Towards an Inclusive Virtual Dressing Room for Wheelchair-Bound Customers

Brooks, Anthony Lewis; Petersson, Eva

Published in:
Proceedings of the 2014 International Conference on Collaboration Technologies and Systems (CTS 2014)

DOI (link to publication from Publisher):
10.1109/CTS.2014.6867629

Publication date:
2014

Document Version
Publisher's PDF, also known as Version of record

Towards an Inclusive Virtual Dressing Room for Wheelchair-Bound Customers

Dr. Anthony L. Brooks
Assoc Prof Dept Media Technology
Aalborg University, Niels Bohrs vej 8
6700 Esbjerg, Denmark
tb@create.aau.dk

Dr. EvaPetersson Brooks
ADMT: Design, Learning and Innovation
Aalborg University, Niels Bohrs vej 8
6700 Esbjerg, Denmark
ep@create.aau.dk

WORK IN PROGRESS

Abstract*— This manuscript reports on a work-in-progress project evolving aside from a main undertaking; that of making a commercial 'Internet of Things' style product called "The Virtual Dressing Room (VDR)". The project targets the process chain from designer and clothing manufacturer to retailer and end-user customers. The VDR has been subject of other publications, thus is introduced only briefly in this manuscript. VDR is a 'non-groupware-based' project funded under the Danish National Advanced Technology Foundation. A main goal at conception was reducing returns of online purchased apparel, which, at a reported approximately 40%, is crippling the clothing industry. Results from public response surveys (including at The Scandinavian Health & Rehab Messe) to a VDR simulation system clearly indicated how the wheelchair-bound community perceived benefits from the system. This was unexpected and aside from the original VDR project design requisite. Interviews highlighted problems of high street fitting rooms not being sized to accommodate wheelchairs, and often so minimally sized as to not enable a second helping person to be present to support the involved undressing and dressing procedures. Existing online purchasing systems were also considered problematic including a need to improve social networking to enable others Online to view clothes considered for purchase to assist decision making. The production suffered problematic cooperation, coordination, communication, and collaboration that prevented early product. This resulted in additional surveys and the evolution of this additional work-in-progress. Following introducing the VDR, key issues such as interface design, body measurement, and cloth representation in the VDR is discussed. The finding of wheelchair-bound-need is envisioned as a next-generation iteration and is thus the focus of this contribution to position the work-in-progress and invite like-minded interested parties to collaborate towards optimization of a system to realize potentials.

Keywords*— *Cooperation, coordination, communication, and collaboration; Virtual Environment; Collaborative System Generation; Human Computer Confluence; HCI

The Danish National Advanced Technology Foundation *(sponsors)*

I. Introduction

The Virtual Dressing Room is a commercial product to advance the field of online clothes shopping. At outset, end-user clients (customers) were the general public – as much as possible including all ages, abilities/disabilities, and locations. Conceived goal was to address the high return rates of apparel. Open-ended response surveys were conducted at major malls and Messe events where the general public could test a similar existing simple system. Surveys included those conducted at the "Scandinavian Health & Rehab" Messe held annually at the Bella Center in Copenhagen. It was from these surveys that the wheelchair-bound need was found, which is reported in this paper.

A. Overall outset design strategy, method and technique

A qualitative and social-cultural strategy was core of the methodology. In line with this, a specific participatory design approach was applied in order to foster inter-disciplinary collaboration and innovation potentials for an efficient e-business solution. Based on this, it was expected that the stakeholders would develop a shared ownership of design

Figure 1. LazyLazy system interface (as tested)

decisions in an iteratively based product development process.

Typically, in current systems, online images are of an item by itself or as worn by a model. An existing system closer to our concept and tested in this study was a licensed system for the online boutique LazyLazy[1]. This system is based on a customer using their own camera to mirror themselves in the system interface. They then select garments as an overlay superimposing upon their mirrored image (figure 1). Our design was similar but instead focused on using the latest time-of-flight (ToF) camera sensing (i.e. the Kinect by Microsoft). This form of sensing is based upon producing a 2D image that represents the distance from the camera location to each point as seen in the camera's field of view. The result is a ranged image having pixel values that correspond to the distance. The technique measures the time-of flight of the light signal with calculations of distance being based upon the 'speed-of-light'. An entire scene and 'depth of the objects' in that scene can thus be captured. The Kinect has been subject of numerous contemporary publications should one wish to research further to this technique.

Using this technique/camera as the core of the VDR allows a person to be scanned and identified from the background for the superimposing of the apparel layer over the mirrored self (figure 2). Thus, the dynamic movements of the person was to affect the physical (collision, cloth, etc) properties of the clothing so that the experience was enhanced.

The Kinect can also identify a person who has been using the system previously, however the robustness of this feature, in context to a VDR and apparel overlay that may affect, is subject for a future publication.

The system involves a customer standing in front of the Kinect camera (in figure 2 the Kinect camera sensor is mounted on top of a typical home television).

The customer views their mirror image mirrored on the television screen. Apparel is selected from a menu and swipe-dragged (a gesture recognized by the Kinect) as an overlay to superimpose on the appropriate mirrored image 'clothing area'.

The customer is able to then scale and view the clothing as if they were trying it on in a high street boutique looking into a fitting room mirror (figure 2).

Figure 2. Virtual Dressing Room interface

[1] http://www.lazylazy.com

Additionally, as mentioned previously, physical properties of the clothing that responded to the human motion and followed twists and turns (the customers dynamic movement) was envisioned to advance the state-of-the-art, however, innate to this is the challenge of attaining and formulizing the cloth and apparel data so that is is mappable to the layering algorithm.

B. *Team structure*

The project team was divided into 'technical partners' whose responsibility was the system product i.e. front-end client scanning and back-end interface/'cloth scans'/overlay algorithm/ animation/ solution. The authors' role was as the research team responsible for the design input to the technical partners and product testing.

Complexities and potential problems innate to replicating the targeted real-world "trying on" experience and interface design (scaling, gesture does all, etc.) was made clear to the technical consortium partners by three selected expert scientists who were introduced at the project startup. The experts were prepared to join the team as advisory consultants; however, the three professors were not included despite the research partners' (authors) recommendation. In other words, different approaches and interests between the researchers and the company representatives in the project already initially challenged the project's participatory design intentions.

C. *Primary purpose*

The primary purpose of the VDR project at setout was to reduce the volume of returned goods that are currently purchased online. The percentage of returned goods is reportedly 20-40% (figures differ amongst retailers), which is a figure that is crippling the clothing industry and making apparel more costly that it needs to be with costs being passed onto customers.

D. *State-of-the art*

Our research to date suggests that online purchase protection in the form of return of goods policies that give customers peace of mind are being abused. From interviews at demo sessions, it is clear that there are some customers that order multiples, often three of the same garment to ensure one is suitable, then returning the ones that are considered inappropriate.

Returns of opened goods are problematic for retailers as they are no longer in mint condition and accepted as new by other customers. Some even admit to purposefully ordering apparel from sellers that offer an open return policy (i.e. returns accepted even if the product is not damaged). The customer does this to enable them to order apparel (sometimes beyond their price range), then they wear the delivered goods to an event, and the following day they return the worn garment to the seller who refunds the money for the initial purchase. Our research suggests that such return of goods policies that offer a no questions asked benefit may be too open and in need of review. Return policies differ from country to country.

Interviews clearly point out the problem of not being able to feel the clothing to get an indication of the cloth dynamics/flow as when traditionally browsing in physical boutiques. Replicating the tactile feel of materials is a huge challenge. For example the differences between experiencing a silk, polyester, cotton, or wool design are intricate, however, given customer's real-world experiences already and expectation in the VDR project is of a transferred understanding. The recreation of a material's physical dynamic that responds to the human's mirrored image motion is also a challenge as pointed out herein.

Related work (see details in the Industry Trend spotting section III that follows) involves time-of-flight camera array systems that scan the details of the person's physical measurements. The detail is such that the person needs to disrobe to their underwear. A precise 3D avatar is created that is manipulated by computer mouse movements. The avatar can be 'digitally dressed' and viewed in 3D from 360 degrees. Fashion consultants are already using such systems as well as established high street shops in USA and UK. The use of an avatar is included in the next phase of comparative VDR study.

II. VIRTUAL DRESSING ROOM – BACKGROUND/CURRENT

A. *Online shopping: apparel return statistics and policies*

The Office of National Statistics in the United Kingdom informs that the average weekly value for Internet retail sales in June 2012 was estimated to be £493.3 million[2]. Based upon current activities and trends, predictions estimate that by 2018, 35% of clothing sales will be via the Internet. However, current figures show that between 15-40% of apparel purchased online (e-shopping) is returned because customers deem they are not a suitable fit[3] or not the desired look[4].

Trust policies that safeguard customer purchases enabling such returns are influential and, in some cases, these policies are reported as being abused whereby a purchase is received, worn, and then returned with full credit or refund. In the clothing industry, such high volume of returned apparel is economically disastrous and it is in respect of this problem that the project is directed as pointed out herein. [see also 6, 7, 8]

B. *Conceived solution (overview) and approach*

In order to develop a VDR turnkey solution to reduce consumer returns, a participatory design (PD) approach was applied in line with Brandt [1]. Fundamentally PD represents a set of theories, practices and studies whereby user communities play a substantive role in activities that can lead to the creation of software and hardware computer technologies and their application in real-world contexts [2-4].

The benefits of adopting such an approach for the design of the VDR system include a better understanding of the reasoning behind online purchasing behavior. This is important particularly given that these numbers are expected to rise even more in the future with predictions of online sales in Western Europe to increase at a 10% compound annual growth rate over the next 5 years[5]. Given such data it was important to address the process pipeline by researching the industry as well as end-user customers.

In the clothing industry many fit technologies exist. For example, retailers have created virtual mannequins for customers to dress and set up full-body scans in stores. Other solutions scan a customer in 360 degrees to determine a "shape" or size. Examples of such systems are presented in section III – the industry trend spotting study undertaken by the authors.

Findings from our PD field studies were periodically fed into the technical partners process pipeline to support development decisions. This paper refers to the results from the two initial phases of the design process, namely the preparation and the incubation phases [5], which represent the initial inspirational and definition phases where the problem was defined and potential solutions identified (see Customer Trend Spotting sections IV and V).

C. *Shopping trends and VDR*

In our studies, we found shoppers are reluctant to use systems that require much effort and time unless a special purchase is the goal. For women's clothing in particular, sizing is reported problematic due to the many complex issues including the psychological. One brand's size 12 is another's 10 or 14, primarily because fashion labels shape their clothes so differently, using their own closely guarded specifications to create patterns – e.g. see later section on *CAESAR*®. Online retailers often ask shoppers to consult "fit charts" or to type in their body measurements, which can be time-consuming. However, the *True Fit*[6] system reports increased sales and reduced returns up to 30% (premier denims). Consumers create a profile of age, height, weight and body shape. Then the customers select items that fit well from their own closets and identify the brands, styles and sizes to True Fit. Another personalized online shopping approach by *Stitch Fix*[7] involves female customers filling out a similar profile form thereafter online photos of clothing and accessories are rated to give the company an idea of the client's taste. *NoMoJeans*[8] takes precise customer measurements with a 3D body scanner, which are then archived on a database for future client purchases so as to avoid rescanning.

III. INDUSTRY TREND SPOTTING STUDY

At project outset, five selected UK companies were visited to determine state of the art in the industries associated with apparel shopping in order to supplement the PD research. These were:

1. Inition - http://inition.co.uk - a preliminary prototype was presented based on a single Microsoft Kinect sensor live mirroring the customer (similar to LazyLazy). The system was

[2] http://www.ons.gov.uk/ons/rel/rsi/retail-sales/june-2012/stb-june-2012.html

[3] http://online.wsj.com/article/SB10001424052702304724404577293593210807790.html

[4] http://www.imrg.org

[5] http://www.forrester.com

[6] http:// www.truefit.com

[7] https://www.stitchfix.com

[8] http://www.nomojeans.com

demonstrated to the author who also interviewed the system creator and VP of sales. Clothes are selected from an image menu and a superimposed overlay positioned onto the live video feed, thus, in this system there is no requirement to disrobe as measurements are not taken.

2. Shape Analysis - http://shapeanalysis.com - a proprietary multi-camera system marketed in partnership with a majot clothing industry company TC^2 from USA[9]. The customer needs to disrobe for precision scanning. Their latest systems offer a choice between a single Microsoft Kinect sensor or a four Kinect sensor aray system (3D – 360 degrees). The software generates an avatar (wireframe but can superimpose own face or selected clothing) giving precise measurements. The system was demonstrated by creating the author's body scan. Furthermore, interviews with the creator and marketing person were conducted.

3. Bodymetrics - http://www.bodymetrics.com - a proprietary four-camera system installed at leading stores in London (Selfridges – where the author tested and interviewed staff and clients) and USA (Bloomingdales). The latest system uses single or multiple Kinect cameras for boutiques and home uses. The software generates an avatar that mirrors customer rotation in real-time.

The author tested the system together with the CEO/creator's representative and VP of sales. Furthermore, staff (2) and customers (2) were interviewed. Customers complained of a need to initially disrobe for scanning, then having to dress to get clothing from staff in the public area, and then to go to a fitting room to disrobe again to test apparel feel and fit. This process is being changed using a female only area.

4. Holition - http://www.holition.com – this system was the same as (1) where a single camera was used. The company has a history of working in Augmented Reality (AR) e.g. for *Tag Heuer* watches[10].

5. Cristina Holm, Personal Image Stylist - http://www.cristinaholm.com - a four-camera scanner setup with software generating an avatar (static generated for precise measures – as 2). The TC^2 system from USA was installed in a private consultancy studio where custom made-to.measure clothing designs were realised for special occasions e.g. weddings, anniversaries, royalty etc. This specific model was the NX16 scanner which precisely measured through 360 degree scanning. In February 2012, TC^2 launched an affordable Kinect-based solution[11]. The system was demonstrated with resultant scan obtained. The consultant/stylist, was interviewed alongside the system inventor. The resultant 3D avatar can be rotated by a mouse and personalized with an image of the client's face.

The protype by Holiton/Inition was without accurate measures and used flat screen monitors in landscape mode for viewing of an image overlay. All of the companies are developing a single Kinect for home use and multiple systems targeting boutiques, custom tailors/designers, etc.

[9] http://www.tc2.com

[10] http://www.holition.com/portfolio/tag-heuer/

[11] http://www.tc2.com/newsletter/2011/113011.html

IV. CUSTOMER TREND SPOTTING STUDY 1

Shortly after the industry visits (section III) an initial field study with public interviewees was conducted at a major Scandinavian Trade Fair event that attracted more than 7000 attendees to the Health & Rehab Scandinavia at the Bella Center, Copenhagen 22-24 May 2012. This included video observations, questionnaires and unstructured interviews where the freely available *LazyLazy* system was used (figure 1).

Questioning of attendee trends in shopping (online/offline) was conducted from a large stand where videos of current state-of-the-art systems and simulations were used to question public opinions of online shopping for apparel systems. Wheelchair bound interviewees (n=13) made clear their need for improved means to purchase clothes without having to leave their homes. The perceived ease of use (PEOU) and perceived usefulness (PU) toward enhancement and reduced effort of an online apparel purchasing system (as detailed elsewhere) were seen as key factors for wheelchair-bound consumers. In respect of questioning their experiences of high street shopping, interviewees highlighted how accessibility issues seemed to stop once they had managed to enter a boutique, as changing facilities were commonly too small. This affected their enjoyment of a shopping trip and therefore they preferred to shop from home.

V. CUSTOMER TREND SPOTTING STUDY 2

A "Customer Trend Spotting Study" was conducted using the *Lazy Lazy* system (with company approval). This included a purchasing behavior analysis that questioned shopping trends (online/offline). The demonstration and research was at a major shopping mall in Denmark's second city Aarhus. The analysis also led to a personas generation phase to inform the design. The following main trends were identified from the purchasing behavior analysis:

– Fusion between online and offline shopping: The customers would like to see big screens in the stores where it is possible to link to the online web shop.

– Service level: Some of the customers considered online shopping convenient and stressed that offline service should be improved to give value to offline shopping.

– Convenience: The customers preferred online shopping due to that it is not bound to time and space so they will, thereby, save time; they do not need any transportation; and they do not need to wait in any line.

– Feel, touch and realism: The customers stressed that the feeling of the clothes, the touch, and the realistic trying-on experience are desired features that enhance the shopping.

– Online tools enhancing offline shopping experiences. The customers suggested that online tools, such as size and fit information, texture detail, matching of clothes to the individual's specific body type would enhance the offline shopping experience. Furthermore, social media, such as *FaceBook*, where the customer can share photos of the potential purchase and receive immediate feedback, would also enhance the offline shopping.

Furthermore, the customer trendspotting study showed that personal issues such as sizes is not purely a technical question for virtual dressing room solutions, it constitutes a highly emotional issue. Some of the customer suggested that this issue should be handled with humor, for example the body could be replaced with sketchy models or 3D avatars attached with humor-directed comments, e.g. "yes, you fit into this model, but you cannot breath....". Four personas, fictional characters, emerged from the customer trendspotting study:

— The practical non-shopper, represented by Anna, a teacher, 29 years of age. She works roughly 37 hours per week. Buys clothes one (1) to two times per year, mostly in stores. She always checks the quality in a store before ordering clothes online. She buys for practical reasons, mainly out of necessity. She can go shopping by herself but also with friends to have a good day out. I like to try on the clothes and I like the social experience with my friends. I would definitely also buy clothes online if I could afford it. Since I cannot afford it very often, I choose to make special occasions out of the real shopping experience .

— The lone shopper, represented by Jacob, university student, 23 years of age. Jacob works as a weekend waiter and buys clothes in stores and online. He usually goes for offers and mainly shops alone as he finds it a bit boring. I mostly need functional clothing and in the end it is me who should feel comfortable wearing the clothes. Others should not decide what clothes I should wear.

— The social shopper, represented by Tina, senior college student, 20 years of age. Tina works one or two days per month in a bookstore. She lives with her parents and prefers to buy clothes in stores and often with her friends. She uses 1000 DKK per month on clothes (on average). She looks for the brands and good offers when shopping. Tina shops on average 12-20 times per year and often this is combined with a day with her friends. It is just one of those things that is more fun to do together with friends combined with café-visits.

— The spoiling-mom shopper, represented by Linda, who is a physiotherapist running own clinic, 44 years of age. Linda works roughly 37 hours per week having two children. She most often buys clothes for others than for herself. When she buys clothes for herself, it is moslty for practical reasons. Linda enjoys buying clothes in offline shops, but occasionally purchases via online resources. When buying for others, she is very aware of fashion and trends. When I buy clothes for others, I do so because I see a style in the stores which I think would fit the person, then the price doesn't matter that much.

All surveys and demonstrations were conducted in Denmark's major cities of Copenhagen and Aarhus. Participants were predominantly Danish and it was evident in demographic analysis that answers were specific to online purchasing of apparel and predicted benefit of end-users. The personas generated from the surveys' demographic influences are published in [6].

These personas were developed to aid the design phase and to assist the technical partners constructing the VDR prototype. The clothing industry uses such personas, but in a more generic form, to assess "body types" and population sizing and trends to determine anthropometric variability. This is exemplified in the next section.

This study included video observations, questionnaires and a focus group (n=31; females n=20). Furthermore, observations of consumer shopping behavior was conducted in combinations with focus group interviews with females 18-35 years of age (n=7), expert interviews (sales staff) (n=3), and document analysis (magazines, shopping forums, statistics, industry reports) [6].

Additional field studies followed including another at the Bella Centre, Copenhagen, including 426 participants. They were selected randomly at the location, where each participant could choose to try either the above-mentioned *LazyLazy* system, the first version of the VDR prototype, or both depending on how long time and personal interest that the participants had. The sample had an age range from 2 to 69 years of age and covered both genders (66% were male and 34% were female).

Of the 426 participants, 103 filled out a questionnaire afterwards. Of the participants, only 8% have had experience with similar system (the remaining 92% had never tried it before). 43% of all the participants only tried the LazyLazy system, 18% only tried the new VDR system, and the remaining 39% tried both systems. For the comparative analysis as a whole, only these 39% were included. In relation to the questionnaires, this means that 22 of the 103 are included in this particular field study (for more detailed information about the study [7]). Following, a low fidelity prototyping session was used in order to get useful design feedback from students attending a local university in Denmark. In addition, a study with autistic participants that considered the VDR as a privacy and safety tool when purchasing online was conducted [8].

One outcome from the cumulated studies to date is the need for an improved means for wheelchair customers (and others with special needs) to purchase clothing online. This is seen as a next- iteration in a follow-up to the VDR. In addition to this, our VDR project future work includes exploring potentials of a real-time 3D stereoscopic glasses-free solution using state of the art monitors and custom mounted camera arrays [39]. However, this is refrained from inclusion, as it is not the focus of this paper.

VI. Measuring Bodies For Apparel

Traditional measuring of a human body prior to purchasing clothing is via use of a tape measure by a trained professional tailor/salesperson. Increasingly technology is being used to scan a body to accurately measure with possibly a higher precision.

A database has been constructed using traditional (1-D) anthropometric measurements that were done with a tape measure and caliper alongside measurements using state-of-the-art scanning technology to provide an archive of accurate population size information for those designing new clothing lines. Such data is critical to create better and more cost effective products. The database is titled the *Civilian American and European Surface Anthropometry Resource Project—CAESAR®*[12].

CAESAR® contains anthropometric variability across the age ranges 18-65 with arrays of weight, height, ethnicity, gender, geographic regions, and socio-economic status. The data was collected between April 1998 to early in 2000 using a new technique called Three Dimensional (3D) Surface Anthropometry which collects hundreds of thousands of points in three dimensions on the human body surface in just a few seconds. Three scans were collected from each person in a standing pose, in a full-coverage pose, and in a relaxed seating pose. Advantages of this technique include that it provides precise details about the surface shape as well as 3D locations of measurements relative to each other and enables easy transfer to Computer-Aided Design (CAD) or Manufacturing (CAM) tools. 3-D Scanning optimizes the sizing of products for improving fit to the wide variations in human body shape and sizes improving averages and percentiles to fit the target audience.

Given that the techniques available when the study was undertaken (1998-2000) were primitive compared to what is currently available one can expect an updated anthropometric variability population measure that utilizes the tools as presented in this paper in the Industry Trend Spotting (section III).

Whilst the purpose of VDR was not to achieve an accurate measurement but rather to reduce returns of apparel via an improved Online shopping experience, the authors believe it important to inform readers the innate complexities of the industry from a wider perspective to illustrate the collaboration and technologies involved in realizing such systems. It is also considered how existing scanning techniques could be utilized to offer an all-encompassing solution of accurate measurements and improved experiencing of the "trying on" occurrence such as proposed in the 2003 concept "Online Clothing Store" [9], and, from 2011, the "3D Web-Based Virtual Try On of Physically Simulated Clothes" [10, 11].

However, a major challenge in achieving an improved customer experience is the response of the overlay animated clothing image to the mirrored customer real-world physical movements. Such a challenge has been subject of many publications and a distinct focus of a Switzerland-based laboratory for virtual clothing titled MIRALab. The research at this lab developed the MIRACloth system, which is briefly introduced next.

VII. Cloth-Based Research & Innovation

Cloth modeling has been a topic of research in the textile mechanics and engineering communities for a very long time. How to enable a digitally-based system to give a suitable representation upon which garment decision purchases are based is a challenge. It is as important to the end-user customer who are wheelchair-bound as non-wheelchair-bound.

In the mid 1980s, researchers in computer graphics also became interested in modeling cloth in order to include it in the 3D computer generated images and films. The evolution of cloth modeling and garment simulation in computer graphics indicates that it has grown from basic shape modeling to the modeling of its complex physics and behaviours. In computer graphics, only the macroscopic properties of the cloth surface are considered. Physical accuracy is given less importance in comparison to the visual realism. However, a trend of employing a multidisciplinary approach has started, and the communities of textile engineering and computer graphics have begun to combine their expertise to come up with solutions that can satisfy that of both communities. MIRACloth, a system developed at MIRALab can be used for building and animating the garments on virtual actors. It is a general animation framework where different types of animation can be associated with the different objects - static, rigid, and deformable (key frame, mechanical simulation).

The methodology for building garments relies on the traditional garment design in real-life. The 2D patterns are created through a polygon editor, which are then taken to the 3D simulator and placed around the body of a virtual actor. The process of seaming brings the patterns together and the garment can then be animated with a moving virtual actor. For the purpose of this paper this brief description suffices, however, for the reader that wishes a more in-depth knowledge the following may be of use. The Research history [12]; CAD use in the field [13, 14, 15, 16]; Challenges of animating cloth to give a realistic simulation include the following keywords with related suggested references (1) Nonlinear Tensile Stiffness [17; 18]; (2) Haptic Feeling of fabric [19, 20, 21, 22, 23]; (3) Adaptive Damping [24]; (4) Collision Detection and deformation between bodies and fabrics [25, 26, 27, 28, 29, 30]; (5) Thread Texture [31]; (6) Physical dynamics [32] [33, 34]; (7) Human subjective evaluation [35]; and a reflection overall on methods [36, 37].

VIII. Conclusions (Wheelchair-bound Focus)

The open-structured surveys received wide-ranging input from the public attending the live demonstrations at Malls and Messe events. 13 wheelchair-bound individuals gave direct input as well as others who were either friends or associated with a wheelchair-bound person that they considered would benefit from a dedicated adaptation of the product. This included healthcare professionals (therapists, carers, and others), healthcare students, and salespeople from other stands at the Messe events (i.e. Scandinavian Health & Rehab). Statistic relevance in this work (i.e. how many said what) is not considered as a qualitative / subjective approach was central to ascertain a general opinion on benefit potentials upon testing and being presented with the current solutions available.

To address all sizes of customer as well as children the camera had to "find" the person and that person had to stand at a distance to be able to view the whole body, especially when purchasing trousers or shoes. Yet that distance had to be close enough to allow the person an operable view of the interface control detail.

[12] http://www.shapeanalysis.com/CAESAR.htm

The production suffered problematic cooperation, coordination, communication, and collaboration that prevented early product. The technical teams did not reach the targeted outcome as planned within the planned time frame. However, a change of leadership has resulted in a product delivery and this process and outcome is published elsewhere to inform others on shortcomings. This work-in-progress manuscript report wished to move beyond the negatives, and instead focus on the positive outcomes and future adaptations.

In line with related work, the first generation Kinect was installed into the VDR system according to its means of sourcing a whole body skeleton from its camera's field of view to supplement the segmentation of a person from an environment and then offering such data for mapping algorithms (figure 2). To do this the Kinect required an erect full body skeleton of head, upper and lower limbs, and torso to be 'seen' in the camera's field of view. This 'homo erectus' expectation made *impossible* the possibility of testing the VDR with wheelchair users. However, recent advances in the field enable a sitting pose to be 'seen' and processed by the sensor software to enable a mapping of a person who is wheelchair-bound.

A conclusion of this paper is that specific requirements as stated by the wheelchair-bound survey responders is that a user-friendly easily adapted tool is required to enable customization to an individual's need and situation for online apparel trying on and purchasing to be accessible to all – especially those who are handicapped by physical dressing rooms that are undersized due to the need for maximum profit from sales-floor space. In other words a home-based solution as well as a high street shopping store solution (enhanced with Virtual interaction or not) is a required need so that accessibility is considered more than getting people through the front door (i.e. ramps as well as steps; automatic openings; etc.) Thus, alongside realizing such accessible change spaces in the VDR future work, the importance of informing retailers of the need – even if it means loosing some sales rack space – is essential. This manuscript is thus disseminated at an early stage of the adaptive work with an aim to contribute at a more social cultural level.

In closing it is important to state that we are aware of the generalization (possibly too general for some readers) that may be taken from the perceived ease of use (PEOU) and perceived usefulness (PU) toward enhancement and reduced effort of an online apparel purchasing system that were seen as key factors for wheelchair-bound consumers. However, in our defense this is data that is considered too detailed for a short paper that covers a work-in-progress. Suffice to say that in reporting beyond this generalization and to identify and state each variance and inflection of the wheelchair-bound and related others (see section above) was considered at a micro-data level and thus, for the purpose of this report in context of an international conference sufficient for a work-in-progress. In line with this, as a work-in-progress we are aware that some may consider we confuse participatory design with user-centered design approaches. However, discipline definitions differ according to context and approaches and as stated this is not a CSCW as some may interpret. Results are purposefully qualitative and preliminary, but are considered interesting and reasonable steps toward further work. In line with this, the latest VDR is currently being tested at the Danish university labs where the authors are based.

The VDR is designed as a single-user application (in first-person) with collaborative potentials to include the sharing of images over smart phone personal networks for advised purchasing – a friend/family input (i.e. social shopping). It is not a definitive 'groupware' body of work such that the CSCW-oriented participatory design methodology model is not adhered to but rather a social-cultural model is used. In line with this and 'Interactive Design' approach was undertaken and the technique of personas development was implemented from numerous survey studies of public-responses to the concept. However, as pointed out in [38] (p. 92) it is an important aspect of the VDR to consider that - "The single-user application does not train us to consider users of the same product who have a crucial but entirely different engagement with it". The Kinect requires specific pose and gesture that may be tiresome for those with special needs and limited endurance and strength. Thus, for the wheelchair-bound use an adaptive approach in taken to the next phase of the product design to accommodate use. In line with this, alternative worn controllers to Kinect are being explored, for example MYO[13], as well as located local to person position such as a simple keypad/mouse/joystick arrangement or gesture controllers such as the Leap Motion[14], 3Gear System[15].

Acknowledgments

The Danish National Advanced Technology Foundation and VDR partners; Microsoft Denmark; Virtual Lab ApS; Commentor: Thanks. Additional thanks to collaborative companies in Denmark: Lazy-Lazy; Dressman, Bruuns Galleri, Aarhus and The Health & Rehab Scandinavia – Bella Center Copenhagen, for stand sponsorship used in VDR testing.

References

[1] E. Brandt, "Designing Exploratory Design Games. A Framework for Participation in Participatory Design," proceedings of Participatory Design Conference, ACM, pp. 57-66, 2006.

[2] J. Buur, and S. Bødker, "From Usability Lab to Design Collaboratorium: Reframing Usability Practice," proceedings of DISoo: Designing Interactive Systems: Processes, Practices, Methods, & Techniques, pp. 297-307, 2000.

[3] J. Buur, V. M. Jensen, and T. Djajadiningrat, "Hands-only Scenarios and Video Action Walls; Novel Methods for Tangilble User Interaction Design," proceedings of DIS04: Designing Interactive Systems: Processes, Practices, Methods, & Techniques, pp. 185-192, 2004.

[4] J. M. Muller, "Participatory Design: The Third Space in HCI," proceedigns of the Participatory Design Conference, pp. 147-155, 2000.

[5] M. C. Seifert, E. D. Meyer, N. Davidson, L. A. Patalano, and I. Yaniv, "Demystification of Cognitive Insight: Opportunistic Assimilation and the Prepared-Mind Persopective," in R. J. Sternberg, and J. E. Davidson, (Eds.), The Nature of Insight. Cambridge: The MIT Press, 1995.

[6] K. Kristensen, N. Borum, L. G. Christensen, H. Jepsen, J. Lam, A. L. Brooks, and E. Petersson Brooks, "Towards a Next Generation Universally Accessible 'Online Shopping-for-Apparel' System,"

[13] https://www.thalmic.com/en/myo/
[14] https://www.leapmotion.com
[15] http://www.threegear.com

Human-Computer Interaction. Users and Contexts of Use, Lecture Notes in Computer Science, Springer Volume 8006, pp 418-427, 2013.

[7] Y. Gao, and E. Petersson Brooks, "Designing Ludic Engagement in an Interactive Virtual Dressing Room System – A Comparative Study. In Design, User Experience and Usability User Experience," in M. Aaron, (Ed.), Novel Technological Environments. Second International Conference, DUXU 2013, HCI International 2013, Las Vegas, NV, USA. Proceedings, Part III, Book Part IV, Lecture Notes in Computer Science, 8014, pp. 504-512. Berlin Heidelberg: Springer, 2013.

[8] L. G. Christiansen, T. Rosenørn, and E. Petersson Brooks, "A Virtual Dressing Room for People with Asperber's Syndrome: A Usability Study to Realize Design Goals," "in press" HCI International 2014, Creete, Greece, 2014.

[9] F. Cordier, H. Seo, and N. Magnenat-Thalmann, "Made-to-Measure Technologies for Online Clothing Store," IEEE Computer Graphics and Applications, IEEE Publisher, pp. 38-48, January 2003.

[10] N. Magnenat-Thalmann, B. Kevelham, P. Volino, M. Kasap, and E. Lyard, "3D Web-Based Virtual Try On of Physically Simulated Clothes," Computer-Aided Design & Applications, Vol. 8, No. 2, pp. 163-174, 2011.

[11] N. Magnenat-Thalmann, P. Volino, B. Kevelham, M. Kasap, Q. Tran, M. Arevalo, G. Priya, and N. Cadi, "An Interactive Virtual Try On," Proceedings of IEEE Virtual Reality Conference (VR), 2011, pp. 263-264, March 2011.

[12] N. Magnenat-Thalmann, and P. Volino, "From early draping to haute couture models: 20 years of research," The Visual Computer, Springer, Vol. 21, No. 8, pp. 506–519, October 2005.

[13] P. Volino, and N. Magnenat-Thalmann, "Accurate Garment Prototyping and Simulation," Computer-Aided Design & Applications, CAD Solutions, Vol. 2, No. 5, pp. 645-654, 2005.

[14] F. Cordier, and N. Magnenat-Thalmann, "A Data-Driven Approach for Real-Time Clothes Simulation," Computer Graphics Forum, Vol. 24, No. 2, pp. 173-183, 2005.

[15] N. Magnenat-Thalmann, P. Volino, and L. Moccozet, "Designing and Simulating Clothes," International Journal of Image and Graphics (IJIG), World Scientific Press, Vol. 1, No. 1, pp. 1-17, January 2001.

[16] P. Volino, F. Dellas, T. Di Giacomo, and N. Magnenat-Thalmann, "Integrated Platform for Networked and User-Oriented Virtual Clothing," Encyclopedia on Multimedia Technology and Networking, Idea-Group Reference, M. Pagani (ed.), pp. 424-428, April 2005

[17] P. Volino, N. Magnenat-Thalmann, and F. Faure, "A Simple Approach to Nonlinear Tensile Stiffness for Accurate Cloth Simulation," ACM Transactions on Graphics, ACM, 28, 4, pp. 105-116, August 2009.

[18] P. Volino, N. Magnenat-Thalmann, and F. Faure, "A simple approach to non linear tensile stiffness for accurate cloth simulation," SIGGRAPH 2010, ACM Transactions on Graphics, 28, 4, pp. 105-116, August 2010.

[19] P. Volino, P. Davy, U. Bonanni, C. Luible, N. Magnenat-Thalmann, M. Mäkinen, and H. Meinander, "From Measured Physical Parameters to the Haptic Feeling of Fabric," The Visual Computer, Springer, Vol. 23, No. 2, pp. 133-142, February 2007.

[20] N. Magnenat-Thalmann, P. Volino, U. Bonanni, I. R. Summers, M. Bergamasco, F. Salsedo, and F. E. Wolter, "From physics-based simulation to the touching of textiles: The HAPTEX Project," The International Journal of Virtual Reality, IPI Press, vol. 6, no. 3, pp. 35-44, September 2007.

[21] N. Magnenat-Thalmann, and U. Bonanni, "Haptic sensing of virtual textiles," in Human Haptic Perception - Basics and Applications, Springer Berlin / Heidelberg.

[22] P. Volino, P. Davy, U. Bonanni, N. Magnenat-Thalmann, G. Böttcher, D. Allerkamp, and F. E. Wolter, "From measured physical parameters to the haptic feeling of fabric," Proc. of the Workshop on Haptic and Tactile Perception of Deformable Objects (HAPTEX'05), pp. 17-29, December 2005.

[23] F. Salsedo, M. Fontana, F. Tarri, E. Ruffaldi, M. Bergamasco N. Magnenat-Thalmann, P. Volino, U. Bonanni A. Brady, I. Summers, J. Qu, D. Allerkamp, G. Böttcher, F. E. Wolter, M. Makinen, and H. Meinander, "Architectural Design of the Haptex System," Proc. of the Workshop on Haptic and Tactile Perception of Deformable Objects, Hanover (HAPTEX'05), pp. 1-7, December 2005.

[24] P. Volino, and N. Magnenat-Thalmann, "Implicit Midpoint Integration and Adaptive Damping for Efficient Cloth Simulation," Computer Animation and Virtual Worlds, John Wiley and Sons, Vol. 16, No. 3-4, pp. 163-175, October 2005.

[25] M. Teschner, S. Kimmerle, B. Heidelberger, G. Zachmann, L. Raghupathi, A. Fuhrmann, M. P. Cani, F. Faure, N. Magnenat-Thalmann, W. Strasser, and P. Volino, "Collision Detection for Deformable Objects," Computer Graphics Forum, Blackwell Publishing, Vol. 24, No. 1, pp. 61-81, March 2005.

[26] F. Cordier, and N. Magnenat-Thalmann, "Real-Time Animation of Dressed Virtual Humans," Computer Graphics Forum, Blackwell Publishing, Vol. 21, No. 3, pp. 327-336, September 2002.

[27] F. Cordier, P. Volino, and N. Magnenat-Thalmann, "Integrating deformations between bodies and clothes," Journal of Visualization and Computer Animation, Vol. 12, No. 1, pp. 45-53, 2001.

[28] P. Volino, N. Magnenat-Thalmann, S. Jianhua, and D. Thalmann, "The Evolution of a 3D System for Simulating Deformable Clothes on Virtual Actors," IEEE Computer Graphics and Applications, IEEE, Vol. 16, No. 5, pp. 42-51, September 1996.

[29] N. Magnenat-Thalmann, U. Bonanni, P. Volino and L. Assassi, "Hair, Cloth and Soft Tissues: The Influence of Mechanical Properties on the Real-Time Dynamics of Deformable Objects," Proc. of the 6th Workshop on Virtual Reality Interaction and Physical Simulation (VRIPHYS 2009), The Eurographics Association, 2009.

[30] P. Volino, and N. Magnenat-Thalmann, "Interactive Cloth Simulation: Problems and Solutions," Virtual Worlds on the Internet, IEEE, pp. 175-192, 1998.

[31] N. Adabala, and N. Magnenat-Thalmann, "A Procedural Thread Texture Model," Journal of Graphics Tools, A. K. Peters Ltd., Vol. 8, No. 3, pp. 33-40, April 2003.

[32] C. Luible, and N. Magnenat-Thalmann, "The simulation of cloth using accurate physical parameters," CGIM 2008, Insbruck, Austria, 2008.

[33] C. Luible, and N. Magnenat-Thalmann, "Suitability of standard fabric characterization experiments for the use in virtual simulations," Proceedings of the AUTEX confer-ence 2007, June 2007.

[34] N. Magnenat-Thalmann, P. Volino, U. Bonanni, I.R. Summers, A. C. Brady, J. Qu, D. Allerkamp, M. Fontana, F. Tarri, F. Salsedo, and M. Bergamasco, "Haptic Simulation, Perception and Manipulation of Deformable Objects," Proc. of EUROGRAPHICS '07 (Tutorial Notes), Eurographics Association, vol. 26, pp. 1-24, September 2007.

[35] C. Luible, M. Varheenmaa, N. Magnenat-Thalmann, and H. Meinander. "Subjective fabric evaluation," Proceedings of the Haptex 07 workshop, pp. 285-291, October 2007.

[36] N. Magnenat-Thalmann, "Making 3D Clothes for Synthetic Actors," in Interacting with Images, J. Vince and L. MacDonalds (eds.), John Wiley and Sons, 1993.

[37] N. Magnenat-Thalmann, and Y. Yang, "A Survey on Cloth Animation Methods," in New Trends in Animation and Visualization, John Wiley and Sons, 1990.

[38] J. Grudin, "Why CSCW Applications Fail: Problems in the Design and Evaluation of Organizational Interfaces," Proc. CSCW (ACM*)* 1988.

[39] Y. Gao. E. Petersson, and A.L. Brooks, "The Performance of Self in the Context of Shopping in a Virtual Dressing Room System," "in press" HCI International 2014, 22-27 June, Creta Maris, Heraklion, Crete, Greece, 2014.