with the criteria.

DIGITAL KNITTING

As explained before 3d printing is not suited for the creation of ready to wear garments, therefore alternative means where sought. Digital knitting proved to be an interesting alternative. This process emulates the knitting that keeps many hands going around the world using a machine. While knitting machines have been around since the 14th century the introduction of digital knitting machine was not seen until 1976. These machines used digital patterns stored either in the machine or introduced using a floppy drive. However these machine while effective still require a person to work it in order to create a piece of knitted clothing.

Usually a hand operated system, with which the user moves a sled that creates the actual stitches when passing the needles. Since then fully automated systems have been developed for industrial style production of clothing, these can create complete ready to wear garments. However these machines are extremely expensive and bulky. Which limits there use for local manufacturing, as the investment needed is hard to justify as a community resource.

Next we will discuss some of the current options for digital knitting machines for the Buurt sok concept (also see Figure 17.).

A) Knitic, manual knitting machine hack
This system was recently developed in 2013, where by hacking the old manual knitting machines you are able to create new digital designs. The Knitic design couple is working with this technology using several interesting input signals to create uniquely patterned designs. The machines are reliable as they basically hack into an existing flat knitting machine [15].

The main problem this creates is the sheer size and weight of these machines. The machine also is not able to knit full garments as it only allows for sheet knitting, this increases the manual workload after the initial knitting.

Although possibly more reliable they are hard to modify. And while an interesting project it seemed unsuited for the current goal of local exposure.

B) Circular knitting machine
When looking at the criteria most of the selected garments are tubular in shape. One of the fastest ways to knit in this fashion is using a circular knitting machine. These are very reliable as the knitting motion is never interrupted. They also allow for increasing and decreasing needles, which allows the knitting of heels.

However no progress into digitizing this progress on a small scale has been made at this time. This is also likely related to the fact that sizes are only changeable by switching out the complete needle ring for one with more or less needles.

So while good at what it does it can only do so much. The digital knitters are currently in use on an industrial scale but so far have not been scaled down for personal use.

C) True 3d Knitting
Another revolution within the field of Digital Knitting has come from Scott E. Hudson, he has developed a method to knit in full 3d allowing the creation of soft interactive objects. This project is interesting for two reasons, it includes a range of additive manufacturing principles creating a combination of several techniques. Secondly it allows for digital design to work with soft materials in a new way. This research has opened up several new avenues of additive manufacturing to be used and his initial object, an articulated teddy bear, speaks to the general public as it fully embodies the qualities this technique creates. [16]

D) Openknit
This project was created by Gerard Rubio, as part of his graduation thesis. The OpenKnit system is an open source project working towards creating a digital knitting machine. The designs and software are available for free and together with the bill of materials can be built anywhere in the world. The current design uses 3d printed parts, lasercut parts and some vendor parts. This enables anyone who lives close to an fablabs or has a small workshop at home to reproduce it and contribute to the further development of the device. This opens the project up for wide spread testing and exposure. It works by programming the pattern into Arduino which can be modified to the users specifications. [17]

The machine however is bulky and in its early stages of development. It also has some issues regarding reliability. The machine does offer the freedom to create several different types of garments. Currently ranging from dresses to sweaters to beanies. While not ready for complex patterns it does allow for different colours.

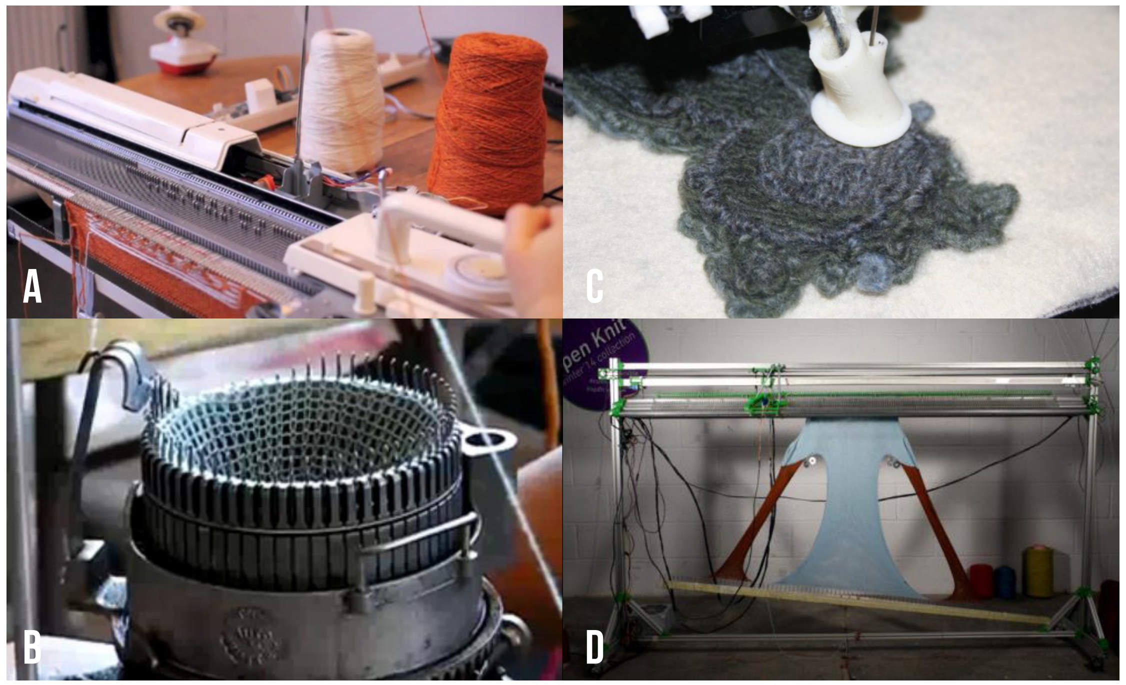


Figure 17. Overview of digital knitting possibilities.

Figure 18. Overview of problem areas and issues on the Openknit machine (later renamed Wally 340).

DEVELOPING A MOBILE SOLUTION

The OpenKnit system was selected as it offers a combination of open/digital design combined with an open source machine. This allows end users or communities to create their own machine while also allowing the designers to adapt them to their specific needs. However the current design of the OpenKnit system was not suited for mobile use, several adaptations would have to be made.

Therefore the machine was redesigned to be smaller, lighter and sturdier. Several tests were executed to test the new components durability and reliability, this was done on the main machine. The main components were all tested and (partially) redesigned. This was mainly focused on the carriage and the rack & pinion. The carriage is responsible for both guiding the thread as well as controlling the motion of the needles. Where the rack & pinion is vital to the accuracy of the machine as it creates the input for the software to determine the carriage position on the needle bed.

MACHINE IMPROVEMENTS

There were several issues with the current iteration of the machine. Most crucially the machine sometimes drops a stitch, which might not seem that important but this means the garment isn't fully knitted and will come apart. This means it's a crucial flaw. There was also a lot of vibration in the machine and twisting of the carriage.

CURRENT PROBLEM AREAS AND ISSUES

In order to identify what causes this we went over the entire machine to see and identify problems in geometry and construction that might explain the current issues (also see Figure 18.). When looking at the general geometry it seemed straight and true, however some clearance issues were present. The fixtures that kept the frame together were to wide and allowed for movement, together with the fastenings used this created a lot of room for movement (1). This would have to be addressed. Another problem that was identified was the yarn carrier this little piece seems all most irrelevant, however it proofed crucial for a reliable machine. Its alignment regarding the pickup and catching of the needles was far from optimal and needed a new approach in order to get a more reliable system (2).

Another problem that was encountered was the inaccuracy of the coder, this piece translated the analogue movement of the carriage to a digital signal for Arduino read-out. This piece however had some problems caused by the overall shape of the gear used to run it. Together with the positioning it caused the system to miss the step which would eventually cause the pattern to shift ruining the garment (3).

The overall carriage design also suffered from some construction problems, which resulted in force being applied outside of the base of the carriage generating momentum en drag. This greatly hinders the movement of the machine and results in more noise and required more power than necessary (4).

These main issues together with minor alterations would be the main focus during the stay. However something that was still to be added to the machine was the possibility to increase and decrease needles. While increasing needles did not pose a serious challenge, decreasing the needles in such a way that the knit is self-locking proved much more challenging. In order to create this the loop needed to be transferred from the outside needle(s) to the new outer most needle (5). This required a very specific and precise range of movements and actions. This however would proof to be a great improvement should we be able to achieve this as it allows for the creation of rounded shapes. This would enable the machine to create all manner of garments without any intervention or square patterns.

This initial analysis of the system provided the following points of improvement;

- Improve overall reliability, automation of the machine and knitting process.
- Create a new drive train for the coder allowing for accurate conversion from analogue to digital.
- Redesign the carriage so it creates less/ absorbs vibration.
- Redesign the yarn carrier so it is more reliable, centralized.
- (re)Design a needle decreasing system.

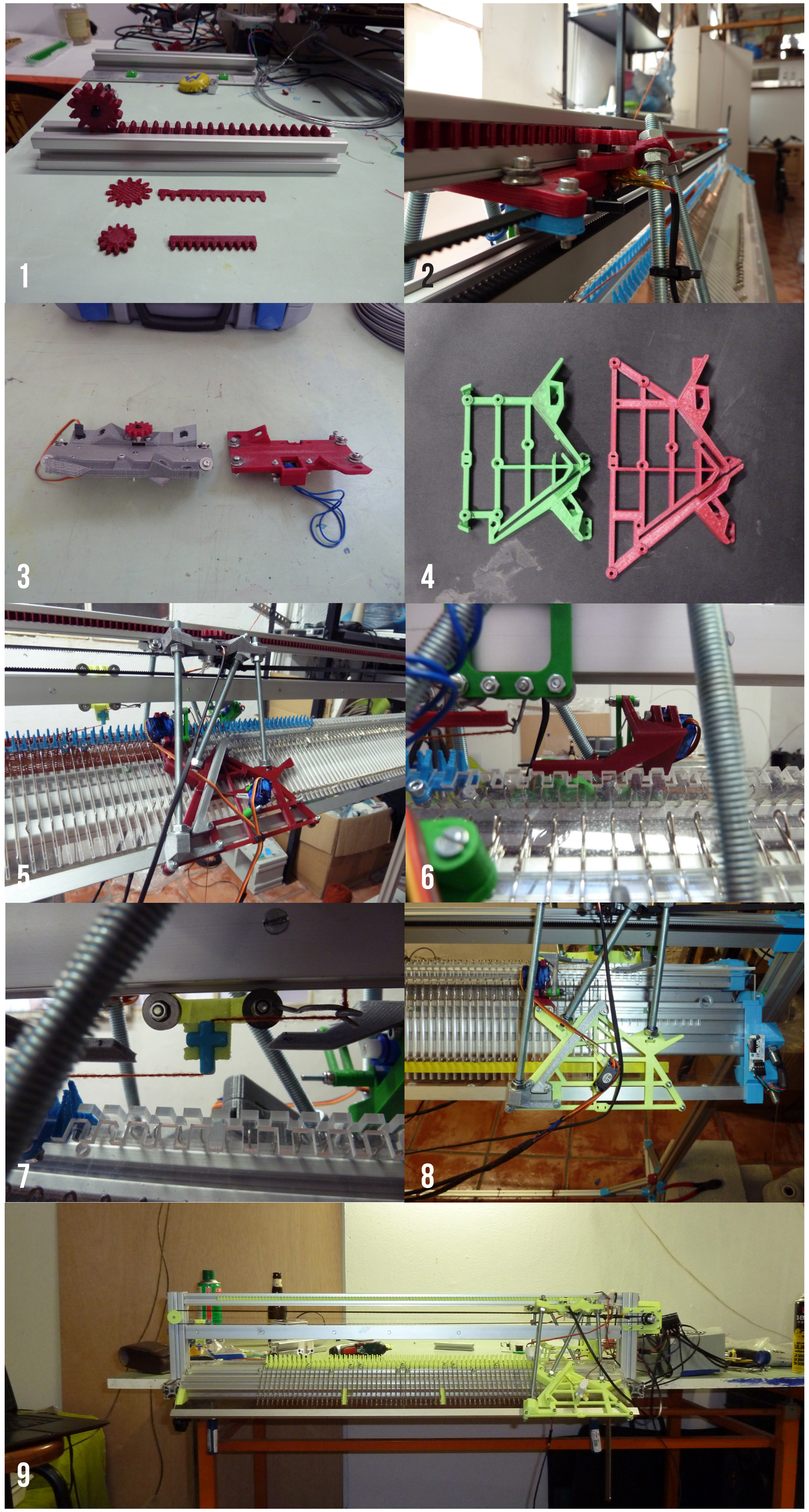


Figure 19. Overview of redesign steps leading up to the end result, Wally 120.

OPEN KNIT REDESIGNS

The identified problem areas were tackled in very intensive design iterations. Here designing prototyping and testing were executed as seen in figure 19. The improvements resulted in a strong and reliable machine. See Appendix C for a detailed overview of the iterations.

REDESIGN STEPS

During the redesign process several key components and mechanisms were redesigned, one of the main issues was the lack of accurate position awareness of the machine. In order to rectify this a new rack and pinion system was designed and build (1). This was placed on the top carriage (2), and showed higher resolution and greater accuracy in regards to the old system. However mounting the system exposed structural weaknesses in the carriage system. In order to strengthen the construction the entire carriage was redesigned top to bottom (3&4). This combined with a switch from a two beam to a three beam support between top and bottom carriage (5). This greatly increased the structural strength of the carriage and also greatly reducing shaking in the entire system. Another aspect that was changed was the thread sled (6) this was elongated and the outer curve soften to create a smoother knitting action, further decreasing the vibrations in the system. This thread guide (7) was then redesigned to position the thread in the exact center of the two needle beds. This greatly increased overal knitting accuracy and uniformity. The needle pick up mounting was also slightly addapted to offer better pick up and a stronger motion (8). In order to mount the Wally system a new support frame was also designed which provided a sturdier machine (9). As the connection where now metal to metal eliminating the sideways shaking of the machine during operation.

An endurance test was done in order to check prolonged use and its effects on the redesigned parts. This resulted in a 4,70m scarf that was knitted during 3 hours 25 minutes non-stop session, with three or four minor errors. A huge improvement over the previous design which had a minor error rating of around four every hour. But more importantly the old design had a jamming issue with a frequency of about once every 5-10 minutes.

RESULT

The resulting machine was mountable on any flat surface using two clamps, weight was reduced to 5,5 kg. Its needle beds have a total of 120 needles, 60 a side (see Figure 20.). This is sufficient to produce a small wearables. It is battery operated using a 12v battery and converter circuit to power both the stepper motor and servos which run on 12 and 5 volts respectively.

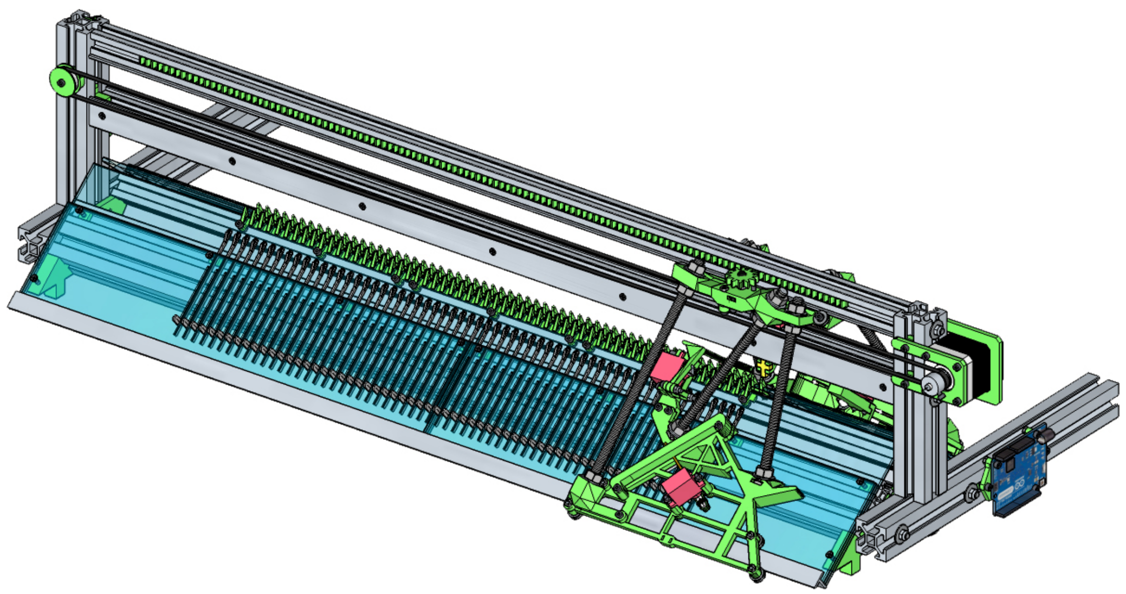
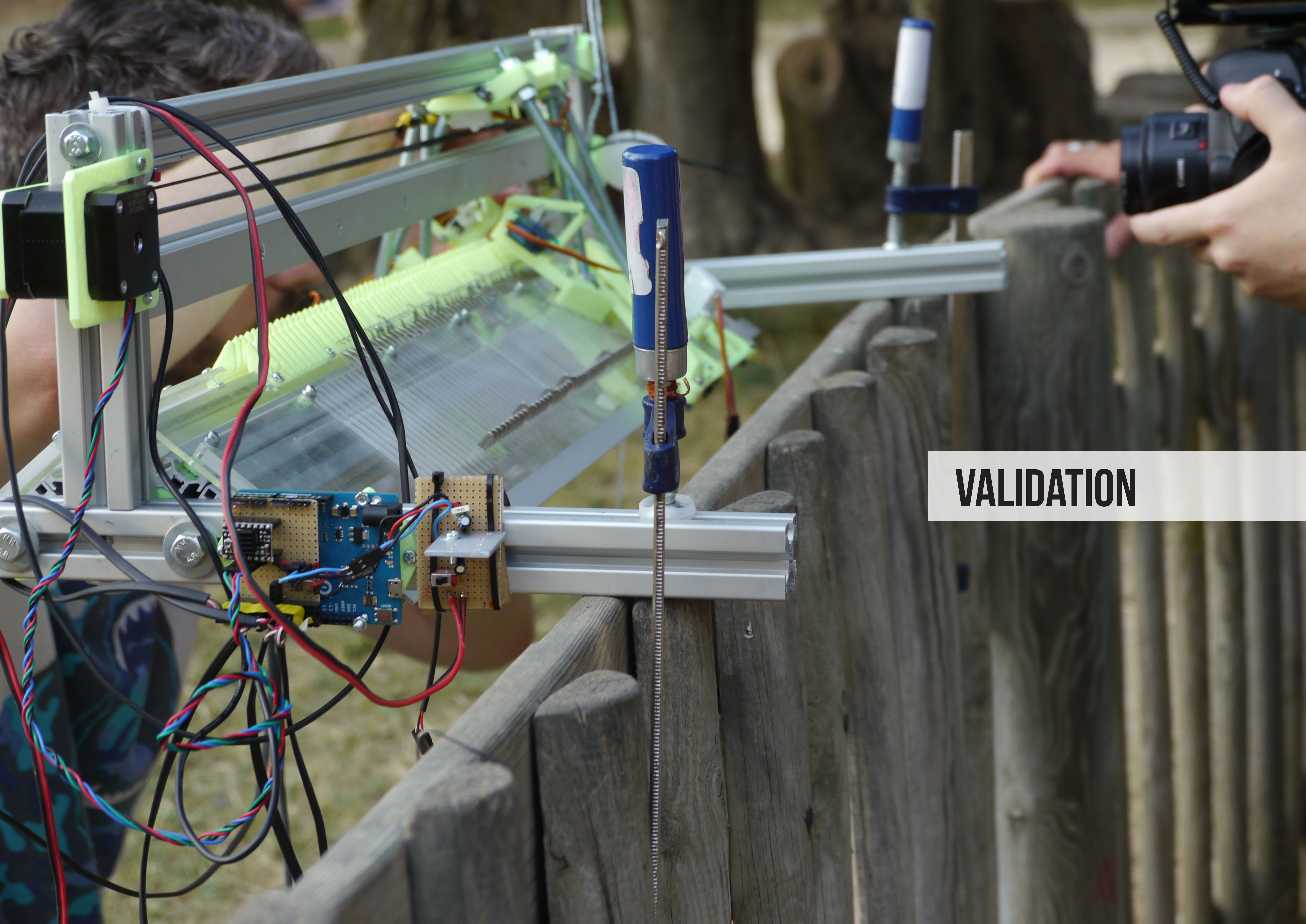


Figure 20. Graphic representation of the Wally 120, indicating the different components.

VALIDATION



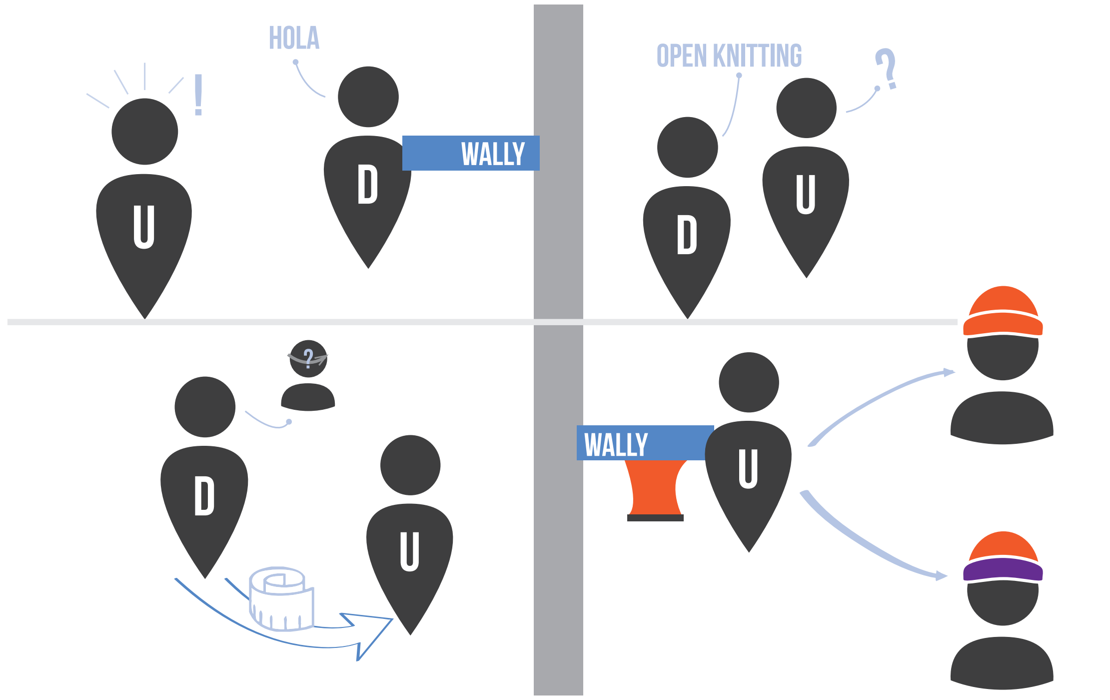


Figure 21. Scenario test

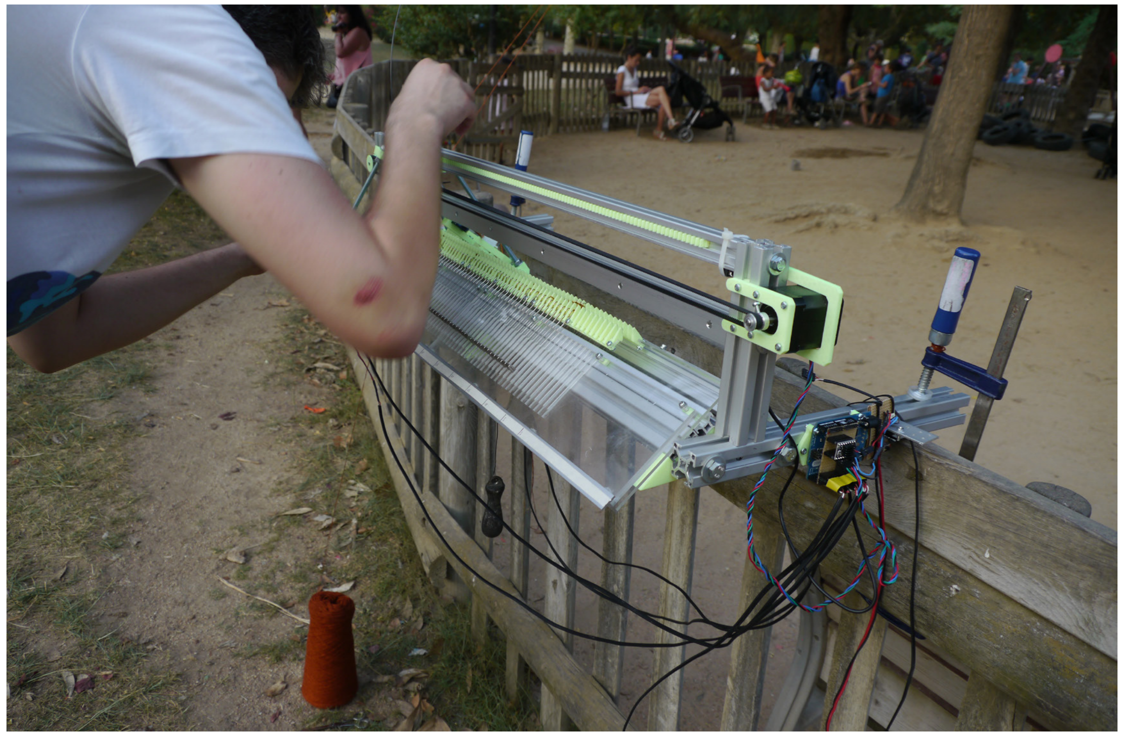


Figure 22. Test set-up. Wally 120 mounted on a fence in Parc de la Ciutadella, Barcelona, Spain.

FIELD TESTING THE WALLY 120

In order to test the actual exposure effects in a local environment the machine was prepped and taken to a local park in Barcelona. Here the overall impact of the machine on the people present could be evaluated. This would help determine the effectiveness of this proposed step in the overall design vision.

TEST SET-UP

When selecting the type of garment to make it was decided to make a beanie. This simple woolen cap design would allow for a quick turnaround during the sessions and would allow the machine to run without interruption for a long period of time without spending too much time on the production of the garment. In total it takes 35 minutes to create.

The following set-up was used, it follows the shown scenario as seen in Figure 21. The test scenario consists of several steps each with their own function. The first step is to set-up the machine on its location, this means attaching the machine to a supporting structure. This can be a structure available on site or one that is brought. Attaching Wally is done with clamps, which ensures a solid connection without damaging the structure. The second step is to hook up the electronics, this consists of connecting the battery and the USB cable to the laptop. For the third step an interested onlooker is approached, a short explanation is given about the purpose of the machine and the general theory. If the person is interested a short production track can be started. This started with the fourth step here we measure the size of the head in order to make a beanie made to measure. This data will be insert into the Arduino software upon which the needle bed is prepared. The fifth step is threading the machine and setting up the first two lines manually. Afterwards the Wally takes over and knits the garment to its desired length. An optional step is to cut and splice a different colour thread during the knitting process. For the last step the garment is closed manually while still on the machine and then removed from the comb and needle bed. It is then ready to wear (Figure 21).

During the knitting of the wearable and afterwards, the users are asked to express the experience and they are given the opportunity to ask any questions they might have.

Secondly they are asked to share their expectations and desires regarding the machine and its applications. This ranges from what they would use it for themselves, to what they would eventually want to be able to make with it. This will give an insight into their standings in relation to the technology and might also illustrate the changes herein, as a result of this new experience.

The sessions will be documented by both video and camera footage. This will later be used to analyse the effect of this new interaction that occurs within the public space. Important is to also document the range of interactions and steps the public goes through.

TEST LOCATION

In order to get enough exposure the test location is of significance. While the centre of Barcelona is lively and full of people, the tourist is not the target audience. While people are very open to new things while on vacation the main goal of the test is to see if the general public is willing to accept AM technology and maker culture. To this end the Parc de la Ciutadella was selected, this city park is visited mainly by the local population. The park is still crowded enough to have enough exposure while not including to many tourists into the test group.

The mounting of the machine did limit the selection of the test site as most of the surfaces where unfortunately rounded and therefore unsuited for the chosen mounting system (see Figure 22.). The chosen site was located near an intersection of the walkways and the playground. Especially the proximity to children was useful lase their curiosity and lack of inhibitions will help pull in more people.

TEST RESULTS

The results of the test session held in the Parc de la Ciutadella, show a great variety of interest. The session created a good crowd of people looking at the machine at work. The steps described in the scenario were followed as closely as possible as the installation would allow (see Figure 23.2-23.5). As expected the children were first to explore, drawing in their parents and later more bystanders joined to see what was going on. As can be seen in Figure 23.1 the public was rather mesmerized by the machine.

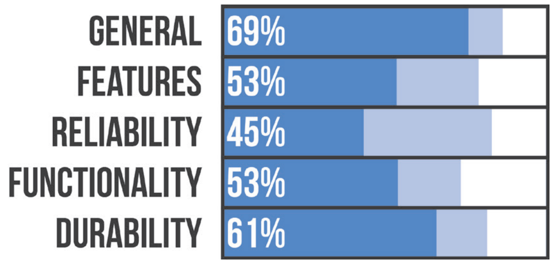
The movement and sound creating interest and upon closer inspection questions start to arise about the project, the overall goals and future use. Ranging from remarks about the look of the machine to the technical specifications used to create it. This wide range of interest was already very useful. The wonderment seemed to suggest that most people had never seen a machine like this in action, not to mention in the middle of a public park.

Figure 23. Representative pictures field test results.

1. Gathered audience
2. Meassuring the size for the beanie
3. Realtime construction of the beanie
4. Childeren gathered to watch the machine
5. The finished beanie and satisfied costumer.

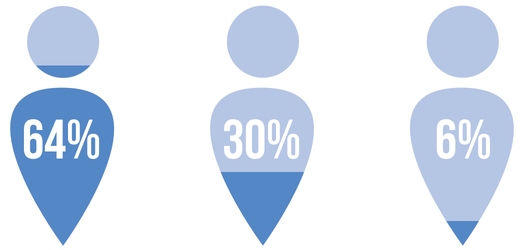
When discussing their possible future use of this technology, the responses were categorized as well. This question was aimed to determine the likelihood they would use this machine or something similar in the future. The responses ranged from; definitely, possibly & never. This resulted in the following overview (see Figure 24.):

Figure 24.



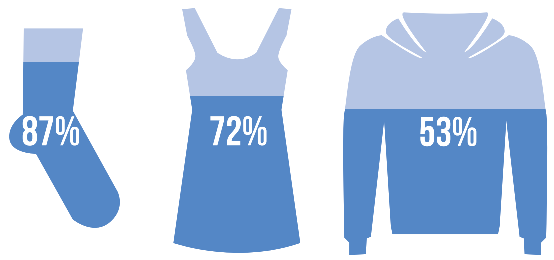
With regards to the type of desired use the following categories were given: small wearables/ Simple sweaters, dresses & vests/ Hoodies, buttoned & other complex garments. This was to see what type of garment they want to create should they use the machine themselves. They were told to ignore size or current technological limitations in this answer. The results were as followed (see Figure 25.):

Figure 25.



When asked why they would use the machine instead of buying ready made garments their response were mainly focused around the following properties; better fitting clothes (72%), more freedom in creation/personal style (45%) and lower price (30%). This was in within the context of made to measure patterns. Were they can enter their measurements and select patterns/colours freely (see Figure 26.).

Figure 26.



EVALUATING TEST RESULTS

The concept of introducing a localized manufacturing tool into an urban community resulted in a positive response from the general public. When looking at the results it is clear that when confronted with AM technologies in an urban context general interest is increased.

In order to test the overall exposure effect the Attention Interest Desire Action or AIDA model was used and the following can be concluded. The Attention was created, the Wally drew in a large crowd before it was even turned on. The Wally was considered intriguing, because of the colour, sound and overall shape that stood in stark contrast with its surroundings.

Attentiveness was high, 70% of the people that stopped to take a longer look asked questions, made pictures or were talking amongst themselves about the machine. When looking at the answers in regards to future use the crowd was positive. 64% of the participants of the questionnaire would use this machine if it would function similarly to the test conditions.

53% of the participants would use the machine for complex garments, while 87% of them would use it for small simple garments. This shows significant interest and desire in regards to using the machine.

Action was not addressed in this test as the machine is still in development. However the initial responses regarding the Wally 120 were positive and several machines are currently under construction around the world.

An important thing to notice is their need for better fitting clothes as 72% of the participants claim this as a reason to start using this type of clothing manufacturing. It seems that even though the standardisation of clothing is able to facilitate the industrial production of clothing it does not seem to fill the needs of the users.

When looking at the role of the designer in this process, it can be concluded that this has been altered. The designer is no longer just creating products that fill the needs of the consumers. Instead we see a new task taking shape, designing and defining the tools and design space for the end user. This is partially done with a co creation process at this time. However this can be further developed to let the users freely design and manufacture their products without any direct contact. The contact between user and designer will then be through the design space created by the designer.

When looking at the results of the engaging local community test case seems to check all the boxes in regards to the successful realisation of greater acceptance. However when looking at the test set-up and general several issues came to light.

First, the test location in combination with the time the test was held at. The test was carried out during the late afternoon early evening 18:00 -20:15. This might have an effect on the results in that the public could be tired, on their way home. In order to exclude these and other factors from the results a second session at a different location and time of day would be needed.

Secondly, while the machine performed well it struggled due to the method of placement. The gate it was attached to resulted in an off level position which created a greater strain on the system then initially anticipated. In order to prevent this in future tests either the mounting system or mounting location will need to be addressed. As the struggling machine has effect on the perception of durability and reliability as mentioned by one of the participants; “It seems to struggle a lot, especially going towards the edges of the beanie, does it always do this?”. In order to create a positive image for AM technologies the reliability will need to be increased.

Another effect of the Wally 120 system that limits the testing at this point is the lack of interface design integrated into the system. In order to let the public use the machine by themselves, an interface will need to be developed. This also ties into the limitations currently attached to the machine as it is still not able to decrease needles, needed to be able to do short stitching. This is still under development and once completed will greatly increase the range of designs the Wally 120 could handle.

Also there was the matter of language. Even though a Spanish native was present during the testing the researcher himself did not speak Spanish this created some difficulties explaining the machine and answering the questions. While this did not affect the general insights into the effect of the machine it did limit detailed discussions.

CONCLUSIONS

RECOMMENDATIONS

Looking at the Wally 120 machine and the test there are still several aspects that could be further improved upon. This chapter will contain an overview of the most important of the improvement areas.

CONNECT THE MACHINE TO A USER FRIENDLY INTERFACE

One of the aspects of the envisioned exposure aspects that was missing in the final test was the interface. This had two reasons, one the physical machine needed a lot of redesign and time in Barcelona was limited. Secondly the interface design is partially a shared project with the lovely people from Knitic. They are focusing on the interface design which is also used for their machine the Knitic. While they visited Barcelona we did discuss the interface design and ideas and suggestions were shared. The main recommendations given towards the future interface design were mainly focused on the work flow. The main reason for the interface is to get the relevant measurements for a piece of clothing. The required measurements were based of a rough pattern or template system. The desired data was asked for by the software but explanation on the why and how was missing. It was suggested to add in a sort of how to properly measure the needed data. This would be done by illustrations and short animations and would show the points of interest regarding each specific measurement.

DECREASING NEEDLES, ADDS MORE OPTIONS

Another element that was lacking on the Wally 120 Prototype was the option to decrease needle count. This gives us the option to knit round shapes, instead of just tapered or straight. This greatly increases the options in regards to types of garments that can be made. However the machine cannot use the methods used in industrial machines. Here the outermost needle is put under tension and the loop is jumped back to the needle next to it. Decreasing the needle count. This put a lot of strain on both the needle bed and the carriage drive train. The 3d printed parts simply could not cope with this level of strain. So an alternative method of decreasing the needle count will need to be developed. The method that was designed by Gerard was a mechanical arm that actively picked up the loop and carried it to the next needle presented a great number of challenges still to overcome. The margins are so small and the effect of a faulty pickup so great we excluded it from the wally 120 prototype as not to negatively influence the public's perception of the machine. It is an area that clearly needs future improvements.

WALLY'S MOUNTING SYSTEM

When looking at the mounting system used for the wally we encountered several issues. Its current mounting points are hard to use on gates or surfaces that are rounded. This excludes a lot of the mounting surfaces available in the public space. Another issue that was encountered was the fact that it is extremely difficult to get a perfectly level mounting. This results in the machine struggling as a lot of the strains on the needle bed and drive train change. This creates a difference in speed and accuracy between the two knitting directions. An alternative mounting method needs to be explored that allows for the mounting on more of the outdoor surfaces while also allowing for a level machine in order to create better quality products. Mounting sideways to land posts and street lights seems like it would possible hold a lot more promise in regards to the number of mounting points. However the level mounting holds some difficulty still as the machine is still somewhat heavy.

DISCUSSION

Looking back at the project several of the decisions made played an important role in the outcome. In this chapter these decisions will be re-evaluated and alternatives will be discussed.

TEST (SET-UP)

Looking back at the user test I cannot help but wonder how this test would have gone in the Netherlands. Unfortunately the machine has suffered from glitches and break downs since it was shipped back from Barcelona. As such the second test was unfortunately never carried out within a Dutch context. This is something that I believe could have made a difference as the local culture and people are different.

The test itself several aspects would have to be changed, or at least be compared. The timing of the test and the location I believe have had an impact on the test. The simple fact is that one test is not enough. More intensive testing in regards to the acceptance needs to be done and especially over a longer period. While more machine have been build these have not used been used to test similar situations. This is a missed opportunity that should have been used. As it would result in more data points and as such strengthen the overall result of the research.

ALTERNATIVE MEANS

Was the Wally 120 the only way to test this, or even a good product to begin with. While I do believe it was a valid way to test the effect of local exposure to technology in order to close the gap, it does however suffer from issues. The fact that we use technology which on its own still requires a machine to be build, which still uses up a lot of materials and energy, is not the best sustainable solution.

There are other ways with which to achieve a greater maker movement, local manufacturing that could rely on more social aspects. Take the innocent smoothies knitting action. Here the elderly are asked to knit miniature hats for bottles to raise money for elderly welfare organisations. It requires no added technology but simply connects people to people in a way that is beneficial to both.

These types of solutions I believe hold a lot of merit and show that while technology is helpful we tend to overstep as designers and introduce it as an “easy” fix.

Likewise looking at the machine and the types of garments that were knitted a simpler circular knitting machine would also have worked. This would have greatly reduced the complexity of the machine. As such this could have been an interesting alternative.

RELEVANT DEVELOPMENTS DURING THE PROJECT

As mentioned before circular knitting might also have sufficed in the type of testing and exposure done with the Wally 120. One of the developments that surfaced shortly after the summer in which the Wally 120 was developed, Knitic released the Circular Knitic. This is a redesign of the old Circular knitting machines to be build by local manufacturing tools and means. It offers less overall options in garment construction as it just knits a singular tube. It does however have greater reliability and due to its construction is also able to reduce and increase needles more easily. This machine might have been a very suitable alternative to the Wally 120.

Some other relevant developments were the mesh lingerie and Knyttan:”Factory of the Future”. These two inspiring concepts both have great value to the overall vision and research. The Mesh lingerie is a system that use 3d scans to 3d print supportive structures for bra's. This greatly increases the comfort of these garments as this is a product that greatly benefits from a high tailored fit. It shows how the technology could be used to give greater value to this type of garments by fully integrating the technology.

The Knyttan is a store concept where the costumer can fully design and define a sweater or scarf. This is then knitted using a very high quality industrial knitting machine. This concept shows what can be done when we fully localise industrial quality production. While expensive the excellent finish and quality of the products combined with the high level of user input create even great value.

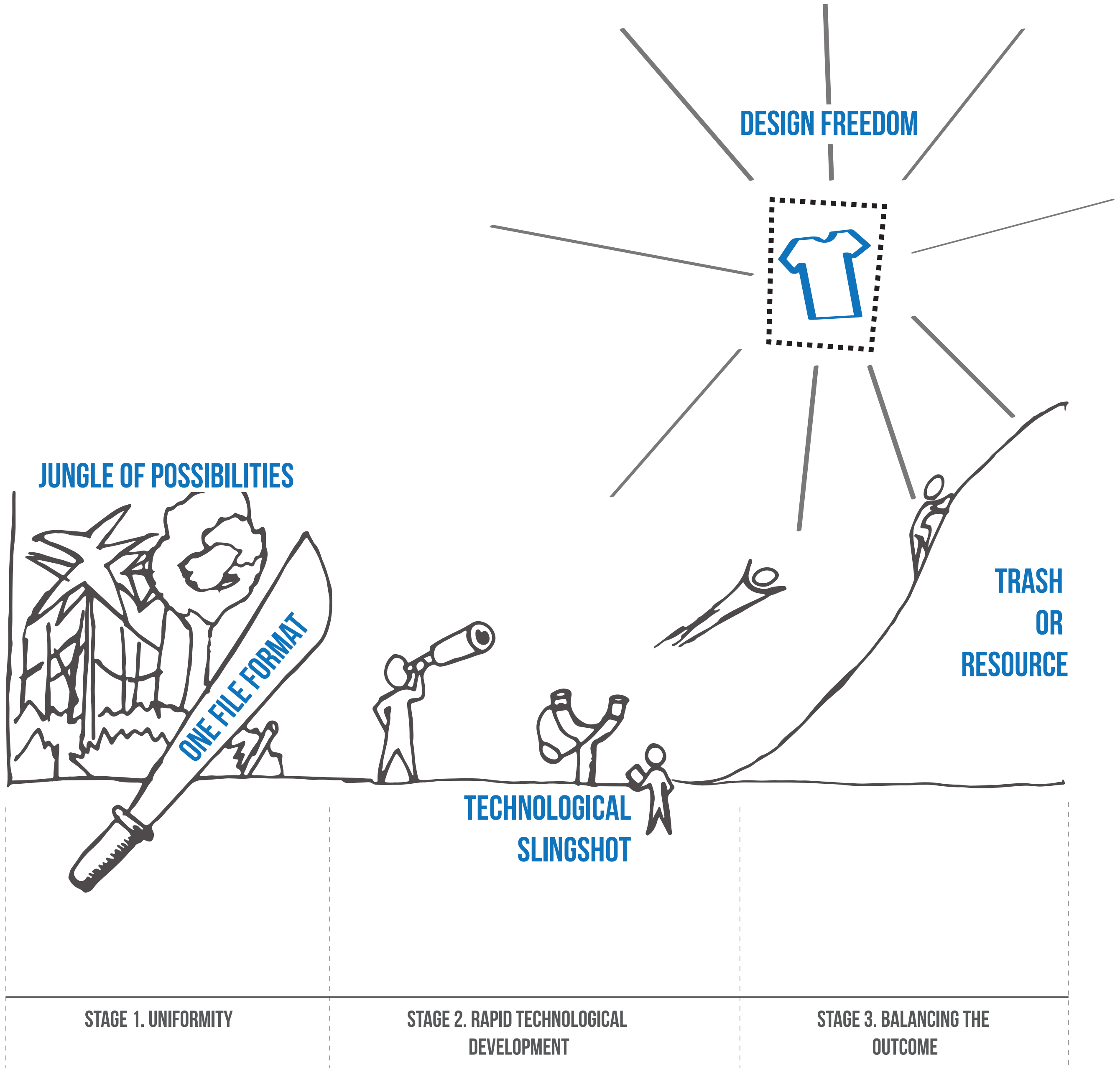


Figure 27. Roadmap.

FUTURE OF USER GENERATED LDM

While certain aspects of the visions core necessities like local manufacturing culture and technological opportunity are slowly becoming more and more common there is still a lot to do. In order to provide both the user and supporting industry the best chance for success there are several aspects that require further development. So what is needed and how far along are we in reaching these goals? In this final overview we will take a look at current and possible future developments within this scope (Also see Figure 27.).

UNIVERSAL FILE FORMAT

In order for more of the supporting industry to take root within this movement, a level of standardisation in data-files needs to occur. This will ensure that we will all be able to use each others designs and techniques no matter the location as the source material will be uniform. The design team from Knyttan/Unmade have been working on this. Their file system currently called .knit has potential to become this universal data system that could help realise this need for generalisation in the same way slicing software has made it possible to provide 3d printers with their files no matter the origin of the 3d model. This could open up the market for new loom and knitting machines that could help shape and speed up the development of the technology.

DESIGN FREEDOM

While in the field of true personalisation the main drivers are still customisation instead of true one of design. Several companies have started offering opportunity for high level customisation of a set design this usually means it is all very superficial. While integrating 3d scanning data within this process could allow for the product fit to be excellent it still works of the same design. To offer real design freedom on a pattern level for garments has not been used within the current industry. This “true” free-form design seems to be a bridge to far for most companies. Why this is the case can be debated, it might be that the design is such an integral part of the brand identity. Releasing this completely to the consumer might be seen as a loss of brand value. This would require a different take on brand value. As such it might be up to the maker community to try and facilitate this. However it also raises the question; Is the general public eager to be fully responsible for their design work, or would the generally speaking be satisfied with superficial personalisation.

SUSTAINABILITY

How do we ensure sustainability? Within the possible freedom of creating your own garments on a whim, material components might end up being the only limiting but also draining factor. Within the arts and craft movement the value and product attachment comes from the time spend creating it. Investing more then just creativity into the objects made. With the possibilities granted by the development of more intuitive and easy to use software and machinery this is perhaps not attachment defining any more. In order to deal with a post product life cycle that is more limiting then the current clothing industry due to the highly personalised nature of the garments. This means that we need to take end of product life into account more during the designing/manufacturing stages. As attachment is no guaranty for long product use in a society where it is easy to replace it with something new made just for you. This requires the technology and services related to end of product life to make headway in ensuring material recovery. A nice example of a way to deal with this is the Wool 2 project that is recycling woolen clothing into new garments through a reclaiming process of the core material. These types of processes need to be taken into account in the early stages to ensure the highest recycling potential possible.

ALTERNATIVE TECHNOLOGY

Another aspect that is needed to further develop the field is the research into alternative means to generate fabric like materials. An example of this is the Electroloom project, this project uses electically charged “printbeds”.

PROJECT EVALUATION

Looking back at the project there are several things that I believe are worth mentioning. This include some of the high and low points of the project as a whole and how they have effected the project and myself. (also see Figure 28-29).

WALLY 120

One of the things I really wanted to do during my graduation is to build a physical prototype. While I can value the potential of digital design, it sometimes seems to be used without exploring the physical alternatives. This drives me to look at both and when possible take the physical interaction over the digital one. The interaction qualities are very different when you can physically manipulate the product or service elements. These to me are very valuable. As such being able to provide a physical prototype in the shape of the Wally 120 was a great outcome of the process. The machine provided me with technical brain teasers that still occupy my mind. This is something I feel is intrinsic to industrial design and should always be valued and treasured.

BARCELONA

The stay in Barcelona to work on the openknit redesign characterizes what I love about design. Working hard and putting in 300 hours in 3 weeks but also getting great results. The design iterations were fast and intuitive, the digital design and manufacturing providing us with a fast turn around time in regards to new parts. Allow us to design, build and test components in a matter of days or sometimes hours. Working with Gerard was a great pleasure as he was as hands on and motivated as I was resulting in a incredible work environment. Not to mention the actual city and my daily longboard commute down the mountain. One of the best design experiences of my life.

ICAT

After the visit to Barcelona Natasha suggested I would write a paper for the ICAT convention (See Appendix D). This convention focuses on the 3d printing industry and its developments. While my project has stepped away from 3d printing the underlying research and the social impact I want to achieve still held relevance. As such I wrote a paper about the Wally 120 development and testing. The project was presented at the convention and it was well received. It showed that the industry has a lot of related fields that can hold valuable information and opportunities. The industry is already being put in a box and this should not be the case just yet. All in all a great experience and proved that the research was still relevant for the field of 3d Printing.

ADVANCED PROTOTYPING

During the course of advanced prototyping the focus is on taking an existing prototype and improving on it. Jouke asked if I would be interested in taking part in the course with Wally. The project was presented to the

students together with a short design brief containing problem areas and possible alternatives. The students then took to the prototype, analysing it and building alternative components. A damper on the project was the Wally 120 still failing to operate. This made extensive testing impossible. Non the less great progress was made on the problem areas. While also making a solid start to the build of a full Wally 340 machine. A great project, in which I learned a lot from the students perspective on the prototype. It also helped generate more publicity for the project resulting in newspaper articles and some more online buzz (see Appendix E & F).

Figure 28. Memorable moments form my graduation.

CHALLENGES AND REALIZATIONS

When looking back at the project we see a project that has been done based on the core design methodology based at Industrial Design Engineering. However we also see personal preference and character shine through. An overview of the whole project is shown bellow. Its very obvious that during the analysis phase the project went extremely wide in scope. It took the Aalto session to put me back on track and help make some decisions. Looking back the main issue is a strong sense of intuition. I tend to make decisions based on a gut feeling. This off course sometimes leads to mistakes or more difficult project trajectories. It does also offer potential for extreme high speed iterative designs. This proved very useful in the three weeks spend in Barcelona. Here the ability to make fast decisions resulted in a very extensive redesign with good results. However the chaotic nature of this process makes it extremely stressful and hard to follow and convey for people outside of the project.

Looking at the duration of the project it also obvious that the planning aspect of the project was a struggle. This is something I struggle with in most projects. As such the project ran longer then anticipated.

PERSONAL DEVELOPMENT

Planning; What did I learn? Well I believe if one thing I learned not to give up. Even tough the project ran a lot longer then anticipated its still resulted in a strong vision. I tend to be an emotional motivator. As such when I don't see a solution I can demotivate myself. This was especially true for the early stages of the project with no clear goal and scope it was easy to loose yourself in the possibilities. Restructuring these steps helped create a bit more clarity. I since realize I need to document differently when working in the analysis phase.

Teaching; Something I have always been interested in is education. The option to be a part of the advanced prototyping course was a welcome aspect of this project. Sharing knowledge and being part of another teams project in a supervisory roll was very interesting. It offered some great opportunity in regards to what working in this field would be like. It became apparent that it is something that would be a good fit for a future function.

Lonely designer syndrome; I am a designer that feeds off a group process. I need a feedback loop in my design process. The fact that Barcelona was so successful is because I had a partner in crime. For me design is a dialogue, in a monologue project this graduation was a struggle. As such I had to go back to the design tools taught to us. Using these instead of the dialogue. This was a very staining part of the project and it has showed me I need people around me. While also showing me that I do have to potential to do it on my own, even if it is a lot harder.

Figure 29. Memorable moments form my graduation 2.

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Johansson, A., Kisch, P., & Mirata, M. (2005). Distributed economies–a new engine for innovation. Journal of Cleaner Production, 13(10), 971-979.

Lee, W. B., & Lau, H. C. W. (1999). Factory on demand: the shaping of an agile production network. International Journal of Agile Management Systems,1(2), 83-87.

ILLUSTRATIONS AND PHOTOGRAPHS

All illustrations were made by the author.
All photos except the fllowing are made by the author:

page 6, Figure 1 .
Iris van Herpen Designs

page 6, Figure 2.
Softmesh Aalto university of Design
Freshfibers, Freshfiber.com

page 14 Figure 4.
Barcelona Fablab, Barcelonafablab.com
Paris Maker Faire, Makerfaire.org
Thingyverse, thingyverse.com
3d Hubs, 3dhubs.com

page 33. Figure 17.
Knittic, Knittic.com
Rottary knitter, google, source unknown
3d Knitting teddy, DisneyResarch.com
Openknit, Openknit.org

APPENDICES

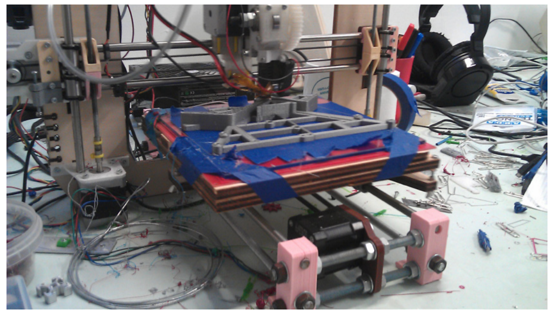
APPENDIX CONTENT

APPENDIX A. AM TECHNOLOGIES

While the general public assumes fused deposition modeling (FDM) is the only additive manufacturing technique there are several others that are also considered for this project. Each will be explained shortly.

FUSED DEPOSITION MODELING (FDM)

The more well know AM technology, it can be compared to a single color inkjet printer. It generally simple to use and cost effective. The FDM systems are being released to the general public at lower and lower prices, creating opportunities for all sorts of users to get their hands on 3d Printing technology.

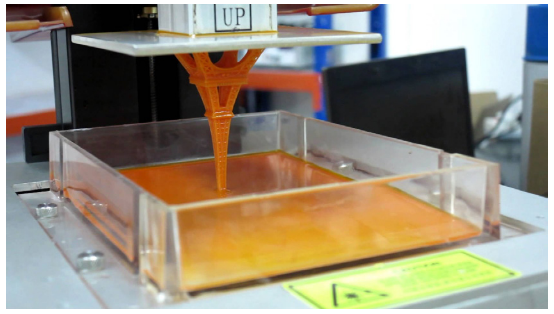


FDM works by heating thermoplastic materials and depositing these using a print nozzle. The product is then build layer for layer. Upon completion the print bed is lowered and the process repeated until the product is fully formed. For this system the materials will most likely be input as a filament. The product is then This allows for controlled intake of the material while also making it easy to replace or change out the filament. It will take most Thermoplastic materials or filaments which consist of a base material with an additional material imbedded into this carrier. This makes this system rather straight forward. This method is very efficient in making products that do not require support material, however the use of solvable support materials had made it possible to construct more complex structures . it is remarkably accurate, with print filament thicknesses of 0,4 mm and up.

The finished products have a layered appearance, which is exaggerated when going for a thicker filament. This will allow the system to speed up the production process. However the speed will always relate to the material properties of the print medium. The wide variety of materials and colors allow the user to create the products using the material and color he/she prefers. Using materials with different physical properties allows for flexibility and rigidity on material level which can help create additional functionality. Combination of materials are also possible, either using multiple nozzles or a filament selector. This can create additional properties to allow for additional functionality or esthetics.

STEREO LITHOGRAPHY (SLA)

This AM technology works somewhat differently from the previous. Instead of depositing the material the material is fully present in the machine. It uses a reservoir filled with heat curable resin. This is then cured using a laser instead of a printing head. Upon layer completion the print support platform is lower, or raised, a fraction of a mm and the process is repeated.

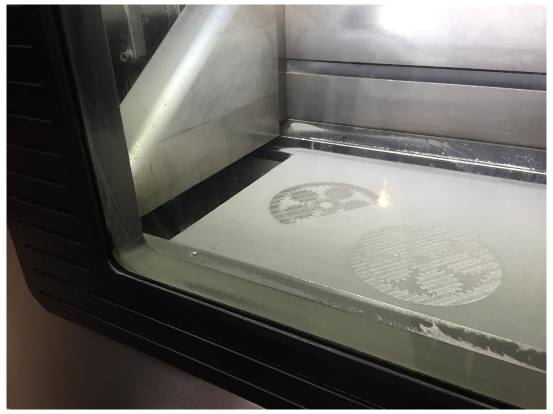


This system while very efficient in its use of material is considered to be too expensive for consumer use, this is caused by the costs of the resin more than any other factors. While several new machines have been developed for consumer use, Form 1 from formlabs for example, dropping the overall price the print medium is still a limiting factor. It is also very limited in material choice since it can only use a single material during a run.

Yet its accuracy in the z axis is greatly increased with this technology 0,05 mm and up, which makes this technology very useful for extremely accurate products. It does still require support material if the overhang of the products during the print process are too great. Yet it does not tend to warp the product during printing, as there is no physical movement on the print surface. One added aspect to this technology is that in order to prevent the encapsulation of uncured material within the design enclosed spaces need to have a slight outlet to release the material either during or after the print process.

SELECTIVE LASER SINTERING (SLS)

This AM technology steps away from both filament and liquid print medium, instead working with a granular print material. This material is then fused using a laser beam, as such most thermoplastic materials are usable including several metal compounds and even greensand. The system operates by applying thin layers of the granulate over the print bed and when the laser has completed its run it lowers the print bed and applies a new layer. This process is repeated until the product is complete. The material is sintered together with the laser, the heat created melts the outer layer of the sinter granulate. This molten outer layer adheres to it surrounding material. This eventually creates the finished product.

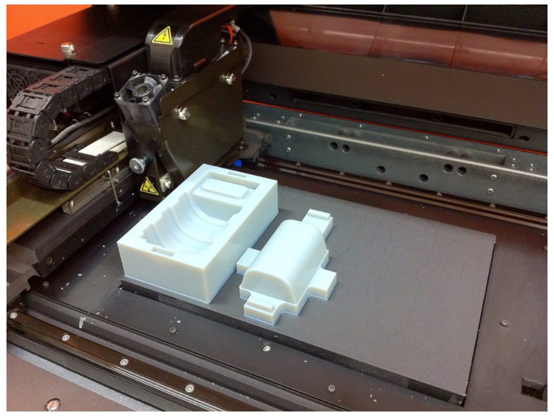


This technology is gaining momentum in the aviation and car industries as it allows for complex parts to be completely constructed in a single run. This allows for greater complexity then conventional casting or milling methods. As such limited production runs have become part of the tools available to the industries designers. One of the greatest advantages to SLS is that no support material is needed as the product is fully supported by the unused granulate. Not unlike SLA enclosed spaces will hold unused material, so in order to remove this the design will need to allow for its extraction after the print process is completed.

While slightly different Selective Laser Melting (SLM) is closely related to the SLS method with the added benefit of being able to fully melt the granulate allowing the creation of different material properties. Depending on the application either method can proof useful.

POLYJET PHOTO POLYMER (PPP)

This technology is closly related to th inkjet printers most consumers have around them already. This system prints UV-curable liquid compounds onto a print bed, which is then cured using a strong UV light. While very accurate this also allows for the in print combination of materials, and not only just within the same product but within the surfaces themselves, even being able to create gradual transitions between the two materials. This is done by altering the quantities of each material. As such it allows a product to contain several different material properties that transition into each other.



It is also able to handle complex shapes and intricate designs using a gel like support material. Unlike other techniques were this support material is generally though to remove, this material is removable by hand and water jet leaving no traces on the product. The lack of any cure time also helps speed up the overall print process.
The technology also allows the creation of very high quality surface finishes mainly due to the extremely thin slices 16 µm and up. Thin combined with the precision offered by the print head enables a user to create detailed and finished products. The use of colour is also easy to include and allows for the product to be nothing less than a finished product.

APPENDIX B. AALTO HELSINKI

SESSION PLAN AALTO HELSINKI

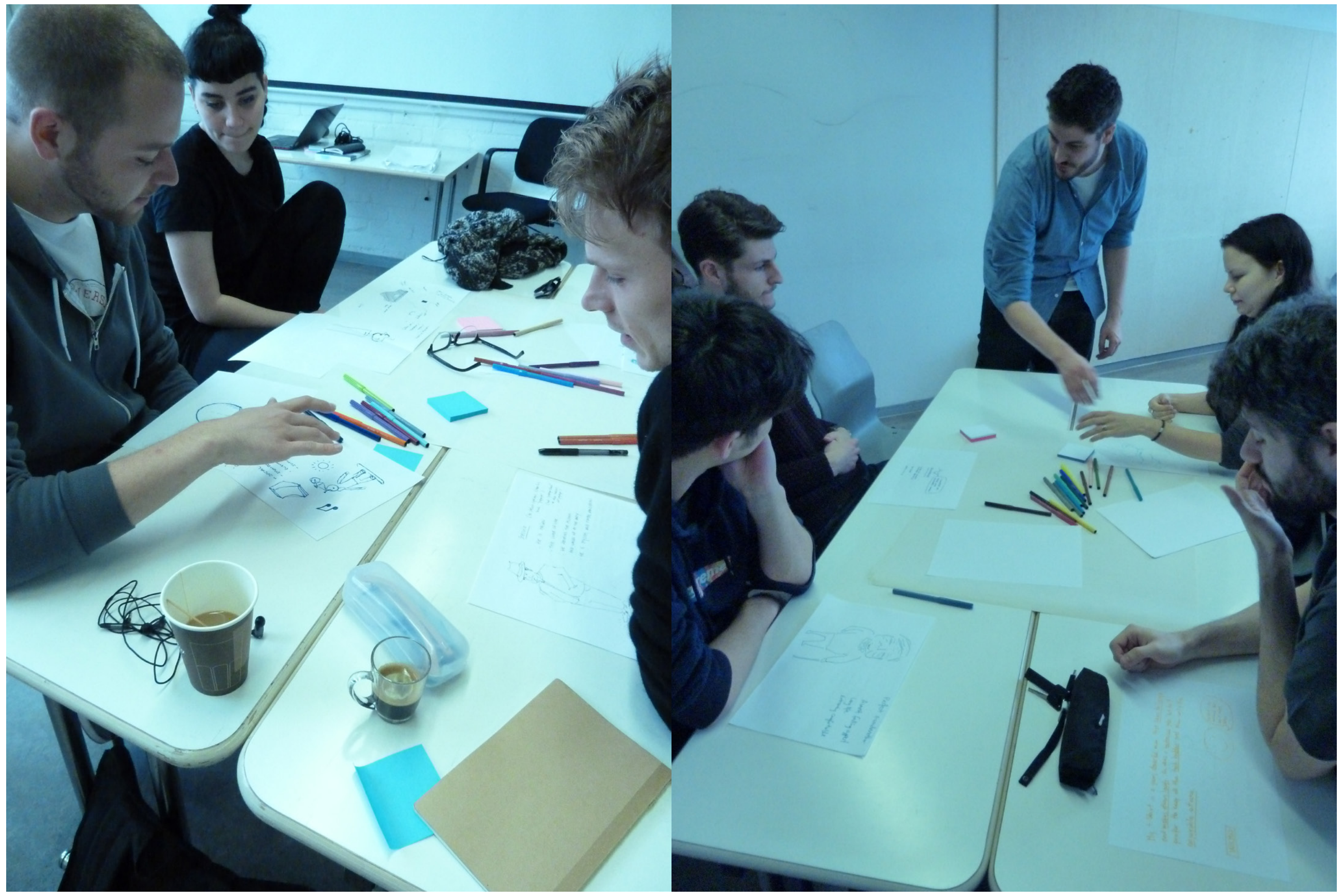
2-2,5 hour session

┐ Short introduction (10 minutes) – take questions, however no leading answers regarding content
┐ Favorite piece of clothing(30 minutes) - draw it and explain to your group why it is your favorite. Write the main attributes on post-its.
┐ Develop an persona for your piece of clothing(20 minutes)- create an persona with characteristics linked to the attributes.

Short break. (10 min)

┐ Switch up the groups
┐ Share your persona's with your new group. (10 min)
┐ Brainstorm about 3d Printing(20 minutes) - what do you know, what do you associate with the technology?
┐ Create an Persona using the associations to create characteristics (30 min).

Figure. Representative pictures of the Aalto sessions.



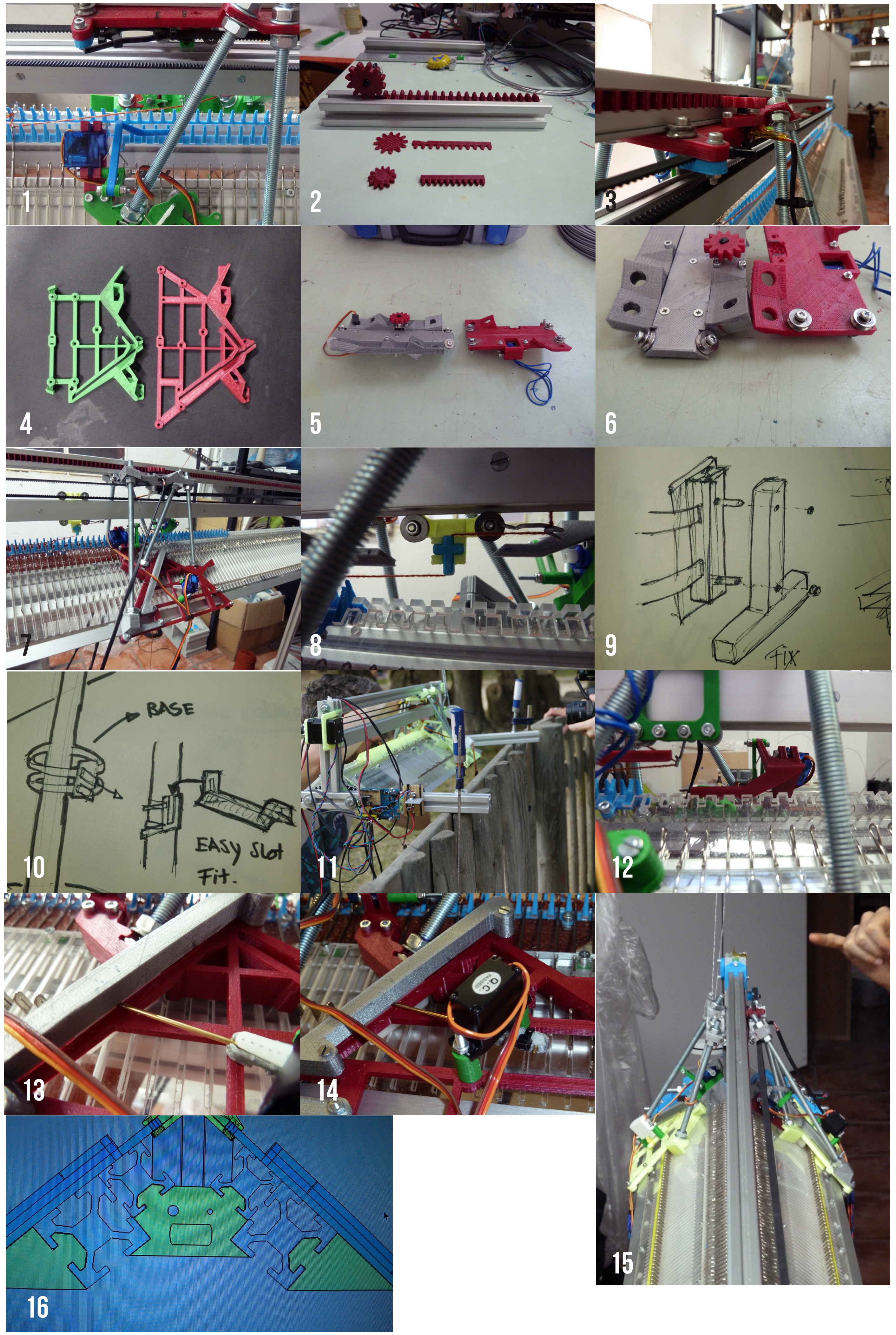


Figure. Overview of the different re-design steps.

APPENDIX C. OPEN KNIT RE-DESIGN

CONVERTING THE CODER DRIVETRAIN.

In order to create a more accurate rack and pinion system then was currently being used. There were two things to take into account, the shape of the gear and the location of the system in relation to the rest of the machine (1-3).

As is visible in the photograph the old systems design had some issues regarding the shape of the gear and its rack system consisted of the slots cut for the needles. However the narrow nature of both the teeth and the slots meant several times in a pass it would miss the slot and as such the positioning would shift with great consequence to the quality of the knitting. So in order to create a more reliable system a rack and pinion system was selected to replace it. This is more accurate due to the shape of both the rack and pinion teeth. This creates greater contact, which ensure not steps are missed and the overall resolution was also increased as the number of teeth could be increased. Both great improvements in comparison to the current system.

The location was a little more tricky, the current location would not allow for the placement of a rack as this would interfere with the movement of the needles. Then the shape of the frame profile being used popped into view and it seemed like it would provide a solid frame for an enclosed rack and pinion system. After some prototypes we found a gear ratio the provided enough resolution and also fit the shape of the bar.

After some trial runs it showed a great improvement in accuracy and reliability. The rack is mounted using a pressure fit and has been working well ever since the redesign of the top part of the carriage to provide a solid mounting point. This will be shown latter one when the carriage redesign is discussed.

REDESIGN CARRIAGE

When analyzing the movements and vibrations in the system when it is operating it was obvious there were some geometrical problems with the forces being applied in relation to the frame and its supports. There was a lot of force being generated outside the base creating momentum and drag as a result. This was the case both from the side as top perspective, this was amplified by the asymmetrical design of the system, which is needed in order to make it work. So in order to keep this in place some changes to the overall shape of the lower and top carriage is needed (4-7).The top carriage mounting points would need to be adjusted and the overall part stiffened .

As is visible in the photographs there are some issues with the force distribution when it is operating. This generates vibrations which in turn create several problems for the accuracy of the overall system. This creates collision with the needles and the increased tension on both the yarn as the motor. In order to prevent this a third threaded support was added in order to generate better stability, this was coupled with a redesign of the mounting points for the bearing which resulted in minor alteration for the overall frame layout. These adaptations resulted in the following redesign. In order to keep the new parts printable while maintaining optimal strength the mounting point on the bottom carriage was kept separate. The top of the carriage got a complete redesign in order to hold both the converter and to allow for the placement of the third beam.

REDESIGN YARN CARRIER

One of the main issues with the yarn carrier is that it is generating high amounts of frictions as well as failing to deliver the yarn in the exact center of the knitting space. This is mainly due to the material and shape used. The mount would be bend into shape and position but this would not stay that way during prolonged operation.

In order to rectify this a new carrier was designed that uses a lower friction delivery method while also staying in the center of the knitting space. As such it ensured smoother operation and better uniformity as the yarn would be held at the same tension in both left and right knitting directions (9).

NEW MOUNTING TECHNIQUE FOR MOBILE APPLICATION

In order to make a mobile machine a new frame design was needed which would be small and light enough to travel while also sturdy enough to deal with the stresses caused by moving and operating the machine. This mend going away from the system currently used as it was too unstable and slow to assemble. In order to facilitate the new frames mounting a redesign was made which used vertical support structures around its urban environment to mount the machine to (9-10).

When evaluating this design however the fact that we were using public property in such a manner might be seen as vandalism so in order to have a less impactful mounting system the following was developed. This system used 2 clamps to mount to any flat and level surface using 2 outriggers mounted to the frame. These would allow for a sturdy and level mounting. Because the clamps can be padded no damage should be done to the supporting structure. This resulted in the following design (11).

REDESIGNING THE SLED

The sleds are responsible for keeping the thread down allowing the needles to shed their original loops and catch the new ones. However during the testing the shape and orientation of the sleds caused a lot of interference within the system. Hitting the teeth of the needlebed and getting stuck behind the active needles.

The redesign created a smoother knitting action due to altered shape and length (12). This greatly improved the overall knitting quality.

Redesigning the slider

The slider guide and slider have been under close inspection since the initial tests, as these had a lot of issues. Getting stuck, slipping and dropping the needles, rising half way through a stich row. In order to better control the sliders two main attributing factors were looked at. The servo's controlling the sliders and the slot and shape of the sliders themselves, the slot was altered and placed at a slight angle helping reduce the drag of the needles on the slider (13-14). Secondly the servos were exchanged for metal gear ones. This was done as the plastic gears slipped when under strain. Thirdly several shapes were tested this also to ensure the machine could pick up needles from the bottom row. This was later abandoned for the testing as the added length seemed to create more drag which strained the servos in a way that resulted in several jams. In order to further develop this alternative drivers for the sliders will need to be explored. Micro stepper motors are considered as an alternative their configuration should allow for greater accuracy and less noise in the movement.

Redesign needlebed

In order to give more room to the thread comb when setting up the garment the notches in the needle bed where enlarged and the teeth enlarged in order to still reach a similar bed to bed distance, which is important for creating a seamless garment. In order to do this the sloths in between the teeth were made 5 mm longer to allow the comb to grab the thread without touching the bed (15-16).

However during use we encountered that due to the frame redesign the comb teeth now touched the top frame which might result in a snag. Due to time constrains it was an non amendable issue. This will need to be altered slightly in the next iteration. Another unforeseen side effect was the needles being hinged to far because of the shifted touch point. This resulted in the needle getting stuck in the slot. While alterations to the needles were attempted to mend this it did not have the desire result. Another secondary problem was that the distance between active and non-active needles was now half what it was previously with the servo issues this resulted in more snags then in the prior set-up. As such this part will need to be further developed to a higher standard in the near future.

Appendix D. ICAT Paper

Redefining the role of designers within an urban community using digital design and localized manufacturing of wearables.

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Abstract— **The maker culture has created a dynamic in which designers are less responsible for the design and quality of the final product, but for the tools the consumer uses to create their own.**

While additive manufacturing (AM) is gaining acceptance among the general public, it is still seen as a prototyping tool instead of a high quality production technology. This limits its acceptance within co-design and maker culture. The research question is: How to create greater acceptance among the general public regarding the AM technology and its products?

One way to create greater acceptance of digital design and manufacturing is to apply co-design principles on a local scale. By this means the public will be exposed and included in the design and production process, which will ensure the end product is better accepted. In time this could help spark a maker movement within the community. To validate these assumptions a test case was developed in which local design and production of simple wearables, small ready to wear garments like socks or hats, within an urban community will play a major role.

During the research a digital design tool combined with a mobile digital knitting machine was developed to allow for a rapid co-design track. Wearables would be produced by the consumer themselves. The final design of the garment depends on the consumer's choice of material, shape and pattern. A mobile set-up provides the means to test the principle at different locations and allows the consumer to be intensively involved in the maker movement in their own neighbourhood. We implemented a small, low-cost knitting machine that was tested outdoors by park visitors.

The anticipated results for this test case were: increased engagement in the production process, larger acceptance of digital design and an initial maker culture. Although the last result will be difficult to determine as it takes some time to develop. If successful, the maker culture will obtain greater exposure, acceptance and demand for digital design services and products. Even though the maker culture changes the role of the designer will definitely change, their importance to the design process will remain, not as a creator of designs but moreover as a guide to the making of consumer products.

Keywords-component; Co-design, Digital manufacturing, Wearable's, Maker Culture, Sustainablity, Local manufactoring

1. General Introduction

Even though digital design has made big leaps in the last years, most consumers are still very much unaware of its potential. This is limiting the development as more users and cases within the field will help mature the technology. In order to facilitate a greater awareness and eventually acceptance we need to look outside the current scope of the exposure of the technology. How to create greater acceptance among the general public regarding the AM technology and its products? This will be the main question addressed in this paper.

There are several means to try and achieve greater acceptance among the general public however, not all are aimed towards this particular issue. When looking at the general knowledge about the production of user products most people are blissfully unaware. This creates a lot of preconceived notions about the difficulties and also possibilities during the production steps. In order to get a more realistic perception regarding AM it is therefore imperative to expose the general public to its difficulties and more importantly its opportunities.

Even though the freedom created by digital design and manufacturing is not necessarily desired by the consumers, it also allows the design community to develop and define this design space through tools and methodology. This ensures that the users of AM facilitated design and production will be able to freely explore its possibilities without being overwhelmed.

The chosen product group, wearables, was selected for it duality. While on one hand garments and other body orientated products are used as an expression of personal style and preference. Yet at the same time it also follows mass consumer behaviour. These two seem to be in direct conflict with each other.

Another aspect in regards to wearables is product fit (Van Der Velden, Patel & Vogtländer, 2014). While no two people are exactly alike the consumers have to cope with standardized sizes. This in stark contrast to the fact that a correctly fitted product can greatly increase the product satisfaction. As such it is an area well suited to the possibilities of digital design and production, as it allows the users to design and wear made to measure or even bespoke tailored garments. Which in turn should result in a greater product attachment which carries value in the field of emotional sustainability.

To ensure that consumers are aware of the possibilities granted by these technologies and expose them to it in a proper way is a challenge. This creates possibilities for designers to reshape their roles within this dynamic. As designers now get the opportunity to create the tools with which the everyday consumer could design and create their own wearables.

To achieve this the following activities were undertaken to test the public's receptiveness to AM produced clothing. First of all a more detailed overview of the developments in local design & manufacturing will be given, as it defines the scope of the research. Followed by selecting a method of creating this acceptance, it will need to fit the context of not just creating acceptance but also instigating a maker spark in the consumer. This will then be applied to an interaction design to create the desired outcome. This interaction will be tested within a public area to validate its effect on the public. After which it will be evaluated and suggestions for adaptations to further improve its effectiveness are given.

2. State of the art local design & manufacturing

2.1. Redefining the role

Within the current wearables market the interaction is based on the industrial production of clothing. This results in a gap between designer and end user, with producer, wholesalers and retailers as the stakeholders (Figure 1). This construction has benefits, since each stakeholder has a clear task which can be optimized and perfected. However it also results in a lot of global shipping and a gap between designer and end user. The process also relies on large production numbers in order to function creating the need for standardization.

When looking at the new dynamic that is created though local design & manufacturing (LDM) we see that the stakeholders change and that they take on new roles. This contrasting dynamic creates new opportunities and benefits. The close proximity both physically and structurally allows for different design methods and interactions. It creates room for personal/ one off designs as well as small locally influenced series of products. This new dynamic however does ask for different design tools and methods. As such redefining the role of a designer in this context will be imperative. Localized manufacturing has other benefits regarding sustainability, when looking at shipping and emotional sustainability. As the involvement with the creation of the product grows so will the attachment.

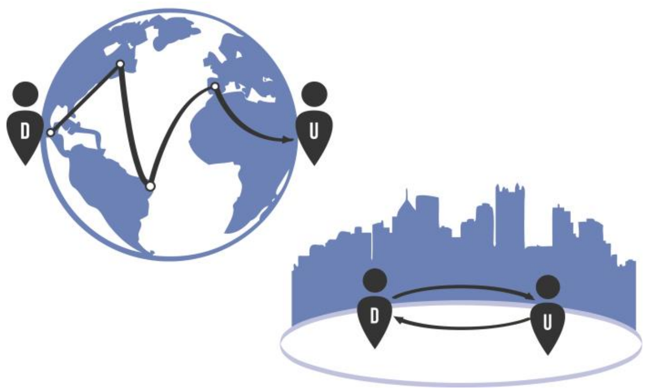

Figure 1. Current interaction and the envisioned interaction between designer and consumer

2.2. Maker culture

One of the main drivers behind localized manufacturing , and a redefining one for designers, is the rise of the maker culture. This cultural shift from mass produced to home-/self-made products is driving a new wave of development in localized manufacturing and design tools and methodology. One of the ways designers can reinvent themselves is to tap into this movement and create the design tools needed for the general public to design and create their own products. While the early adapters have the skills to design and make what they come up with, this will not be the case for everyone. So this leaves a group to design for.

The exposure of this maker culture is something else to consider, the current methods are aimed at the first group. They consist of several facilities/activities:

a) Fablab

The fablab principle is something that fits into the maker culture, as it allows makers to build more complex products for which they do not own the tools or have the expertise to build. These workplaces are stocked with digital manufacturing tools like; 3d printers, CNC machine and laser cutters. These are augmented by the more common tools like; drills, laves and band saws. These spaces are either open to the general public or are linked to educational or artistic institutes. While most major cities around the world have a fablab facility, most are hidden from public view due to location or lack of recognizable markings. This results in a lack of public knowledge about the facilities and as such fails to connect to the general public (http://fablab.org).

b) Makerfairs

These events are generally held in public areas/ buildings and generate more public awareness and attention. While still visited mainly by makers, they also attract people generally interested but not (yet) participating in maker culture. These event help to showcase, educate and create appeal for the results of maker culture. This has a great benefit in helping the movement to grow and develop. As fellow makers can meet and exchange ideas. This is augmented by the physical nature of the event in that the products and tools are there and can be used/touched and explored. Still most of the visitors are already interested in or connected to the movement, creating a new wave of makers from yet unengaged people is not the aim of these events. (http://makerfaire.com/)

c) Digital Maker Culture

One of the effects of the digital design is the ability to share it using digital media. This does not exclude other non-digital designs as tutorials are also wide spread. This helps to create exposure for the products that can be made. While most users of digital and social media will come into contact with maker culture the effect of seeing a picture or movie is not the same as holding the actual product. This gap between exposure and contact is a limiting factor in creating attraction in regards to the final product (Doctorow, 2009).

3. Method

3.1. Co Creation

In order to test the new dynamic between designer and end user it is important to redefine their relation. The freedom created by LDM also creates a larger design space. In order to help guide the end user in this process designers have an opportunity to lend their expertise by means of Co Creation.

Within this design method designers are moving away from translating the needs of the end user into a product. Instead they are facilitating the creation of this product by the end user (Sanders & Stappers, 2008). This shift not only redefines the role of the designer but does the same for the role of the end user. Since They will have a greater influence on the front end of the design process, and as such on the final product

This coincided with the change in dynamic envisioned for the application of LDM as the method allows for local influences to guide the design process. It is not just limited to the local users but also local materials and cultural heritage. This will be used in combination with the design of wearables, were a correct fit and integration of personal style is valuable.

3.2. Concept testing

In order to evaluate the success of a localized manufacturing process concept testing will be used. The concept will be evaluated on several key aspects; general, features, product, durability and reliability. These aspects represent the desired overall qualities of the concept.

By testing the concept using the intended target group as well as the intended context, the following data can be collected photographs, video and interviews. These will show the general public's overall interaction with the concept as well as offer detailed accounts of individual interactions. These results will then be used to create a concept testing matrix. This will either validate or invalidate the concept as a means to achieve the desired goal of creating greater acceptance and interest.

4. Developing Wally 120

4.1. Preperations

In order to facilitate the localized manufacturing aspect of the test case, a mobile digital manufacturing tool was needed. In order to use the tool within the local context several criteria where listed:

- It needs to be mobile, or light enough to be moved by a single person (less than 10 kg.)
- Big enough to create small garments; socks, scarfs, hats.
- Self-sustained when in use, no external power needed at the production location.
- Allow for a made to measure approach, allowing the user to take his or her own measurements by adapting an existing template.
- It needs to be reliable, as a minor error will ruin a garment.
- The product coming out of the machine should require little to no extra actions, as close to ready to wear as possible.

In order to create clothing without directly using traditional methods there are several options. There are methods that work with regular yarn and use weaving/knitting techniques. Furthermore 3d printing clothing is being considered within the design community as a replacement of these traditional material and production techniques. However the aim of this research is to test ready to wear garments. While 3d Printing allows for great freedom in shape and construction it is seen more as an haute couture fashion technique for example the works of Iris van Herpen. This combined with the long production time makes it unusable for this research as the aim is to create more acceptance a more intermediate step is needed. As such the following possibilities were taken into consideration. Each will be shortly addressed and checked with the criteria.

a) Knitic, manual knitting machine hack

This system is a recent development, where by hacking the old manual knitting machines you are able to create new digital designs. The Knitic design couple is working with this technology using several interesting input signals to create uniquely patterned designs. The machines are reliable as they basically hack into an existing flat knitting machine.

The main problem this creates is the sheer size and weight of these machines. The machine also is not able to knit full garments as it only allows for sheet knitting, this increases the manual workload after the initial knitting.

Although possibly more reliable they are hard to modify. And while an interesting project it seemed unsuited for the current goal of local exposure.

Figure 2. KNITIC digital design knitting machine & pattern example

b) Circular knitting machine

When looking at the criteria most of the selected garments are tubular in shape. One of the fastest ways to knit in this fashion is using a circular knitting machine. These are very reliable as the knitting motion is never interrupted. They also allow for increasing and decreasing needles, which allows the knitting of heels.
However no progress into digitizing this progress on a small scale has been made at this time. This is also likely related to the fact that sizes are only changeable by switching out the complete needle ring for one with more or less needles.

So while good at what it does it can only do so much. The digital knitters are currently in use on an industrial scale but so far have not been scaled down for personal use.

Figure 3. Circular knitting machine manpowered

c) Openknit

This project was created by Gerard Rubio, as part of his graduation thesis. The OpenKnit system is an open source project working towards creating a digital knitting machine. The designs and software are available for free and together with the bill of materials can be built anywhere in the world. The current design uses 3d printed parts, lasercut parts and some vendor parts. This enables anyone who lives close to an fablabs or has a small workshop at home to reproduce it and contribute to the further development of the device. This opens the project up for wide spread testing and exposure. It works by programming the pattern into Arduino which can be modified to the users specifications.

The machine however is bulky and in its early stages of development. It also has some issues regarding reliability. The machine does offer the freedom to create several different types of garments. Currently ranging from dresses to sweaters to beanies. While not ready for complex patterns it does allow for different colours.

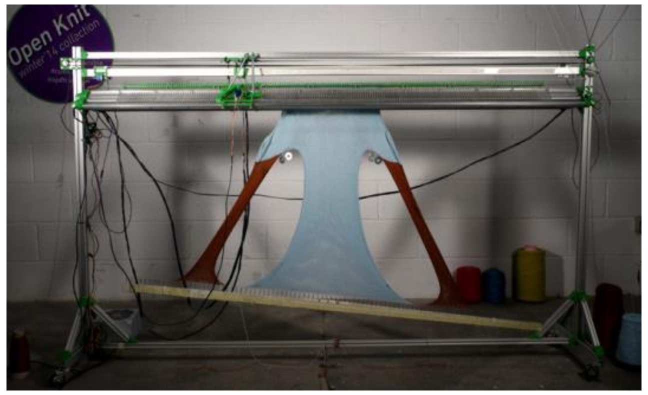

Figure 4. OpenKnit, open source knitting machine

4.2. Developing a mobile solution

The OpenKnit system was selected as it offers a combination of open/digital design combined with an open source machine. This allows end users or communities to create their own machine while also allowing the designers to adapt them to their specific needs. However the current design of the OpenKnit system was not suited for mobile use, several adaptations would have to be made.

Therefore the machine was redesigned to be smaller, lighter and sturdier. Several tests were executed to test the new components durability and reliability, this was done on the main machine. The main components were all tested and (partially) redesigned. This was mainly focused on the carriage and the rack & pinion. The carriage is responsible for both guiding the thread as well as controlling the motion of the needles. Where the rack & pinion is vital to the accuracy of the machine as it creates the input for the software to determine the carriage position on the needlebed.

The resulting machine was mountable on any flat surface using two clamps, weight was reduced to 5,5 kg. Its needle beds have a total of 120 needles, 60 a side. This is sufficient to produce a small wearables. It is battery operated using a 12v battery and converter circuit to power both the stepper motor and servo's which run on 12 and 5 volts respectively.

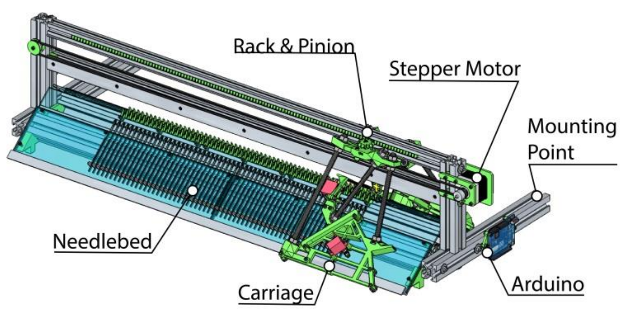

Figure 5. The redesigned OpenKnit machine "wally 120" also shown are the main components if the machine

5. Engaging local community

5.1. Test set-up

When selecting the type of garment to make it was decided to make a beanie. This simple woolen cap design would allow for a quick turnaround during the sessions and would allow the machine to run without interruption for a long period of time without spending too much time on the production of the garment. In total it takes 35 minutes to create.

The following set-up was used, it follows the shown scenario. The test scenario consists of several steps each with their own function. The first step is to set-up the machine on its location, this means attaching the machine to a supporting structure. This can be a structure available on site or one that is brought. Attaching Wally is done with clamps, which ensures a solid connection without damaging the structure. The second step is to hook up the electronics, this consists of connecting the battery and the USB cable to the laptop. For the third step an interested onlooker is approached, a short explanation is given about the purpose of the machine and the general theory. If the person is interested a short production track can be started. This started with the fourth step here we measure the size of the head in order to make a beanie made to measure. This data will be insert into the Arduino software upon which the needlebed is prepared. The fifth step is threading the machine and setting up the first two lines manually. Afterwards the Wally takes over and knits the garment to its desired length. An optional step is to cut and splice a different colour thread during the knitting process. For the last step the garment is closed manually while still on the machine and then removed from the comb and needlebed. It is then ready to wear (Figure 6).

During the knitting of the wearable and afterwards, the users are asked to express the experience and they are given the opportunity to ask any questions they might have.

Secondly they are asked to share their expectations and desires regarding the machine and its applications. This ranges from what they would use it for themselves, to what they would eventually want to be able to make with it. This will give an insight into their standings in relation to the technology and might also illustrate the changes herein, as a result of this new experience.

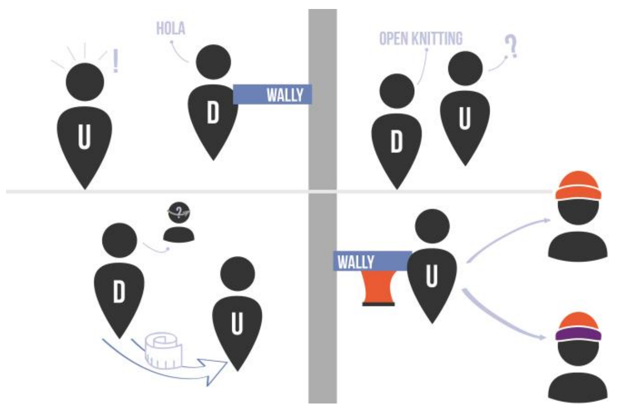

Figure 6. The Test scenario

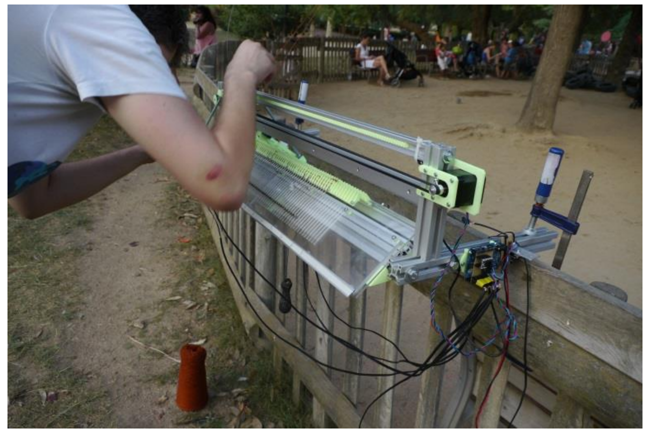

Figure 7. The set-up

The sessions will be documented by both video and camera footage. This will later be used to analyse the effect of this new interaction that occurs within the public space. Important is to also document the range of interactions and steps the public goes through.

5.2. Test location

In order to get enough exposure the test location is of significance. While the centre of Barcelona is lively and full of people, the tourist is not the target audience. While people are very open to new things while on vacation the main goal of the test is to see if the general public is willing to accept AM technology and maker culture. To this end the Parc de la Ciutadella was selected, this city park is visited mainly by the local population. The park is still crowded enough to have enough exposure while not including to many tourists into the test group.

The mounting of the machine did limit the selection of the test site as most of the surfaces where unfortunately rounded and therefor unsuited for the chosen mounting system. The chosen site was located near a intersection of the walkways and the playground (Figure 7). Especially the proximity to children was useful lase their curiosity and lack of inhibitions will help pull in more people.

5.3. Results

The results of the test session held in the Parc de la Ciutadella, show a great variety of interest. The session created a good crowd of people looking at the machine at work. The steps described in 4.2 were followed as closely as possible as the installation would allow (Figure 8). As expected the children were first to explore, drawing in their parents and later more bystanders joined to see what was going on. As can be seen in Figure 9 the public was rather mesmerised by the machine. The movement and sound creating interest and upon closer inspection questions start to arise about the project, the overall goals and future use.

Ranging from remarks about the look of the machine to the technical specifications used to create it. This wide range of interest was already very useful. The wonderment seemed to suggest that most people had never seen a machine like this in action, not to mention in the middle of a public park.

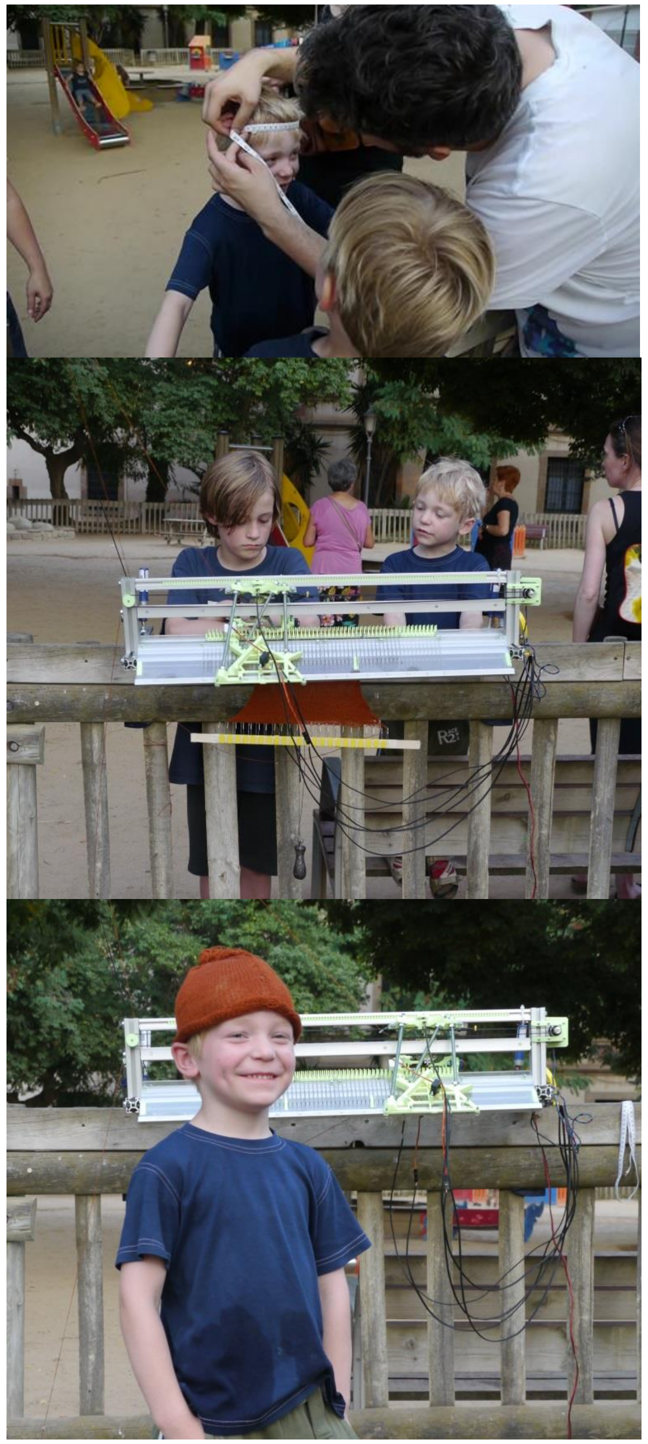

Figure 8. Testing the machine (top) measuring the size,(middle) knitting the beanie, (bottom) ready to wear

Figure 9. Some of the gathered audience

The answers to the questions were mixed and varied wildly in detail so in order to get a quantitative overview they were categorized as positive, negative or indifferent. This creates the following overview in regards to the questions, as seen in Figure 10. In total 26 people took the questionnaire during the session. The questions focused on the following aspects of the concept: general impression, available features, reliability of the machine, functionality of the product and the durability of the machine.

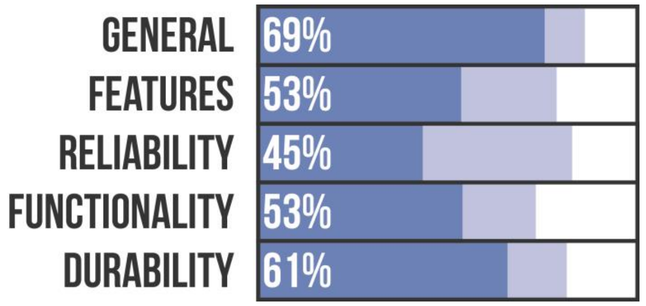

Figure 10. Quantative overview of the questionaire positive/negative/indifferent

When discussing their possible future use of this technology, the responses were categorized as well. This question was aimed to determine the likelihood they would use this machine or something similar in the future. The responses ranged from; definitely, possibly & never. This resulted in the following overview:

Figure 11. Possibility of future use definitely/possibly/never

With regards to the type of desired use the following categories were given: small wearables/ Simple sweaters, dresses & vests/ Hoodies, buttoned & other complex garments. This was to see what type of garment they want to create should they use the machine themselves. They were told to ignore size or current technological limitations in this answer. The results were as followed:

Figure 12. Percentages off desired use for Small/Simple/Complex garments

When asked why they would use the machine instead of buying readymade garments their response were mainly focused around the following properties; better fitting clothes (72%), more freedom in creation/personal style (45%) and lower price (30%). This was in within the context of made to measure patterns. Were they can enter their measurements and select patterns/colours freely.

6. Discusion

When looking at the results of the engaging local community test case seems to check all the boxes in regards to the successful realisation of greater acceptance. However when looking at the test set-up and general several issues came to light.

First, the test location in combination with the time the test was held at. The test was carried out during the late afternoon early evening 18:00 -20:15. This might have an effect on the results in that the public could be tired, on their way home. In order to exclude these and other factors from the results a second session at a different location and time of day would be needed.

Secondly, while the machine performed well it struggled due to the method of placement. The gate it was attached to resulted in an off level position which created a greater strain on the system then initially anticipated. In order to prevent this in future tests either the mounting system or mounting location will need to be addressed. As the struggling machine has effect on the perception of durability and reliability as mentioned by one of the participants; "It seems to struggle a lot, especially going towards the edges of the beanie, does it always do this?". In order to create a positive image for AM technologies the reliability will need to be increased.

Another effect of the Wally 120 system that limits the testing at this point is the lack of interface design integrated into the system. In order to let the public use the machine by themselves, an interface will need to be developed. This also ties into the limitations currently attached to the machine as it is still not able to decrease needles, needed to be able to do short stitching. This is still under development and once completed will greatly increase the range of designs the Wally 120 could handle.

Also there was the matter of language. Even though a Spanish native was present during the testing the researcher himself did not speak Spanish this created some difficulties explaining the machine and answering the questions. While this did not affect the general insights into the effect of the machine it did limit detailed discussions.

7. Conclusions

. The concept of introducing a localized manufacturing tool into an urban community resulted in a positive response from the general public. When looking at the results it is clear that when confronted with AM technologies in a urban context general interest is increased.

Looking at the Attention Interest Desire Action or AIDA model the following can be concluded. The Attention was created, the Wally drew in a large crowd before it was even turned on. The Wally was considered intriguing, because of the colour, sound and overall shape that stood in stark contrast with its surroundings.

Attentiveness was high, 70% of the people that stopped to take a longer look asked questions, made pictures or were talking amongst themselves about the machine. When looking at the answers in regards to future use the crowd was positive. 64% of the participants of the questionnaire would use this machine if it would function similarly to the test conditions.

53% of the participants would use the machine for complex garments, while 87% of them would use it for small simple garments. This shows significant interest and desire in regards to using the machine.

Action was not addressed in this test as the machine is still in development. However the initial responses regarding the Wally 120 were positive and several machines are currently under construction around the world.

A important thing to notice is their need for better fitting clothes as 72% of the participants claim this as a reason to start using this type of clothing manufacturing. It seems that even though the standardisation of clothing is able to facilitate the industrial production of clothing it does not seem to fill the needs of the users.

When looking at the role of the designer in this process, it can be concluded that this has been altered. The designer is no longer just creating products that fill the needs of the consumers. Instead we see a new task taking shape, designing and defining the tools and design space for the end user. This is partially done with a co creation process at this time. However this can be further developed to let the users freely design and manufacture their products without any direct contact. The contact between user and designer will then be through the design space created by the designer.

8. Acknowledgment

Furthermore thanks go out to Prof. Dr.ir. J.C. Brezet for proof reading this paper, and adding his particular view as a soundboard during this research project. His focus on circular economy was a driving force during the entire process.

Thanks also go out to the people at Arduino. There financial support to the OpenKnit project enabled to the fast creation of the Wally 120 machine. And allowed Cees Jan to prolong his stay in Barcelona further improving on the OpenKnit project in general.

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APPENDIX E. PUBLICATION NEWSARTICLE

De robots moeten nog even oefenen

Handige machines

In Delft stond deze week een robot die helpt om IKEA-meubels in elkaar te zetten. Luxe toch? Maar de robot kon er nog niet veel van.

FOTO JOUKE VERLINDEN

Baxter houdt een lamp vast.

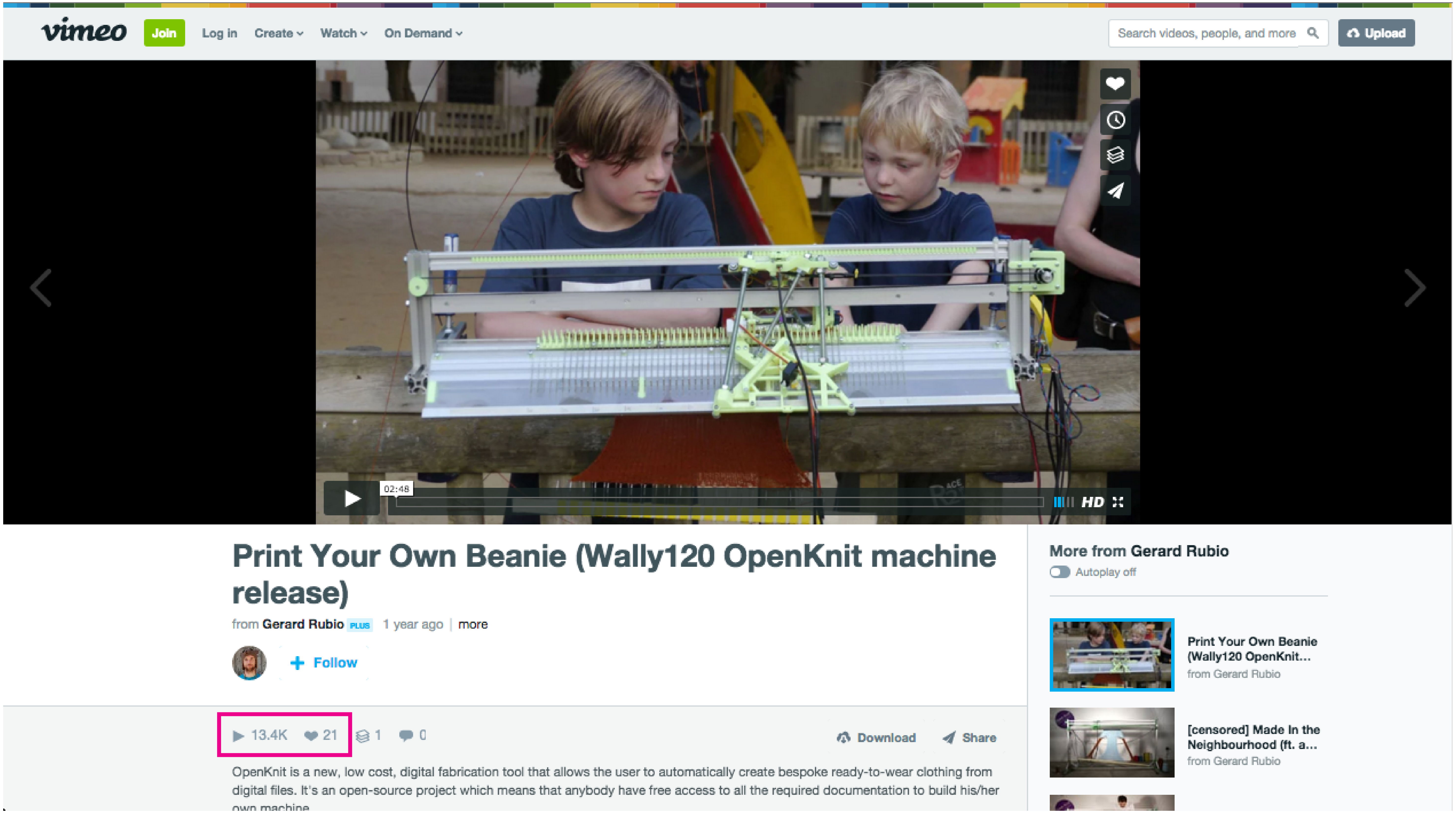
Baxter is een robot. Hij wil je graag helpen bij het in elkaar zetten van een IKEA-lamp. Afgelopen dinsdag stond Baxter op een tentoonstelling aan de Technische Universiteit Delft. Daar hebben ze deze robot uit Amerika net aangeschaft. Hij kost 25.000 euro. Studenten leren hem hoe hij kan helpen bij het monteren van een lamp of een kast.

Maar deze week luisterde Baxter nog niet zo goed. Met zijn rechterhand (nou ja, een zuigend kokertje) probeerde hij onderdelen van de lamp voorzichtig vast te zuigen en ze aan te geven. Het wilde niet echt lukken. Hij zoog niet op de goede plek, of het onderdeel viel van zijn hand. Pas na een keer of tien ging het goed. „Hij moet nog veel leren", zei student Joyce Rietveld.

Een paar meter naast Baxter stond een breimachine. Die had ook een grappige naam: Wally 340. Je kunt met je computer breipatronen naar Wally sturen. Als het goed is breit hij binnen twee uur een trui, sokken of een mutsje. Maar afgelopen dinsdag ging dat ook niet goed. De breimachine was net in elkaar gezet, vertelde student Rita Balrak. Hij werkte nog niet zoals het hoorde. Er bestaat wel een kleinere versie, Wally 120. Die was niet op de tentoonstelling, maar die doet het wel. „Je kunt hem ook zelf bouwen", legde Rita uit. Als je een 3D-printer hebt en ongeveer 550 euro. Als je dan toch een 3D-printer hebt, kun je ook een soort legoplaatjes printen waarmee je een oorprothese kunt printen. In de toekomst zijn die voor mensen met een kapot oor, bijvoorbeeld door brandwonden. Dat was in Delft ook te zien, en dat werkte gelukkig wel. Handig!

Marcel aan de Brugh

APPENDIX F. PUBLICATION MOVIE



video can be accesed at:
https://vimeo.com/102520966