

The Virtual Dressing Room: A Perspective on Recent Developments

Michael B. Holte

Department of Architecture, Design and Media Technology
Aalborg University, Esbjerg, Denmark
mbh@create.aau.dk

Abstract. This paper presents a review of recent developments and future perspectives, addressing the problem of creating a virtual dressing room. First, we review the current state-of-the-art of existing solutions and discuss their applicability and limitations. We categorize the existing solutions into three kinds: (1) virtual real-time 2D image/video techniques, where the consumer gets to superimpose the clothes on their real-time video to visualize themselves wearing the clothes. (2) 2D and 3D mannequins, where a web-application uses the body measurements provided by the customer, to superimpose the standard sizes to fit a customized 2D or 3D mannequin before buying. (3) 3D camera and laser technologies which acquire 3D information of the customer, enabling estimation of the body shape and measurements. Additionally, we conduct user studies to investigate the user behavior when buying clothes and their demands to a virtual dressing room.

Keywords: Human-computer interaction, virtual reality, augmented reality, user interface design, computer graphics, interaction design, review, survey, clothing industry, 3D imaging, and 3D scanning.

1 Introduction

Today people are increasingly shopping online; most of them are satisfied buying certain types of goods online like books, electronics, tickets etc. However, when it comes to buying clothes online, they are not entirely satisfied [1]. Many people choose not to shop online due to privacy (e.g., sharing body measurements) and security issues [2]. Online shopping has undergone many changes in the past decade; the sellers are always pushing the boundaries to provide the ultimate shopping experience for the consumers. From online cataloguing of products (amazon.com) to live online shopping assistants (3LiveShop, Sweden), the industry has made many innovations in the delivery models. Products like books and electronics, given the nature of the values that they provide the consumers, serves appropriate for the see-click-buy online shopping protocol. However, shopping for clothes online raises some challenges.

A report shows that there is approximately a 25% return rate of the ordered goods in the online clothing industry in Denmark. The reason for the returns at this moment can be speculated as, the clothes do not fit the customers properly or the customers simply

dislike the cloth when they actually wear it. As a result, there is an increase in the costs for the online retailers and dissatisfaction among the consumers. Apparently, the consumers are looking for more reliable solutions for buying clothes online. The industry is beginning to recognize that new technologies like virtual-reality and 3D camera-based systems have great potential to solve this problem. Hence, the virtual dressing room (see Fig. 1) addresses this problem by enabling the consumers to, e.g., try on the virtual version of the clothes on their virtual 3D avatar/profile before buying the real clothes, from the convenience of their home computers, TV or hand-held devices.

The advantages of using a virtual dressing room from your home/office are several: reducing the proportion of returned items; competitive advantages since the customer can try the clothes by using the application from the web shop before buying and then reduce risk in the buying process; increased opportunities for customization - the customer are able to create their own customized clothes; customers can easily record and upload a video showing them with different clothes on social medias to have their friends opinions; the possibility to make different visualizations/augmented reality, e.g., if you try a bikini, the background can be changed to a sunny beach, so you are able to see the clothes in the situations you actually use it. In addition, installing a virtual dressing room physically in a retail store can have the following advantages: faster trying of different clothes, reducing queues to the dressing rooms; reducing inventory (the need for having a lot of garments in different colors and designs in the store); after you have found a piece of cloth using the virtual dressing room, you are able physically to try the clothes in the store and get a feeling of the garments; generates fun and attention.

In this paper we give a review of recent developments and future perspectives, addressing the problem of creating a virtual dressing room, and discuss and compare the performance of existing solutions. First, we review the current state-of-the-art and discuss the applicability and limitations. Based on this review and discussion we explore the integration of virtual-reality technologies in a user-friendly fashion for the online clothes shopping industry, dealing with both design and technological research aspects. Next, we conduct user studies to investigate the user behavior and their demands. To this end, we discuss existing solutions and their usability based on the environment and settings: retail store, home/office web-shopping, mobile platform or for social networking.



Fig. 1. A concept sketch of a virtual dressing room

2 Existing Solutions

The industry is attempting to improve the aforementioned scenario by developing a more holistic virtual dressing room with an acceptable quality of use. The current state-of-the-art solutions can be categorized into three kinds: (1) virtual real-time 2D image/video techniques, where the consumer gets to superimpose the clothes on their real-time video to visualize themselves wearing the clothes. (2) 2D and 3D mannequins, where a web-application uses the body measurements provided by the customer, to superimpose the standard sizes to fit a customized 2D or 3D mannequin before buying. (3) 3D camera and laser technologies; these types of solutions are new to the industry, yet to prove their full benefits. In the following we look further into existing solutions in each of the three categories.

2.1 Virtual Real-Time 2D Image/Video Techniques

This set of techniques superimposes 2D graphical models of clothes on top of input image/video of the user in real-time. These 2D solutions only give a simulated impression of how the clothes might look on the customers, and are often inaccurate, failing to take into account the consumer's 3D body proportions. Furthermore, the models of the cloth are rigid and need to be adjusted in size and translated to the correct position manually. In Fig. 2 some examples images of these solutions are shown.

Metaio Inc. Business. A product where clothes are applied onto a webcam image of yourself. The clothes consist of images on the center of the screen which you can scale up and down in size to get a close as possible fit to the size (distance to the webcam) of your body. Funny, but does not show clothes in a natural and photorealistic way. Uses non-flexible garment models and is not a virtual mirror [3].

Facecake's Swivel. A virtual dressing room, where clothes are applied to a real-time image of yourself. The clothes are images shot from different angles which change to the rotation of your body. While the clothes do not fit perfectly, it does allow you to see how it looks in a more appealing way. Only uses non-flexible 2D models of clothes, and does not follow the person's curves and movements [4].

ImmediaC. A digital dressing room, where clothes are applied to a real-time image of yourself. Again, the clothes are images shot from different angles which change to the rotation of your body. While the clothes do not fit perfectly, it does allow you to see how it looks in an attractive way. Uses 3D model of clothes, however they are non-flexible, meaning that garments does not follow your curves and movements [5].

EyeMagnet. A virtual dressing room, where clothes are applied to a real-time image of yourself. The clothes are images shot from different angles which change to the rotation of your body. Again, the clothes do not fit perfectly but it does allow you to see how the clothes look in a more appealing way. Uses non-flexible 3D clothes [6].

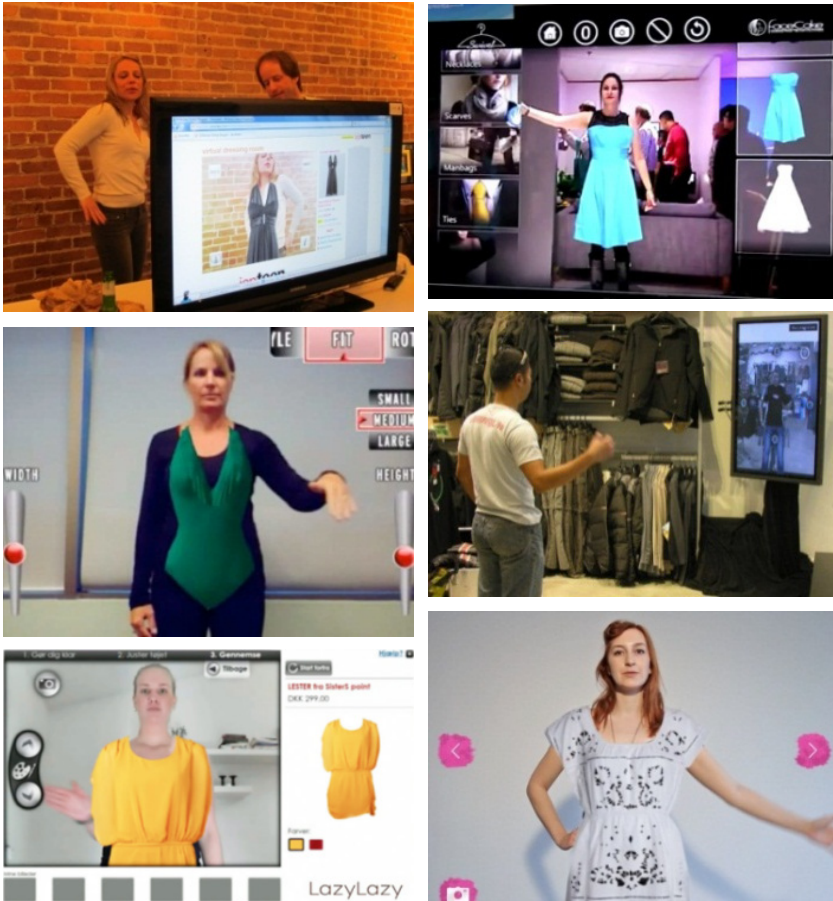


Fig. 2. Example images of the virtual real-time 2D image/video techniques, where the consumer gets to superimpose the clothes on their real-time video to visualize themselves wearing the clothes. Read row-wise: Metaio Inc. Business [3], Facecake’s Swivel [4], ImmediaC [5], EyeMagnet [6], LazyLazy [7] and Indiska’s Jade Jagger [8].

LazyLazy. A virtual dressing room, where clothes are applied to a real-time image of yourself. The clothes consist of images in the center of the screen which you can scale up and down in size to get a close as possible fit to the size (distance to the camera) of your body. Funny, but does not show clothes in a natural and photorealistic way [7].

Indiska’s Jade Jagger. Also a virtual dressing room, where clothes are applied to a real-time image of yourself. This solution uses a place holder object (a piece of paper with a certain pattern) to place the cloth on top of the costumer. Hence, it is up to the user to navigate the augmented cloth correctly on top of the input video. The need of a place holder object and manual placement is obviously not desirable [8].

2.2 2D and 3D Mannequins

This is a set of solutions where a web-application uses the body measurements provided by the customer, to superimpose the standard sizes to fit a customized 3D mannequin before buying. These solutions simply lack real-time simulation, are not virtual mirrors, and do not provide the kind of user interaction as the virtual real-time 2D image/video techniques. Fig. 3 shows some examples images of these solutions.

Fits.Me. A solution where manufactures send their clothes to the Fits.me company in Estonia. They then apply the clothes to a shape shifting mannequin and take pictures of each shape. All these photos are then stored in a database and used in their online application, and the closest fit is shown to the user when they input their measurements [9].

My Virtual Model. A gaming/social network solution where 3D clothes are generated by the user base and applied to a generic female 3D mannequin, which can be altered in shape and look by the user. The model can be rotated so it is in theory similar to how you see a mannequin in a store. Funny, but does not show clothes in a natural and photorealistic way [10].

Upcloud. A webcam-based solution for body measurement. This is not really an interactive virtual dressing room, but serves solely for measuring the proportions of the costumer. The body measures are store and used for determining the size of the clothes when shopping online [11].

HM Virtual Dress Room. A gadget solution with a dull that you can dress up with a few different garments that look like some of the HM models. This is solely a 2D photo-based dressing room with no inputs related to the look of the costumer [12].

2.3 3D Camera and Laser Technologies

These solutions use 3D/range cameras or lasers to acquire 3D information of the costumer, enabling estimation of the body shape and measurements (see Fig. 3).

Bodymetrics. One such solution is Bodymetrics, which uses a rig setup of multiple Microsoft Kinect sensors to measure the user's body proportions, followed by an expert in the shop floor guiding the buyer with the fitting. This is a costly and time consuming process. Hence, this is not a real-time interactive virtual dressing room, but serves solely for measuring the proportions of the costumer [13].

Fitnect. A solution similar to the virtual real-time 2D image/video techniques, however, instead of standard image/video input, the Microsoft Kinect sensor is used to

acquire input video and depth/3D information of the user. The additional 3D information of the body facilitates automatic fitting of the cloth to the body, which follows your movements. The clothes are flexible but do not fit the body shape and follow your movements accurately. The garments look alright but not photorealistic [14].

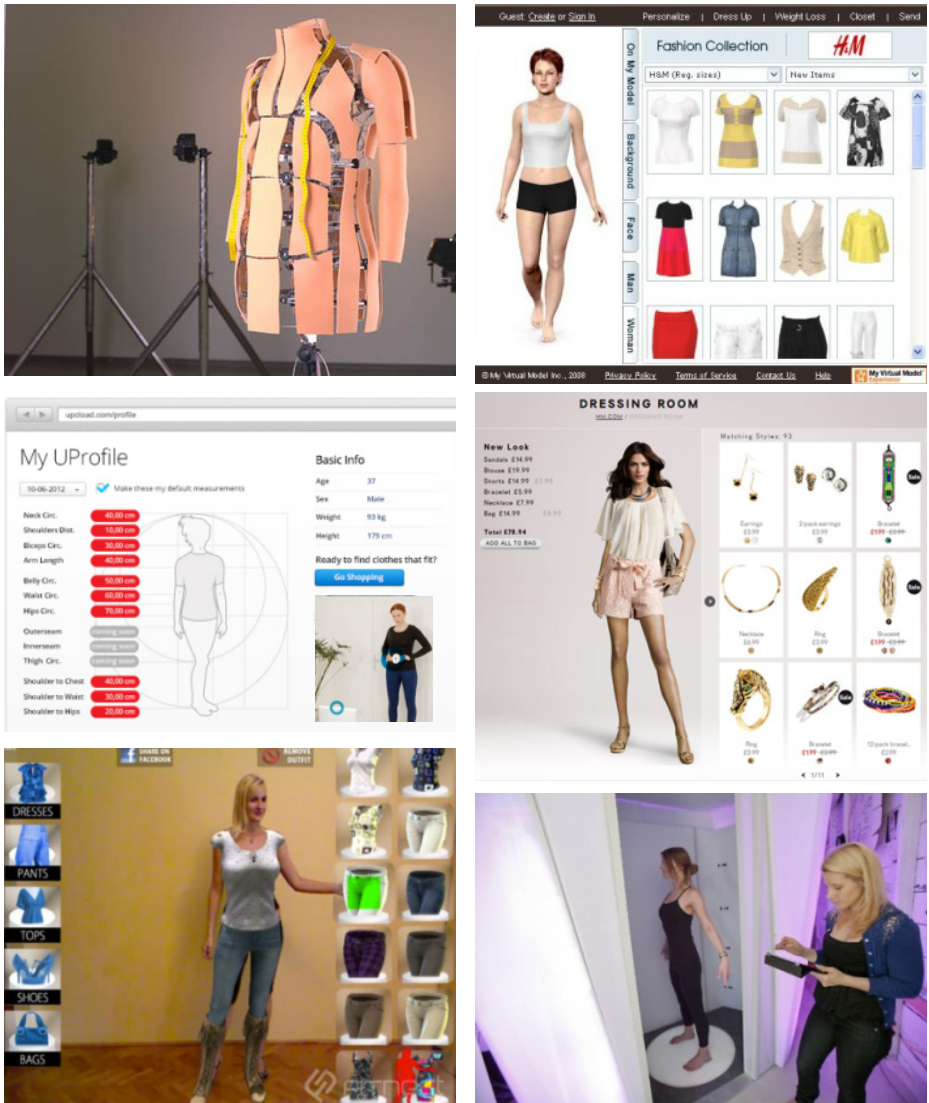


Fig. 3. Example images of 2D and 3D mannequins, and 3D camera and laser technologies. These solutions let the costumer dress up 2D or 3D mannequins for better visualization of the clothes and how it matches. In addition some acquire 3D information of the costumer, enabling estimation of the body shape and measurements. Read row-wise: Fits.Me [9], My Virtual Model [10], Upcloud [11], HM Virtual Dress Room [12], Fitnect [14] and Bodymetrics [13].

In Table 1 some significant characteristics, limitations and usability of the exiting virtual dressing room solutions are listed for an easy comparison. Note that the usability of the different systems varies, hence, some systems are applicable for retail stores, home/office, mobile platforms and/or social networking. Commonly for the virtual real-time 2D image/video techniques, is that they can be applied both in retail stores and at home/office, while some of the 3D mannequins and 3D camera/laser technologies are mostly applicable in retail store or similar settings. Several of the systems can be adapted to mobile platforms but only the simple web application-based solutions are so far suited for mobile usage. Additionally, some systems have utilities allowing the user to share resulting images of them wearing the virtual clothes through a social network media, e.g. Facebook.

Table 1. Significant characteristics, limitations and usability of the exiting virtual dressing room solutions.

Product	Input / Interface	Dim.	Real-time	Limitations	Usability
Metaio Inc. Business [3]	Camera Monitor	2D	Yes	Rigid models	Retail store Home/office
Facecake's Swivel [4]	Camera Monitor	2D	Yes	Rigid models	Retail store Home/office
ImmediaC [5]	Camera Monitor	2D	Yes	Rigid models	Retail store Home/office
EyeMagnet [6]	Camera Monitor	2D	Yes	Rigid models	Retail store Home/office
LazyLazy [7]	Camera Monitor	2D	Yes	Rigid models	Retail store Home/office
Indiska's Jade Jagger [8]	Camera Monitor	2D	Yes	Rigid models Requires place holder object	Retail store Home/office
Fits.Me [9]	Mechanical mannequin	3D	No	Not a virtual mirror	Retail store
My Virtual Model [10]	Web application	2D	No	Not a virtual mirror	Home/office
Upcloud [11]	Camera Monitor	2D/ 3D	No	Only for body measurements	Retail store Home/office Mobile
HM Virtual Dress Room [12]	Web application	2D	No	Not a virtual mirror	Home/office Mobile Social network
Bodymetrics [13]	Laser	3D	No	Only for body measurements	Retail store
Fitnect [14]	Kinect Monitor	3D	Yes	Inaccurate fit to body move- ments	Retail store Home/office Social network

3 User Studies

In this section we present user studies, which we have conducted to investigate the user behavior when buying clothes and the users' demands of an acceptable virtual dressing room solution.

3.1 Cloth Shopping Behavior

To study the shopping behavior of costumers, we asked 39 (14 males and 25 females) subjects within the age range of 16 - 62 years with an average age of approx. 30 years. The subjects were mainly working full-time or students with part-time jobs, and with an average income. Nearly all subjects buy clothes monthly or more often, while only a few buy clothes once or a few times a year. 95% of the subjects buy clothes in retail store, 54% from online web shops, 21% in second hand stores and 8% on flea markets (multiple selection were possible, hence, the percentages do not add up to 100%). The online shoppers prefer online web shops, since it is cheaper, faster, easier and more convenient, and have a larger selection than the retail stores. On the other hand the costumers buying clothes in retail stores prefer to see and feel the fabric and texture. Additionally, the size can vary especially for pants, dresses and suits, and they want to check the fit before buying it. Actually, 18% of the subjects check the quality in retail stores before buying it online.

The need of returning cloth bought online varies; from never to a couple of times in total, while some return cloth for nearly every time they make an order. Mostly because it does not fit, match or the appearance differs from the online version. This seems to correspond well with the fact that there is approximately 25% return rate in the online clothing industry in Denmark. In conclusion, over the half of the asked subjects buy clothes online, due to several advantages. However, there is relative high return rate of the bought cloth, due incorrect size or the cloth does not live up to the expectations. A virtual dressing room could address some of these issues by estimating the body measures of the individual and let costumer virtually try the cloth, e.g. to see if it fits or matches other pieces of clothes.

3.2 User Tests and Demands

Next, we conducted an experimental study to get feedback on how satisfied the users are with the exiting virtual dressing rooms. For this purpose we tested LazyLazy's solution, which represents the current standard of the virtual dressing room well. In this experiment 30 subjects (within the age range of 13 - 47 years with an average age of approx. 21 years) tested the virtual dressing room, and we received the following feedback. 7% though the system was very good, 43% good, 27% neutral, 17% bad and 0% very bad. Hence, the overall impression was fairly good. The system was fun, interesting and for most fairly easy to use. However, the test subjects had a lot of comments and complaints during the test. Some of the most important ones were: slow reaction/lag; the cloth does not adapt to the body shape; the graphic of the clothes is poor; not the same feeling of trying real physical cloth; you cannot feel the

fabric and how it fits your body; you cannot turn and see how the cloth looks from behind or different viewpoints; it is difficult to reach and press the correct buttons; takes some time to get used to the navigation; would be nice if the cloth moved on top of your body automatically; it is easier to move yourself than the cloth; the cloth should follow and adapt to body movements; the cloth should adjust to the correct size automatically, so you can determine your size.

Most of the subjects were not more likely to buy clothes online using this system. Mainly because the system did not help them much in the end, since they only got a poor idea of how they look wearing the cloth, due to poor graphics and rigid models of clothes. Furthermore, the navigation and reaction time were not satisfactory. In conclusion the tested virtual dressing room has to be improved significantly to become a useful tool for shopping cloth online than just a fun gadget.

4 Conclusion and Future Perspectives

In this paper we have given a review of existing virtual dressing room solutions, and conducted user studies to reveal users' cloth shopping behaviors and their demands to a virtual dressing room. Based on this review and user studies, one can conclude that none of the existing solutions have, so far, managed to develop a holistic solution with an acceptable quality of use. However, the current solutions are more fun to have gadgets than a need to have tool.

Concretely, a turnkey-solution needs to meet all the demands of (a) user satisfied interfacing, (b) accurate fitting of the virtual clothes, (c) photorealistic virtual clothing, (d) reliable and low cost, while (e) meeting real-time performance. The recent 3D camera and laser technologies, e.g. Microsoft Kinect, make it feasible to fuse the advantages of a real-time virtual video-based mirror and the estimation of 3D body measurements similar to the 3D mannequins. Combined with an improved user interface, more photorealistic graphical models of garments, and more accurate 3D fitting of virtual clothes, a turnkey virtual dressing room solution meeting the users' demands might not be far away.

Furthermore, a user-friendly buying process is much preferred among the online shoppers [15], it is also one of the biggest challenges this new interaction domain poses to the designers and developers. The online shoppers also like comparing the prices of the clothes they want to buy [16], especially due to the flexibility that the web medium provides. In order to encourage and enhance the consumers' online shopping experience, one needs innovative ideas to make the shopping a fun and more social experience [16], that can be compared to outlet shopping, which offers social interaction with shopping partners, people enjoy this.

In this work we have been focusing on the customer interface of the virtual dressing room. Another part of designing and developing a virtual dressing room is the company interface, where a major concern is how to design and produce digital clothes for the virtual dressing room. Creating digital clothes using specialized programs, e.g. Marvelous Designer [17], is a time consuming process, and it might be difficult to convince the manufactures of an investment in digital cloth.

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