Effective visualisation of textile for a Digital Showroom

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Abstract

This report studies and examines the process of investigating and creating a visualisation that aids with the judgement of fabrics in sale setting. Throughout this project, an animation that aims to do this and the presentation of this animation has been developed. The idea is that the animation can replace the physical "feeling" of fabric visually.

During the course of this project an end product in the form of a hi-fi prototype has been produced. This end prototype is then subsequently user tested in order to determine whether the end product is able to meet its goal of being reliable, easy to use, aesthetically pleasing, simple and informative.

It can be concluded after testing the end product that the animation and presentation method spark interest, enthusiasm and does aid the user reach their goal. However, end users do miss the sensation of physical touch and the animation alone does not prove to replace this sense.

Acknowledgement

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1. Introduction

This report presents and describes the development and designing process of creating a successful visualisation of judgement of fabrics with the support of technology for a Digital Showroom. The project has been facilitated by the company Hecla Professional in association with PVH Corp.

The challenge of this project is to interpret the wishes of the client in order to create the “feel” of textile with the use of technology. This is realised by using the basis of physic based theory of textile in order to create an animation that contains pictorial correctness and verisimilitude. Furthermore a prototype of this animation and presentation method will be created. In order to corroborate this plan, a literature research which is described in section 2.5, has been executed in order to answer the sub research question: What are the key elements of effective visualisation of textile materials? The remainder of this report then addresses the main question: What is the best presentation method for this visualisation?

1.1 Overview

The following section in this chapter aims to give an overview of this project’s subject, including the problem statement, some background information about the client, the objectives of the project and the research questions.

1.1.1 Current situation

The customer, PVH Corp. is a global apparel company that is the parent company of many established brands. Their clothing and accessories are sold worldwide in their own shops, franchises and through partners. In order to support sales to their retails partners, the company Hecla Professionals is committed to the implementation process of the Digital Showroom. The Digital Showroom is a new concept that is realised in order to create an unforgettable and innovative interactive digital sales experience. So far, the showroom has been an inconceivable success from a sustainability perspective, as well as an economical perspective since sample production is almost fully eliminated.

When a buyer, such as Wehkamp or de Bijenkorf comes to a PvH Corp. head office in order to stock clothing, they used to enter a traditional Showroom. In this showroom, key pieces of a collection were displayed on mannequins. The buyer would be able to view collections through books and by looking at the clothing that was exhibited. In this case the buyer is able to walk around and view and touch any clothing and the textile it consists of, up close.

Nowadays, a buyer does not enter a tradition Showroom, but instead, enters a Digital Showroom. The Digital Showroom consists of a room where a table and chair are located in the middle. A Theater, which a big collection of screens, fills a wall facing the table. At the head of the table, there is an interactive touchscreen control panel built into the table, which manages the Theater, a floor plan of the Digital can be seen in Figure 1b. There associates of PvH Corp can commence their presentation, giving the buyers a more in-depth experience by showing them catwalk shows, showcase capsule collections, videos of the

production process and other inspirational media in order for the buyer to get a better idea of the collection. This is a full experience accompanied with music and ambient lighting.

1.1.2 Problem statement

However, photography, videos and images used so far, are not satisfactory substitutes for real-world samples. At this point, books containing small textile samples are created in order for the buyer to still judge the quality of the fabric. With over 100 countries of distribution, each containing at least one headquarter, making these fabric sample books is very expensive. These textile samples are sometimes created in different and multiple factories scattered all over the globe. The logistics of creating the sample books are therefore very expensive and cumbersome. The samples are also sewed by hand, since they have not been mass produced yet. This also leaves a big ecological footprint. In order to aid the buyers in their discernment, a solution in order to further judge textiles needs to be explored.

1.2 Objectives

The objective and goal of this research is to develop and create an prototype that leads to a product that aids with the visual judgement of textile with the use of technology for a Digital Showroom. The showrooms that are located on the top floors of PvH Corp. that are located in their Europe headquarters in Amsterdam, Danzigerkade 165 all contain a similar floor map. Visual representations can be seen in Figure 1a and 1b.

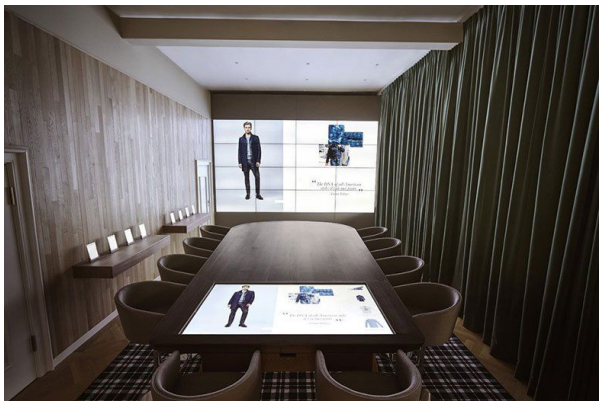


Fig 1a. Tommy Hilfiger Digital Showroom

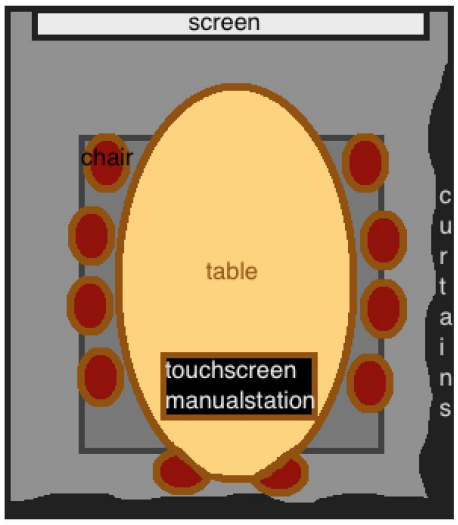


Fig 1b. Floor map of Digital Showroom

The idea is that the prototype and product design created, can be installed and utilized within this Digital Showroom setting.

1.3 Research Question

In order to effectively carry out the research and create the most fruitful prototype and product, research questions (RQs) bring organisation, focus and theme during this project.
The research questions for this project are as following :

RQ: What is the best presentation method for this visualisation?

With sub-question:

SQ1: What are the key elements of effective visualisation of textile materials?

After the ideation phase, the main research question is answered since a decision about the product plan has been defined.
Sub-research question 1 will then be answered throughout the specification phase of this research.

1.4 Report Outline

The report will be structured in chronological order of research. Chapter 2 describes the methods and exploration, based on reviewing the literature, including the design method that is utilised. Chapter 3 a description of Ideation phase of this project can be found. Chapter 4 zooms in on the specifications and the detailing of the product design. In Chapter 5 these details will be decomposed into utilitarian constituents which will be applied in order to create a buoyant prototype. Chapter 6 documents the evaluation of the prototype and chapter 7 finishes the report with a conclusion.

2. Methods and Exploration

This chapter centers and researches the ideation phase and its methods in order to create a stout base for this graduation project.

2.1 Methods

In order to fully explore the techniques that are available for this project, the Creative Technology design process as described by Angelika Mader et al [30] are followed. This process consists of four crucial steps namely: ideation, specification, realisation and lastly evaluation. Since the development of this graduation project is largely parallel to this design process, these steps will fully be followed, developed and explored with a chapter devoted to delineating that stage.

2.1.1 Ideation

The first step of the process is the investigation of the “design question”. This process is constituted by Chapter 6: Ideation. This stage uses a cyclic process in order to develop an detailed product idea. In this cyclic process there are three main pillars that aid this phase. Firstly the userneeds/stakeholder requirements, technology and creative ideas. Therefore an investigation into the key elements of effective visualisation of fabrics (research question 1) is crucial.
This product idea plan will serve as the output of this phase and beginning point of the specification stage.

2.1.1.1 User Analysis

The user analysis is a good pillar to determine the needs and the wants that the end product needs to include. The user analysis should identify the users that will utilise the product and observations.

2.1.1.2 Technology

Another pillar of this cyclic process, is exploring the technology aspect. This includes looking at related work and dissecting the technological requirements and possibilities that can and need to employed in order to make an effective product. In this case, a part of the Technology pillar can also be found in Chapter 2.5 State of the art, which has been executed in the last chapter of 2 Methods and Exploration. This has been done in order to obtain a solid base and extensive background information before starting the Ideation phase.

2.1.1.3 Creative Thinking

The creative idea pillar is the process of investigating creative resolutions for the project. This includes brainstorming about the different ways that textile can be better understood from a visual perspective, how this should be presented and how the end product should look like whilst still including the previous two points. Other designs can be explored in order to draw inspiration.

2.2 Specifications

During the second stage of the Design Process, the specifications stage is explored. In this phase the requirements are profiled and a use scenario is explored. The spiral highlights three pillars: experience specification, functional specification and early prototypes. For this phase the MoSCoW prioritisation technique[31] which can be seen in Figure 2 is implemented.

Letter	Meaning	Description
M	MUST	Describes a requirement that must be satisfied in the final solution for the solution to be considered a success.
S	SHOULD	Represents a high-priority item that should be included in the solution if it is possible. This is often a critical requirement but one which can be satisfied in other ways if strictly necessary.
C	COULD	Describes a requirement which is considered desirable but not necessary. This will be included if time and resources permit.
W	WOULD	Represents a requirement that stakeholders have agreed will not be implemented in a given release, but may be considered for the future.

Fig 2. MoSCoW analysis scheme

This output will then results into the input of the realisation stage.

2.3 Realisations

The next phase of the Design Process, which includes building the prototype/product of the graduation project. This phase consists of decomposition of realisation of components and the integration of each component. These will be argued with a clarification to why these components have been chosen. The realisation process will be split up into two parts. Firstly, the simulation and animation of the textile and secondly, the incorporation of the animation in its presentation method.

2.3.1 Modeling

When a design has been decided upon, the modeling stage is initiated. Allegiance to the material needs to be closely observed in order to achieve the most accurate visualisation as possible. The process, issues and application program tool will be documented.

2.3.2 Simulation

Once the model has been made, a virtual prototype will be created. Again, the integrity of the material will be kept in mind in order to create the most accurate virtual prototype as possible. Again, this process will be documented.

2.3.3 Presenting the visualisation

Lastly once the virtual prototype is completed the presentation manner for the Digital Showroom is taken into account. This presentation manner needs to fit the user requirements.

2.4 Evaluation

The final and last stage of the project an evaluation is made. It consists of: usertesting, functional testing, related work and reflection. Thus, user testing will be done in order to verify the prosperity of the graduation process and a reflection of the end-result will be undertaken.

2.5 State of the Art

A state of the art about the visualisation of fabrics is crucial in order to get an understanding about the subject and what kind of research has been done and what kind of technology is already on the market with the focus of animation and applications.

2.5.1 Introduction

In the last decade, Virtual Reality (VR) has rapidly grown, making advances in many different fields due to its flexible application. Not only does VR deliver assistance in the fields of entertainment [1] and education [2], but it also aids with extensive visualisation support on a level that is unprecedented and revolutionary. In this case, the precise display and inspection of textile materials using VR technology constitutes many different research fields such as computer graphics, education, gaming, mathematics and physics[1][3] and assists with their industrial applications.

Recreating and modelling the substantial conduct of textile, rooted on actual data of textile material samples is a complex process. However, it is a necessary one, since obtaining believable and realistic representations of materials is a crucial part of VR[4]. Since this graduation project leans on this foundation and is based on how to virtually judge fabric, it is a fundamental core requisite to understand how to visually display textile elements.

Therefore the goal for this literature research is to create an in-depth understanding about the factors affecting effective visualisation of textile in an VR setting. This has been done by exploring the different methods that are used to visualise textile in VR, in addition to analysing the key elements of the internal structures of textile materials in order to visualise them within the domain of virtual textile display. The focus has been on how the above affects successful visualisation so judgement of textile is optimised, created and maintained.

In more detail: this literature review will consist of the following chapters:
First virtuality and the current types of virtual textile presentations applications are explored in *VR and textile*. Secondly, in the section *Cloth modeling and animation*, the history of cloth modelling is investigated especially in relation to animation of fabrics. The third section, *Fiber, Yarn and Fabric*, consists of looking at the premises of fabrics and lastly we delve into the structures and categorisation of fabrics in the last section *Key elements of structure*.

2.5.2 VR and Textile

Virtual Reality (VR) makes an excellent candidate for virtual presentation and aided design. Surpringly there are only few virtual textile simulation programmes that support this on the market.
The reason VR is an excellent candidate for virtual presentation is because it possesses multiple qualities. These can best be described by 5 I's as noted by VR specialist Judkins and Sherman [19], which are: interactive, immersive, illustrative, intensive and intuitive [5]. Mantovani et al., [24] and Sulbaran and Baker [25] support this claim. Virtual product presentation is a system that replicates and substitutes the experience according to the property of the product. This predominantly manifests in online try-ons, virtual shopping and online shopping etc [6].

There are two main ways in which virtual presentation are based, that of 2D images or 3D models [7]. 3D models offers more observation stages in comparison to 2D, but also requires special software to run [8]. Textile generally contains many meaningful details such as hundred-thousands of microstructures, fibres and wrinkles which are generally difficult to realise in 3D synthesised cloth. The accuracy of texture and colour are crucial [20], Fairchild [20] and Goldstein [21] state that depending on the product, it is essential to choose the right virtual presentation.

2.5.3 Existing Software

VR representations of textile are done through textile simulation programs. Currently, there are six identified main programmes on that are available on the market: Firstly there is Vision Easy Map [9] which is a texture mapping program that has been created NedGraphics. This software allows you to realistically visualise different surfaces on photographs of your product. Secondly, Kaledo style [10] is a software that has been created by Lectra. This software has been created for professional fashion designers which contains templates on which clothing or other products can be modelled on. The Design and Practice Strip Textile [11] is a new application that supports the design process by matching different textiles with an endless source of colours in an harmonious way. Fourth, Hangzhou Saihu Network technologies Co. Ltd came with a way to try on garments online with a programme called "On-line garment exhibition system" [12]. The fifth identified application is Marvelous Designer [41], which is the most specialised application in simulating fabric, giving the user options to input specifications about the textile which also differentiates the way it falls or drapes. The last programme is Browzwear V-Stitcher [42] which is mainly utilised by clothes manufacturers. Profiles of different fabrics including the patterns of clothing pieces can be made including their specifications.

The above mentioned software all possess two main noteworthy deficits. Namely, products sometimes look unrealistic because when using texture mapping the input textile material distorts. Secondly, the material occasionally looks unrealistic due to incorrect shadows, namely on dark coloured textile [13]. The high complexity rate of the structure of textile causes many problems when virtually

simulating textile [5]. The utensils that are available at present time need improving since only a handful of VR textile simulations programmes are present.

2.5.4 Cloth modelling and animation

There are a few important contributing factors that aid in successfully animating textile in the most realistic way. Before delving into those, it is important to investigate the history of cloth modelling and animation for virtual cloth replication. This process is also described in the research conducted by Wu et al. [15]. So going back in time, before the time of computer succour, the textile industry grappled to find a reliable model for predicting fabric. In 1930, the Pierce model was introduced, in addition, Computer Aided Design methods were inaugurated which were founded on laws of elasticity [3]. This was unprecedented since these systems were much more precise in prognostication than any previous system. Then, the computer graphic field emerged. The goal of this new industry was to create realistic textile visualisations with the least computational fetch [18]. The latter group coordinated most of the research on how to virtually simulate fabrics with their end product being computer generated images. These visualisations were then utilised by fashion designers, game designers and the film world. When these visualisations were used, there was not much care for the correctness of the fabrics [18]. This is in opposition to the computer graphic field, who's main objectives when trying to duplicate the visual conduct of cloth simulations is the correct and realistic deformations of the textile and the way it drapes, the texture and the illumination as also described in the research by Wu et al. [15]. These objectives contribute to the goal of successfully animating textile in the most realistic way however, this is usually restricted by computational limitations. In order to fulfill these objectives in the best way, textile mechanics need to be observed since the notions for virtual fabric modelling lean on fundamental engineering abstractions [23]. Therefore, it is key to understand textile in general. This takes us to fiber mechanics, yarn mechanics and lastly fabric mechanics.

2.5.5 Fiber, yarn and fabric

There are different premises of clothing, such as fiber mechanics, yarn mechanics and fabric mechanics. As mentioned before, in order to visualise textile with the use of VR in a correct manner, it is important to investigate the different premises of clothing so that realistic replication can take place.
The first step for this comprehension is looking at fiber mechanics. Fiber mechanics can be grouped into: submicroscopic struct, fine structure, microstructure and macrostructure of fibers, as backed up by Cheeseman et al.[16]. These structures are placed into categories based on their length, width and furrow. It can also be concluded that the properties of fiber are the most important aspect of understanding textile mechanics since the flexibility rate of recovery of the cloth is based on it as established by Eischen and Bigliani [26]. The fiber structure works like an elastic spring where the stress jerk is a linear curve. Besides, fiber moulds according to conventional mechanical models. In these models, fiber friction is the vigour that clasps together the yarn. In this case lower friction means a looser weave and texture and a higher friction leads to a more sturdy yarn. The next step to comprehending the different premises of clothing are the yarn mechanics. Here, the distribution of the fibers plays a big role. The method of how the fibers are gyrated seed the variable helix radius of the yarn which in turn determines the compressional factors of the cloth.

It is important to understand the mechanics of fabric can be described as inhomogeneous, anisotropic and discontinuous as established by the research of Breen et al. [17]. The structure of the fabric is determined by the fibers and yarn. Yarn consists of hundreds of thousands of fibers. Fabric is then constructed by the use of hundreds of thousands of yarn threads[17]. Fabric waft is the quantity of the yarn in a length perspective whereas the fabric weft is the quantity of yarn in a width perspective. The balance between these two and the fabric weight per mass of unit area determines a big part of the fabric and its complexity which is a non-linear deformation[17].

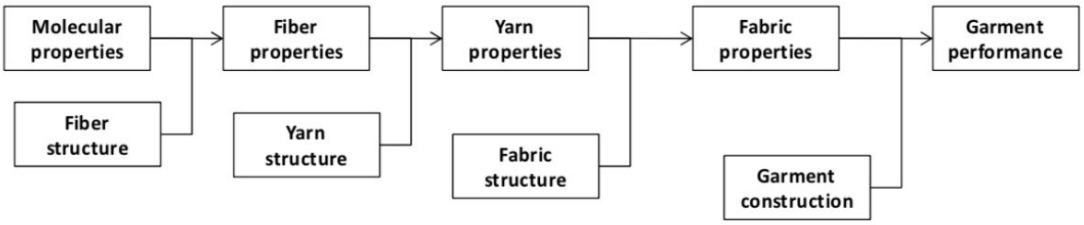


Fig 3. Hierarchical relation of fiber, yarn and fabric according to the execution on a biomechanical level of textile

2.5.6 Key elements of structure

The second step to the comprehension of the different premises of clothing are the structures of the fabric. Structures are key features that warrant different textiles to be differentiated [14] [22]. In this case this concerns the binding patterns of interlacing threads of yarn in knitted and woven fabrics [14] [22]. When looking at the topological study of textile structures, two main categories are highlighted: woven and knotted structures[3]. These structures can be ordered by inspecting the physical, geometric and mechanical characteristics of textiles.

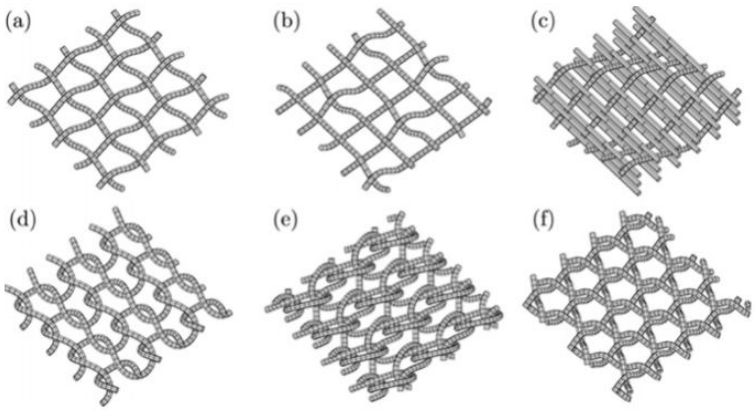


Fig 2. Textile Woven Structures

When inspecting the woven structures of textile, 6 categories can be formed: (a) plain weave, (b) sateen, (c) multi-layered woven fabric, (d) single jersey, (e) warp knit and (f) triaxial woven fabric as also concluded by Boudaker [23] and Zhou [22]. These categories are formed since the majority of fabrics

contain a repeating structure of interlacing yarn threads that are produced in methodical interludes. When woven fabrics are produced, the interlocking of threads can be: interweaved, interlocked, intertwined and a combination of the above[23].

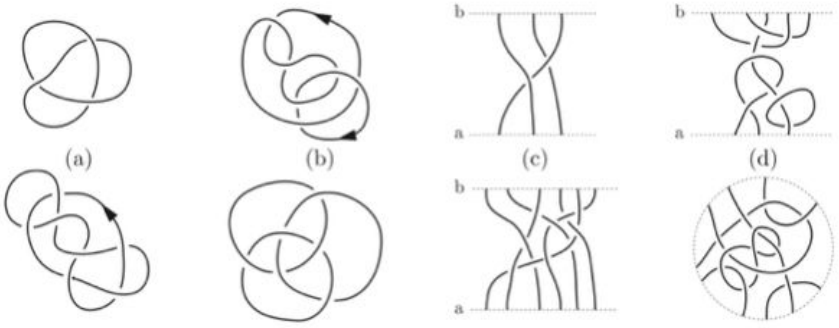


Fig 3. Textile Knotted Structures

The other type of structure is knotted textile. These consist of: (a) knots, (b) links, (c) braids and (d) tangles this has also been concluded by Zhou [22]. Knotted textile structure can be regarded as a textile that is made of unlimited threads that are constantly deformed without breaking. In mathematics a knot can be regarded as a closed smooth curve [15] [22] [23]. A braid consists of parallel ascending threads and a tangle can be a combination of knotted textile types a-c.

Since our world is fast paced, the gaming and designing industry is interested in fast renders which results in their focus lying more on the appearance of the cloth then creating an actual replica[15]. More realistic simulations rely heavily on a high computational rate, however the development of technology is making realistic cloth simulation more accessible due to virtual simulations being feasible[1]. VR helps upgrade the process of design in the industry, cutting down time when creating designs and prototypes, allowing sharing more easily and making testing a much more meaningful process[1].

2.5.7 Conclusion and Discussion

The goal of this literature research was to create an in-depth understanding about the factors affective effective visualisation of textile in an VR setting. In order to identify these elements an investigation in identifying these aspects of textile has successfully been completed. The building components of textile have been identified which are fiber, yarn and fabric itself. The structure of the yarn is further categorised in either woven or knotted structures. With this understanding textile can be successfully visualised, recreated and maintained.

However, the successful visualisation of textile, proves to be easier said than done. So far, a lot of research about fabrics has been done, especially in comparison to the lack of research about the correct implementation textile in an online setting. With new technology such as VR and haptics developing daily on our horizon, it is clear that there is room and need for more development.

Following the research, the verdict is that clothing and textile play an important role in daily life. Whilst the non accurate effect of textile can be replicated, a true virtual representation of textile is hard to achieve however it is not impossible. Using the background knowledge, a good base has been created in

order to use more in depth applications such as Marvelous Designer that require a certain type of knowledge on the science of fabrics to be successfully used.

2.5.8 Recommendations

Evaluating this state of the art critically there are a few remarks that could be made. When looking at other research, most papers on similar topics conclude with the same conclusion and recommendation that has been made during this literature research, namely with the general deduction that a lot more computer power and further research needs to be done to unlock further potential in the fields of education and entertainment. For future work, it would be interesting to further investigate the practical side of this research by looking at user based observations and tests, and analyse the results.

3. Ideation

This chapter explores the first phase of the design process, ideation. The steps of this cyclic phase can be seen in Figure 4. During this phase, by conducting a user analysis, the user needs are pinpointed together with the stakeholder requirements. Other observations and creative thinking are also included in this chapter.

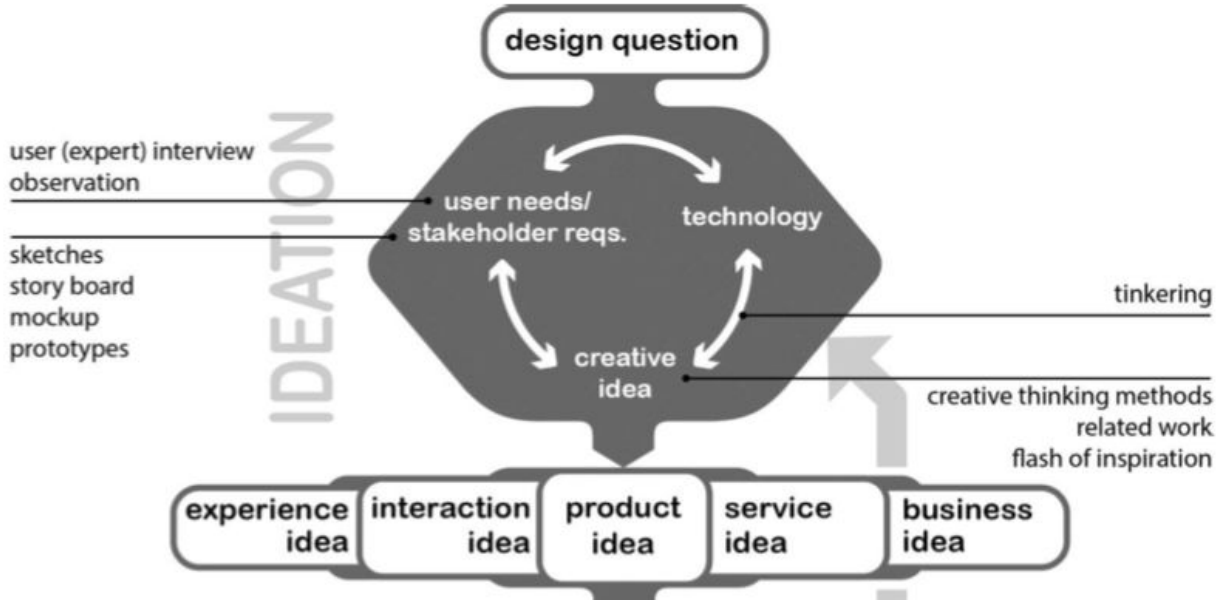


Fig 4. Ideation Phase of the Design Process for Creative Technology by Angelika Mader et al. [30]

3.1 User Analysis Research

For this project, there are three key users/stakeholders that have been determined. The first main user is the client, Hecla Professional, who will eventually build and maintain the end product. The second key user is PvH Corp., since they will place and present the end product in their Digital Showroom. The third and final main users are the buyers. They are the audience and use the end product in order to meet their goal, which is being able to judge fabric. Experts in material science and the client are interviewed and observed in order to decide and regulate the benchmarks and attributes that will be examined and appraised during the next phase of the design process, namely the 4. Specification phase.

3.1.1 Client

One of the stipulations of the final Creative Technology assignment is that the research topic has to be suppported by an external client. In this research paper, the main client is Hecla Professional who in their turn, is investigating innovative ways to support their project “Digital Showroom” for PvH Corp.

3.1.1.1 Hecla Professional

Hecla Professional is a company located in Hengelo and Waddinxveen [27]. Hecla installs and maintains audio- and video systems for the professional market. It was founded in 1969 in Apeldoorn bij Dhr. W.G.J Slutter, the father of the current owner Peter Slutter, who started the company in order to sell electronic devices to consumers. Later their focus shifted to the B2B (business to business) market and the first LCD videoprojecteur in The Netherlands was sold by Hecla [27]. Hecla Professional is currently in the top-5 Dutch total solution providers with clients such as universities, government and municipalities and retail customers. After the demand of installation of products and AV-systems grew, Hecla started to focus on the installation and maintenance of those systems which they do to present day.

3.1.1.2 PvH Corp.

Founded in 1881, PvH Corp. (Phillip- van Heusen Corporation) [29] is an American company and the parent company of many well established brands such as: Tommy Hilfiger, Calvin Klein, Van Heusen, Speedo, Arrow, IZOD, BCBG Max Azria, Kenneth Cole New York, Michael Kors to name a few. In 2017, PvH Corp. generated over $ 9 billion in revenues [28], with 100+ countries of distribution and 36,000 associates globally and counting. PvH sells to many department stores such as Macy's, JC Penney, Sears, Dillard's in North America and de Bijenkorf, Wehkamp, Zalando in The Netherlands. Their products are also available in over 700 brand stores scattered over the globe, worldwide.

3.2 Interview with experts

The third user, as mentioned before are the buyers. Here 3 experts in material sciences and user representatives are interviewed about their idea of creating an animation for textile judgement during a sale setting. The choice of interview type that has been in chosen is a semi-structured interview. This is chosen in order to retrieve information and answers that would otherwise not be apparent in a closed structure type interview and to give the expert the space to share salient details that may not have been bluntly asked. A copy of the loosely worded guideline questions have been placed in Appendix A.

3.2.1 Results of Interview with fashion sale experts

The sale process that is now utilized during the purchase and stockage of clothing has tremendously changed during the past years. This is due to the more widely implementation of new technological advancements. Especially in the fashion industry, an industry that focuses extensively on trends, the use of more innovative tools is encouraged. This is why most traditional sale experiences have heavily evolved the last past years and have also been replaced with more supportive tech-based tools.

However, even though almost all steps of the sale experience have been replaced, the textile samples have remained unchanged. This is because the element of touch, and physically sensing the fabric remains very important and no replacement has been developed up to date. The reason textile samples are used is because touching the fabric conveys information that can not be seen during a modelling picture. Therefore, the textile book is often used during the sale experience, this can be as many as 10-20 times

during a +/- 2 hour sale session. When the fabric from the fabric book is inspected, it takes approximately an average of 20 seconds per sample. The information that is gained during this inspection is the confirmation of the quality of the fabric. This regards mostly the thickness, the feel (is it comfortable to wear?) and the weight of the fabric. These properties also emit and corroborate the quality of the fabric, that needs to match up with the pricement ratio. These important factors need to counterpart the user profile goal of the buyers to optimize the sale target.

One expert explained that when judging the fabric by touch, the fabric is run through the thumb and index finger in a rubbing motion. This way the thickness, the waft and the feeling of the fabric is the most apparent. The feeling of fabric includes if it is soft, hard or even scratchy on the skin. This is important since customers expect a certain feeling of comfort which emits luxury, when wearing the clothing. This is especially helpful in justifying a certain degree of pricing. Furthermore, two of the experts used a monocular magnifying glass loupe lens in order to inspect the textile from up close. All experts agreed that when viewing the textile from a closer perspective, the woven structure of the cloth becomes more apparent, giving a more in-depth understanding of the type of fiber and yarn. This is important because the fiber and yarn make up the properties of the cloth and therefore influence the quality of the textile.

3.2.2 Conclusion

It can be concluded that all experts agree that judging the fabric is implemented as a tool to measure the quality of the fabric. Therefore using a textile-book is an essential part of the sale procedure and is utilized a significant amount times. This is coherent with pricing and sales and therefore is a good measure to calculate profitability. The experts mention that viewing the fabric from a closer angle in order to view its structure is an essential step in the judgement process.

3.3 User analysis

As can seen from above, Hecla, PvH Corp and the sales material experts are the three stakeholders that share heed in the development of this project. The stakeholder analysis can be found in Figure 5. This figure visualises the involvement of each stakeholder in regards to interest, usage, affectedness, prior knowledge about the product's subject, targetness and means of resistance.
This visualisation helps identify the key stakeholder who will be the main focal point when developing the end product.

Furthermore the level of interest and power can be weighed against each other. This is visualised in a power-interest matrix that can be found in Figure 6. This is also significant when determining the correct requirements in regards to the main stakeholder.

As can be seen in both Figure 5 and 6, it can be concluded that when analysing all stakeholders, the Sales Expert scores the highest for all of the variables. The second highest stakeholder is PvH Corp., since they have a great (cost-reducing) interest in the end-product and are utilising the end-product in their sales experience. It can be thus deduced that the most pertinent user and therefore the key stakeholder is the

Sales Expert. Their needs and requirements are hence crucial and germane for the development of the end-product.

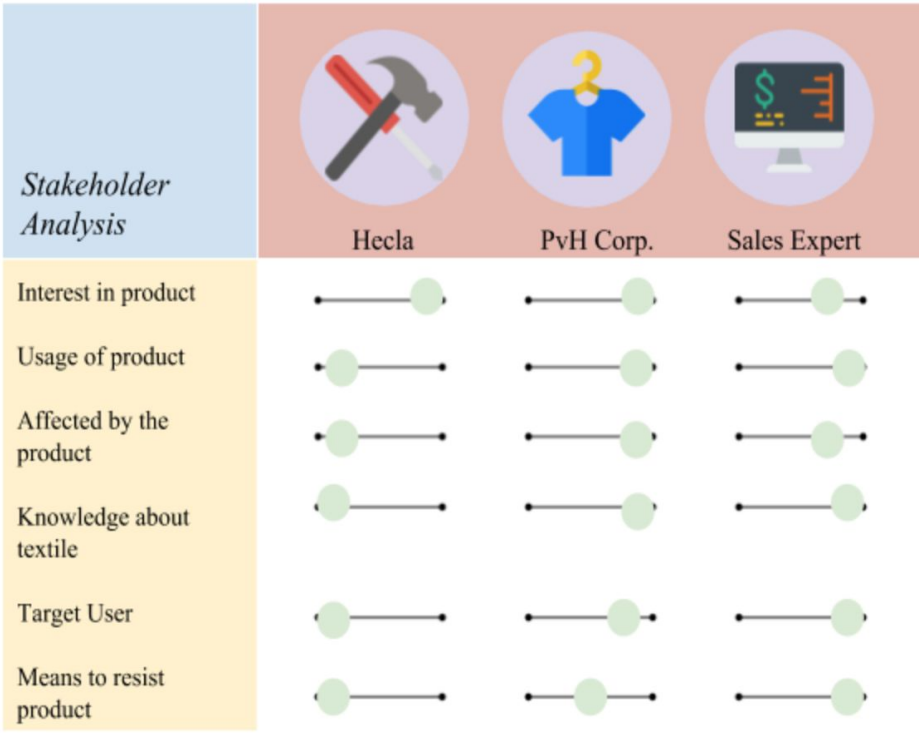


Fig 5. Stakeholder analysis

Fig 6. Power-Interest Matrix based on Stakeholder Analysis

3.4 User Personas

When envisioning the end-product, close care to the experience of the user needs to be kept. A user persona in combination with a scenario helps to uncover the motivation and goals of the main stakeholder. It is also implemented in order to produce ideas during this ideation phase of this project.

3.4.1 Persona

The following personas regard a representative user from the two most important stakeholders. These have been developed according to information acquired during interviews with the clients and during the interview with fashion sale experts that can be found in section 3.2.1.

3.5 User requirements

Based on our stakeholder analysis, the Sales Expert has been identified as the key stakeholder. Furthermore a user scenario and persona have been created in order to get an depth understanding of the process in which the end-product will be implemented in. Furthermore the user requirements are based on the ACCESS FM model by P. Omodeinde [34]. This model focuses on the **A**esthetics, **C**ost, **C**ustomer, **E**nvironment, **S**ize, **S**afety, **F**unction and **M**aterial of the product design based on the requirements of the main user.

Based on this, a list of user requirements has been formulated and extracted:

- The product's usage is self-explanatory
- The product is easily implemented in all Digital Showrooms
- The product does not make use of wearables
- The product replaces the Textile Book

- The product is cost efficient
- The product is visually attractive
- The product is safe to use
- The product can only be assessed by authorised users
- The product is time-efficient
- The product aids in the judgement of fabrics

3.6 Creative Thinking

As described in 2.1.1.3 Creative thinking is a pillar in the process of investigating creative resolutions for the project. This also includes brainstorming about how the textile visualisation should be presented.

3.6.1 Brainstorming

To get a feeling of the subject, different types of brainstorms have been done. In this first brainstorm session, words are written down on sticky notes and then stuck on the corresponding scopes, see Figure 5. This gives an idea of how the subject, VR and fabric in a retail setting, is connected and what things to keep in mind. It helps to remember these thoughts when coming up with plausible ideas.

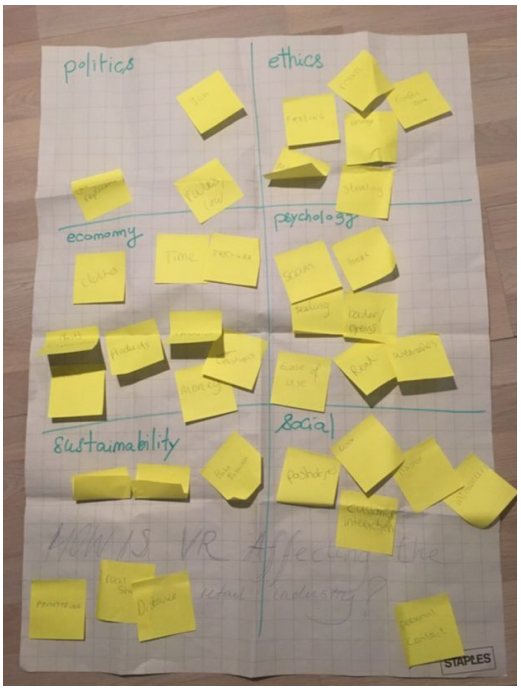


Fig 5. Brainstorm session in 6 scopes

Noteworthy were words that have to be with ethics, economy and psychology and sustainability. A few examples of such words were: job replacement, real shops, production, manipulation, border, ease of use, fake, time, texture, fast exploration, advertising and web shops.

Viewing these elements of VR in retail from different scopes support other brainstorm and ideation sessions.

3.6.2 Mindmap

The next thing step in the Creative Thinking process was creating a mind map (see Figure 6) with words or phrases that are more directly linked with brainstorming for actual solutions.

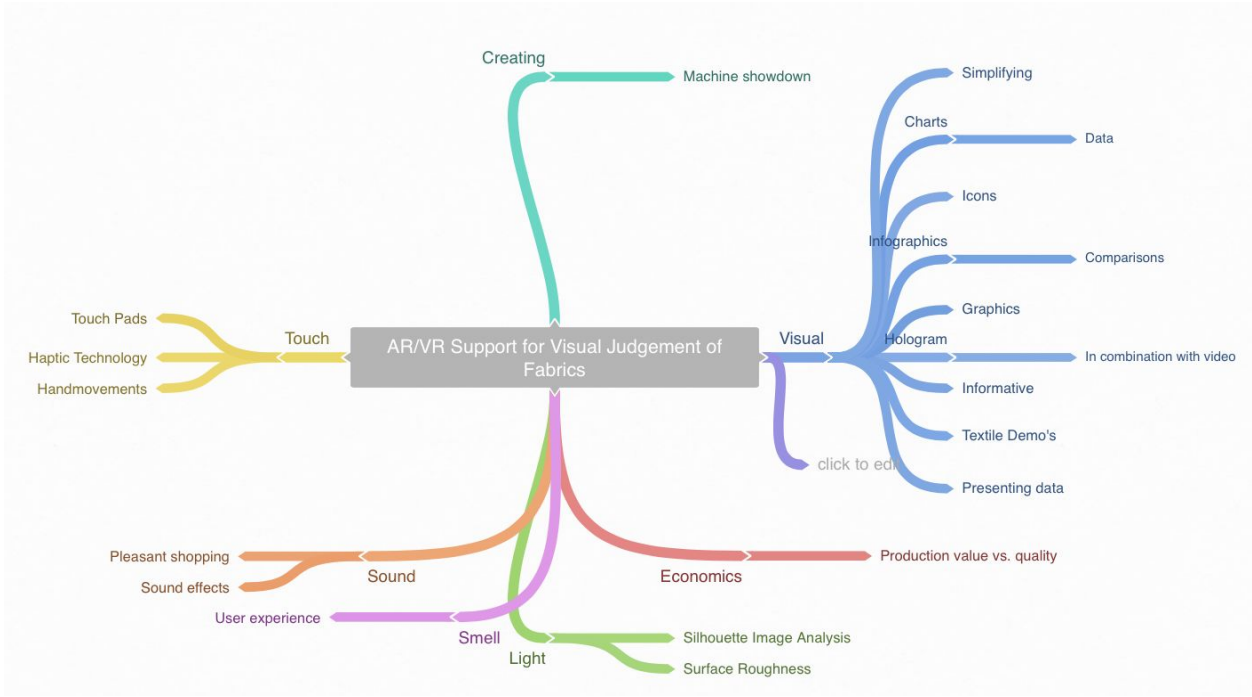


Fig 6. Mind map during Creative Thinking

By creating a mind map, multiple ideas for Mixed Reality Support for visual judgement of fabrics arose.

3.6.3 Diverging Brainstorm

During this part of the brainstorm process, two different types of brainstorms are held. The first brainstorm has been done together with the first stakeholder, which is the Sales Expert, in this case the stakeholder will be classified as the expert. The second brainstorm is done with the second most important stakeholder, which will be classified as the user.

3.6.3.1 Brainstorm with expert

1. An app that replaces the Textile Book that shows animations and textile properties
2. A haptic technology plate the vibrates at the frequency to simulate the feeling of different types of fabrics

3. An immersive (semi) VR room that allows to view the catwalk show from up-close and different angles
4. An interactive hologram that shows an animation and works with hand gestures
5. A box to put your hand in that uses mid-touch ultrahaptics air technology
6. An animation that can be shown on the Theater
7. An presentation that can be given in advance that shows all the different materials that have been used in the collection
8. An online textile catalogue that can be assessed by uploading a picture of the textile you want to learn more about
9. An app on your phone that shows more information when hovering over a part of the textile with your camera

3.6.3.2 Brainstorm with the user

10. Showing an animation of textile that aids with the understand of the fabric by showing the textile from different angles
11. An animation of textile that uses shaders
12. An animation of textile using shadow image analysis
13. A piece of textile is scanned during the designing process and this photograph is then converted in an animation
14. An animation showing the microscopic structure of the fabric
15. A programme that tracks the eyes and when looking at certain parts of the garment in question, automatically gives information by audio
16. An exoskeleton that can be put on the hand in order to create Tactile Haptic Feedback
17. A glove that vibrates with the use of water to simulate certain fabrics
18. A robot that demonstrates and makes the piece of fabric in question
19. A simulation of how the fabric in question is made (woven process)
20. A gel liquid that can imitate the zoomed in structure of the fabric with the use of electric pulses
21. A 3D printer that prints a close up of the fabric
22. An animation that shows how the properties of the fabric by draping over a ball
23. A piece of white material that can have other materials projected on
24. A hovering simulation/projection of the fabric that can be projected on your hand so that it can be viewed up close

25. A programme that remembers the most asked about fabrics and shows an animation with explanation beforehand
26. An animation of the fabric showcased on a modelled human
27. Virtual reality glasses that allow you to zoom in and move the fabric around
28. Application on your phone that allows you view a hologram

3.6.4 Converging Brainstorm

After the divergent brainstorm is done, the converging phase is implemented. This phase eliminates ideas based on different factors. In order to create an overview, an elimination table is made this can been seen in Figure 7.
The first round of elimination is done by checking which ideas have done before and additionally weighing them against the outcome of the State of the Art. The next and second elimination round is done by weighing the ideas based on user requirements, this list can be found in chapter 3.5. The third elimination round takes time restriction of this project into cogitation. The fourth elimination round focuses on if the goal of the product is met and weighs this against the outcome of the idea.The last elimination round measures the idea against the current capabilities and aptness that are available.
After converging, a main idea will arise that can further be developed. Other ideas that have been eliminated and do not fit this current project, can however be developed in the future.

Elimination Table	
Ideas that have been done before :	*14*, 22*, 26,*
Ideas that violate the user requirements :	*3, 11, 12, 27,*
Ideas that do not fit the time constraint of the project :	*1, 4, 8, 9, 13, 15, 23,*
Ideas that do not fit the goal of the project :	*7, 21, 18, 21, 25,*
Ideas that do not fit the current capabilities :	*2, 5, 16, 17, 20, 24,*

Fig 7. Elimination table of the brainstorm ideation phase

The ideas that were not eliminated and or still remain are the following:

6. An animation that can be shown on the Theater

10. Showing an animation of textile that aids with the understand of the fabric by showing the textile from different angles during sales in the Digital Showroom

19. A simulation of how the fabric in question is made (woven process)

28. Application on your phone that allows you view the animation via a hologram

The ideas that have to a certain degree been done before, but are still noteworthy have been marked with an asterisk (*). These ideas can be used for the core requisite of the understanding of fabric and can be further developed and tweaked to suit the product goal requirements.

14. An animation showing the microscopic structure of the fabric*

22. An animation that shows how the properties of the fabric by draping over a ball*

3.6.5 Resulting idea

The outcome of the diverging and converging process have resulted in making a supportive animation that can evidently be implemented into the Digital Showroom in many different ways. It is important to keep in mind that firstly, the animation needs to be able to contribute to the judgement of fabrics, thus transmitting valuable and crucial properties of the fabric. Secondly these crucial properties of the fabric are utilised in a sale setting, where the animation needs to be understood and easy to use by the main user, the Sales Expert.

3.7 Design Decisions

3.7.1 Introduction

In this phase we look at the designing aspects that will be modelled and animated. Therefore mockup sketches of idea 6. and idea 28. have been made in order to get a feeling on how the animation should be presented.

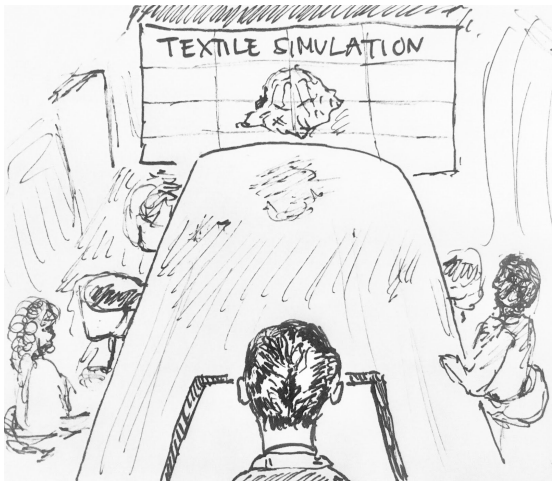


Fig 8. Animation implemented in Digital Showroom

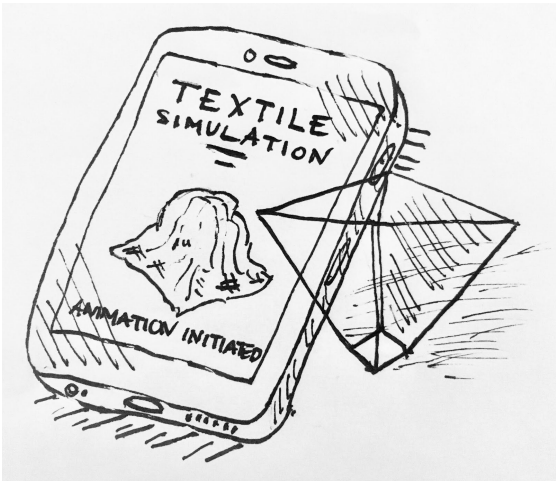


Fig 9. Animation and hologram viewed on a phone

In this case it can be concluded that the developed animation could be viewed in the Digital Showroom Theater, as well as on the phone of the Sales Experts. Thus no regards have yet to be made on the the presentation method.

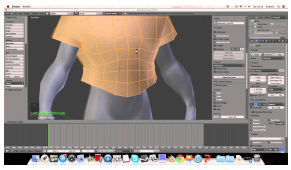
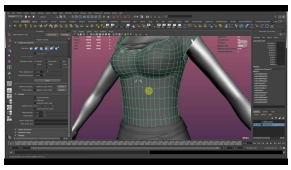
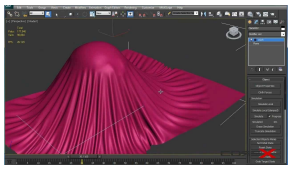
3.7.2 Animation, Modeling and Design

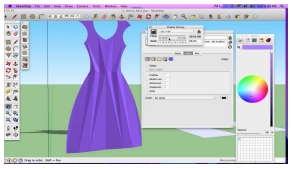
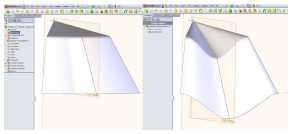
Modelling the animation is also dependent on the type of softwares that is currently available on the market. In order to make a decision which animation application is going to be used, a table containing an overview of the information about the system, its compatibility, is difficulty and cost is created.

After inspecting the table, a software programme that fit the capacity to be able to realise the needs of the end-product animation will be chosen.

3.7.2.1 Software Information Table

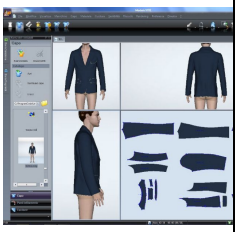
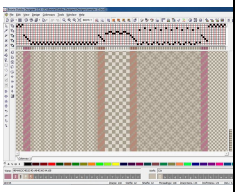
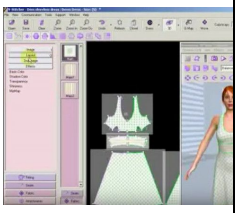
The following software is focused on modeling:

Tool Name:	***Blender***	***Maya***	***3DS Max***
Example of User Interface:			
Compatibility:	Mac, Windows	Mac, Windows	Mac, Window
Tool Description:	Blendr is open source and is mainly used to create 3D models and animated movies.	Maya is the most straightforward choice for animations and modelling.	Used for designing and visualising 3D models and often used to create worlds for games.
Difficulty Entry Level:	Beginner	Moderate	Moderate
Costs:	Free	$ 3,675	$ 3,675

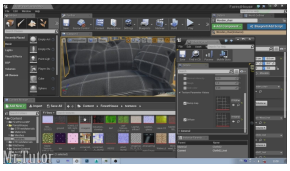
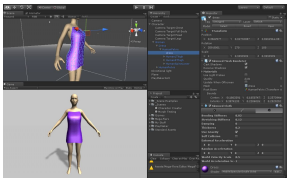
Tool Name:	***SketchUP***	***SolidWorks***	***AutoCAD***
Example of User Interface:			
Compatibility:	Mac, Windows	Mac, Windows	Mac, Windows
Tool Description:	3D Modeling tool that mainly focuses on interior and	SolidWorks mainly runs on Windows and is an computer-assisted	AutoCAD is an design software application that is commercially

	architectural modeling. Is also sometimes implemented for engineering purposes.	engineering modelling programme.	used.
Difficulty Entry Level:	Beginner	Expert	Expert
Costs:	$ 695	$ 5495	$ 6,295

The following software is also focused on modeling but have a specialization that includes textile:

Tool Name:	***Marvelous Designer***	*Modaris 3D Fit*	*Booria Dobby Designer*	*Browzwear V Stitcher*
Example of User Interface:				
Compatibility:	Mac, Windows	Windows	Windows	Windows
Tool Description:	Marvelous Designer is a 3D tool that focuses on clothes and fabric for the use of moving film and gaming platforms.	3D Virtual Prototyping software specialises in clothing-fit.	Software that aids in creating carpet weaves and designs	Software that is utilized in garment prototyping and is about to modify clothing patterns.
Difficulty Entry Level:	Expert	Expert	Expert	Expert
Costs:	$ 490	Not released	On request	On request

This last table contains software used for simulation:

Tool Name:	*Unreal Engine*	*Unity*
Example of User Interface:		

Compatibility:	Mac, Windows	Mac, Windows
Tool Description:	Game engine that mainly supports visualisations and special effects	Mainly used to develop 2D and 3D simulations with a focus on video games.
Difficulty Entry Level:	Moderate	Moderate
Costs:	Free (5% if profit exceeds $3000)	Pro version for $ 125 per month

3.7.2.2 Comparison between Software

In order to find the right match of modeling software, a matrix is made that grades important properties out of 5 stars "★", and can be seen in Figure 10. The significant properties are: the relevancy, tool match, compatibility, costs and ability to simulate fabric properties.
An overview depicting the rating values of the stars can be found in Figure 11.

Name / Properties	*Blendr*	*Maya*	*3D Max*	*SketchUP*	*SolidWorks*	*AutoCAD*	*Marvelous*	*Modaris*	*Booria*	*Browzwear*
Relevancy	★★★	★★	★★★★	★	★★	★	★★★★★	★★★	★★★	★★★★
Tool Match	★★★★	★★	★★★	★	★	★	★★★★	★	★	★
Goal Compatibility	★★	★★	★★★	★	★	★	★★★★	★	★★	★★
Software Costs	★★★★	★	★	★★	★	★	★★	★	★	★
Textile Simulation Support	★★	★★	★★★★	★	★	★★	★★★★★	★★★	★★	★★★

Fig 10: Modeling Software Match Matrix

Fig 11. Software Rating Guide

The result of adding up the modeling software star rating leads to the following results:

Blendr	Maya	3D Max	Sketch UP	Solid-Works	Auto-CAD	Marve-lous	Moda-ris	Booria	Browz-wear
15	9	15	6	6	6	20	9	9	11

After adding up the star ratings, it can be concluded that Marvelous Designer ranks as the highest match modeling software with 20 out of 25 possible stars. Blendr and 3D Max both follow through landing a shared second place with 15/20 stars.

Name / Properties	*Unreal Engine*	*Unity*
Relevancy	★★★★	★★★★
Tool Match	★★★	★★★
Goal Compatibility	★★★	★★★
Software Costs	★★★★★	★★★
Textile Simulation Support	★★	★★

Fig 12. Simulation Match Matrix

The same process has been repeated for the simulation software:

Unreal Engine	Unity
17	15

After adding up the stars, Unreal Engine proves to be the best match with 17 out of 25 stars.

3.7.2.3 Software Conclusion

In order to find the right match for the most suitable modeling software and animation software for this project, important properties of each other software were rated out of 5 stars. It seems that Marvelous Designer offers the most possibilities that supports our end product goal. Blendr and 3D Max score a shared second place. However, Marvelous Designer scores an “Expert” rating when it comes to ease of use. Whilst Blendr has a “Beginner” entry level and 3D Max “Moderate”. In order to proceed with quick Lo-Fi prototyping, 3D Max/Blendr will be used in some cases in order to create simple renders for tests and illustration purposes. For simulation software, Unreal Engine proves to be the best match.

3.8 Ethical Implications

In this section the ethical aspects of the user analysis is explored in order for the user analysis to be conscientious. The goal of exploring the ethical implications is to identify any ethical predicaments or difficulties that could arise throughout the trajectory of this project. Consequently aside from privacy and data collection complications, health issues and manipulation has also been touched on.

3.8.1 Overview of Ethical Implications

During the development phase of this graduation project, the Design Process by Angelika Mader et al.[30] is employed as mentioned before in 2.1 Methods. User needs and evaluation are described as a very important part of the process, so in order to understand the exact needs of the user, observations needs to be made. Consequently, the interpretation of the needs also has to be tested in order to measure the level of success of the product.

3.8.2 Data collection

These observations will resort to human subject research in the form of covert research. During any form of human subject research, ethical appraisal is to be contemplated. The Ethics Committee of University of Twente has to approve a Research Proposal in order for this kind of research to take place. The collection of personal data that is assembled is to be handled with respect and only limited to the necessary data. The data should also will not be abused by using it for other purposes than the research.

3.8.3 Privacy

Also, a few points that such observation must meet center the subject’s privacy. The data of the observation is stored in a file that is not encrypted so in order to protect this data, the subjects enter the observation anonymously. Entering the observation anonymously ensues that any findings cannot be connected with a specific subject. In this case, the use of the data will to correlate to benefit the quality of the product. Lastly, the subject has the option to withdraw from the research within a time frame of 24 hours after the observations has taken place, which ensues the full removal of their data.

3.8.4 Manipulation

As mentioned before, the product that is created which is located in the Digital Showroom influences buyers/user so that they have a better judgement of the textile at hand. This judgement is done with the use of technology. The user does not have to be equipped with any additional tools e.g VR glasses, in order to utilise the hologram. In a way, this can be interpreted as a form of persuasive technology. Persuasive technology is technology that is designed to influence the behaviour or attitude of the user[32] without the use of coercion. Some forms of more severe persuasive technology needs explicit consent from the users, but in this case, the research is innocuous in nature with a very low probability rate of developing any psychological or physical harm.

3.8.5 During observation

During the observational research, no culturally offensive materials will be included. No propaganda, explicit sexual material or material including substances such as drugs will be shown, mainly because these subjects don't have any connection to this research and can interpreted as offensive. Since this observational research is mostly a user test, participants will be interviewed independently from each other so they do not influence each other. This ensures that there cannot be any foul-play and harassment or similar complicated that are related to group research.

3.8.6 Health Risks

Another important issue that arises when viewing this project from a critical point of view, are the medical and health risks that are linked to using mixed virtual reality. In the case of this graduation project, there are no external tools that are used. This eliminates the risk of tripping over wires and injuring yourself. Since there is no emergement into a completely different environment, there is no risk of damaging any objects in the proximity or other people. Also, because the surroundings stay unchanged when using the end product , the risk of "motion sickness" like symptoms are eliminated [33]. Furthermore children are not included in the user base, further eliminating any risk of being misused.

3.8.7 Staying Objective

Since incorporating new technologies in business is growing exponentially, the addition of practicing the use of virtual reality, augmented reality or mixed reality is nothing new. The users utilise these tools that serve a higher purpose or in order to enhance their initial experience, by their own free will. The goal is that the trade-off between privacy and the merit of the design is as favorable as possible. Even though this project's product serves to improve the overall experience of the user, animations can be manipulated in order to control the user's opinion and therefore buying behaviour. Therefore it is important to create firm guidelines and reflect on the matter steadily. In this case, the animation will only serve as tool in an objective light.

4. Low-Fi Prototyping

This chapter builds on previous findings from the brainstorm sessions, user analysis and the State of the art in order to reduce and refine design choices for our end product. The goal is that by the end of this chapter a final design will have been developed.
In order to do so, specifications regarding the project requirements need to be made. To support this process, the Design Process for Creative Technology by Angelika Mader et al [30] is kept in mind and can be seen in Figure 13.

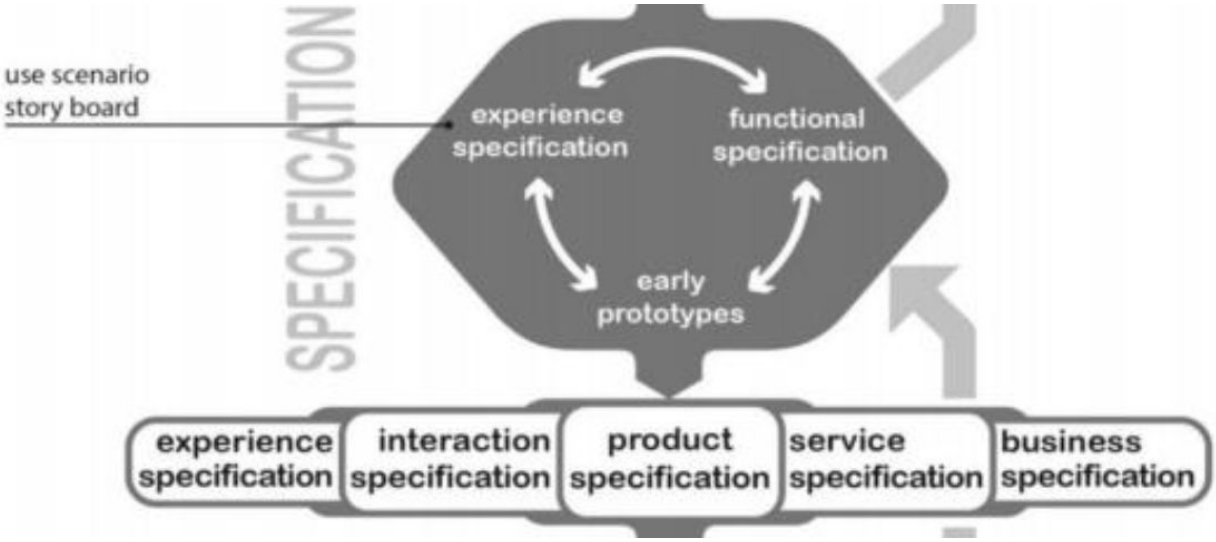


Fig 13. Specification Phase of the Design Process for Creative Technology by Angelika Mader et al. [30]

As mentioned before, during this phase the requirements of our end product are profiled and the user scenario explored. Therefore this chapter will consist of firstly taking a look at the main goals of the first stakeholder. In order to have a comprehensible interpretation of the extent of the project, a use scenario is created. The second step of the specification phase is to refine design choices that have been made during the Ideation phase. This will be done through testing with rapid low fidelity (lo fi) prototypes. The Lo fi prototypes are performed in iterations and then tested and discussed with the main stalkerholder, the Sales Expert. Figure 14 shows the low fidelity design process.

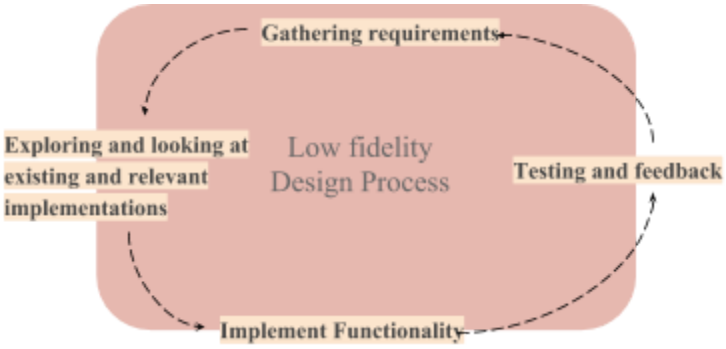


Fig 14. Lo fi Design Process

The conclusions that result after lo fi testing will result in the required project specifications that are supported by the MoSCoW proposition. The analysis scheme was mentioned earlier and can be found in Figure 2.

4.1 Use Scenario

During this use case scenario, the ideal success story is achieved and described. The use scenario will consists of numerous different procedures. Each stage of the process describes the motion of events that result in the successful goal achievement of the main user, the Sales Expert. The floor map of the Digital Showroom, where the use scenario takes place, can be seen in Figure 1b.

Central Actors:

- Sales Expert X
- PvH Representative Y
- Digital Showroom S
- Hecla O
- Animation A
- Product P

Use Case Scenario:
Motion of events:

1. Sales Expert X enters the Digital Showroom S and is welcomed by PvH Representative Y
   (a) Sales Expert X is seated at the main table
   (b) PvH Representative Y boots up the touchscreen manual station as provided bij Hecla O
   (c) PvH Representative Y fills in their username and password
   (d) Log-in is confirmed
   (e) Main Brand Page Interface is opened
   (f) Digital Showroom S is prepped for the presentation
   (g) Curtains close and the presentation is shown on the Theater

2. Sales Expert X is presented the new collection by PvH Representative Y
   (a) A video of the catwalk show is shown
   (b) The product page of capsule collections is shown by PvH Representative Y
   (c) The product page consists of photos of Product P and additional multiple angles of a model wearing Product P

3. Sales Expert X is interested in Product P
   (a) Sales Expert X inspects product on the Theater
   (b) Sales Expert X needs to confirm and judge if Product P is to be purchased
   (c) Sales Expert X requests to learn more information about Product P

4. PvH Representative Y uses the touchscreen manual station provided by Hecla O in order to initiate Animation A
   (a) Animation A is activated and played on the Theater
   (b) Animation A shows information that re-enforces the judgement of fabrics by Sales Expert X
   (c) Sales Expert X requests to see Animation A up close
   (d) Animation A is shared with Sales Expert X to view on a mobile device
   (e) Sales Expert X is able to decide upon ordering Product P and its quantity

5. Sales Expert places order with PvH Representative Y
   (a) Through the touchscreen manual station Sales Expert X requests an order to be placed for Product P
   (b) PvH Representative finalises the order
   (c) PvH Representative concludes the presentation
   (d) Curtains of Digital Showroom S open and lighting is adjusted
   (e) The presentation is concluded

6. Sales Experts prepares for the next presentation

Potential Errors in Use Scenarios:

- Due to invalid Username or Password
- Due to lost internet connection
- Due to system error
- Due to no access to server

However, in order to exercise error control, such as mentioned for the relevant potential animation error 3, which can be seen above, animations can be pre-loaded and saved onto the hard drive of the system that is being used, thus eliminating these problems.

4.2 Low Fidelity Prototyping

In order to create animation mockups for low fidelity prototyping, 3D Max was used to create quick prototypes. These prototypes were used in order to perform user testing with user representatives of the main stakeholder. The goal of the user test is to assess the level of effectiveness, understanding and usability of the animation.
The user test consists of different questionnaires that are used to evaluate the mockup animation in order to specify design choices. The user test embodies the motions of step 4 of the use scenario, where the animation is used to create a better judgement of a fabric.
The first two user tests are done with images, in order to determine whether animations give the user more information than a still image. The last user tests includes animations.

4.2.1 User Test #1

During this first user test, mockups were created in 3D Max. Test participants are asked to answer a questionnaire about which image gives the most information about the fabric properties. A full overview of the questionnaire can be found in Appendix B.

Users are asked to compare the following two images that can be found in Figure 15. The goal is to evaluate whether a 3D model that shows a piece of fabric draped over a ball, gives more information about the properties of the fabric (quality, weight, thickness, etc). The fabric shown draped over a ball makes creasing more apparent, which also ensues more depth perception because of the shadows that are created. This gives more information about the fabric to work with, such as information about the thickness of the fabric. Because of this extra information, our hypothesis will be that the image with the fabric over a ball will be interpreted as the image that gives the most information about the fabric properties.

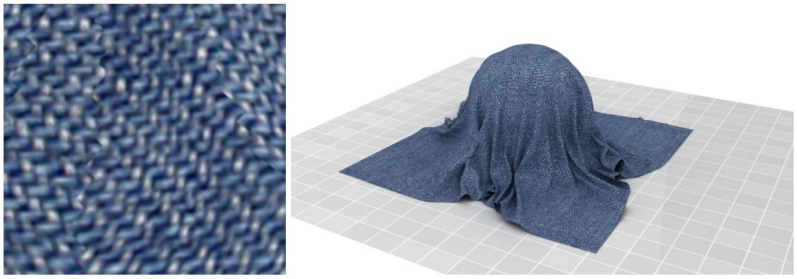


Fig 15. Mockup for User Test #1

4.2.1.1 Results of User Test #1

The results of this first user test concludes 83,3% found that the image shown draped over a ball gives more information about the properties of the fabric. Furthermore 66.7% rated the fabric draped ball image, 5/5 rating on information given from the image.

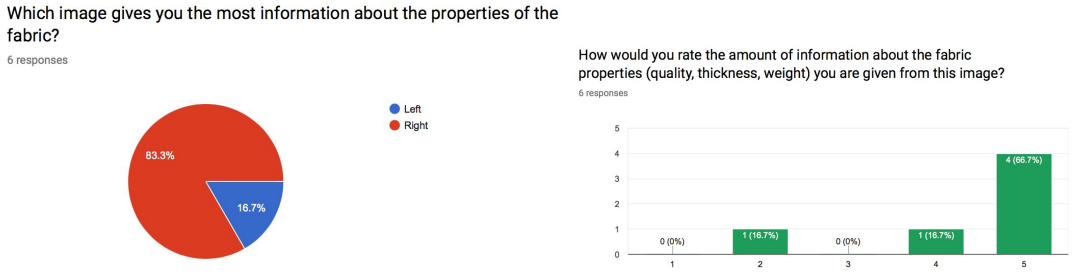


Fig 16. Test results for User Test #1

It can be concluded that the image of the fabric draped over a ball gives more information about the fabric. This means we confirm our hypothesis.

4.2.2 User Test #2

During the second test, mockups are again made in 3D Max. The full questionnaire can be found in Appendix C. During this test we explore angles and the judgement of textile properties. The first question asks which perspective of a fabric over a ball image is deemed to be more effective when it comes to understanding the fabric properties. A sideway perspective and a top view perspective are given as choice, these can both be seen in Figure 17, the image on the left side has been zoomed in, so more textile properties seem to be apparent.
The second question during user test, is whether a user is able to recognize fabric property differences. Two balls with fabric draped over them are presented, both have the same draped fabric but with a different colour and print and can be seen in Figure 18. Because the fabric is the same, the user is tested on being able to see that the density of the fabric is exactly the same, even though the print and colour are misleading.

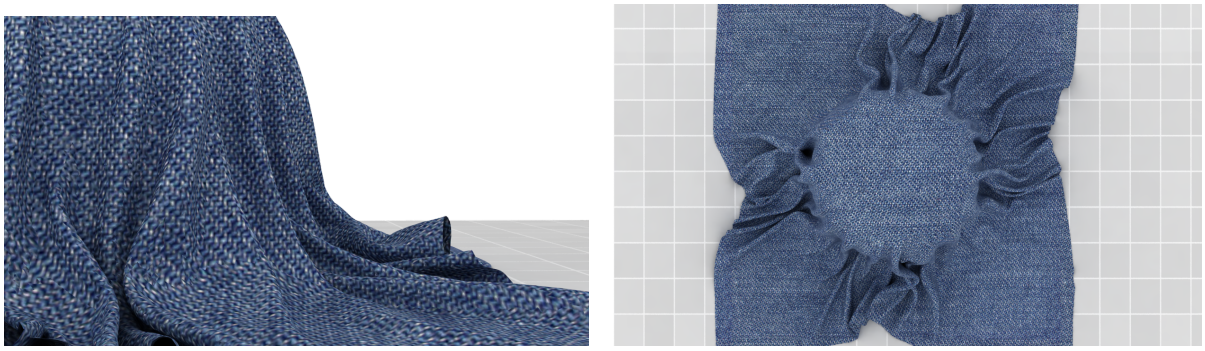


Fig 17. Different perspectives for fabric over ball for User Test #2 Question 1

The last question uses a GPU-based image from the High-Resolution Cloth Simulation Research done by Min Tang et al [35]. This image has been made in Marvelous Designer in order to modify the textile and physical properties. In the image we see a blue buddha statue and can be found below in Figure 19. This statue is duplicated three times, with a green piece of fabric draped over it. Each piece of fabric has been given different types of textile and physical properties, with the first image being the correct one. During this question, the participant is tested whether they can recognise which of the 3 pieces of fabric is realistic.

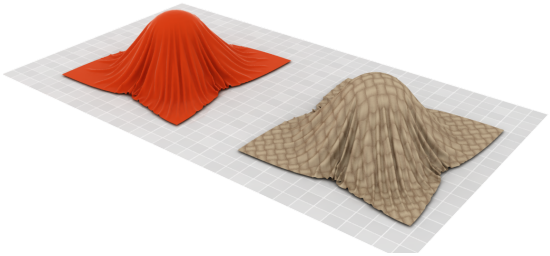


Fig 18. Mockup for User Test #2 Question 2

Since the user of our end-product needs to make crucial judgements about the fabric, it is important that the fabric is depicted in a realistic way. Furthermore it is also important the user is able to recognise which 3D model is realistic or not, in order to determine whether an animation can replace the textile samples from the sample books. Since in this case, user equivalent participants are used that have some background in fashion or textile, we expect that the test participants are able to detect and judge whether modeled properties of fabric are noticeable and whether it is important to apply the right physics.

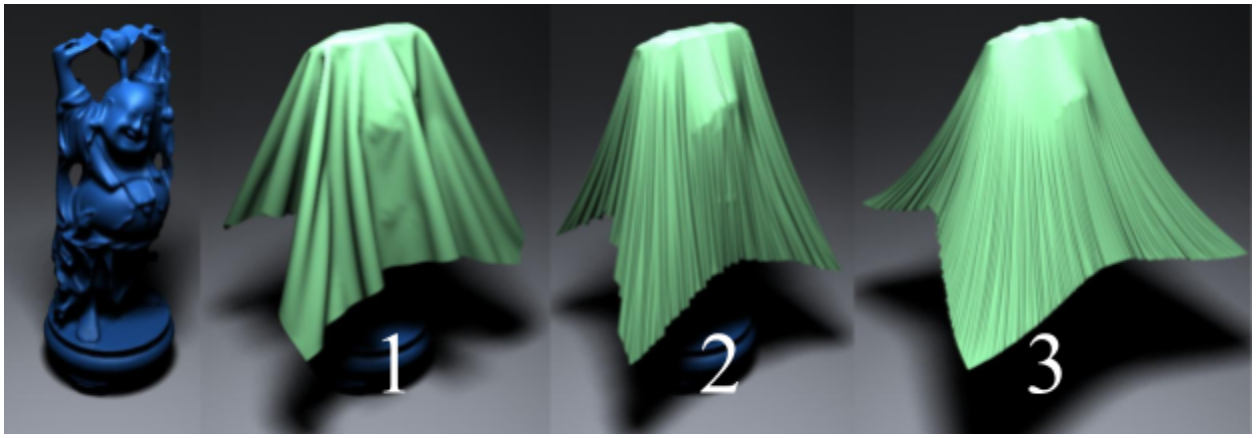


Fig 19. GPU-based image from Research done by Min Tang et al [35] for User Test #2 Question 3

4.2.2.1 Results of User Test #2

User test 2 was conducted and lead to the following results. In question 1, 85,7% of the test participants found that the image that showed a side view perspective conveyed more information. The piechart of these results can be found below in Figure 20.

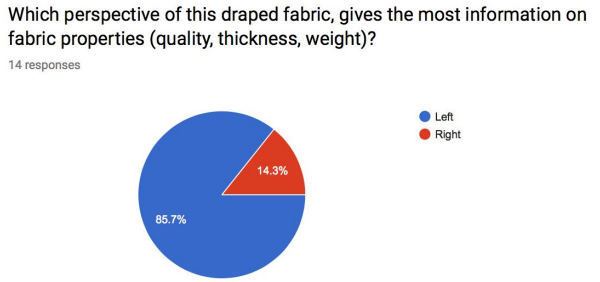


Fig 20. Test results of Question 1 for User Test #2

For question 2, 92,9% of the test participants recognised that the same fabric in different colours was utilized. This confirms that the image is able to convey fabric properties and even when tainted misleadingly, the differences are recognized. The test results for question 2 can be found in Figure 21.

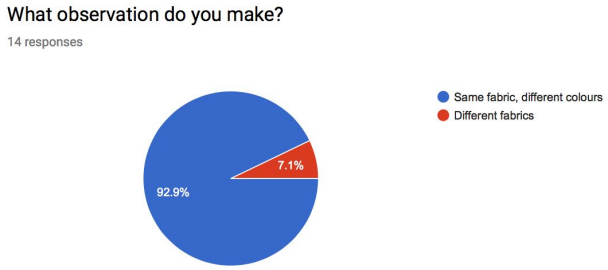


Fig 20. Test results of Question 2 for User Test #2

For question 3, 92,9% found that the first and correct draping was the most realistic. The test results of this question can be found in Figure 21. These results validate our assumption of importance that our animation is correctly modeled with the correct physical properties.

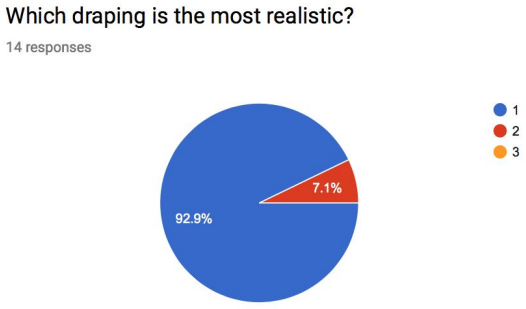


Fig 21. Test results of Question 3 for User Test #2

4.2.3 User Test #3

During user test 3, still images are tested against animations in order to determine whether animations enable more understanding about the fabric properties. The mockups and animation made for this test are made in 3D Max. A full overview of the questionnaire can be found in Appendix D.

Fig 22. Still Image for User Test #3

The first question of this user test determines whether a still image or an animation proves to convey more information about the fabric properties. The still image can be seen here above in Figure 22. The test participant is asked to pick whether the animation (Animation 1) or the still image gives the most information about the fabric property. Since it is not possible to include an animation in this report, a time reel of the animation has been added and can be seen in Figure 23. The animation duration is 2 seconds. For this question it is expected that the animation, since it is a moving image that contains more information about the fabric due to being able to see it move, will emanate more information. Thus, being a more significant candidate for the judgement of fabric.

The purpose of question two of this user test, is to test which perspective gives the user more information. The participant is asked which animation gives the most information about the fabric properties. Animation 1 is the same animation that was used in question one. The perspective of this animation is from a bird perspective, slightly elevated and looking on to the ball with fabric. This top view is quite zoomed out as can be seen in Figure 23. Animation 2 on the other hand, has a perspective that is more a frog perspective, closer and on the same ground level. A time reel of Animation 2 can be found in Figure 24. As observed in the interview with an expert, some experts use magnifying tools in order to inspect the properties of the textile. Furthermore, more distant view of the textile used in the clothing has already been seen in the catwalk show. The experts use the magnifying tools because it gives them more information about the fabric, therefore it is expected that Animation 2 will support the understanding of fabric more than Animation 1. The duration of Animation 3 is 3 seconds.

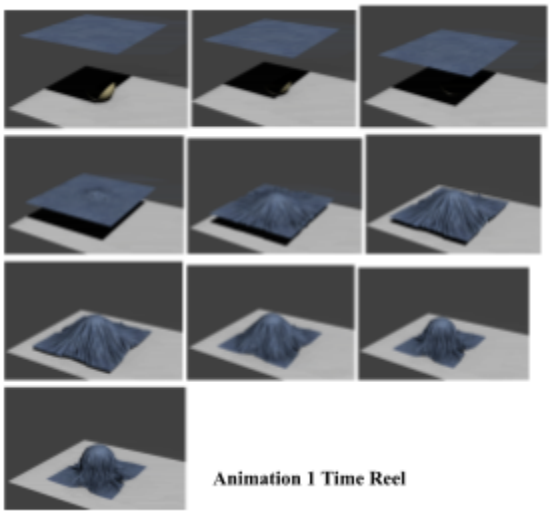


Fig 23. Time reel of Animation 1 for User Test #3

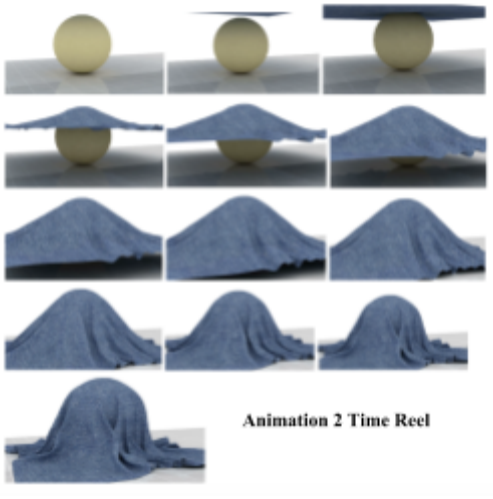


Fig 24. Time reel of Animation 2 for User Test #3

Question 3 of the user test, adds another animation option. Animation 3 consists of close up of the textile that is flowing and moving. A time reel of Animation 3 can be found in Figure 25. The test participant is asked to choose which of the 3 Animations, or the Still Image, emits the most information. In this case, the expectation is that the user prefers Animation 2 or Animation 3, since these are both moving images that show the textile from a closer perspective.

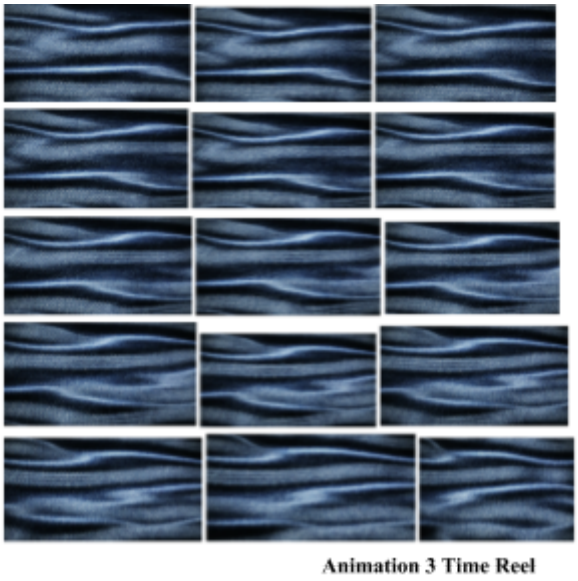


Fig 24. Time reel of Animation 3 for User Test #3

4.2.3.1 Results of User Test #3

The following results were collected after conducting user test 3:
For question 1, 100% of the 24 participants thought that the animation conveyed the most information

about the fabric property. This confirms the expectation that moving images are prefered to a still image. The pie chart of the results can be seen in Figure 25.

For question 2, 87,5% of the participants thought that Animation 2, which was the more closer and grounded perspective, gave the most information about the properties of the fabric. This again confirms that viewing a fabric from a closer perspective, gives the user more insight about the fabric. The pie chart of the results can be seen in Figure 25.

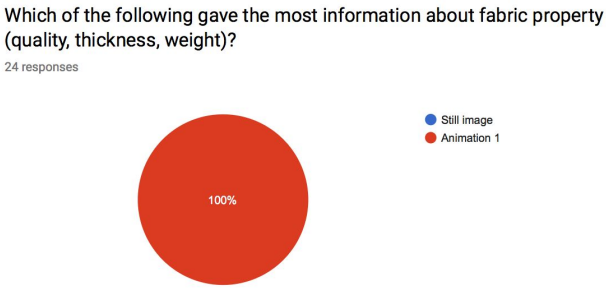


Fig 25. Results for question 1 for User Test #3

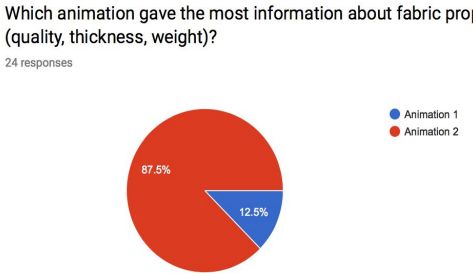


Fig 25. Results for question 2 for User Test #3

For question 3, 16,7% of the participants found Animation 1 the most informative. 58,3% thought that Animation 2 gave the most information, this is the animation that was also used in question 2. 25% thought the flowing fabric of Animation 3 was the most informative and 0% thought the Still image was the most informative. An overview of the pie chart is presented in Figure 26.

It can be concluded that the test participants prefer moving image where the fabric is draped over an object, from a closer perspective.

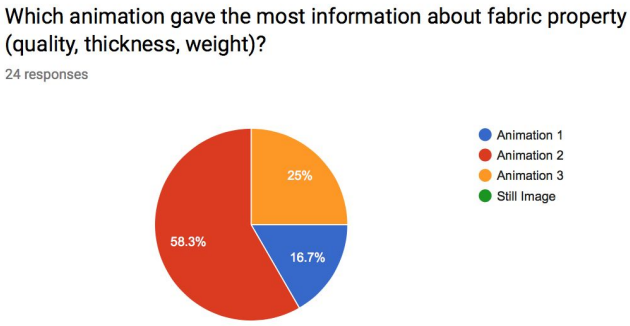


Fig 26. Results for question 3 for User Test #3

4.3 Revised Requirements

A prefatory list of user requirements were made earlier after conducting the user analysis in the Ideation phase, this list be seen in chapter 3.5. Through conducted different user tests, the needs, preference and suppositions of the main stakeholder has been explored. With this new information, an improved list of user requirements can be formulated. The requirements have been approached using the MoSCoW Analysis [36] method, an explanatory table of the MoSCoW Analysis can be seen in Figure 2.

4.3.1 MoSCoW

4.3.1.1 Must Have

As the name of this category suggest, the “must haves” of the the end product, are the necessary features that the end product needs to contain. In the case of creating an animation, we divide this section into hardware and animation related must haves.
The animation must be able to play on the touchscreen manual station. The animation must be a working simulation, meaning that the animation is an exact copy of the textile.

4.3.1.2 Should Have

The animation should be self-explanatory so that the user is guided through the animation and understands what they are looking at. The animation should aid the user with the judgement of fabrics and the animations should be secure. The animation should fit the overall style and allure of the Digital Showroom and therefore be aesthetically pleasing.

4.3.1.3 Could Have

The animation could be educative about textile, through giving information about the textile through the animation. Furthermore, the judgement of fabrics could aid in sales by helping the Sales Expert make the right choices and purchasing the right amount of products.

4.3.1.4 Won’t Have

The animation won’t be interactive and won’t make use of any Virtual Reality tools, such as VR glasses or headsets, since this was a user requirement that was set before. The animation will also not show multiple angles.

4.3.1.5 Conclusion

A concluding overview of the MoSCoW analysis can be found in the MSCW-table.

MSCW-table:

Requirements	**MSCW**

Be able to play on the touchscreen manual station	M
Simulation of Textile: - Animation is a copy of the fabric - Animation shows close up - Animation shows draping of the fabric - Animation is on ground perspective - Contain correct physical forces	M
Implementation into the Digital Showroom sale presentations	M
Be a reliable animation	S
Be aid with the judgement of fabrics	S
Be self explanatory	S
Be secure	S
Be aesthetically pleasing	S
Be simple	S
Encourage the user (Sales Expert) to purchase more	C
Be educative about textile	C
Interactive hand gestures	W
Make use of any Virtual Reality tools	W
Show multiple angles	W

5. Realisation

In this chapter we focus on a next iteration, where we build, prototype, and observe the final product. In order to create more structure, this chapter is split into two parts. The first part goes in depth about the transformation of the requirements that were formulated in previous chapters and how they are realised in a solid animation design. The second part of this chapter will be develop the right presentation method for the Digital Showroom to present the animation.
Furthermore, any choices made during this phase will be explained and later evaluated according to the realisation phase as described by Angelika Mader et al. [30]. A depiction of this phase can be found in Figure 27. This Design Process phase is utilised in order to obtain the most satisfactory end product, this means that we iterate based on Requirements → Design → Implementation/Testing → Review → Complete or ↩Requirements . At the end of this chapter, the concluding prototype that is ready for evaluation will be delivered.

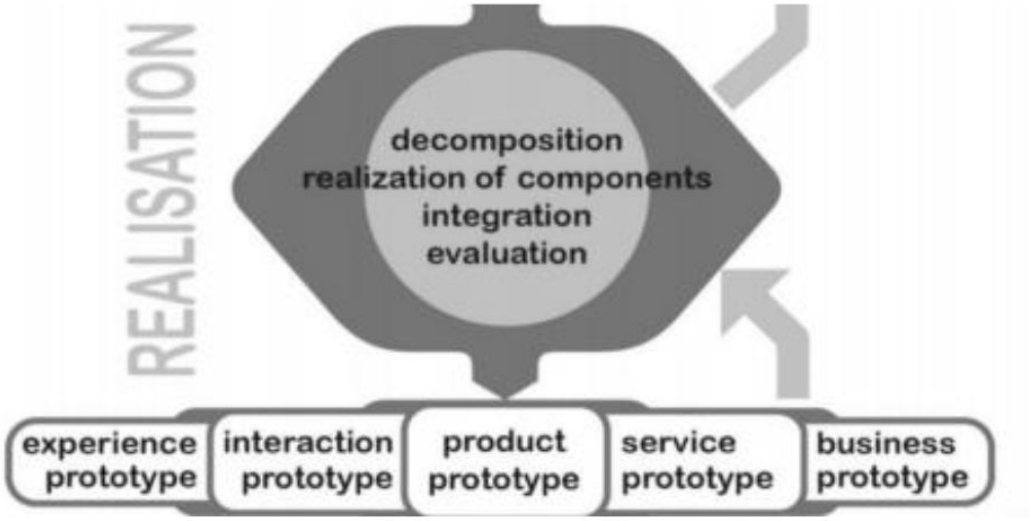


Fig 27. Realisation Phase of the Design Process for Creative Technology by Angelika Mader et al. [30]

5.1 Animation

In this subchapter of Realisation the translation of textile in the form of an animation is created. Lo-fi prototypes have previously been made in 3D Max in order to define the requirements.
The goal is to translate in a digital and visual way the “feeling” of textile by supporting the judgement of said textile.

5.1.1 Realisation of Animation

During the software analysis, Marvelous Designer (abbrev. MD) was selected as the most qualitative software to simulate fabric. During the realisation of this animation, Marvelous 7.5 version 4.1.99.32511 was utilised. Firstly, it is important to check if Marvelous Designer proves to simulate cloth in a physical faithful way.

5.1.1.1 Simulation Test

The Product 3D Design department of PvH Corp. provided data regarding the Cotton Jersey knit of the 2017 collection in order to test whether the simulations match up. This data can be seen in a screenshot of their fabric property software in Figure 28. A 3D model of the Cotton Jersey knit used in a simple Tommy Hilfiger t-shirt can be seen in Figure 29.

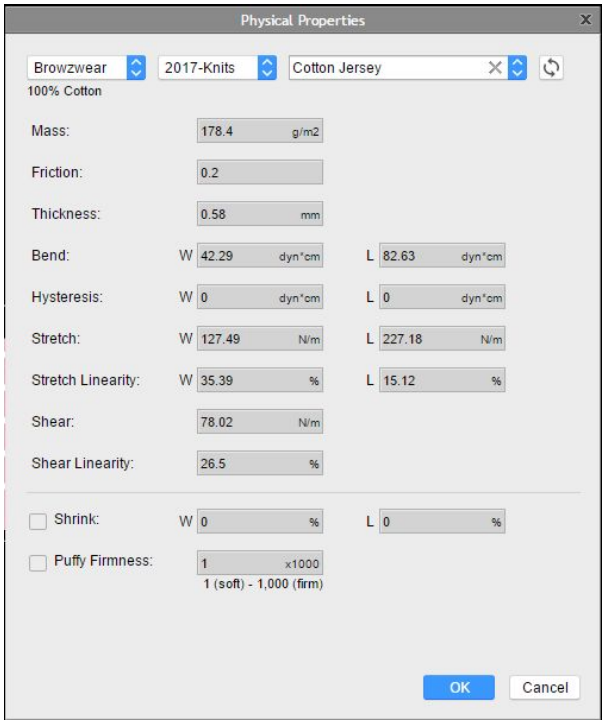


Fig 28. Cotton Jersey knit

Fig 29. Cotton Jersey knit used in a Tommy Hilfiger shirt

In order to create a textile simulation, an OpenDocument file (.ods) was made and can be seen in Figure 29. These files are compatible with Marvelous Designer, the conversion can be seen in Figure 30. Here the Physical Properties are translated into data that is able to be read by MD. The following translation has been done with Luca Robustelli from the 3D Design Department.
The Stretch Weft and Warp correspond to the Stretch Width and Length. However the data given bij PvH Corp. is given in N/m (newton meter) which is divided by /1000. Since MD works with a scale from 0-100 the values are converted to 12,7 and 22,7 respectively. The Shear is identical, and the Shear Stretch corresponds to the Shear Linearity. The Bending Weft and Bending Warp correspond to the Bending Width and the Bending Length. The Buckling Weft Ratio and the Buckling Warp Ratio correspond to the Stretch Linearity Width and Length. The Density corresponds to the Puffy Firmness and the Friction Coefficient corresponds to the Friction, but is again converted into a scale from 0-1 to a scale of 0-100, so the value is 20. The thickness in mm is identical in both which is 0.58mm. The values in MD however are integers, so the filled in values have been rounded up and done (up at 0,5).

A	B	C	D	E	F	G
0_user	Stretch Weft	Stretch Warp	Shear	Shear To Stretch	Bending Weft	Bending Warp
COTTON_JERSI	12,7	22,7	78	26,5	42,29	82,63

H	I	J	K	L	M	N	O
Buckling Weft Ra	Buckling Warp Ra	Buckling Stiffnes	Buckling Stiffnes	Internal Damping	Density	Friction Coefficie	Thickness
35,39	15,12	0	0	0	1	20	0,58

Fig 29. ODS file for Cotton_Jersey_1

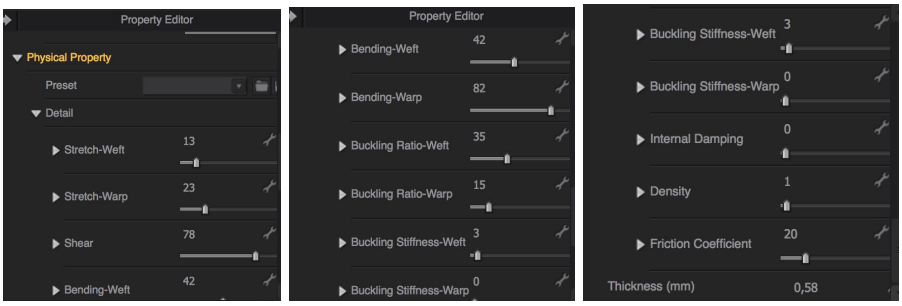


Fig 30. Property Editor in MD

Once the properties were filled in, a T-shirt has been simulated on MD. This can be seen in Figure 31. Even though the t-shirt is slightly differently shaped, it can be clearly seen that on first sight the fabric on both the simulation and the image provided are almost identical.

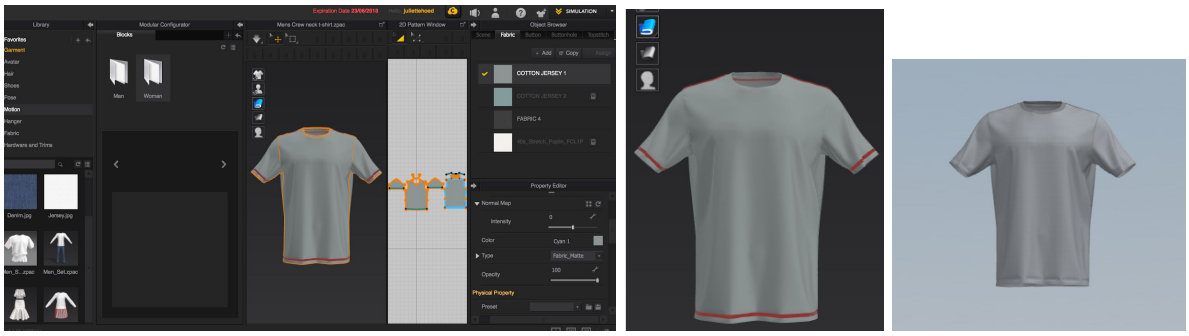


Fig 31. Simulating a T-shirt

When zooming in on the fabric, it can also be seen that both materials seem very similar. The original Cotton Jersey can be seen in Figure 32 and the simulated MD fabric can be seen in Figure 33.

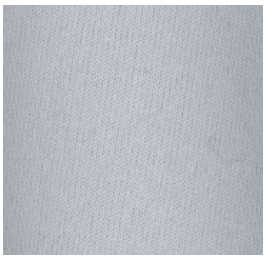


Fig 32. Left - Original Cotton Jersey

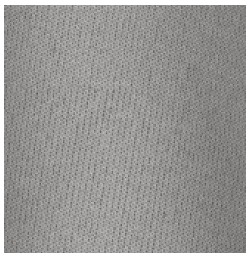


Fig 33. Right - Simulated Cotton Jersey

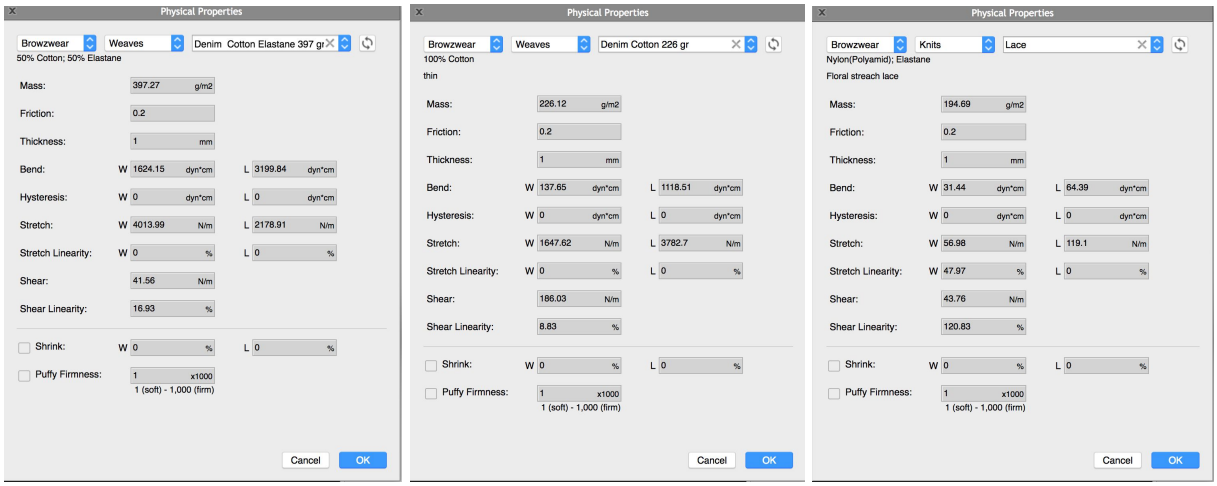
It can thus be concluded that MD is able to simulate fabric accurately for the end prototype.

5.1.2 End Animation (Hi-Fi Prototype)

Now that it can be concluded that a successful simulation can be made, the animation of cloth draping over a ball can be made. Close attention is made to the MoSCoW overview and the user requirements that have been determined earlier.

Fig 34. Left to Right - Different Textiles: Carbon fiber, Denim, Lace, Velvet

In order to demonstrate the judgement of fabrics when the use of a simulation, four very different types of fabrics have been selected in order to make a prototype for. These fabrics have all been selected in order to be able to simulate a wide variation of different types of textiles.
The property windows are converted into .ods files and the bump maps of the textiles have been provided and can be seen in Figure 35.



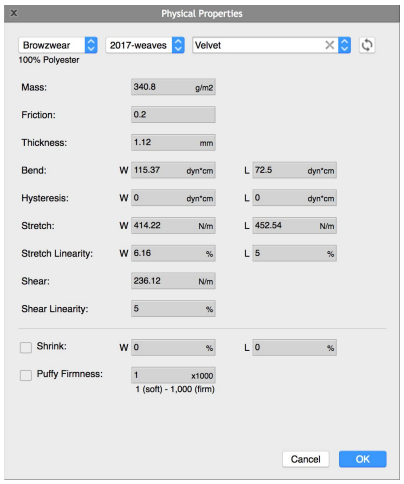


Fig 35. Property Windows

5.1.2.1 First Iteration

During the first iteration, a ball was modeled by importing a simple sphere and saving this as an avatar. MD cloth is only compatible with avatars and the ground. Next the .ods files are loaded and the bump map included. The simulation of the carbon fiber fabric can be seen in Figure 36.

Fig 36. Time Reel of Animation Carbon

This same process was repeated in order to create the animation for the velvet fabric. The ball remains the same, however the textile properties have been altered, which changes the draping and weight of the fabric and therefore also the way that the fabric folds and falls. A time reel of the velvet fabric can be seen in Figure 37.

Fig 37. Time Reel of Animation Velvet

5.1.2.2 Second Iteration

During the second iteration, a different version of the textile draping of a ball has been creating with the use of Blendr and MD. In this case Blender is used because of a much faster rendering time. In this iteration a ball was again imported into MD and the textile properties adjusted. After this the ball was again imported into Blendr and adjusted by adding the bump map to look aesthetically pleasing. The time reel for the Denim Close-Up animation can be seen in Figure 38 and the lace Close-Up animation can be seen in Figure 39.

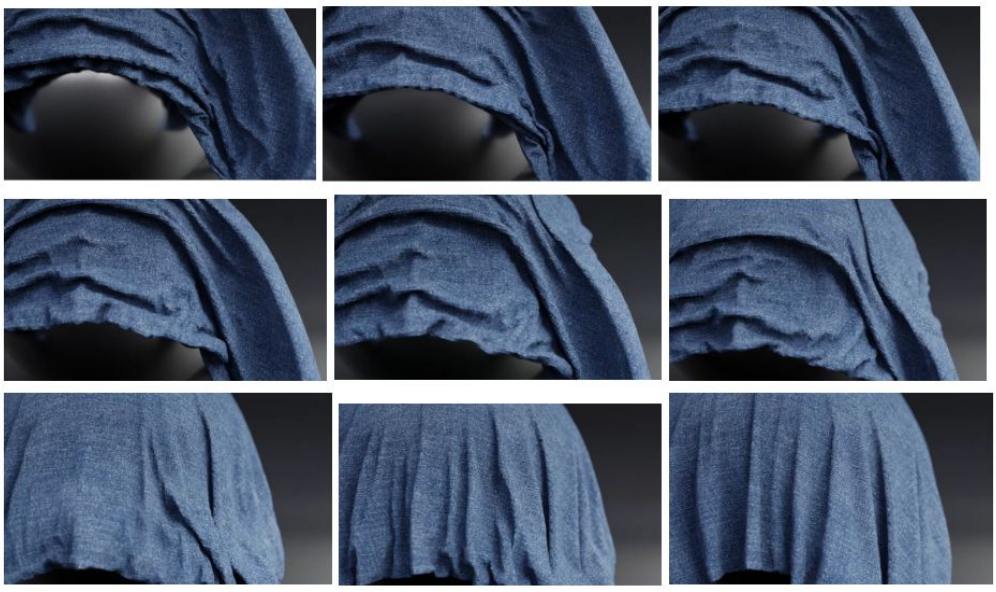


Fig 38. Time Reel of Animation Close-Up Denim

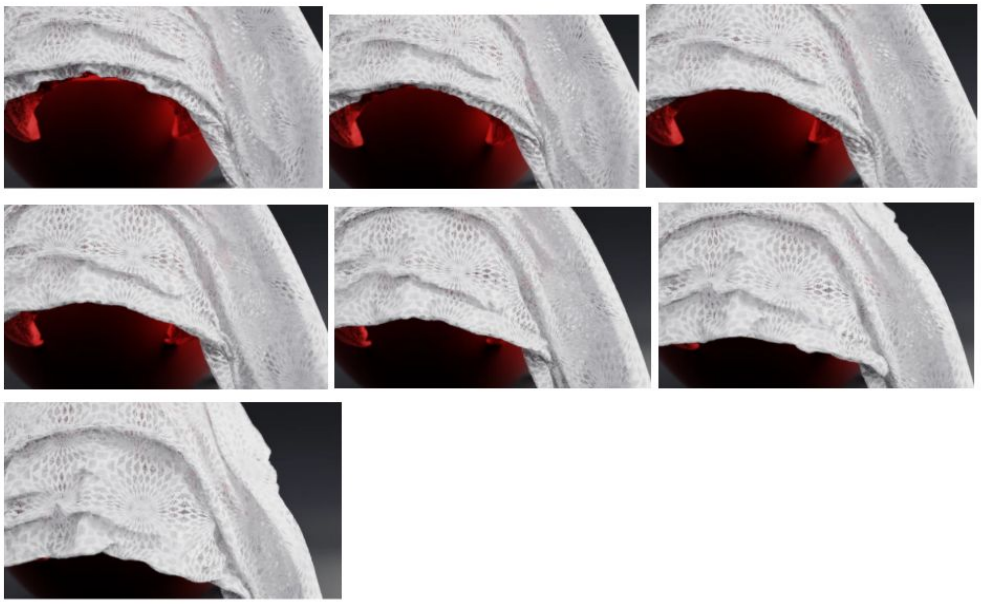


Fig 39. Time Reel of Animation Close-Up Denim

5.1.2.3 Conclusion

Both normal distance and close up animations prove to convey different type of information. Therefore a simulation for both far and close for all of the different needs to be created and used in combination with each other in order to enhance the judgement of the fabrics.

5.3 Presentation Method

Once the animation has been created, the main research question “What is the best presentation method for this visualisation?” is explored. Firstly, the animation needs to be shown in the Digital Showroom and fit the new technology atmosphere. The design needs to be aesthetically pleasing and clean.
The animation can subsequently be shown on the Theater however, in order to innovate the Digital Showroom an additional presentation method has been developed: the “hologram”.
PvH Corp. already utilises hologram prototypes in different parts of the building, so it fits the general idea, look and style PvH Corp. is going for. Furthermore such a presentation method is simple for Hecla to install and maintain. As discussed this idea was originally developed to be viewed on a phone.
Both options are inspected.

5.3.1 Hologram for the Digital Showroom Table

Since during meetings multiple people are situated at the table, it is important that the animation can be viewed from multiple angles. This presentation methods consists of a big hologram that would be situated in the middle of the table. A representation of the floorplan with hologram can be seen in Figure 40 . This would consist of a screen that is either situated above or under a plexiglas pyramid. This pyramid is built at a 45 degree angle with the following ratio, 1 cm for the top of the pyramid, 3,5 cm for the sides and 6

centimeters for the long bottom side. Note that the pyramid can be flipped either way. A depiction of these ratios can be seen in Figure 41.

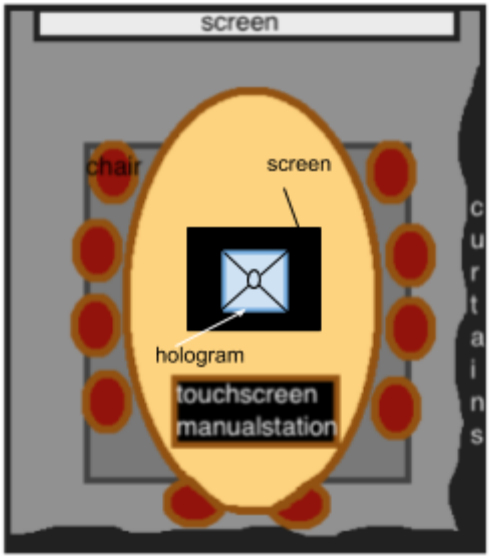


Fig 40. Floor plan with hologram

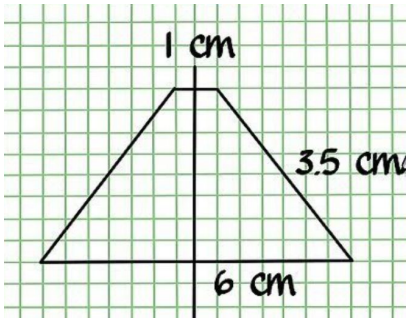


Fig 41. Ratio for Plexiglass Pyramid

5.3.1.1 Hologram Animation

Once the pyramid is built, the next step is to convert the animations so that they can be played on the hologram. The programme to realise this is Adobe Premier Pro CC 2018. The resolution used to make the new playable animations is 1920x1080. With a black background, the animation is pasted four times with a 90 degree angle. The first attempt can be seen in Figure 42. When testing this animation, two things proved to not be functional. The images were placed too close, which cut off the animation in the hologram. The second change that had to be made, was that every image had to be flipped 180 degrees, in order to be played on the system that was made the mobile phone (see Figure 9 in section 3.7.1) since this requires the image to be flipped since the screen is placed on top of the pyramid instead of the pyramid balancing on top of the screen. The new and improved version of the hologram animation can be seen in Figure 43. However, this means that the animation will be flipped upside down during the regular hologram tests. For this reason, some photos have also been flipped in order to view the hologram the right way up. A suggestion for future hologram setups to be developed by Hecla are holograms that include the screen being on top, these setups do exist in China, but close to no manufacturers were found to be located in Europe. An example image of how this setup would look like can be seen in Figure 44.

Fig 42. First Attempt at Creating a Hologram Animation

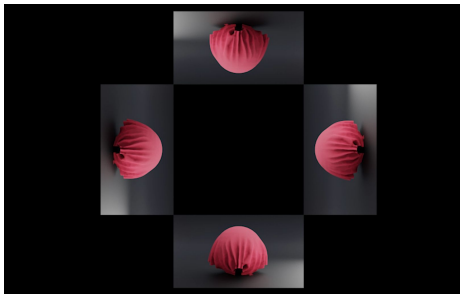


Fig 43. Improved Version of Hologram Animation

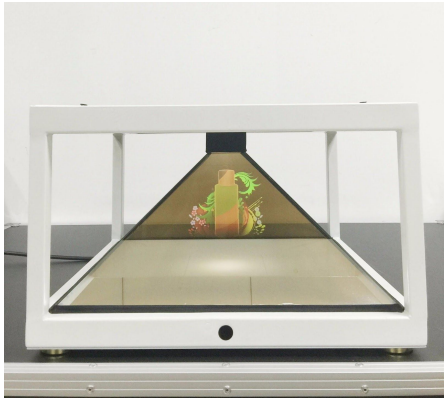


Fig 44. Example of Big Hologram with Flipped Pyramid and Screen on Top

5.3.1.2 Testing the Hi-Fi Prototype

After the animations were converted into playable hologram animations, the hi-fi presentation prototype was tested. The setup consisted of a 32 inch screen and the hologram put on top. The setup can be seen in Figure 45 . The plexiglass hologram that was put on top has a 10 cm base, 35 cm sides and 60cm top side. In Figure 45 it can also be seen that the colours are distorted. The colour red seems purple. This can easily be fixed by making sure a true colour setup is selected.

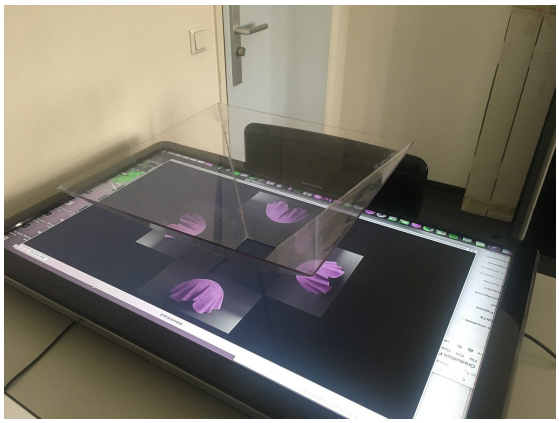


Fig 45. Hologram Set up

After the screen set up had been corrected to depict true colours, the animations were tested. The first test was done in a light environment, which can be seen in Figure 46 . For the sake of demonstration, this

image has been flipped, to represent how the hologram would accurately look like. Even though the animation is visible, another test with the lights dimmed was done and can be seen in Figure 47.

Fig 46. Hologram in Normal Daylight

Fig 47. Hologram with Dimmed Lights

The third and final test was done with the light completely off and the blinds shut. The results of this can be seen in Figure 48. For convenience this image has also been flipped.

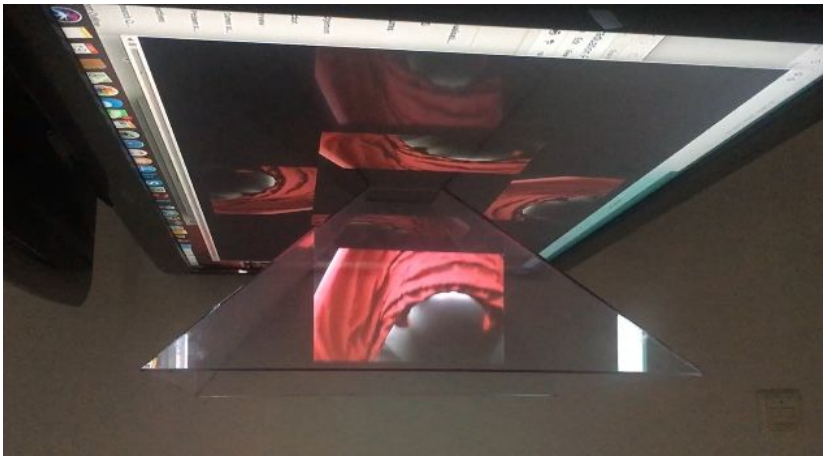


Fig 48. Hologram with Blinds Shut and Lights Off

5.3.2.1.1 Conclusion of the Hi-Fi Testing

When comparing the visibility of all the different holograms and different lighting, it can be concluded that the hologram with the blinds shut and the lights off (as seen in Figure 48) is the most visible and thus supports the judgement of fabric the most.

5.3.2 Mobile Hologram

Since the original idea was to make a hologram that is (also) usable on a mobile phone, the same Hologram Animation that was described in section 5.3.1.1 was used.

The only difference is that a hologram tool that is compatible with a mobile phone is utilized. This hologram tool can either be 3D printed or parts bought through mainly Chinese webshops such as “t-mart” [43]. This tool consists of two plates of identical sides for the top and the bottom. The top plate is cut out so that a pyramid can be played inside. The pyramid is made of thick foil that has been slightly cut to bend. A screw fastens the pyramid to the base of this tool. 4 plastic staffs are used as connectors. Figure 49 shows all the components of this tool. Since this tool was quite slippy, four pads to the bottom have been added, this can be seen in Figure 50.

Fig 49. Components of the Mobile Phone Hologram Tool

Fig 50. Pads of the Mobile Hologram Tool

A photo of what this tool looks like when it is assembled can be seen in Figure 51. A mobile phone playing the simulation animation is placed on top. In this construction the mobile is placed on top, the pyramid is facing down. Therefore the animations have to be rotated by 180 degrees as mentioned before so that they seem upright in the hologram.

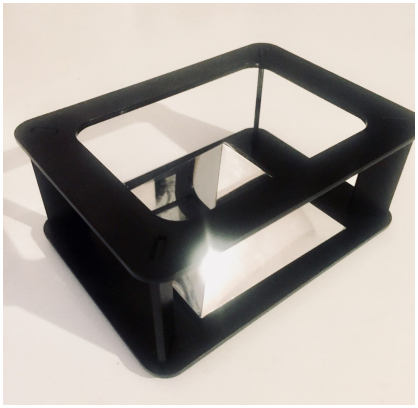


Fig 51. Assembled Mobile Hologram

The animation is able to be seen in the mobile hologram, however it needs to be viewed close to eye-height in order to view the animation correctly and inspect the details of the textile correctly. Two photos for demonstration purposes in order to show what the animation looks like when using the mobile hologram have been made and can be seen in Figure 52. The pictures were made with a laptop with blinds shut and lights off, therefore there is some grain in the photo and the resolution is quite low. Also because the photos were made with a laptop, the hologram is a little shifted because it is not shown at eye-height.

Fig 52. Photos of Mobile Hologram Showing Animation

6. Evaluation

The end product has been created according to the specifications and requirements that were explored in previous chapters it is time to reflect whether the end product truly meets its goals and supports the judgement of fabrics.
In order to perform this test, a plan was formulated with respect to comparative evaluation formulated by Babbar [37]. This means that the efficiency, effectiveness and the satisfaction level of the user play an important role in determining whether the end product(s) has been a success.
First, the efficiency is dependent on the time of the judgement of the textile. The effectiveness is measured based on whether the animation helps the user correctly judge the fabric. Finally, the user satisfaction will be calculated by using the likert scale and taking that average. The users rate a number of statements out of the 6-point scale as described by McLellan [39] and Brooke [40] that ranges from "Strongly Agree" to "Strongly Disagree" . According to Nielsen, it is possible to perform an effective and conclusive usability test with an average of 3-5 users [38]. Therefore, 3 users are tested, consisting of 2 experts and one end user.
The tests have been executed on the same users, both for the Hologram and the Mobile Hologram.

6.1 Participant Selection

As mentioned before, the main stakeholder of this project were the Sales Experts that utilised the animation to make decisions for buying clothing stock. Therefore two expert representatives and one sales expert were interviewed.

6.2 Statements

The following statements are mainly based on the user requirements and the test users will be asked to rate these statements out of 10. These will then be averaged out in order to get a good idea about the user satisfaction.

1. The product is self-explanatory
2. The product is visually attractive
3. The product aids with the judgement of fabrics
4. The product is time-efficient
5.The product replaces the Textile Book

As mentioned before, these are rated on a likert scale which can be seen in Figure 53..

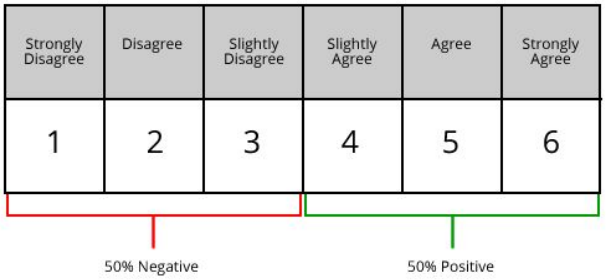


Fig 53. Likert Scale

6.3 Results Hologram

First the regular hologram is tested. The test has been filled in through Google Forms which generate charts regarding the results. The results of the test can be seen below and the complete Evaluation Test can be seen in Appendix D.

6.3.1 Efficiency

During this question, the user is tested based on the time it takes to judge the fabric that is presented to them. As can be seen, one user knew within 1 second, the second user within 2 seconds and the last user knew within 3 seconds. The average ((1+2+3)/3) that the user was able to judge the fabric was within 2 seconds. The pie chart of the results can be seen in Figure 54.

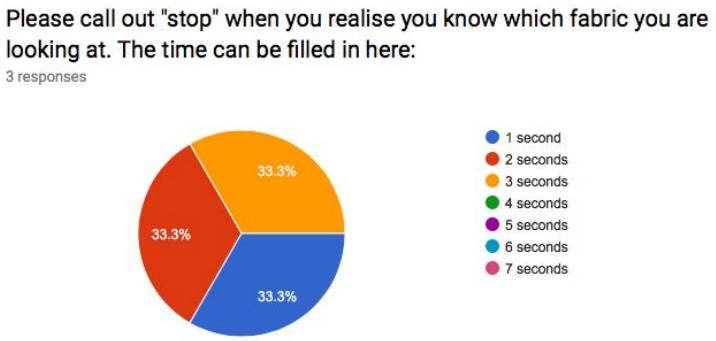


Fig 54. Pie chart of the Reaction Time During Evaluation Test

6.3.2 Effectiveness

The effectiveness was measured by presenting the test users with 4 pieces of physical cloth. These fabric pieces were all the same colour and only consisted of the material and did not contain any noticable prints that could make recognition easy.. After they inspected the fabric, the test users were asked to look at the animation and fill in which fabric they were looking at. The results can be seen in Figure 55. All three test users were able to answer this question correctly.

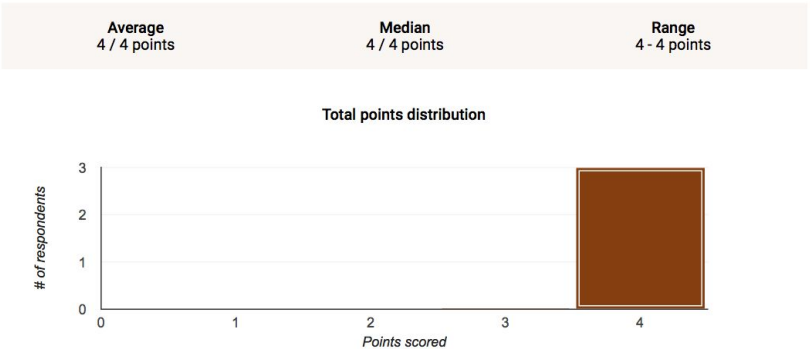


Fig 55. Bar chart of Effectiveness During Evaluation Test

6.3.3 User Satisfaction

The last evaluation question provided the test users with a 1-5 satisfaction likert scale in order to answer the statements which can be found in section 6.2. The Bar chart showing the satisfaction levels can be seen in Figure 56. For the first statement 2 test users agreed that the product was self explanatory and one test user strongly agreed. The second statement showed identical results. To the statement "The product aids with the judgement of fabrics" 2 test users were neutral and one test user agreed. For the fourth question, two users agreed that the product was time-efficient. Lastly, all users disagreed with the statement that the animation replaced the Textile Book since they found that the element of physical touch was still missing. Being able to physically touch the fabric meant that the users would be able to determine other factors such as the softness of a fabric.

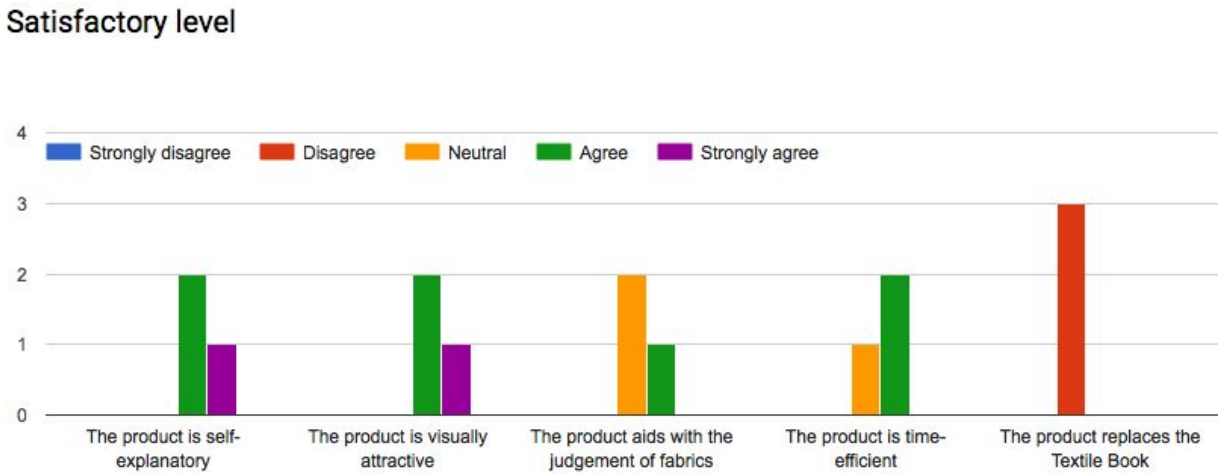


Fig 56. Bar chart of User Satisfaction during Evaluation Test

6.4 Results Mobile Hologram

This evaluation test, tests the mobile hologram so that hopefully a conclusion can be found which of the two presentation methods seems to be the most helpful when it comes to the judgement of fabrics. The

test users were all presented with a mobile phone and the hologram tool. They were then asked to fill in a form with the same questions as shown in the regular hologram test (Appendix D).

6.4.1 Efficiency

Again the efficiency in the form of time was tested when using the mobile hologram. The results varied slightly, with one test user taking 1 second to judge the fabric, one test user taking 2 seconds and lastly a test user taking 4 seconds. The average time to realise which fabric is shown during the mobile hologram is ((1+2+4)/3) = 2,33.. seconds. The pie chart of the results can be seen in Figure 57.

Fig 57. Pie chart of the Reaction Time During Evaluation Test with Mobile Hologram

6.4.2 Effectiveness

Again the effectiveness is judged based on being able to recognize which animation corresponds to which textile. The score per answered question has been changed to 2 per question in order to differentiate from the first hologram user test. Again, all 3 the test users have answered this question correctly. The bar chart of the results can be found in Figure 58.

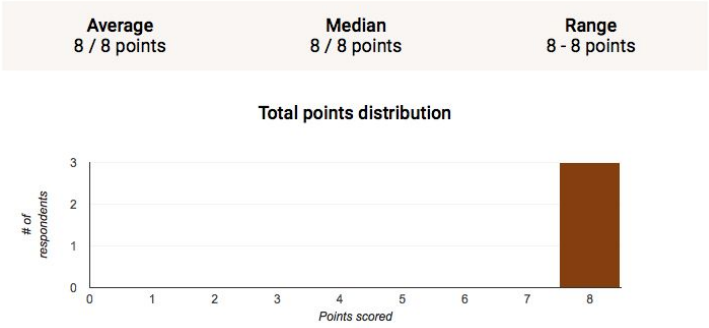


Fig 58. Bar chart of Effectiveness During Evaluation Test during Mobile Hologram

6.4.3 User Satisfaction

The last question is again identical to the previous user satisfaction test. The results can be found in Figure 59, this figure somehow cut off the statements.
During the mobile hologram it can be seen that for the first statement 2 test users strongly agree that the product is self-explanatory and one test user is neutral. For the second statement, all three the test users strongly agreed that the product was aesthetically pleasing. For the statement that the product aids with the judgement of fabric, one test user disagreed and two test users agreed. For the fourth statement which

was whether the product is time efficient, all three the test users were neutral to this statement. The last and final satisfactory statement was whether the animation could replace the textile book and all three the test users strongly disagreed.

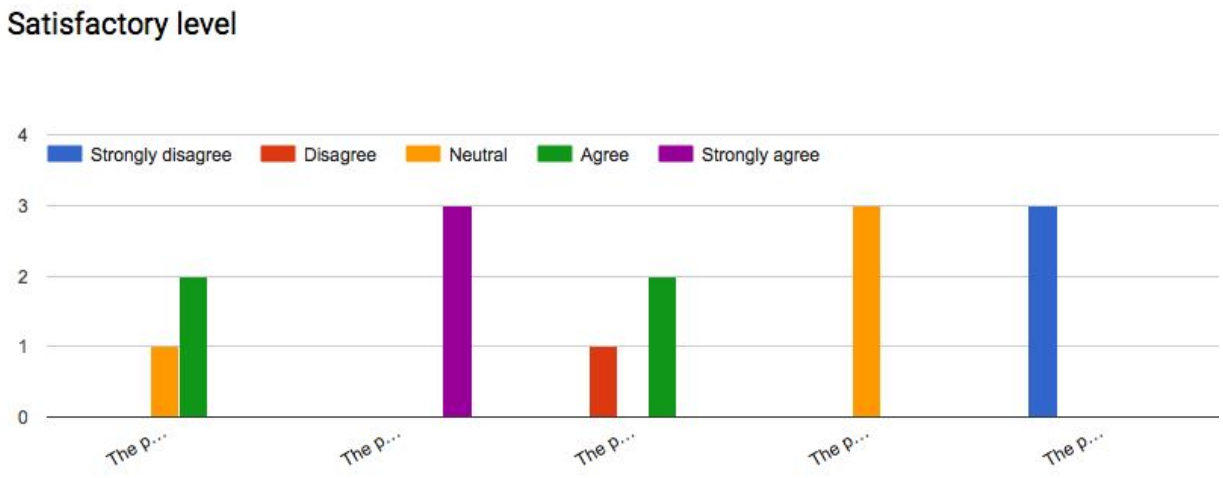


Fig 59. Bar chart of User Satisfaction during Evaluation Test during Mobile Hologram

6.5 Conclusion of Evaluation Tests

When comparing the results of both tests, certain conclusions can be made. During the first question, the average time it took in order to judge the fabric took 2 seconds for the normal hologram and 2.33 seconds for the mobile hologram. The test users stated that because the hologram was bigger, it was slightly easier to view the fabric animation. For the second question regarding the effectiveness, all the questions were answered correctly for both the normal hologram and the mobile hologram. Therefore it can be concluded that differences between different fabrics can be effectively be seen. Lastly, when looking at the user satisfaction some interesting observations can be made. For the first statement, both hologram and mobile hologram found the product to be self-explanatory. During the mobile test, one test user rated this neutral since they found that it is crucial not to move the tool because the mobile phone could move and disrupt the hologram, but this was a mistake. The suggestion to add rubber grips to the top of the hologram tool was made. All the users seemed very impressed by the hologram and there was a preference for the mobile hologram since it seemed like a new concept and the test users were enthusiastic about it. The third statement regarding the aiding judgement of fabrics is a bit controversial with the test that was done. During the first test, 2 users were neutral and during the mobile test one user disagreed. They all stated that they were still missing the element of touch even though the users were able to successfully differentiate the fabrics from each other. For the fourth statement which determines whether the product is time efficient, the test users were mostly neutral feeling slightly indifferent. For the last and a very crucial statement, which asks the user whether the the textile book can be replaced and if real touch can be replaced with a visual, it has been remarkable that all the test users found that the animations were not able to replace the Textile Book, again because they stated that they were missing the element of touch.

7. Conclusion and Future Works

Being able to completely digitally replace something physical with the use of technology is complex because it involves multiple senses including the sense of touch. This graduation project aimed to delve into the question whether it was possible to do this with the use of solely visuals, including animation. The literature research which can be found in section 2.5 “State of the Art”, answered the subquestion:
SQ1: What are the key elements of effective visualisation of textile materials?
There the key elements of effective visualisations were identified and a deeper knowledge of textile and textile simulations were found. This offered to be the base of this project in order to answer the following the main research question:
RQ: What is the best presentation method for this visualisation?
Even though the presentation method has been identified and appreciated and test results show that the animation is able to help aid the user with the judgement of fabric all test users stated that the animation was not sufficient to completely replace tactile feedback as provided by the Textile Book.

In an sale setting the animation was utilised but based on the user evaluation the animation deemed as a supportive and entertaining tool, which fit the overall style including the want to technically advance in the fashion industry. However, the users were missing the element of touch, in order to also feel whether a fabric is soft or hard. Even though the type of fabric was able to be judged, it became apparent that all the users commented that they were missing crucial information such as the type of yarn used for the fabric could not be identified by sight alone, which left the user with some unanswered questions. However all users did show interest in the animation and its tool and found that it was a good additional tool to add to the overall experience.

It seems that the missing component is found in understanding the type of thread/yarn that is used for the fabric. For the future, testing whether an animation explaining the type of yarn that is used could be done in order to see whether or not this could be the element which makes sure the Textile Book is completely replaced. Furthermore adding interaction to the animation could heighten the level of understanding for the user.

Suggestions:

- Adding interactive controls
- Adding the ability to zoom in
- More explanation on a microscopic level regarding the fabric (so that yarn can be identified)
- Adding a technical replacement for the element of touch (like haptics)

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11. Appendix

Appendix A. INTERVIEW POINTS USER_3 MATERIAL EXPERTS

My graduation project consists of creating a helpful tool and supportive textile animation for the judgement of fabric in a sale setting. The goal is to investigate to which extent it is possible to replace textile-books with a digital equivalent. This digital equivalent will consist of an informative animation that translates to an equal magnitude the understanding of the properties of a piece of fabric. In order to develop the most useful aid to realise this, I would like to have a better understanding of what is important during this process.

I would like to kindly ask you if you would be open to participate in an interview?
If this is not possible, feel free to answer and comment on the following questions:

- How often are textile books used?
- How much time do you usually spend inspecting the fabric in the textile book?
- What kind of information and understanding do the textile books convey that is missing from the Mannequin/Catwalk show videos?
- When using the textile book, what kind of properties of the textile do you focus on?
- Could you describe how you judge the fabric when physically feeling the fabric in the textile book?
- Are any additional tools used (magnifying glass, etc) when inspecting the textile?
- Additional general remarks or comments?

Thank you so much for being part of this process!

Appendix B: USER TEST #1

Evaluation Form - User Test #1

Welcome to this user test.

In order to develop a successful tool that aids with the judgement of fabric, I'd like you to answer the questions situated below. Rest assured that the test results are handled anonymously.

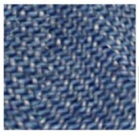
If you have any remarks or questions before starting the test, please feel free to ask.

* Required

How old are you? *

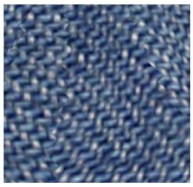
- ◯ < 19
- ◯ 20 - 29
- ◯ 30 - 39
- ◯ 40 - 49
- ◯ 50+

Which image gives you the most information about the properties of the fabric?



- ◯ Left
- ◯ Right

How would you rate the amount of information about the fabric properties (quality, thickness, weight) you are given from this image? *



	1	2	3	4	5	
No Information	◯	◯	◯	◯	◯	Full Understanding

How would you rate the amount of information about the fabric properties (quality, thickness, weight) you are given from this image? *

	1	2	3	4	5	
No Information	◯	◯	◯	◯	◯	Full Understanding

What aspect of the image gave you a better understanding of the properties of the fabric? *

Your answer

Any additional Remarks?

Your answer

Appendix C: USER TEST #2

Evaluation Form - User Test #2

Welcome to this user test.

In order to develop a successful tool that aids with the judgement of fabric, I'd like you to answer the questions situated below. Rest assured that the test results are handled anonymously.

If you have any remarks or questions before starting the test, please feel free to ask.

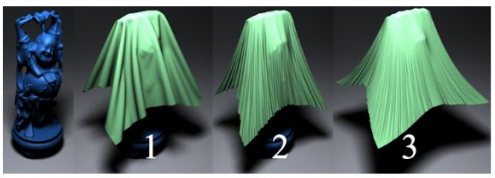
Which perspective of this draped fabric, gives the most information on fabric properties (quality, thickness, weight)?

- ○ Left
- ○ Right

What observation do you make?

- ○ Same fabric, different colours
- ○ Different fabrics

Which draping is the most realistic?



- ○ 1
- ○ 2
- ○ 3

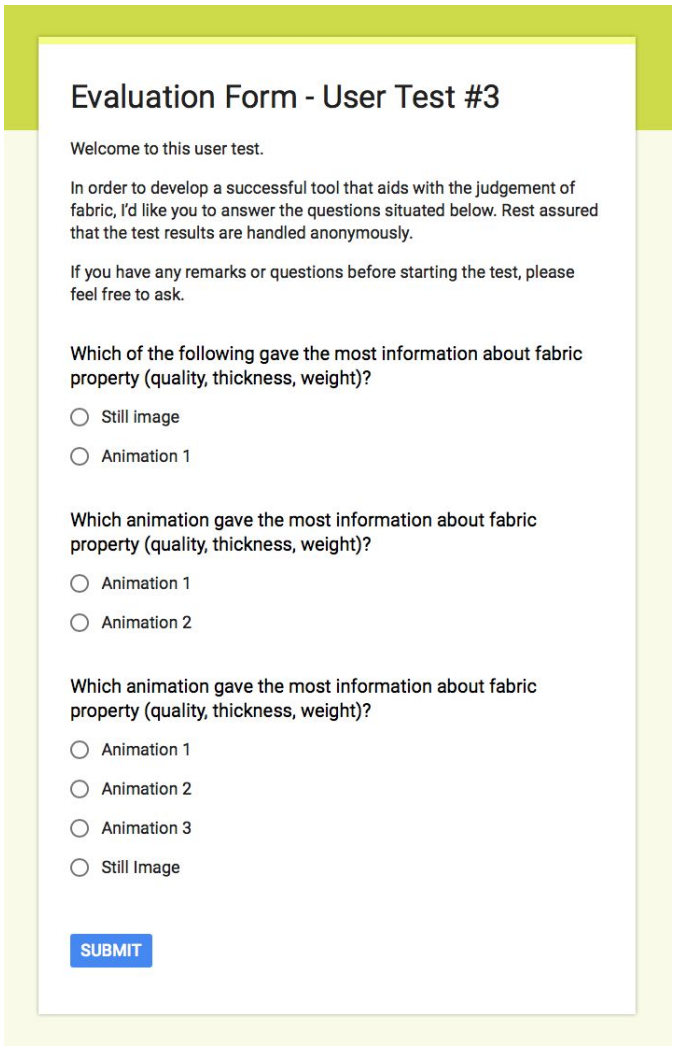
Thank you! Any remarks?

Your answer

SUBMIT

Never submit passwords through Google Forms.

Appendix D: USER TEST #3



Evaluation Form - User Test #3

Welcome to this user test.

In order to develop a successful tool that aids with the judgement of fabric, I'd like you to answer the questions situated below. Rest assured that the test results are handled anonymously.

If you have any remarks or questions before starting the test, please feel free to ask.

Which of the following gave the most information about fabric property (quality, thickness, weight)?

- ○ Still image
- ○ Animation 1

Which animation gave the most information about fabric property (quality, thickness, weight)?

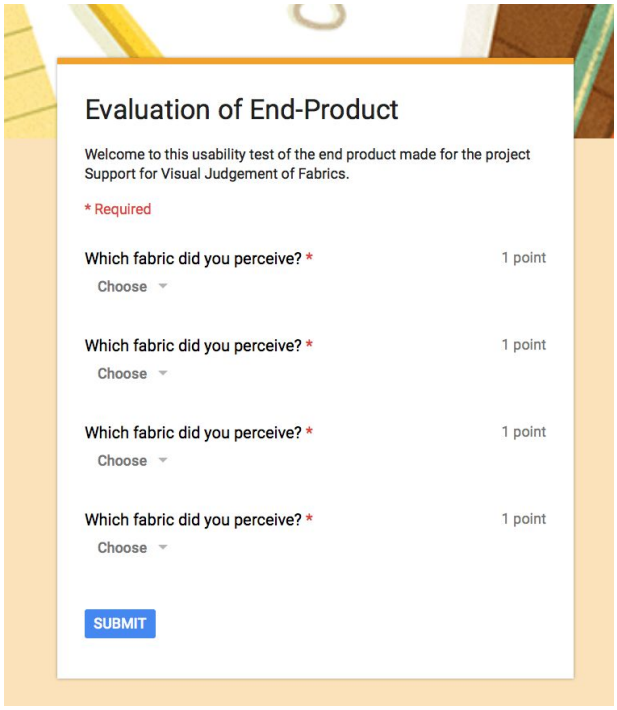
- ○ Animation 1
- ○ Animation 2

Which animation gave the most information about fabric property (quality, thickness, weight)?

- ○ Animation 1
- ○ Animation 2
- ○ Animation 3
- ○ Still Image

SUBMIT

Appendix D: Evaluation Test



Evaluation of End-Product

Welcome to this usability test of the end product made for the project Support for Visual Judgement of Fabrics.

* Required

Which fabric did you perceive? * 1 point

Choose

Which fabric did you perceive? * 1 point

Choose

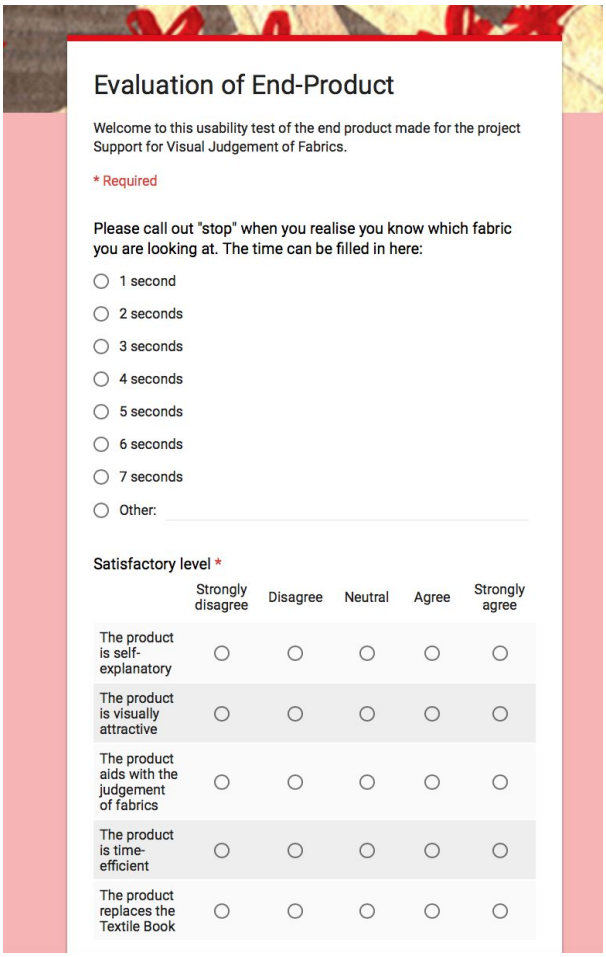
Which fabric did you perceive? * 1 point

Choose

Which fabric did you perceive? * 1 point

Choose

SUBMIT



Evaluation of End-Product

Welcome to this usability test of the end product made for the project Support for Visual Judgement of Fabrics.

* Required

Please call out "stop" when you realise you know which fabric you are looking at. The time can be filled in here:

- 1 second
- 2 seconds
- 3 seconds
- 4 seconds
- 5 seconds
- 6 seconds
- 7 seconds
- Other:

Satisfactory level *

	Strongly disagree	Disagree	Neutral	Agree	Strongly agree
The product is self-explanatory					
The product is visually attractive					
The product aids with the judgement of fabrics					
The product is time-efficient					
The product replaces the Textile Book					