71 Virtual fashion ID: a reality check

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Abstract
Virtual fashion consists of three things: virtual avatar, digital apparel design and material simulation. A virtual avatar serves as the platform upon which virtual clothing can be developed. It is very important to morph the avatars in their correct anthropometry first before initiating any virtual fashion simulation process to ensure the right appearance and drape of any virtual prototype simulated on to them. It is also a precondition for assessing the fit of virtual clothing and making decisions on the accuracy of digital pattern pieces used in simulation. Commercial fashion CAD (computer-aided design) systems come with a library of parametric mannequins and provide tools and facilities for adjusting their sizes and shapes before using them for virtual clothing simulation. This paper deals with the features and techniques of avatar morphing in available 3D systems to evaluate how realistically they can generate a virtual fashion identity (ID). A comparative study on the existing 3D (three-dimensional) CAD systems, and a case study including two in-depth interviews with industrial users of such systems were conducted. Findings show that the avatar technology has not developed evenly across all available systems and none of the systems is free from limitations. It is revealed from the case study that technophobia, high upfront cost and the need for training are the main barriers for implementing this technology. There are also certain areas for improvements within the existing systems.

Introduction

To generate a virtual fashion identity (ID), the first thing you will need from the technical point of view is an appropriate three dimensional (3D) computer-aided design (CAD) system capable of producing a virtual prototype. Based on the underlying working procedure of creating 3D designs, commercially available CAD systems for virtual garment visualisation and virtual try-on can be categorised into two broad groups (Sayem et al. 2010). One group allows designers to create garment outlines and styles on 3D platform according to their preference, such as the software TPC Parametric Pattern Generator (TPC, HK). The other group of 3D systems wrap digital two-dimensional (2D) pattern pieces from the appropriate 2D CAD software onto virtual human models in order to visualise the virtual clothing coupled with drape and fit simulation. This group includes Vstitcher from Browzwear (Israel), Accumark 3D from Gerber (USA), Modaris 3D from Lectra (France), TUKA3D from Tukatech (USA), 3D Runway from OptiTex (Israel) and Vidya from Assyst (Germany). These virtual prototyping solutions usually come with a 2D module to process 2D pattern pieces, a drape simulation engine, a set of 3D virtual avatars and a material library. Usually the integrated virtual avatars can be customised by manipulating a range of parameters including age and gender, body measurements and posture, skin tone and hairstyle, and even the stages of pregnancy. Using a physically-based simulation engine, 2D pattern pieces can be realistically wrapped on these virtual avatars to develop virtual prototypes, which represent the realistic fabric drape according to the physical and mechanical characteristics of fabric. A built-in library of fabrics and other related materials together with their mechanical characteristics is available within these systems. With accurately sized avatars and realistic fabric drape, the systems allow the evaluation of the fit of simulated garments in virtual environments; and allow the virtual designs to be communicated with any remote partner via the Internet platform. This may reduce the dependency on physical prototyping and shorten the product-development lead-time and the associated costs, as claimed by the software suppliers (Ernst 2009; Sayem et al. 2010).

Commercial fashion design and development (FDD), which involves interplay between fashion designers and manufacturers, requires a process of iterative garment prototyping that increases the resources and time taken to develop and refine garments. Operating in a truly global context, contemporary fashion supply chains involve complex offshore sourcing strategies that result in the separation of design and manufacturing operations. A disconnect between design and manufacturing results in: i) communication challenges and errors between the designer and manufacturer, and ii) iterative production and transportation of physical prototypes between manufacturers and designers. While this process is ultimately effective, it is not efficient. 3D virtual garment simulation and visualisation technologies have the potential to increase the accuracy of the communication of design data, enhance designers' creativity, and reduce the need for production of multiple garment prototypes, yet their adoption in the fashion industry is limited. No academic literature reports the reasons behind the slow and sluggish adoption of virtual simulation technology within the fashion industry (Poterfield and Lamar, 2017). This paper aims to conduct a reality check on the technical capability of the available technology to generate virtual fashion ID.

Methodology

For the fulfilment of the aim of this research, two research techniques have been implemented. One is a comparative study of the available 3D CAD systems, and the other a case study with the industrial users of such systems. The comparative study was done to identify the capabilities and weaknesses of the avatar technology within prevailing software systems. The purpose of the case study was to get an idea about the stakeholder perception and needs of this technology. Further details of the comparative study and the case study are presented in the following two sub-sections.

Comparative study of 3D systems

Four commercially available CAD systems, hereafter mentioned as CAD system A, B, C & D, were selected to investigate into their tools and features of avatar morphing and fit analysis. Their compatibility with the standard body measurement tables (see Table 1) from academic textbooks (Aldrich, 2012, 2015) and the body measurements extracted from two sample body scans (one male and one female), as can be seen in Figure 1, in KX-16 bodyscanning system (TC^2, USA) according to the SizeUK measurement extraction protocol (MEP) were tested. One male and one female avatar representing the anthropometry of a young man and woman were selected from the mannequin library of each CAD system to review each of them individually, and to compare with each other.

Table 1 Standard body measurements of young man and woman

#	**Measurements of young man (Aldrich, 2012)**		**Measurements of young woman (Aldrich, 2015)**	
	Parameters	*Measurement (cm)*	*Parameters*	*Measurement (cm)*
1	Height	173	Height	160
2	Chest	96	Bust	88
3	Seat	98	Waist	72
4	Waist	82	Low waist (5 cm below natural waist)	82
5	Trouser waist (4-6cm below waist)	86	Hips	96
6	Half back	19.5	Back width	34.4
7	Back neck to waist	43.8	Chest	32.4
8	Scye depth	23.6	Shoulder	12.25
9	Neck size	39	Neck size	37
10	Sleeve length one piece sleeve	64.2	Top arm	28.4
11	Sleeve length two piece sleeve	81	Wrist	16
12	Inside leg	79	Ankle	24
13	Body rise	27.8	High ankle	21
14	Close wrist measurement	17.4	Nape to waist	41
15			Front shoulder to waist	41
16			Armscye depth	21
17			Waist to knee	58.5
18			Waist to hip	20.6
19			Waist to floor	104
20			Body rise	28

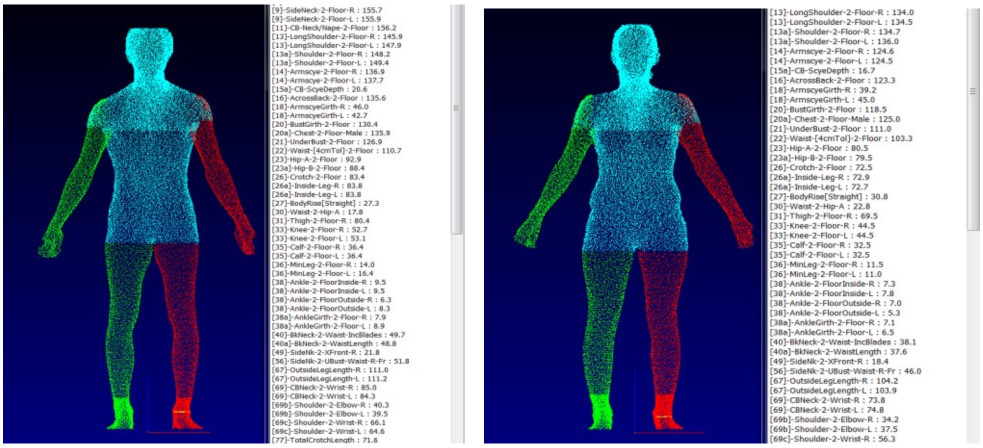

Fig. 1 Male and female bodyscans and part of extracted measurements

Fit analysis tools within the CAD systems were tested using the pre-drafted pattern pieces. Tension mapping tools available in the systems were also evaluated.

Case study with a fashion company

As mentioned earlier, a case study was conducted on the technical design team of a UK-based multinational fashion retailer having more than 2,000 stores across the UK and sourcing clothing items from more than 10 countries in the world. Purposive sampling technique was followed to identify the fashion company, which is using both 2D and 3D clothing CAD systems in their product development process. As a part of this case study, two semi-structured in-depth interviews were conducted with two technical designers of this chosen company to collect data as a part of this case study. Both participants are frequent users of 2D/3D CAD systems but they represent two different generations. One is at the early stage of their career with less than three years of professional experience, while the other is at mid-level position of the hierarchy having more than twenty years of professional experience. Both closed and open-ended questions were asked to understand their perception of virtual fashion technology and their needs from the technology. The interviews were audio recorded and transcribed anonymously following the research ethics policy of our university. A thematic analysis (Morris, 2015; King and Horrocks, 2019) of the interview data was done for synthesising the findings. It is noted that one case study including two interviews is not deemed sufficient for reaching any firm conclusions. Therefore, the research is being continued. However, this is being presented here as an initial finding from an on-going research.

Results & discussion

Findings from the comparative study

i) Avatar Morphing

The CAD systems analysed in this research differ significantly from each other in numbers of anthropometric parameters they use for avatar morphing. As can be seen in Table 2 and Figure 2, systems A and B use more than sixty parameters for adjusting the size and shape of a male avatar, while C and D use thirty or less. Similarly in case of the female avatar, systems A and B use more than a hundred parameters, whereas C and D use forty or less (see Table 3 and Figure 3). In most cases, systems A, B and C allow direct input of numerical measurements as well as sliding-bar option. However, system D allows only sliding-bar option to adjust measurement, but no direct input. In general, direct measurement input was experienced as more accurate for avatar morphing. However, it has been experienced that none of the systems provided absolute freedom to adjust all avatar-morphing criteria to reproduce the target anthropometry completely. Tables 4 highlights the interconnected measurements, which are influenced by the change of others. This is a big challenge in accurate avatar morphing.

Table 2: Morphing categories and anthropometric parameters of male avatars

Morphing Category/Segment	Number of Parameters for Male Avatar			
	A	**B**	**C**	**D**
Height	2	2	1	1
Body silhouette & shape	15	15	6	8
Torso length	9	2	4	3
Torso width	3	1	2	0
Torso circumference	7	5	5	4
Arms (lengths & circumference)	5	6	4	1
Legs (lengths & circumference)	9	8	7	2
Pose	13	24	9	0
Face	0	2	0	0
Total =	**63**	**65**	**39**	**19**
i) How many accept direct measurement input?	*33*	*39*	*2*	*0*
ii) How many need sliding-bar adjustment only?	*30*	*16*	*30*	*19*
ii) How many offer both i & ii options	*33*	***39***	*30*	*0*

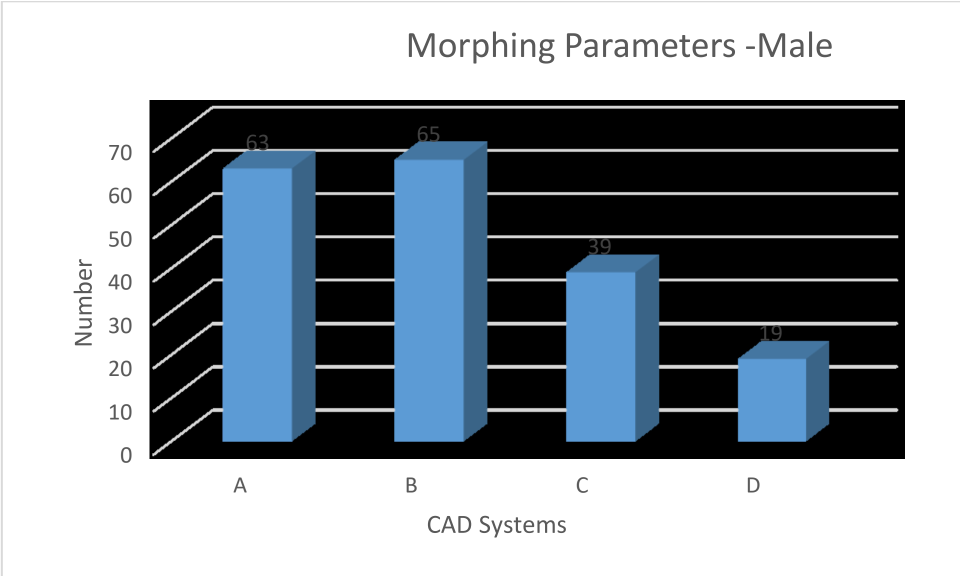

Fig. 2 Anthropometric parameters used by different CAD systems for morphing a male avatar

Table 3 Morphing categories and anthropometric parameters of female avatar

Morphing Category/Segment	Number of Parameters for Female Avatar			
	A	B	C	D
Height	2	2	1	1
Body silhouette	19	29	6	7
Torso length	11	2	5	5
Torso width	3	1	2	0
Bust	13	1	2	2
Torso circumference	8	6	6	4
Arms	6	7	4	1
Legs	13	9	7	1
Pose	12	27	9	0
Face	14	30	1	0
Total =	**101**	**114**	**42**	**20**
i) How many accept measurement input?	47	68	32	0
ii) How many need sliding-bar adjustment?	54	46	34	20
iii) How many offer both i & ii options	47	68	32	0

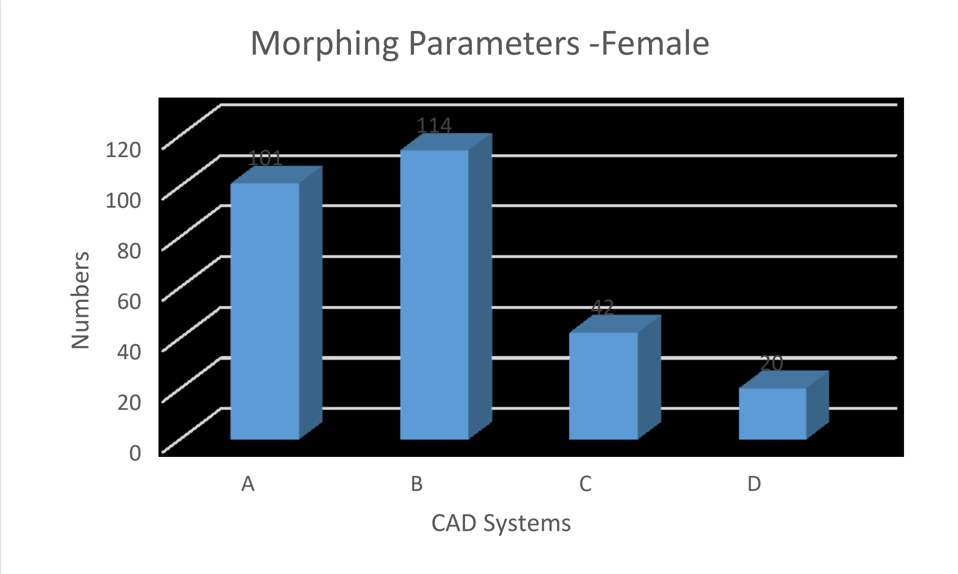

Fig. 3 Anthropometric parameters used by different CAD systems for morphing a female avatar

Table 4 Interconnected measurement parameters of male and female avatars

CAD Systems	Interconnected Parameters in Male Avatars		Interconnected Parameters in Female Avatars
A	- Chest and under-chest - Outseam, hip height, high-hip height and waist to hip (in case of mannual imput) - Biceps and upper biceps are interconnected		- Body depth, inseam, hip height, high hip height and low thigh height - Bust, over bust, under bust - Knee and calf - Bicep and upper bicep
B	- Shoulder and chest - Waist, high waist, hips and rise, - Thigh and knee - Outside leg, rise and inseam measurements		- Bust, cup and under-bust - Hip, belly and high hip - Outside leg and inseam - Thigh, knee, calf and ankle - Armhole, biceps, arm, wrist. - Wrist, over arm measurement
C	- Height influences across back, across front, shoulder length & slope, back height, bust, waist, mid hip and pelvis. - No other parametesr are interconnected.		- Bust, underbust, neck to bust apex - Waist-floor side length, bust apex, inseam and body rise
D	- None		- None

The standard body measurements used for pattern cutting include only 14 and 21 size parameters for man and woman respectively (see Table 1), which are far less from the number of anthropometric parameters used by most of the CAD systems for avatar morphing. While systems A, B and C can utilise most of the measurements from Table 1 for male and female avatar morphing, system D uses only very few. When size and shape were modified using the measurements from Table 1, significant differences in appearance and shape could be noticed (see figures 4 and 5).

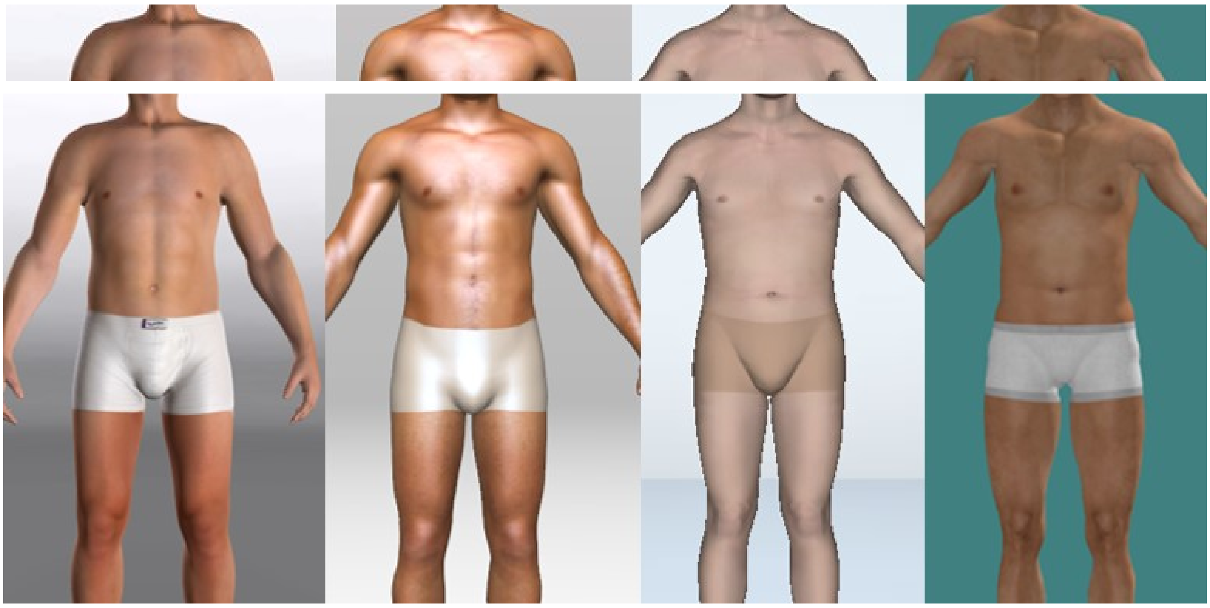

Fig. 4 Male avatars morphed using the measurements from table 1

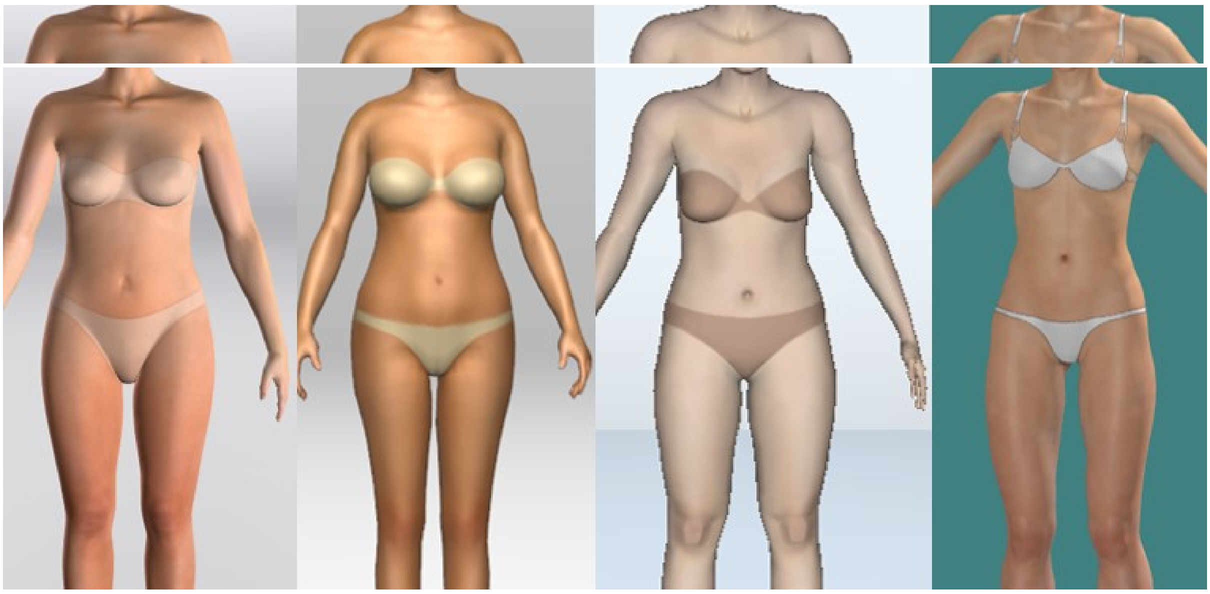

Fig. 5 Female avatars morphed using the measurements from table 1

Following the SizeUK measurement definitions, as high as 144 measurements could be extracted from both the male and female scans. These measurements include individual measurements for both left and right limbs and parts of the body. However, as clothing is usually made symetrical, averages of the left and right limbs/parts in relevant cases, for example biceps, thigh girth etc., are enough for avatar morphing. Systems A, B and C utilise the majority of the torso measurements from bodyscans for morphing both male and female avatar morphing. However, visible differences in the appearance and shape can be noticed among the morphed avatars (see Figures 6 & 7) as the CAD systems include some morphing criteria that do not accept any numerical measurement inputs. Moreover, the bodyscanning system offers opportunities of extracting many critical measurements from the body that can be used for effective avatar morphing. For example, additional measurements can be extracted from the shoulder area of bodyscans (see Figure 8) for better reproduction of shape on the virtual avatar. Currently none of the CAD systems makes use of them.

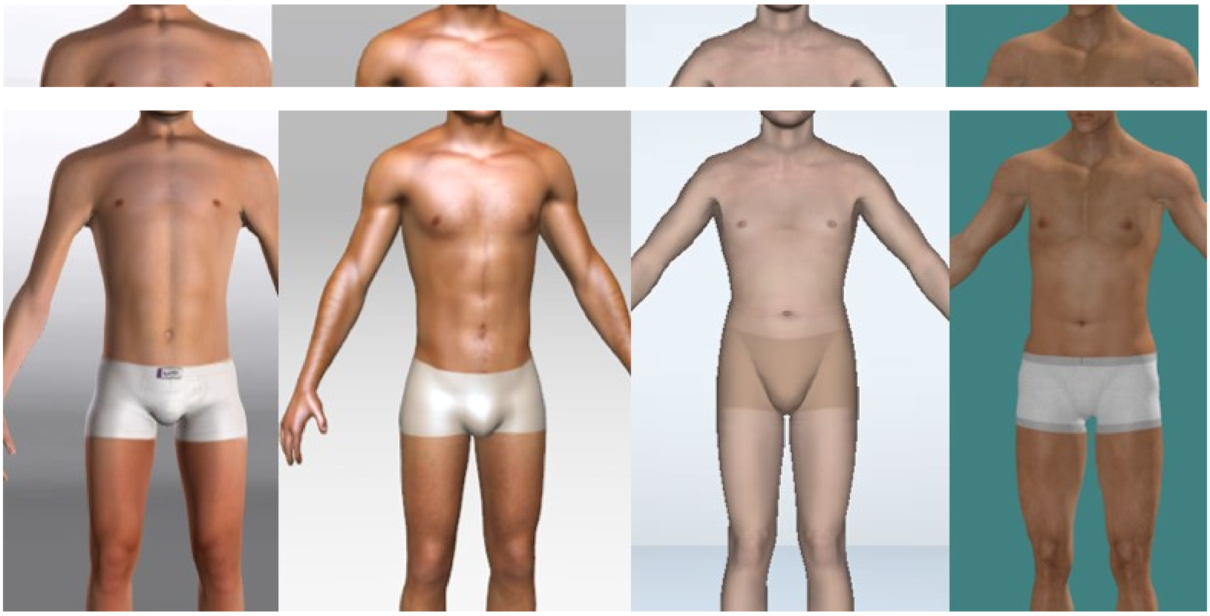

Fig. 6 Male avatars morphed using extracted measurements from bodyscan

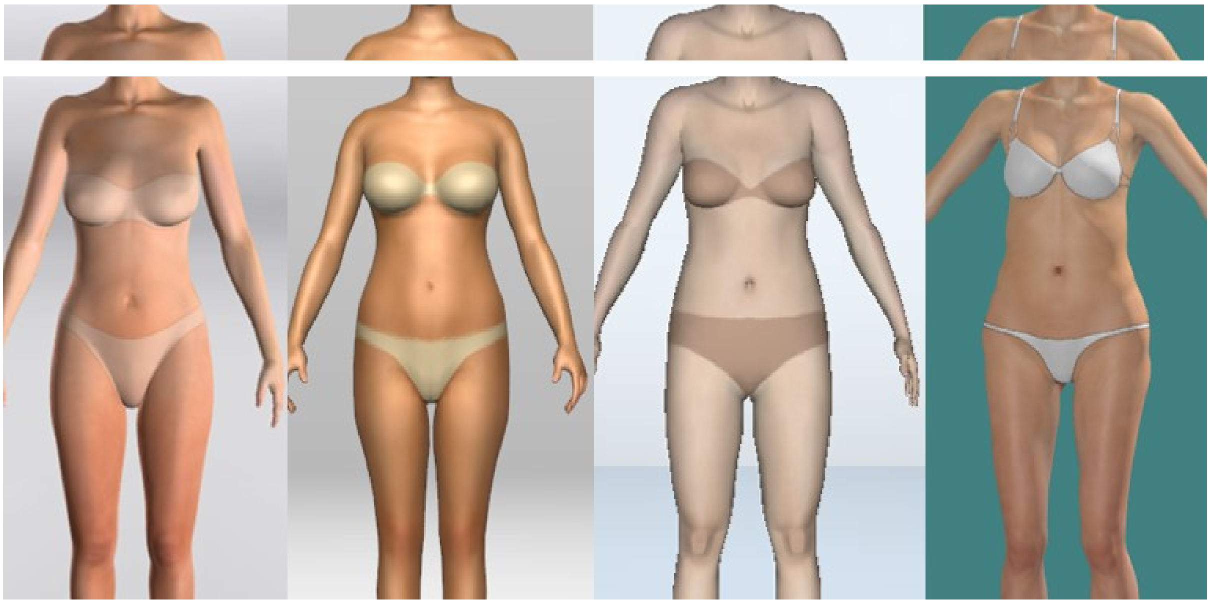

Fig. 7 Female avatars morphed using extracted measurements from bodyscan

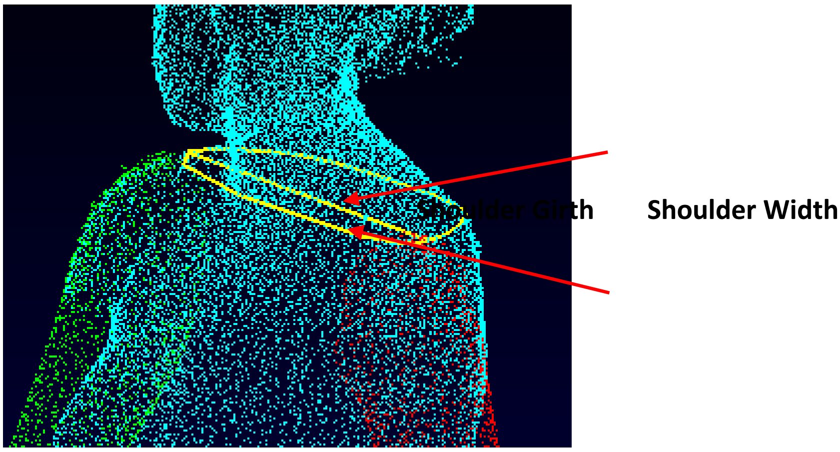

Fig. 8 Shoulder girth and width measurements from bodyscan

ii) Fit analysis

All four of the systems included in this study offer 360-degree rotation of virtual prototypes to facilitate visual analysis of fit. In addition, there also several technical fit assessment tools, such as tension, pressure, stretch and ease mapping tools, available within the systems. These tools offer both subjective and objective analysis of fit in combination with the visual check of the simulated fit on the computer screen (Sayem et al. 2010, Lim and Istook, 2011). This provides an opportunity to review and forecast the clothing fit at the pre-manufacture stage and to take decisions on the correctness of drafted pattern pieces. According to the suppliers, there are several benefits of using these 3D systems, such as better communication of design throughout the supply chain, and reduction of product development lead-time and costs.

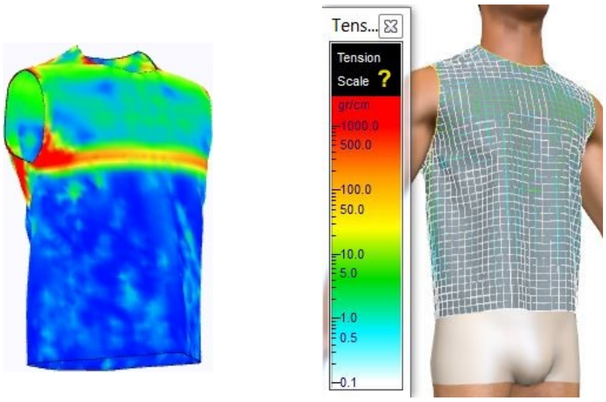

Fig. 9 Examples of tension mapping in two CAD systems

Figure 9 presents two examples of tension maps on virtual prototypes in two different systems covered in this research. These tension maps provide an idea about the tightness and closeness of virtual garments on virtual bodies. However, taking decisions based on visual colour codes or colour bands of tension, pressure and stretch maps is in some way a subjective approach, which can be quite misleading sometimes. As it can be seen in Figure 10, the colour bands of the tension maps from two different fabrics look similar, but maximum tension values are very different from each other. Therefore, a true objective approach would be to consider the numerical values of fabric tension, stretch and the collision pressure of the virtual drape of a simulated of garment to evaluate virtual fit and thus make a decision on the accuracy of pattern pieces (Sayem, 2017a, b) .

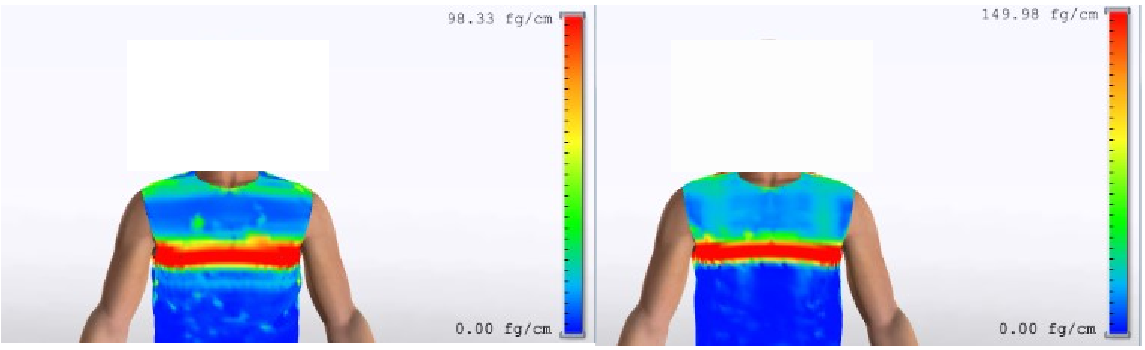

Fig. 10 Tension maps produced on virtual prototype with the same design but different fabrics

This is supported by the works of Kim (2009) and Kim and LaBat (2013), that only a visual check of the virtual sample does not provide any conclusive clues for decision making on the state of virtual fit. Lim (2009) compared virtual simulations of womenswear produced in two different systems utilising identical material properties, and found that visual appearances of simulated garments differed in two systems.

Power et al. (2011) also highlighted the limitation of visual assessment of virtual fit. They found that fabrics with vastly different properties appeared to have a very similar appearance in virtual simulations, which is also the case identified in this work (see Figure 10). This demands the use of an objective approach to meaningful evaluation of fit of virtual clothing. Lim and Istook (2011) and Sabina et al. (2014, 2015) took stretch and tension maps on virtual simulation of garments into account in addition to drape image to evaluate fit. Power (2013) indicated that virtual simulations with insignificant visual difference could show significant differences in a pressure map.

Findings from the case study

Findings from the case study covering two interviews are discussed under the following three themes – 'advantage of virtual prototyping', 'barriers in implementation', and 'needs for further improvement'. It has become apparent from the study that the 3D system is mainly being used by the technical design but not by the creative design team. It is already mentioned in the methodology section that only one case study is not considered to be enough to validate the findings of this research. At the time of the preparation of this paper, it was not possible to include any more cases as no responses from the target companies had been received. However, the case covered in this work is a big fashion company, which has been using 2D CAD systems for a long time, and adopted 3D CAD system in recent years. Therefore, the findings from this case study will also provide an insight into the stakeholder perception and needs of virtual fashion technology.

i) Advantages of virtual prototyping

Both participants stated that the use of virtual prototyping technology helps reduce product development lead-time and the number of physical prototypes. Their buying team can review the virtual designs and prototypes and can recommend changes before an attempt is made to create a physical prototype.
This results in better communication of design and reduces the chances of any error in the product development phase as visual evidence can overcome any language barrier in both verbal and written form. This delivers a positive impact on their work process and they can engage better with designers, buyers, merchandisers and prototype makers; although the technology is not primarily being used by the creative designers.

ii) Barriers in implementation

It is revealed from the case study that technophobia, high upfront cost and need for training are the main barriers for implementing this technology. However, the young designers who are trained with 3D digital tools during their academic study do not find it difficult to use this technology. Another barrier to the implementation of this technology is the difficulty of sharing virtual prototypes with vendors. Different clothing manufacturers use different CAD systems, so the participants found it difficult to share the 3D design with their clothing vendors who do not have the same system. Both participants reported that the high upfront cost is one of the major barriers in acquiring such technology.

iii) Needs for further improvement

The participants of the interviews also highlighted some limitations and areas of improvement in the existing CAD systems based on their professional experience. They do not think the look of the mannequins that come with 3D Systems are fashionable enough. This is an area that needs to be improved. This is also supported by the findings of the comparative study presented in the previous section. Pixelation of the 3D view of virtual prototyping is another area of improvement. The participants also feel that the system should facilitate the importation of 3D prototypes from other systems similar to the options of digital 2D pattern pieces.

Conclusion

The aim of this paper was to check how smart the available 3D virtual prototyping systems are in reality. A comparative study of different CAD systems and a case study on industrial users were conducted. The findings from the comparative study show none of the 3D systems are free from limitations when it comes to avatar morphing. This is also reiterated in the findings from the case study. Although the virtual technology can reduce the product development lead-time and the need for physical prototypes, the technology is not used by the creative designers at present. It is also found that technophobia among professionals, the high upfront cost of the systems, and the need for training are the main barriers for implementing this technology. The limitation of this research is the limited number of case studies. It was found to be very difficult to convince fashion companies to take part in this study. However, the work is in progress and the number of case studies will be increased to consolidate the findings of the study.

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