An Approach of applying Motion-Sensing Technology to Design and Development Processes of Apparel Value Chains

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Our vision with this thesis has been to create an understanding of motion-sensing technology and the current established 3D design and development processes in the apparel industry. The aim was to combine both areas while integrating motion-sensing technology as a possible design tool in the design and development processes of apparel value chains. Moreover, this research intends to build a base for future studies in this area.

This thesis was written at the Swedish School of Textiles - Boräs University during the spring semester 2015 to finalize our Master studies in Textile Management with specialisation Value Chain Management.

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Thank you!

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Abstract

The area of the research comprises the field of virtualization as specified to the field of three-dimensional user interfaces (3D UIs). It is an approach of applying the field of motion-sensing technology to potential areas of apparel value chains focusing on design. The background of this thesis is the industry’s established 3D design and development process and new digital tools that enable embodied interaction. So far companies are still working with a limited 3D design approach, which requires several non-value-adding activities, e.g. technical sketching and pattern creation, before a product can be virtually simulated and evaluated. As the current fashion industry’s human-computer interaction (HCI) applications have non-embodied interaction technologies, which deny natural hand movements, it was evaluated, if motion-sensing technology can enable the feeling of natural handcrafting.

The purpose of the project was to investigate the designer’s attitude towards motion-sensing technology as a design tool and the potential of embodied HCI in design and development processes of apparel value chains. Enabling the designer the feeling of handcrafting in a 3D world opens a new area of research within the use of 3D fashion design tools. Moreover the thesis expected to prove the desire towards embodied interaction during the apparel design and development processes and the designer’s openness to try out new things. To fulfill the purpose, the motion-sensing technology tool Leap Motion was used as a practical device, which enables embodied interaction in design applications. A team of various designers was used to conduct a practical experiment, combined with interviews and observations. The experiment has been analysed on the designer’s attitude towards the use of a motion-sensing technology tool within the design field and possible implications on the design and development phases of apparel value chains.

The results show, that the designers supported embodied interaction and experienced the use of motion-sensing technology as an enhancing and powerful tool. However, it has become clear that the designers experienced the usage of free-handed motion-sensing technology as not natural or intuitive and rather prefer tangible tools. Presupposing a crucial improvement of the technology, different ways of substituting current design activities like enabling the draping process on a virtual basis could enhance the value chain regarding speed, flexibility and waste. This would enable earlier entry into the evaluation stage of virtual simulated prototypes while directly starting the design and development process in 3D and reducing several iterations of non-value adding activities.

Keywords: motion-sensing technology, virtualization, 3D UIs, embodied interaction, HCI, apparel value chain, design and development
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1 Introduction

The introductory chapter gives an overview of the established 3D applications in design and development processes of apparel value chains and the future of design, which tends to pursue embodied human-computer interaction (HCI) with focus on the device Leap Motion that has been further used within the study. The research gap will be described along with the purpose of the study, the research questions and the motivation for this research.

1.1 Area of Research

The area of the research comprises the field of virtualization as specified to the field of three-dimensional user interfaces (3D UIs). It is an approach of applying the field of motion-sensing technology to potential areas of apparel value chains focusing on design and development.

1.2 Background

Today there is almost no product, which is designed without the use of computers. Until the late 1970s technology professionals and computer enthusiasts were the only humans interacting with computers. It was in the early 1980s when the idea of human-computer interaction (HCI) became more popular (Carroll, 2014). Especially the aerospace and automotive industries quickly realized the importance and benefits of using computers as effective tools within the product design and development processes and therefore are considered as the pioneers in the use of computer aided design (CAD) programs. The early beginnings were based on simple two dimensional (2D) geometry computer design applications (Bordegoni and Rizzi, 2011).

Nowadays HCI is much more than computer science itself. Initial graphical user interfaces (GUI) have long been supplemented and frequently overtaken by interaction techniques, new innovations and developments to enhance and create human activity and experience (Carroll, 2014). The shift from 2D to 3D finally took place in the year 1990. This enabled the development of virtual prototyping based on the use of virtual reality (VR) technologies. Due to highly realistic visualization techniques in a computer-simulated environment, a product can be displayed as if physically existing. The visual product experience enables the user to evaluate the aesthetic aspects of a product (Bordegoni and Rizzi, 2011). Although VR technologies have been primarily used in military and aviation, it did find its way into the textile sector and changed the textile industry revolutionarily (Yi, 2013).

Strengthened by globalisation and offshore sourcing, the traditional apparel product development process underlies a long sample development process. As the majority of the world’s apparel production is allocated in the lower labor-cost countries, the samples are transported from the designated manufacturing plant in the Far East to the European and American clothing companies. This is not only combined with high cost, but also with an inevitably increased development lead-time. In order to respond to the changing dynamics of the fast fashion industry and an increasingly demanding
market, companies are starting to work with new technologies. The use of 3D applications within the apparel industry enables the reduction of physical prototypes and shortens the product development process (Sayem et al., 2010).

The apparel value chain, as an integral part of the Textile Management, consists of different steps that products have to go through from first idea to commercialization (Burns et al., 2011; Early, 2015). In the apparel industry, the value stream starts with the design and development process. Even though there exist various 3D fashion design modelling software programs (Fontana et al., 2004), companies are using 3D applications only in a limited way. Figure 1 shows the main steps of today’s established 3D design and development process.

![Figure 1: The apparel industry's 3D design and development process](image)

After the season’s kick off and line briefing, designers are elaborating their creative ideas in a handcrafted way, such as physical draping on mannequins, style modifications on ready-made garments and garment sketching. Depending on the designer, this process includes many design steps of back and forth, followed by the creation of a detailed technical CAD sketch. Once the design has been technically created, further style specifications, such as accessories and materials are decided. In a next step pattern makers are transforming the designer’s sketches into patterns. Only after this point, the designer starts to work in a 3D environment where the patterns get transformed into a virtual prototype that is displayed in 3D (Wildermann and Haase, 2013). At this point, the virtually displayed prototype enables the evaluation of the product before the physical garment is produced. Depending on the outcome of the evaluation, the designer often has to go back to scratch and either do some rework or create an entire new design, which as a consequence means a restart of the design and development process. From a value chain point of view, this process includes a lot of iterations of non-value-adding activities, such as creative design, technical design, style specification and pattern creation. Processes that are not adding any obvious value for the customer and justifying higher prices due to wasted time of reworking designs are not matching the lean principle of operating in the most efficient way (Early, 2015).

According to Lakovic’s (2015) statement of future design trends, interaction design tends to go back to the original design roots by becoming more natural and enabling creative handcrafting in a virtual way. Looking into other fields, especially gaming, new inventions have overtaken the barrier of separating human beings from digital

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1 Zhu, Zizi Wj., Designer Apparel Teamsport, PUMA SE, Interview, 01.05.2015
worlds by 2D mouse based computer input and strive towards the integration and merging between user interface and physical world (Geiß, 2014). Innovations tend to pursue natural user interfaces (NUIs) with natural embodied interaction. This includes motion-based functions in 3D space, which is known as 3D user interfaces (3D UIs). Spatial tracking enables the sensing of motion, position, orientation and movement (Bowman, 2014). An example for devices that track the required 3D movements and positions of specific body parts is the Microsoft Kinect, which is shown in figure 2, in relation to the whole body and the Leap Motion in relation to hands and fingers, as shown in figure 3.

New technologies in VR can bring back the hand feel and enable natural movements for creative handcrafting in its original purpose (Lakovic, 2015). Applying the technology of motion-sensing to the design and development process opens up possibilities to positively affect the apparel value chain.

### 1.3 Leap Motion

The use of Leap Motion creates and enables interaction between the user and virtual objects by mixing physical reality and virtual reality (Yu et al., 2010; Sterling, 2012). It is an optical tracking system that maps the human hand and its free-handed motion (Leap Motion a, 2015). To get started, the Leap Motion device needs to be plugged into the USB port of a computer or laptop and gets placed in front of it. The device consists of two cameras and three infrared LEDs. Due to its wide-angle lenses, the Leap Motion enables skeletal tracking of hands and fingers, as shown in figure 4, within a defined tracking radius of 150 degrees, figure 5. Its viewing range is limited to 60 cm above the device and allows moving the hands free in front of the screen (Leap Motion a, 2015).
The device is not only made for general computer applications, but also for several design functions like drawing, painting, sculpting and designing in a 2D or 3D environment (Uloop, 2013; Leap Motion c, 2015). An example for a sculpting program is the free Sculpting App by Leap Motion. This app enables the user to sculpt own 3D creations with a variety of tools as can be seen in figure 6. Leap Motion promotes it as an application that allows the user to reveal his creative potential by intuitive self-expression (Leap Motion d, 2015).

![Figure 6: Leap Motion Sculpting App (Leap Motion d, 2014)](image)

1.4 Research Gap

It is in humans’ nature to use and move the hands. According to every day’s life, which is taking place in a 3D world, the usage of hands is essential. However, the usage and movements of hands in common HCI is mainly done in a different way than in its fundamental movement. This includes clicking and sliding gestures but almost no natural ones (Victor 2011).

Also in the fashion industry, the currently available 3D technology tools are based on non-embodied interaction technologies, which deny natural hand movements. The established apparel design and development process that is using 3D applications is still starting with the creation of handcrafted drafts and 2D design sketches, which are only later translated into virtual prototypes on a 3D basis for evaluation (Wildermann and Haase; 2013; Wibowo et al., 2012). As a consequence, this approach includes several iterations of tedious and non-value-adding activities.

Although there are a few initial studies about trials how to bridge between natural physical movement and the fabrication of objects (Willis et al., 2010), as well as some trials of embodied computerized fashion systems with tangible tools (Wibowo et al., 2012), there is only a limited amount of research about effective VR design applications that enable physical handcrafting and self-expression.

1.5 Purpose

The purpose of this thesis is to investigate the designer’s attitude towards motion-sensing technology as a design tool and the potential of embodied HCI in design and development processes of apparel value chains.
The designer’s attitude is crucial for further studies whether it even would be adopted by them as a potential design tool and how far a motion-sensing technology tool could encourage the designer’s workflow. The idea of starting the design and development process directly in 3D could positively affect the product creation process. Designing on a virtual basis with the feel of natural handcrafting could virtualize the whole design and development process from the first step of design onwards thereby enabling earlier entry into the evaluation stage.

1.6 Research Questions
The research questions are as follows:

1. What is the designer’s attitude towards the use of motion-sensing technology tools in the area of design and development?

2. What are the possible implications on the design and development phases of apparel value chains by applying motion-sensing technology?

1.7 Motivation
Research is a working process that aims to create knowledge (Bryman, 2012). Therefore the motivation for this research is focusing on generating knowledge and personal attitudes regarding a new area within the apparel sector. The demonstrated gap is opening a new research field of enhancing the ordinary apparel design and development process. Looking into other areas like automotive and aerospace, a from scratch on virtualized product design and development process has already been established successfully. The reason is, that these areas deal with the usage of hard composite surfaces, which differentiate the requirements from those in the textile one. Garments are made out of materials that have a soft apparel character and thereby adding a special note to the product (Bordegoni and Rizzi, 2011). Fashion designers are commonly known as apparel material enthusiasts, who love to play around with materials by designing with their hands in a natural way. Enabling the designer the feeling of handcrafting in a 3D world opens a new area of research within the use of 3D fashion design tools.
2 Methodological Framework

The methodological approach of this thesis is an exploration of new research fields in the apparel value chain. This chapter gives more information about the data collection, sampling and analysis used for this research. It is followed by the assessment of the research to discuss the validity and reliability of this study.

2.1 Research Design

The research design used for this research is an exploratory approach. An exploratory research is defined as an initial research within a specific field (Given, 2008). It is a useful means to investigate new insights and phenomena with the aim of finding out what is happening to create a better understanding about it. It gathers preliminary information to further initiate hypotheses (Saunders et al., 2009). The exploratory research does not provide final or conclusive answers but focuses on the exploration of new research fields (Singh, 2007). It tends to be flexible and adaptable in changing foci during collecting data (Saunders et al., 2009).

As motion-sensing technology tools within the fashion industry are a new area, the investigation of the potential regarding usage and application within apparel design and development processes motivates the choice of this research design.

2.2 Methodology

In accordance with a qualitative research, this thesis premises on epistemological considerations and is influenced by interpretivism. Moving from specific observations, the research aimed to identify patterns and the generation of broad generalizations to infer explanations and concepts that lead to hypotheses. The approach of applying motion-sensing technology to design and development processes of apparel value chains was based on a practical experiment and ended up with the initiation of hypotheses. While this approach resembles an inductive reasoning, a broader study within this research field would request further research in order to investigate the proposed hypotheses. This would expand the scope of this thesis and consequently lead to an abductive reasoning (Bryman, 2012; Dubois and Gadde, 2002).

2.2.1 Data Collection

The data collection for this exploratory study is conducted in two phases. The first phase is based on secondary data, several discussions with industry professionals and the own practical and theoretical experiences of the authors. A literature review narrows the research area and defines the research fields. The introduction provides the reader with the fundamental justifications of performing the research. As the thesis is bringing together two different fields of research, the literature review is based on different areas. The explanation of the established 3D design and development process and its relation to the field of virtualization is supported by the use of process mapping, which is revived during the thesis work. Process mapping is a useful tool for specifying different activities that a product is passing through during a process. It aims to identify possibilities of improving the value chain or minimizing waste (Dickens, 2007).
In order to find out the potential of the combination of the two research fields, phase two collects data with two different ethnographic research strategies. These are in-depth semi-structured interviews and observations whereby a practical experiment serves as a base as seen in figure 7. To generate an in-depth understanding semi-structured interviews have been chosen (Bryman, 2012). This allows the interviewees to disclose their experiences of a specific situation in their own words and from their personal point of view. The interviews assure the investigation regarding the desire of embodied interaction within the apparel design and development process. In order to keep the interviews manageable, questions are supposed to be short and clearly understandable with scope for own thoughts, ideas and suggestions. The interviewees need to feel comfortable to talk freely but also behave and act in a natural way (Kvale, 1996).

**Figure 7: Structure of data collection**

In order to simulate the starting point of the design and development process already in a 3D environment, the free-handed motion sensing technology tool Leap Motion was serving as a practical device. As current 3D modelling programs are denying the natural way of designing, the authors chose this tool as it enables embodied interaction with virtual space. The device was provided by the University of Borås and loaned for the duration of the thesis project. To find out the designer’s design preferences and needs, part one of the semi-structured interviews was set before the practical experiment. After having the designers instructed to the technology of the computer hardware sensor device Leap Motion, a quick introductory practice helped the designers to get to know how to work with a motion-sensing technology tool. The designer’s behaviour was monitored from the first practical step onwards. The designer’s primary task was to virtually sculpt a 3D heart out of a form of a sphere, which was done with the Leap Motion Sculpting App as seen in figure 8.

**Figure 8: Practical task to create the shape of a heart**
In order to avoid influencing the designers, the observer was allowed to help with advice regarding the usage but not giving any observational comments on the designer’s behaviour. During the practical experiment, the designer’s way of designing was directly observed by the authors. Part two of the interview, which was conducted after the practical design experience, investigated the designer’s personal attitude and opinion regarding the implementation of new digital tools to design and development processes as well as possible effects concerning the apparel value chain. Without getting immersed in the context, the researcher is watching from a rather detached perspective instead of taking part (Trochim a, 2006). Videotaping the designer’s behaviour, the direct observations focused on moods, emotions and behaviours. As the designers were aware of being watched, this approach could have been reactive due to the risk that the designer is playing to the observer (Bernard, 2012). All interviews were audio-recorded and later on transcripted.

2.2.2 Sampling

As the thesis is related to the design field, the samples are chosen with a certain purpose in mind. Purposive sampling is a method of nonprobability sampling that avoids the random selection of samples and seeks for specific groups (Bryman, 2012). The selection of the designers is based on expert sampling, which represents people with a specific field expertise (Trochim b, 2006). According to Patton (2002), even a small group of a few designers like e.g. seven designers might provide findings in a qualitative research. Therefore, phase two of this research study is initiated with seven in-depth semi-structured interviews and seven observations.

The sample group consisted of seven designers. While five of them were design students of the University of Borås doing their Master (Sofie, Sandy, Elias, Erik) and Bachelor (Maryam) studies in Fashion design, another two were chosen from the Design Agency Berge in Gothenburg, a trained sculptor (Hans) and a software developer (Jonathan). As both are specialized in interaction design, they are further referred to as experts. The demographic characteristics of the designers varied in several ways. The designers included three females and four males, of which four were Swedish, one Chinese, one Italian and one German. All designers, except Jonathan, had a background in fashion design and were familiar with the ordinary design and development processes in the apparel industry.

On average, the interviews of each interviewee varied between 40-60 minutes in total comprising of interview part one and part two. Five interviews took place at the Swedish School of Textiles - University of Borås, whereby the group interview with the experts has been conducted at the Design Agency Berge in Gothenburg.

2.2.3 Data Analysis

For the analysis of the data an exploratory thematic analysis method was used. It is a typical categorizing strategy for a qualitative research that helps to get a deeper understanding of the subject. First, interview transcripts and observation notes were reviewed several times in order to get familiar with the gathered data and to identify emerging themes. In the next step, all collected data were reread and rethought. All
responses and notes were reduced under the emergent themes headings (Miles et al., 2014).

2.2.4 Assessment of the Research

For this thesis, the triangulation method was used as a validity check. Instead of relying on only one single form of evidence, multiple forms of diverse types of evidence are used in order to check the consistency of the findings (Maxwell, 1996). Several methods of data collection (interview part one, observation, interview part two) were applied and helped to gather rich data around the subject matter. To prove the validity of the description of observations and interviews, the experiments were video taped and the interviews were audio-recorded and later on transcripted (Kvale, 1996).

As this study is an exploratory hypothesis generating approach, the authors were aware of a rather low reliability when repeating the study. The small group of seven designers is statistically not valid, which requires the verification of the emerged hypotheses by further statistical approaches. The chosen group of designers, however, seems to be sufficient to fulfill the aim of this study’s exploratory design to open up new research areas by initiating possible hypotheses for future studies (Saunders et al., 2009; Patton, 2002). Conducting the study with solely the tool Leap Motion cannot generalize the usage of motion-sensing, but gives an initial impression about the technology’s potentiality. As this is an exploratory thesis study, certain deficiencies are accepted (Bryman, 2012).

The reliability of the sample group has been strengthened by purposive sampling as well as by appropriate preparation (Dolores and Kongco, 2007). Especially the experts promised a significant contribution to the research due to their professional experience within the field of interaction design. Knowing how to ask appropriate questions in advance is important and indispensable to be able to define and control the interview. The researcher should moderate the interview and listen actively to its interviewees. Answers are more authentic the more spontaneous an interview is structured and conducted (Bryman, 2012).

During the experiment it also became clear that the students had to a lesser extent experience with CAD programs, not to mention using an interaction tool for designing. In contrast to the designers of Berge Agency, the students were only familiar with design methods they had learned during their education: the traditional way of physical designing with their hands.

The ethical aspects within semi-structured interviews and observations affirm research to be morally valid. This includes the information of each designer about the aim of the research, the way of data collection, the analysis and further usage of the new findings (Bryman, 2012).
3 Theoretical Frame of Reference

The understanding of the product creation process in apparel value chains, which belongs under the sector textile management is necessary for this research. Thereby it is essential to know about virtual prototyping enabled by virtual tools. Furthermore motion sensing is described within the sector of HCI and three-dimensional user interfaces, which relates to the practical device Leap Motion.

3.1 Textile Management

Textile Management encompasses the process of making and managing goods within the textile and apparel value chain with regards to the design, manufacturing and distribution of textiles and garments. The textile industry is a complex business and requires a deep understanding of today’s fast-paced, interchangeable and unpredictable demand. Trends come and go; therefore it is important to be able to react to increasing customer and market changes with the focus on the product’s functionality and durability (Burns et al., 2011).

3.1.1 Apparel Value Chain

The apparel value chain, as an integral part of Textile Management, includes a set of activities in order to deliver a product to the market. It consists of creating, manufacturing and distributing products to meet the demand of the market in time and fulfil the customer’s expectations (Harrison and van Hoek 2011). All parties involved within a value chain are giving contribution to the whole process by adding more or less value to it (Harrison and van Hoek 2011; Burns et al., 2011). Processes need to be speeded up and be able to react flexibly as well as market and customer oriented (Niinimäki and Hassi, 2011). This affects mainly the design and development parts as these steps within the apparel value chain are decisive and the base for the creation of new products (Burns et al., 2011).

3.1.2 Product Creation in Apparel Value Chains

There are different ways and working procedures to create a product. The process flow depends on the company and the product category. As the starting points of the apparel value chain, the design and development process plays a crucial role in the collection’s subsequent success (Burns et al., 2011). Figure 9 shows the industrial workflow of a product creation process in companies that are increasingly using 3D technologies in an advanced way. This process is aligned on the traditional design and development process according to Burns et al. (2011) and has been discussed with several industry professionals. The value chain has been simplified but is valid in the broad commercial practice.
Figure 9: The apparel industry’s workflow of a product creation process

Based on the research, designers elaborate the concept of the collection. Design is a plan of action that is created in response to a situation or a problem. The transformation of ideas as well as the explanation of executing ideas is a very personal act (McKelvey and Munslow, 2002). According to Zhu (Zhu, Zizi Wj., Designer Apparel Teamsport, PUMA SE, Interview, 01.05.2015) the working steps and methods of creative design can vary from person to person and depend on the project. There is an immense number of individual approaches to visualise ideas. One of the methods applied most frequently is the creation of design sketches, which can either be done by hand, with pen and paper or digitally with various CAD programs, such as Adobe Illustrator or Photoshop. Another way is the physical draping on mannequins or by modifying ready-made garments. While some designers prefer to solely use one method, others prefer to vary by going back and forth between these methods. The pressure of creating successful marketable products forces designers to work out numerous ideas, sketches and drafts, which are changed over and over again. This process is very time-consuming and does not add any obvious value for the customer from a value chain point of view (Lanninger, 2013).

Once the best designs have been agreed on, the following steps require a higher level of details to further specify the idea. The designer proceeds to create digital technical sketches that specify the design details. The commonly used program for this purpose is Adobe Illustrator. In a next step, the technical design is handed over to a developer and further style specifications regarding material, trims and fit are elaborated and recorded. Based on the designer’s creative ideas the pattern maker creates a digital 2D pattern that afterwards gets converted into a virtual prototype (Hugo Boss, 2015). Only after this point, the product is simulated in a 3D environment that enables the designer to try out different colours, fabrics and contrasts (Wildermann and Haase, 2013). Designs can be viewed from different angles, which enables decision-making through digital product communication in real time (Lanninger, 2013).

There are already companies that are intensively integrating the use of computer-generated 3D images into the product creation process, so that the evaluation can be executed before creating any physical prototypes (adidas-group, 2014). One example of a pioneer in 3D applications is the sports company Adidas. According to Schneider (Schneider, Karin, Designer Apparel, ADIDAS AG, Interview, 05.05.2015), the creation of physical prototypes for product groups, that are less complex, such as T-Shirts or Tops, is almost entirely omitted. This means that the final evaluation and approval is solely based on 3D simulation. Other companies are more focussing on using 3D files for sampling and selling-in stages (Hugo Boss,

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2 Zhu, Zizi Wj., Designer Apparel Teamsport, PUMA SE, Interview, 01.05.2015
3 Schneider, Karin, Designer Apparel, ADIDAS AG, Interview, 05.05.2015
If the product does not meet the requirements and expectations, the design and development process restarts. That is why the product creation process of getting the right product with the final grip is a long process with “innumerable iterations” till the product reaches the production stage (Lanninger, 2013 p.1). Zhu (2015) argues that “the digital design determines the product death or alive”, whereby the realistic simulation of the product is one of the most important factors during the product creation process.

Garments are made out of soft materials, which is why haptic is still a vital factor for touching and trying. This is one of the main reasons why the stage of physical prototyping cannot be excluded fully, and for most of the products, the need of a physical prototype is still inevitable (Ebbesmeyer, 2014). In the sampling stage, the 3D files are used as a communication tool. Instead of producing extensive product ranges in different colourways for showcasing, the selling-in process is based on virtual 3D files and is followed by production (adidas-group, 2014).

3.2 Virtualization

According to Bordegoni and Rizzi (2011), virtualization has been identified as a mega trend of the next period. It is a useful method to visualize products on a virtual basis. The underlying concept for virtualization is the use of VR techniques. According to Yi (2013), VR is an experience of interacting with objects in a virtual environment. Computer systems are creating simulated environments that can either resemble or differ from the real world. The primary focus of VR environments are visual experiences that can be displayed on computer screens or stereoscopic displays (Bordegoni and Rizzi, 2011). Depending on the sense of immersion, virtual simulation techniques can be either semi- or full-immersive. While a semi-immersive VR system is based on single screens or desktops, a full-immersive system requires special equipment, such as VR headsets or multi screens (Choi and Cheung, 2012).

As Yu et al. (2010) mention, the visualisation technique that enables the interaction between user and virtual objects by a mix of reality and virtual reality is known as augmented reality (AR). Computer-generated data are merged with data from the real world.

3.2.1 Virtual Prototyping

In order to understand the concept of a product, a representation of the product is essential. The creation of prototypes makes it possible to sample designs and identify the character of the product. At this early design phase, designers are exploring and evaluating different kinds of designs before the production of the final product takes place (Bordegoni and Rizzi, 2011). However, the average amount of physical prototypes needed during the product development process is in between two to ten samples. Since this is combined with high cost, much time and effort, virtual prototyping offers the chance to overcome these problems (Sayam et al., 2010) and drastically reduce the number of physical prototypes (Bordegoni and Rizzi, 2011). According to Choi and Cheung (2012), virtual prototyping within the product creation process is a powerful tool to get the product right at the first time and deliver it in time and on budget.
Virtual product innovations realize a way of applying 3D techniques to enable faster product development processes. They have received a lot of attention in recent years. Design can be tested and evaluated in a virtual way before creating any physical prototypes. Virtual prototyping is a computational simulation of a product and gives the user the impression as if the product would exist in reality (Bao et al., 2002). This simulation is achieved through the construction of a virtual product and its virtual environment. Aspects regarding aesthetic, function and manufacturability can be tested and evaluated in the very early design stage. Virtual prototyping is based on the use of VR technologies by referring to a computer-simulated environment and simulating the physical presence of a product. Through the recent innovation of VR techniques and technologies, product visualisations are highly realistic and are able to interact (Bordegoni and Rizzi 2011). Interactive prototypes that can be rendered and manipulated in real time are known as immersive virtual prototypes. They reinforce the user’s belief of working with objects, as if they were actually existing (Tseng et al., 1998).

3.2.2 Virtual Tools within Apparel Value Chains

Today’s apparel industry is increasingly using various CAD techniques in different parts of the value chain (Sayem et al., 2010). Due to their working procedure in creating 3D designs, the various commercially available 3D clothing CAD systems can be distinguished between the following three groups:

- ‘2D to 3D’ approach
- ‘3D to 2D’ approach
- 3D interactive systems

A ‘2D to 3D’ simulation system enables the user the creation of a 3D design, that is based on a 2D pattern input. Pattern pieces from appropriate 2D CAD software are converted into a 3D garment by draping the pieces onto a virtual mannequin. The techniques behind this process are virtual sewing and fitting. While virtual sewing is about applying the pattern on a 3D model, the virtual fitting process aims to adjust the pattern onto the body shape of the model (Liu et al., 2010). Due to physically based simulation the patterns get seamed and merged and are finally fitted on the virtual body (Fuhrmann et al., 2003). Figure 10 shows a ‘2D to 3D’ approach with the necessary steps from pattern input to fitted garment simulation.

As this process is widely applied in the apparel industry, there are a lot of software packages that enable the ‘2D to 3D’ simulation process. Some examples are Vstitcher from Browzwear, Accumark Vstitcher from Gerber (USA), Modaris 3D Fit from
Lectra, Optitex 3D Runway, Vidya from Assyst, Haute Couture 3D from PAD system Technologies Inc. and eFit Simulator from Tukatech (Sayem et al., 2010).

Another approach of creating 3D designs is the use of 3D modelling and a 2D unwrapping approach, which is known as ‘3D to 2D’ approach. It realizes the creation of virtual garments in a 3D environment. A virtual body serves as a platform where the development of 3D designs can be performed. In order to transfer the 3D designs into 2D patterns, the shape of the garment needs to be flattened with a surface-flattening tool. Software tools, such as 3D Runway from OptiTex and TPC parametric pattern generator from TPC (HK) Limited, are based on 2D CAD patterns and various fabric characteristics. Designers can choose from a range of mannequins and visualize garment designs by altering pre-designed garment parts. The design process is therefore performed by the use of 2D input devices, such as computer mouse or pen tablets (Wibowo et al., 2012). A flattening tool transforms the 3D design into a 2D pattern to a very limited extent (Sayem et al., 2010) and only for close-fitting garments (Sayem, 2012). Moreover the created garments are usually simple styles with single layers (Huang et al., 2012). Figure 11 shows the ‘3D to 2D’ application of the software TPC parametric pattern generator from TPC (HK). According to Hernandez⁴ the ‘3D to 2D’ approach is not commonly used in the apparel industry. This approach is not accurate enough and far away from production standards as well as too different from the natural way of designing.

Some CAD systems offer a combination of these approaches and are commonly known as 3D interactive systems (Sayem et al., 2010). Garment changes like resizing, seams, pleats or fabric material are interactively updated either on the 2D patterns or on the virtual displayed 3D garment (Volino et al., 2005). An example for a software program is the Automatic Pattern Generation System from TPC (HK) Limited (Sayem, 2012).

### 3.3 Human-Computer Interaction

HCI emerged in the early 1980s in its initial field of computer science including cognitive science and human factors engineering (Carroll, 2014). HCI implies the process and its interaction between the user and computer while working together. As the name indicates, HCI functions within three interfaces: the user, the computer and its interaction with each other (Baciu and Liang, 2011).

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⁴ Hernandez, Niina, Lecturer at the Swedish School of Textiles, Interview at Borås University, 29.4.2015
3.3.1 Three-Dimensional User Interfaces

3D UIs have found vast applications in various areas such as gaming, modelling, art installations and interactive display walls (Bowman, 2014). New inventions within HCI tend to pursue natural user interfaces (NUIs) with natural interaction. This includes direct contact like multi-touch tablets and motion-based functions in 3D spaces. Nowadays interaction systems are in 3D spatiality, but the interaction with the user is indirect within the space. Due to missing 3D interaction, HCI applications like mouse, pen tablet or joystick cannot be used as 3D UIs (Bowman, 2014). 3D UIs are generally based on a six-degree-of-freedom (6-DOF) tracker that enables spatial tracking of 3D position, orientation and movement of objects within a fixed environment. 6-DOF uses technologies such as electromagnetic fields and optical tracking. It requires video cameras or visible markers to sense the object’s own position and orientation with inside-out vision-based tracking. 3D UIs are interacting within VR systems that enable different levels of immersion with virtual environments (Bowman, 2014).

NUIs as embodied interaction are getting more into the focus of capabilities for free-handed interactions within physical and virtual environments with real-time input and output while using motion-sensing technologies (Kumar et al., 2012). This enables the user to interact with human body movements and natural physical attributes between the real and virtual world (Geiß, 2014).

3.3.2 Motion Sensing

Motion sensors are tracking the movements of objects or human beings to conduct their motion in a given sensor range. The principle of motion sensing is based on technical devices that are able to sense physical motion and convert their tracking into electrical signals to report about captured data or changes (Jain, 2012). Its primary application field is supposed to be security usage like detecting trespassing, controlling lightning and triggering cameras while capturing pictures. However, gaming recognized its potential and developed motion-sensing technologies that create immersive and interactive user interfaces (Chen et al., 2011). Examples for gaming tools using motion-sensing technology are the tangible Razer Hydra Sticks or free-handed interaction tools like Microsoft Kinect or Leap Motion. As the results of this study are based on the practical experiment with the tool Leap Motion, the description of the technology and usage of a motion-sensing technology tool refers to Leap Motion.

The tracking of Leap Motion operates with optical sensors and infrared light while creating a series of single snapshots, which are called frames, and resulting in animated pictures (Leap Motion b, 2015). The infrared LED light is limited by the Leap Motion’s USB connection, which reads the sensor data within its own built-in memory. This data is transferred via USB to the Leap Motion tracking software to enable a reconstruction of the tracked data. With the computer tracked data raw sensor images from the Leap Motion cameras are captured and due to physics expressed in a series of frames (Leap Motion a, 2015). Figure 12 illustrates the Leap Motion technology.
As displayed in figure 13, the most common gestures within the Leap Motion are the general tapping movement screen tap (A), the key tap (B) like tapping a keyboard key and gesture C, tracing circles with your fingers. Gesture D simulates the swipe by moving the hand back and forth.
4 Results

The following chapter is a presentation of the results collected from interviews and observations of the design students Sofie, Sandy, Maryam, Erik, Elias and the interaction design experts Hans and Jonathan. The collected data were assigned to different themes.

4.1 Practical Results of the Experiment

While conducting the practical experiment of sculpting a sphere into the shape of a heart, the designer’s behaviour and reactions as well as their hand movements were observed. Moreover the visual results of the created hearts give further information about the difficulty of the task. Figure 14 shows the visual results of the experiment. The emerging themes are the designer’s reactions when watching the outcome and the observed handling technique.

![Figure 14: Results of the practical task 'sculpting a heart']

<table>
<thead>
<tr>
<th>Themes</th>
<th>Best examples from interviews and observations</th>
</tr>
</thead>
<tbody>
<tr>
<td>Handling technique</td>
<td>Finger pointing as main gesture to design (screen tap, key tap) <em>Erik, Elias, Hans, Jonathan</em>; usage of both hands for object preparation as main gesture (swipe) and execution of details done with one finger (screen tap, key tap) <em>Sofie, Sandy, Maryam</em>; especially zooming and rotating for navigating (swipe) <em>Hans, Jonathan</em></td>
</tr>
<tr>
<td>Reactions regarding the outcome</td>
<td>Unsatisfied with the visual result <em>Sofie</em>; rather annoyed at the end, task was not 100% finished <em>Sandy</em>; anxious about the result, wanted to see the other designers’ results <em>Maryam</em>; unconfident and a little bit ashamed, “I don’t like things to be left half done” <em>Erik</em>; ashamed of the result <em>Hans</em>; quite satisfied with the result <em>Jonathan</em></td>
</tr>
</tbody>
</table>
## 4.2 Results of the Interviews and Observations

In order to give the reader an overview about the data that has been gathered from the interviews and observations, the answers are categorized in themes. Some of them were reinforced by the observations made during the practical experiment.

Before getting started with the practical task, the designers were asked about the usage and the importance of their hands. The emerging theme is the desire towards embodied interaction.

“How important are your hands while designing?”

<table>
<thead>
<tr>
<th>Themes</th>
<th>Best examples from interviews</th>
</tr>
</thead>
<tbody>
<tr>
<td>Desire towards embodied interaction</td>
<td>“very important” Sandy, Elias; “really important” Erik, Maryam; “super important” Sofie; “I use my hands for almost everything” Erik; “I am not using my hands anymore [...] I prefer the digital way” Hans</td>
</tr>
</tbody>
</table>

After the practical experiment the second part of the interview was conducted. In order to investigate the excitement towards motion-sensing technology, the designers were asked about their attitude and thereby showed great enthusiasm. Moreover the designers brought up various engaging features, like fun and immersion, but also a limiting feature, like the need of concentration.

“How did you like the idea of designing with a motion-sensing technology tool?”

<table>
<thead>
<tr>
<th>Themes</th>
<th>Best examples from interviews</th>
</tr>
</thead>
<tbody>
<tr>
<td>Enthusiasm</td>
<td>“It’s so cool, really cool, that’s really cool [...] I like the concept” Erik; “I like the idea [...] it is really tough” Elias; “nice, feels power” Sofie; “Oh…(laughing) [...] interesting idea [...] impressive tool.” Maryam</td>
</tr>
<tr>
<td></td>
<td>Enthusiastic whole time Sofie; enthusiastic in beginning but in the end rather annoyed Sandy; chilled, knew what to expect due to previous experience Hans, Jonathan</td>
</tr>
<tr>
<td>Fun</td>
<td>“much fun” Maryam, Hans, Jonathan; “[...] interacting is fun [...] more playful [...]” Sandy; “fun, but only for 5 minutes” Hans</td>
</tr>
<tr>
<td></td>
<td>Laughing and giggling Sofie, Sandy, Erik, Maryam, Hans, Jonathan</td>
</tr>
<tr>
<td>Immersion</td>
<td>“I can feel a kind of power [...] you lose the sense for the surrounding and get completely lost in the tool, but in a good way [...] reminds me of the movie Minority Report” Sofie; “It cuts the line between mind and sketch.” Erik</td>
</tr>
</tbody>
</table>
|        | “It is like a connection between the brain and you and your hand and the screen. In this way done here it is not intuitive. My biggest problem is not the handling but more the contradiction between physically working in 3D space and seeing the virtual interaction on a 2D screen. This it is not intuitive and natural. I would prefer to act
in a 3D space while wearing headsets, which would enable you to see your arms and extend them to the world, so that you could get the feeling of where your hands are and what they are doing.”

Jonathan

Bending and curving upper body to move with executed movements

Maryam, Sandy

Concentration

“You need your brain [...] requires high concentration” Sofie; “[...] you have to think while doing things.” Erik; “It is tiring” Hans

Strained facial expressions Sandy, Erik, Elias; making a grimace Sandy, Hans, Jonathan; upright and tensed body posture while designing Sofie, Sandy, Erik, Elias, Hans, Jonathan; relaxed Hans

After that, the designer’s feeling of using the hands in an interactive way with the computer was investigated. The emerging themes are the feeling of intuitiveness and the device’s control and accuracy.

“Did you like the feeling of using your hands in an interactive way with the computer?”

<table>
<thead>
<tr>
<th>Themes</th>
<th>Best examples from interviews and observations</th>
</tr>
</thead>
<tbody>
<tr>
<td>Intuitiveness</td>
<td>“It feels more free instead of clicking the mouse only, as you get a feeling for 3D, which is really nice.” Maryam; “finger pointing not natural” Sofie; “Not holding to anything is strange, it is not natural [...] with the Hydra you are holding on to something, that it is more a feeling, it is more intuitive, even if you don't have the freedom to spin with five fingers, it feels more natural [...].” Hans</td>
</tr>
<tr>
<td>Control and Accuracy</td>
<td>“Interacting with only one finger does not give you much control” Sofie; “I missed the control [...]. Sensitivity is missing” Hans; “You have no idea what you are doing. It is like: Oh what happened? [...]” Hans; “[...] patience needed.” Maryam</td>
</tr>
</tbody>
</table>

Due to low control of handling, the designers lost their enthusiasm Sandy, Elias, Hans, Jonathan; some designers even wanted to quit without having finished the task Sandy, Hans

The following questions aimed to investigate the potentiality of substituting general design and development processes by motion-sensing technology tools. The focus was on first inspiration sketching and draping on physical mannequins. Further the question was expanded regarding the potentiality of future development of virtually draping fabric around virtual mannequins. The emergent theme encompasses the different application areas.
“How far do you think can the use of a motion-sensing technology tool substitute the general design processes with regards to first inspiration sketching and draping on physical mannequins? Further imagine you could select a certain fabric and wrap it onto a virtual mannequin. How far would it influence your answer?”

<table>
<thead>
<tr>
<th>Themes</th>
<th>Best examples from interviews</th>
</tr>
</thead>
<tbody>
<tr>
<td>Application areas</td>
<td>“[... ] possible to substitute several physical activities, but still needs a lot of developing.” Hans, Jonathan; “[... ] useful for the beginning of the design process [...] not for details” Erik</td>
</tr>
<tr>
<td></td>
<td>“It is a nice tool for fast sketching [...]” Sofie; “[... ] inspiration sketching” Erik; “It is not possible to substitute sketching with pen and paper [...] too far away” Elias; “Not sure, it is too clunky and not possible to sketch in the same way as holding a pen and a paper.” Hans; “I prefer pen and paper.” Maryam</td>
</tr>
<tr>
<td></td>
<td>“It reminds me of physical drafting on mannequins [...] the draping process could be substituted with virtual draping” Sofie; “I can imagine virtual draping [...] virtual draping would substitute the draping process [...]” Elias; “Virtually wrapping fabric around a mannequin should be way better than the traditional way of working [...]” Sandy; “If it would work probably, then the draping process could be substituted.” Hans, Jonathan; “[... ] hard to substitute the physical process of draping on mannequins due to missing gravity [...] Fashion design is more than this, it is about touching, feeling, hands and materials [...]” Erik; “[... ] I prefer draping on real mannequin. Even virtual draping could not substitute physical draping at all [...]” Maryam; “As it is now, playing around and mocking up could be possible, but not draping [...] but touching or modifying something: No Way! Not as it is today” Hans</td>
</tr>
</tbody>
</table>

In a next step, the designer’s openness regarding the implementation of a motion-sensing technology design tool was investigated. Different ways of integrating the technology were discussed.

“Would you prefer to have a motion-sensing technology tool as an additional tool combined with other 3D modelling design programs instead of using it as a stand-alone tool?”

<table>
<thead>
<tr>
<th>Themes</th>
<th>Best examples from interviews</th>
</tr>
</thead>
<tbody>
<tr>
<td>Integration</td>
<td>“[... ] so far only assisting tool [...]” Sandy; “[... ] A combination of a mouse and Leap Motion both together would be too confusing for your mind [...] multitasking would be necessary (laughing)” Sofie; “A combination is nicer. Mouse clicking could be more safe that it is really working.” Maryam; “It is only suitable for navigating, a substitute for command, shift, swiping to moving around and going closer.” Hans; “[... ] Could be a good tool to complement with 3D scans or pre designed garment [...] to overwork something scanned [...] powerful” Erik</td>
</tr>
</tbody>
</table>
In the next question, the designers were asked if they experienced any difficulties and problems while using a motion-sensing technology tool, intending to investigate the need of specific skills.

“Do you think that the usage of motion-sensing technology tools requires specific skills or design trainings?”

<table>
<thead>
<tr>
<th>Themes</th>
<th>Best examples from interviews and observations</th>
</tr>
</thead>
<tbody>
<tr>
<td>Skills</td>
<td>“It is not necessary to have specific skills or training.” Sofie, Sandy, Maryam, Erik, Elias, Hans, Jonathan; “Just a little bit of learning and trying out [...] a learning process that you have to get over” Hans</td>
</tr>
<tr>
<td></td>
<td>Fast learning progress during usage Sofie, Sandy, Erik, Elias, Maryam</td>
</tr>
<tr>
<td></td>
<td>All designers often forgot to place their hands horizontal about the Leap Motion so that the optical sensors and the infrared light within the Leap Motion were able to track the motion to transfer and reconstruct it virtually</td>
</tr>
</tbody>
</table>

While attempting to investigate positive effects of the usage of a motion-sensing technology and its advantages regarding speed, the themes waste and flexibility emerged from the answers to the following question.

“Do you think you can design faster by using a motion-sensing technology tool?”

<table>
<thead>
<tr>
<th>Themes</th>
<th>Best examples from interviews and observations</th>
</tr>
</thead>
<tbody>
<tr>
<td>Waste</td>
<td>“It is possible to reduce so much waste of time, money and materials [...] without [...] creating physical waste.” Sandy; “It saves waste with regards to material and time.” Sofie</td>
</tr>
<tr>
<td>Speed</td>
<td>“[…] it is faster, so much faster.” Hans; try out […] faster.” Sandy</td>
</tr>
<tr>
<td>Flexibility</td>
<td>“Try out as often as you want” Sofie; “If you don’t like your creation you can do a restart, you have more possibilities to have undo functions […] You can see the results immediately.” Hans; “You can immediately see the result and try out things easier […]” Sandy</td>
</tr>
<tr>
<td></td>
<td>Designers easily changed the object and restarted their task Maryam, Erik, Hans</td>
</tr>
</tbody>
</table>
Further, the designers were asked if using a motion-sensing technology tool influenced their creativity in either a positive or negative way.

“How far does the use of a motion-sensing technology tool effect your creativity?”

<table>
<thead>
<tr>
<th>Themes</th>
<th>Best examples from interviews</th>
</tr>
</thead>
<tbody>
<tr>
<td>Creativity</td>
<td>“Could be good and enhancing when having it in the workflow.” Erik; “It does not stop your imagination.” Elias; “[...] does not affect my creativity much, as my brain is more controlling than my hands.” Sandy</td>
</tr>
</tbody>
</table>

The last question was directed towards the future potentiality of motion-sensing technology.

“If you think of possible future developments, what would you like to add, what do you miss or how do you feel about the potentiality of motion-sensing technology tools in general?”

<table>
<thead>
<tr>
<th>Themes</th>
<th>Best examples from interviews</th>
</tr>
</thead>
<tbody>
<tr>
<td>Incentives</td>
<td>“Imagine this happening, that you can further add smell, touch, temperature then it is gonna change the world” Sandy; “If you find the harmony, it would be really powerful, being free [...]” Erik; “There is something missing, a little ID is missing (sighing). Even my kids prefer crayons.” Hans</td>
</tr>
</tbody>
</table>
5 Analysis and Discussion

This thesis aimed to explore the potentiality of motion-sensing technology within the apparel industry by investigating the designer’s attitude and possible implications on apparel value chains. The following analysis and discussion chapter is structured into the three parts 5.1 HCI with Motion-Sensing Technology Tools, 5.2 Possible Implementations in Design and Development Processes and 5.3 Effects regarding Product Creation that revive the emerged themes.

5.1 HCI with Motion-Sensing Technology Tools

The following chapter analyses the findings regarding HCI with motion-sensing technology tools while focussing on embodied interaction and interaction experience. The outcome of this research is based on the practical experiment of virtually sculpting the shape of a symbolic heart with the Sculpting App of Leap Motion.

As the urge towards natural gestures within the current design and development process pursues to go back to human beings and its fundamental movements (Victor, 2011), current VR tools, like the Leap Motion, tend to go towards HCI, which enables interaction between the user and the computer (Baciu and Liang, 2011). Leap Motion pursues NUIs that are supposed to enable embodied interaction with human body movements and natural attributes between the real and virtual world (Geiss, 2014).

Enthusiasm and Fun

During the experiment, the designers showed great enthusiasm as well as openness and were keen on trying out the Leap Motion. It became immediately obvious, who of the designers already knew the tool and for whom it was the first time trying it out. When the designers for the first time saw their tracked fingers on the laptop, their emotions were either overwhelming, they “felt power” (Sofie) or were rather insecure. But all designers were laughing and giggling at the same time. The designers from Berge Agency whereas, however, who were experienced in the usage of motion-sensing technology tools, were relaxed and calm, as they knew what to expect and already formed a certain opinion about the tool Leap Motion.

The practical task was “much fun” (Maryam) and “more playful” (Sandy). It showed that HCI with embodied interaction nowadays gives designers freedom and pleasure in interacting with computers while creating something new. This is reinforced by the 6-DOF of 3D UIs, which enable spatial tracking of 3D position, orientation and movements within a fixed environment (Bowman, 2014) as done with the Leap Motion device and its skeleton tracking of the hand via optical sensors (Leap Motion a, 2015). Hans however clarified that this kind of motion-sensing technology tool is “fun, but only for five minutes”. This is due to Leap Motion’s low control and accuracy, which might be due to a weak USB connection or the stage of development of Leap Motion’s optical tracking. The captured movements within the given sensor range might not have been properly transferred so that the software had problems to convert its tracking into frames and thereby creating the animated pictures (Leap Motion a and b, 2015). Possible reasons for this, in the authors’ opinion, might be a
weak USB connection or deficiensies in optical tracking, which would have to be verified with the company producing the Leap Motion.

**Reactions regarding the Outcome of the Practical Task**

The annoyance became obvious during the practical task, particularly with Hans from Berge Agency. He was so unnerved that he wanted to stop sculpting the heart even before it was finished. His result was visible as a heart but had lacked his expectation as a professional. It looked like he was not satisfied either but rather ashamed of his final result. In general the results of the hearts were more misshapen and hulking than a show piece (Figure 14 Results of the practical task 'sculpting a heart’). A better result was the least that was expected from both sides, authors and designers. The observation showed that all designers lost some of their excitement and motivation after a while, especially due to the software’s low accuracy and bad controlling. The overall dissatisfaction of the visual results was emphasised by Erik’s comment, that he “do(esn)'t like things to be left half done”. Uncertainty and self-doubts became obvious, when designers asked if they could see the results of other designers in order to compare and evaluate themselves.

**Desire towards Embodied Interaction**

Moreover the experiment showed interesting thoughts about feelings regarding natural handcrafting as well as the difference between free-handed and tangible tools input. As the device Leap Motion also requires the usage of hands to track its motion in the given sensor range in order to enable an interaction with the virtual world, the experiment aimed to investigate the importance of the usage of hands as well as comparing the feeling with traditional handcrafting.

Though Hans from Berge Agency was educated on physical hand sculpting, he clearly stated that today he is not using his hands anymore due to the possibility of working digitally. He is captured by new technologies and would never go back to the physical way of creating by hand. Conversely, all four students see their hands of high importance and as a tool for almost everything. They share Victor’s (2011) position, who argues, that it is in human’s nature to use and move hands. The usage of hands is essential and indispensable, as every day’s life is taking place in a 3D world that requires the need of hands. The feel of natural handcrafting , however, was denied by everyone, which is contradictory with Leap Motion’s promotion.

**Handling Techniques**

Further, Victor (2011) claims that the current use of hands within HCI is mainly focusing on clicking and sliding, far away from natural gestures. In contradiction to Leap Motion’s promotion of natural interaction, the designer’s reaction and feeling were rather divergent. The movements used mostly within the experiment were the screen and key tap as well as the swipe function (Leap Motion a, 2015). Particularly the swipe gesture that can be seen as a similar gesture to move objects in real life was the designers favorite movement. This shows that the tool Leap Motion includes only few natural movements. The circle gestures (Leap Motion a, 2015), however, were not noticeably used by the designers.
Intuitiveness

By performing the practical experiment, the designers revealed some surprising findings. Unexpectedly, all designers felt the free-handed usage and handling of the Leap Motion as unnatural and not intuitive with no reference to the common and daily used movements, be that sketching and draping, either in the traditional nor in the computational way. The designer’s feelings were thereby contradictory to what NUIs originally aim to accomplish. The designers further criticized the missing hand feel and intuitiveness, which contradicts embodied interaction in its initial purpose. Embodied interaction is supposed to be natural but with regards to the results of the experiment, the designers found fault with exactly this detail as a missing feeling. Against it, the designers missed something to hold on, which is not similar to natural gestures either. Even Hans, who is used to digital working, felt a strong restriction due to the missing resistance. For him it was not natural at all, “not holding to anything is strange, it is not natural” (Berge). It became clear that resistance was missing. It was not the fact that material could not be touched or felt but the missing feedback of “push(ing) [...] harder [...] (to) feel resistance“ (Berge). In this context Berge mentioned the tangible Hydra sticks, which is another tool of motion-sensing technology and in which he sees more potential for further usage, especially as a design tool. “With the Hydra you are holding on to something, that it is more a feeling, it is more intuitive, even if you don't have the freedom to spin with five fingers, it feels more natural“ (Berge). The finding that the designers felt negatively about a free-handed tool was unsuspected but in the same way a very interesting and helpful outcome.

Skills

However, all designers stated that the Leap Motion requires no specific skills and is “pretty easy” (Elias) and only “a learning process” (Berge). According to the designers, the Leap Motion can be used by everyone, which could lead to the assumption that this tool has something natural or intuitive and thereby is easy to learn and handle. This has also become clear in the experiment with Jonathan from Berge Agency. As a trained software developer, he showed that it is possible to use the Leap Motion with no previous education in fashion design or similar. He performed the task as the fastest one with an impressive visual result. Different from common CAD programs, the designers, who tried Leap Motion for the first time, had a fast learning process and got quickly familiar with it.

The observation, however, showed that most designers often forgot to put their hands inside the defined and limited tracking radius of 150 degrees and viewing range of 60 cm above the Leap Motion device (Leap Motion a, 2015). They tried to execute movements outside this range. Further the designers’ hands were not always placed horizontally about the Leap Motion to transfer and reconstruct the motion virtually (Leap Motion a, 2015), which could be one reason that reinforced the low and difficult controlling of the Leap Motion.

Control and Accuracy

Getting to know the functionality of the device is certainly a precondition for effective handling and confirms Berge’s statement that it is “a learning process that you have to
get over” (Berge). Hans from Berge Agency further confirmed that it might be useful for zooming, rotating and navigating, but not for more. He missed the control. Sofie stated that “(i)nteracting with only one finger does not give (her) much control” which in turn confirms that the handling techniques in the Leap Motion are limited and one-sided. Also Berge stated that “(y)ou have no idea what you are doing. It is like: Oh what happened?” The overall feedback of all designers made clear that the current technology has not yet been developed far enough for industrial applications and needs improvements first.

**Immersion and Concentration**

While motion-sensing technologies create immersive and interactive user interfaces (Chen et al., 2011), the Leap Motion tool enables an interaction between the user and virtual objects by mixing reality and VR. Similar to the gaming world, the designers were completely immersed into the virtual world. Especially Maryam and Sandy even bent and curved their upper bodies to move with their executed movements. It seemed like they were feeling the immersion while they were diving into illusory worlds. Sofie for example got reminded of the movie Minority Report. It is a science fiction movie, which is about AR where hand tracking and face recognition enables the interaction with virtual space (IMDb, 2002). On the other hand, Jonathan from Berge Agency felt different and even went a step further as his biggest problem was not the handling techniques but more the contradiction between physically working in 3D space and seeing the virtual interaction on a 2D screen. “It is like a connection between the brain and you and your hand and the screen, it is not intuitive nor even natural” (Jonathan). Moreover Jonathan added that he would rather prefer to act in a 3D space while wearing headsets. He believes that such fully-immersive VR techniques, which enable the user to see his or her arms and extend them to the world, could give the user certainty of getting tracked precisely and could enhance the control. It has become clear, that the usage of Leap Motion does not only ”cut the line between mind and sketch” (Erik) but also “requires high concentration” (Sofie) and even “is tiring” (Berge). During the experiment, all designers had an upright and tensed body posture. The observation during the practical task showed that almost all designers strained facial features and made grimaces while performing, which can be seen as a feature for high concentration.

**Incentives**

Almost all designers produced new ideas for future aspects. Sandy even had the vision to add smell, touch and temperature. In her opinion, this would change the world. Erik further added, “if you find the harmony, it would be really powerful, (and allow) being free.” Hans from Berge Agency, however, had a different opinion, as he felt that “[...] something (is) missing, a little ID is missing [...]”. He emphasised his view by stating that even his kids prefer to draw with crayons.

Generally, the designers had a positive attitude towards the use of a motion-sensing technology tool and its ability of embodied interaction. It is interesting to see that the desire of embodied interaction does not tend towards free-handed movements as it feels incomplete and unnatural with no feel for intuitive movements. However, it
became clear that the designers in this study rather desire tangible tools. They prefer to hold on to something in order to feel resistance.

5.2 Possible Implementations in Design and Development Processes

Due to an overall openness of working with new digital design tools that enable embodied interaction, a possible implementation of a motion-sensing technology tool in the design and development process has been investigated. The designers were very open and engaged about discussing possibilities of how to integrate the technology into their way of designing.

Types of Integration

The interviews showed an overall preference of having motion-sensing applications as an additional tool instead of having it as a stand-alone tool. One possible reason might be the low control and accuracy in handling the Leap Motion device. The experiment showed that it is too imprecise and retarding for a proper usage yet. Hans from Berge Agency further claimed that “sensitivity is missing (which makes it) hard to control”. This lack of control and accuracy might have influenced the designer’s feelings of denying the technology as a stand-alone tool. Furthermore the designers argued that mouse clicking would be still “more safe” (Maryam) with regards to general handling and the execution of details. So far it is only suitable for “navigating, a substitute for command, shift, swiping to moving around and going closer” (Berge). While conducting the practical task, it could be observed that all designers intensively played around by viewing the 3D objects from different angles and zooming or rotating with the swipe gesture. This was underscored by Maryam’s comment that it felt “more free instead of clicking the mouse only, as you get a feeling for 3D, which is really nice”. Erik mentioned the possibility of using the technology for working pre-designed garments over or using it complementary to 3D scans. In comparison to the overall opinion of using it as an additional tool, one designer stated that using different tools at the same time would be too confusing, as it would require multitasking. This takes up the overall result that the usage of Leap Motion requires high concentration, thus seeming to inhibit some designer’s workflow additionally.

Relating the findings of the practical experiment with the 3D design tools available in the industry, the additional integration of motion-sensing technology into current 3D modelling design tools, such as 3D Runway from Optitex and TPC parametric pattern generator from TPC (HK) Limited, could be a good way of bringing current non-embodied interaction design tools closer to the natural way of designing and thereby making computational design more attractive. Being able to work out shapes and details with a 2D mouse-based input, but navigating the object’s position with interactive 3D hand movements could enhance the designer’s workflow. This means that designers could combine a tangible mouse-based input with free-handed embodied interaction and bring in their body in an interactive way.

Application Areas

In a further step, the interview aimed to investigate the possible areas of application regarding the design and development process. Due to Leap Motion’s stage of development and its low accuracy the focus was on the first step of the design and
development process, which is the creative design. Activities such as technical design, style specification and pattern creation were not considered to be suitable as these processes require a high level of detail which the current state of the Leap Motion is not able to meet. All designers were positive about the integration of a motion-sensing technology tool for the beginning of the design and development process. According to Berge, the technology could substitute several physical activities as long as the tool’s tracking function would be further developed. With expressions like “No way! Not as it is today”, Berge clearly criticised the limiting features of Leap Motion’s state-of-the-art regarding the limiting features control and accuracy. So far the technology is not able for realistic product simulations, which is, according to Zhu (2015), vital for decision-making in the industry. Presupposing a crucial improvement of the technology, various possibilities of substituting current design activities came up.

Draping

Especially in the area of draping, the designers were very open minded towards altering current design habits. The idea of enabling the designer to virtually drape and pin fabric around a virtual mannequin, evoked a lot of excitement as well as agreement. The designers stated, that such a development “would be even better than the traditional way” (Sandy, Elias). Before even asking the interview question regarding this area, one of Sofie’s first statements after the experiment was that this technology reminds her of physical drafting on mannequins. However, two designers were rather sceptical about this idea. According to Erik, “fashion design is more [...] about touching, feeling, hands and materials [...]”, which goes along with Ebbesmeyer’s (2014) statement, that haptic will always be a vital factor for the textile industry. Erik would miss the gravity and could not imagine to substitute the physical draping process. Also Maryam clearly stated, that she would always prefer draping on real mannequins. However, it should be mentined that Maryam is a very young design student, who had never experienced any 3D design programs, which hence makes the idea of working with new virtual tools more abstract for her.

Sketching

The opinions with regards to the substitution of the sketching process yet varied a lot more yet. While two designers could imagine a motion-sensing technology tool for fast sketching as well as inspiration sketching, the others felt rather negatively. As Berge stated, the reason for not being able to sketch in the same way as holding a pen and paper, is the clumsiness of the Leap Motion. Maryam and Elias had a similar viewpoint, that it is not possible to substitute the traditional sketching process because virtual sculpting is too far away from the feeling of holding a pen and sketching on paper. Above all it has to be considered that the process of sketching with a tangible pen on paper significantly differs from the process of virtual free-handed sculpting, which makes it quite hard to imagine substitution possibilities of two fundamentally different working methods. On the other hand, some 40 years ago hardly anybody could have imagined that using a mouse, a keyboard and a screen would eventually make the typewriter obsolete. The desire of holding on to something, as a pen, goes along with the deduction of the previous part 5.1 HCI with Motion-Sensing Technology Tools.
On the whole, the designers open-minded attitude allows to infer that the basic technology of using the hands in an interactive way has potential to open up a vast application area in creative design by starting the design and development process directly on a 3D basis once the technology further improves. The different opinions regarding the usage and substitution of current design activities go along with Zhu’s statement in terms of individual preferences of different design approaches. As the way of executing ideas is a very personal act (McKelvey and Munslow, 2002), the experiment shows that there are designers who are more open to new design applications whereas some of them prefer the traditional way of designing.

5.3 Effects regarding Product Creation

Concerning different ways of implementing a motion-sensing technology tool into apparel value chains, several effects in the design and development stage can be observed. The high potential of virtual draping as embodied interaction in creative design as well as the application of a motion-sensing technology tool as an additional tool with 3D modelling design programs reveals several impacts.

Flexibility and Speed

According to the principles of Textile Management, product creation is a complex process, that relies on fast changing trends and the indispensable need of flexibility (Burns et al., 2011). The data from interviews and observations indicate a high flexibility, which is enabled by working with motion-sensing technology tools. The designers liked the way of easily discarding designs and frequently restarted their task from scratch. Pursuant to virtual prototyping, the positive aspects like fast sampling and immediate computational visualisation became clear in the interviews. Comments like “(t)ry out as often as you want” (Sofie) or “(i)f you don’t like your creation, you can do a restart […] it is faster, so much faster. You can see the results immediately“ (Berge) further underscored the importance of flexibility.

Another positive aspect of virtual prototyping with motion-sensing technology tools is speed. According to Bao et al (2002) the computational working with 3D objects enables the designer to view objects from different angles as well as to balance the potential of the product before it gets produced, which speeds up the product development process. Designs are tested and evaluated in a virtual way. If a design does not meet the expectations or requirements the design can be revised from a certain stage on. Trying out things easier and faster does not only facilitate the designer’s daily life, but also goes along with today’s increasing demand of creating numerous design options, which mostly have to be changed over and over again (Lanninger, 2013), as well as the need of faster design and development cycles (Niinimäki and Hassi, 2011). Looking back to the industry’s current design and development process, the development of new product ideas contains several design and development activities until the idea gets evaluated and thereby requires a lot of working effort. Keeping in mind the “innumerable iterations” (Lanninger, 2013 p.1) that are combined with several restarts of design and development processes, the evaluation point is only a consequential step following several prior design and development activities that are necessary.
The designers’ answers regarding the implementation of motion-sensing technology affirmed the overall openness of working with new digital tools that enable embodied interaction. The transformation of making current HCI more natural by applying motion-sensing technology could increase the overall acceptance of working with 3D modelling design tools, which are currently claimed as being too far away from the natural way of designing. As a consequence it would change the order of the current value chain while transforming it from a ‘2D to 3D’ to a ‘3D to 2D’ process. Having the possibility of elaborating the creative design on a virtual 3D basis, the act of virtually simulating a product would have significant effects on the value chain. Decision-making could be done immediately without going through further design and development steps, so that the number of dismissed product ideas could be reduced. As a consequence, the product creation process would be speeded up while being more flexible in quickly executing design ideas and bringing forward the evaluation stage.

Waste

The flexibility of quickly creating virtual product simulations in early design stages also reflects several impacts regarding waste. The designers emphasized the key words “time”, “money” and “physical waste”. Executing ideas on a virtual 3D basis does not only reduce the time of reworking designs and creating new virtual prototype simulations, but also reduces the consumption of material. VR enables computational visualisation without using any material while solely relying on VR techniques. In particular, immersive virtual prototypes give a higher impression of working with physically existing objects, as the user is able to interact in real time (Tseng et al, 1989). Supported by the belief of working with physical objects, early decision making in early design stages realizes a way of saving time, money and material.

Creativity

Concerning the enhancement of creativity the designers revealed a range of different opinions. Some of the designers complained about the requirement of high concentration and the lack of control, so that the brain was more controlling than their hands. Thus the designer’s creativity was not really enhanced, as their flow of thoughts was restricted. Erik, however, thought, that the tool theoretically “could be good and enhancing when having it (implemented) in the workflow” as soon as he would get used to it. In addition Elias stated, that this technology was not stopping his imagination, which as a consequence could be interpreted as an enhancement of creativity or at least being neutral to it.

Coming to the inferences, motion-sensing technology could enable designers to start the product creation in a 3D environment by trying out designs more flexibly and faster and directly creating virtual prototypes. As Lanninger (2013) clearly stated, designs, which can be viewed from different angles on a 3D basis enable early decision-making through product communication in real time. The change of directly starting on a 3D basis would bring the evaluation stage even more forward in time than is currently the case in the industry’s ‘2D to 3D’ approach. This would mean that the “innumerable iterations” (Lanninger, 2013 p.1) of several non-value-adding processes, such as technical design, style specification and pattern creation could be
reduced and only be applied for designs, that already have been evaluated on a virtual basis through digital product communication during the creative design stage. The outcomes regarding flexibility, speed, waste and creativity can be seen as possible implications on the design and development phases of apparel value chains by applying motion-sensing technology.
6 Conclusion

The objectives of this thesis were to explore the potentiality of motion-sensing technology within the apparel industry by investigating the designer’s attitude towards the technology and possible implications on apparel value chains. As the current fashion industry’s HCI applications of the fashion industry use non-embodied interaction technologies, which deny natural hand movements, it was evaluated, if motion-sensing technology can enable the feeling of natural handcrafting.

(1) What is the designer’s attitude towards the use of motion-sensing technology tools in the area of design and development?

The practical experiment showed that the designers felt open and excited about motion-sensing technology tools and its ability of embodied interaction with the virtual world. Unexpectedly, it became obvious that the designers prefer to work with tangible tools in order to feel resistance. They even experienced the usage of free-handed motion-sensing technology as not natural and intuitive, which denies the feeling of natural handcrafting. Moreover, their creativity was not much influenced due to Leap Motion’s lack of control and accuracy as well as the need of high concentration. However, the designers supported embodied interaction and experienced the use of motion-sensing technology as an enhancing and powerful tool. The idea of virtually draping fabric around a virtual 3D mannequin by using the hands in an interactive way did not only evoke a lot of excitement of the designers but also showed great potential for further developments.

(2) What are the possible implications on the design and development phases of apparel value chains by applying motion-sensing technology?

The implementation of motion-sensing technology tools in the design and development process could make the product creation virtual from the beginning onwards. This would transform today’s established 3D design and development process, which is still starting on a 2D basis, into a faster product creation process while directly starting on a 3D basis enabling earlier entry into the evaluation stage. As displayed in figure 15, evaluations can be executed directly after the creative design stage, which sorts out the best product ideas in the early beginning and thereby minimizes iterations of the non-value-adding activities technical design, style specification and pattern creation.

Figure 15: Product creation process while implementing motion-sensing technology tools
Besides the effect of making the product creation process faster, further implications could be figured out. Working with virtual design tools reveals a higher flexibility while enabling designers to quickly restart or amend product ideas at early evaluation stages and thereby saving waste like time, money and material.

The findings obtained within this thesis open up a new area of research within the use of virtual 3D fashion design. The idea of directly designing on a 3D platform while interacting with the human’s body was greatly appreciated by the designers and thereby shows high potential for future developments. However, it must be noted that motion-sensing technology and its current state-of-the-art is not sufficient for immediate applications within the fashion industry and requires crucial further development.

This study was designed to be an exploratory hypotheses generating research. Some of the findings of the empirical work underscore expectations that were drawn e.g. from the theoretical frame of reference, while others occurred rather unexpectedly. As a conclusion the authors propose two theses worth further investigations:

(I) Provided certain handling and emotional prerequisites are fulfilled, the application of advanced motion-sensing technology tools in design and development processes of apparel value chains will speed up the product creation by virtualizing the entire process right from the beginning.

(II) A free-handed motion-sensing technology tool is not sufficient to replace natural handcrafting. Further technological advances or alternative tools are necessary. Tangible tools enabling embodied design interaction may be the tools of choice.
7 Future Studies

The hypotheses emerged out of this research may be proved by research projects of the following kind. Based on the findings of this thesis, possible future studies should focus on investigating tangible user interfaces (TUI) and their potentiality within apparel value chains. Regarding Leap Motion, the experiment could be repeated using a tangible pen, instead of freely using the hands. Another option could be the use of the Razer Hydra Sticks that are based on the same technology as Leap Motion, but with tangible tools. Moreover it would be interesting to conduct a further study with the Microsoft Kinect, which enables embodied interaction using the whole body. Various investigations might be helpful for further research studies to find out if the limited sensor range of the Leap Motion might have been an obstacle and might have presented a different outcome as reported in this study. Further it is recommended to conduct a study with the combination of a motion-sensing device with headsets, as for example the Oculus Rift, to explore the advantages of fully-immersive 3D interaction with virtual worlds. It may be advisable to repeat the conducted experiment with different designers and more industry-experienced designers in order to see if the outcome would differ from the reported results.

While this study - due to time and resource constraints - and the suggested further investigations described above concentrate on single solutions for the improvement of the design and development process in apparel value chains by applying motion-sensing technologies, a more general approach would be to conduct a broad-based study incorporating the details described above, with the following cornerstones:

The four most common devices will be investigated regarding free-handed and tangible tools (e.g. Leap Motion, Microsoft Kinect, Razer Hydra, Oculus Rift). A statistically meaningful number of designers (D) will be asked to assess the presumed most important features of VR devices in the value chain. This would yield the following table of assessment:

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**Figure 16: Table of assessment**

Figure 16 would give a comprehensive overview of the available devices in the industry and their assessed benefits to the apparel value chain. Moreover the synthesis
of all assessments could produce the specifications for a device optimally suited to the needs of the improvements of the apparel value chain.

While these observations deal with qualitative aspects, in a next step the quantitative effects of implementing such processes could be evaluated leading to an assessment of the possible savings the introduction of an optimal device would bring to the industry. Putting this into relation with the overall investment costs of such structural changes would finally lead to a cost-benefit-analysis of the introduction of an optimal VR process in the apparel value chain.
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