

3D Virtual Prototyping Traces New Avenues for Fashion Design and Product Development: A Qualitative Study

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Abstract

Design, Development and Production have largely relied on the same, often manual, methods despite all the technological advances happening in the world outside of fashion and apparel. Ten years ago, academic research (by contrast to the existing 3D virtual software solutions) posited about clothing companies complaints' on the lack of effective garment-oriented CAD packages to design directly in 3D and provide the model list with tools for shape modelling and cloth behaviour simulation. Although, common place in other sectors, 3D virtual prototyping in the apparel industry has been slow and complex. A qualitative research investigating the level of the technology implementation in the early adopters, the vision of the big corporations, entrepreneurs and professional users for the global clothing and fashion industry as well as the challenges, opportunities and barriers that need to be overcome in order for digital prototype to accelerate business processes on an integrated basis.

Keywords: Virtual simulation; Fashion industry; Prototype; Automotive; Visualization

Introduction

The fashion industry faces the increasing complexity of its activities such as the globalization of the market, the proliferation of information, the reduced time to market, the increasing distance between industrial partners and pressures related to costs. Digital prototype in the textile and clothing industry enables technologies in the process of product development where various operators are involved in the different stages, with various skills and competencies, and different necessity of formalizing and defining in a deterministic way the result of their activities. Taking into account the recent trends in the industry, the product development cycle and the use of new digital technologies cannot be restricted in the "typical cycle" but additional tools and skills are required to be integrated taking into account these developments [1].

Design, Development and Production have largely relied on the same, often manual, methods despite all the technological advances happening in the world outside of fashion and apparel. Ten years ago, academic research (by contrast to the existing 3D virtual software solutions) posited about clothing companies complaints' on the lack of effective garment-oriented CAD packages to design directly in 3D and provide the model list with tools for shape modelling and cloth behaviour simulation [2]. Nowadays, with the growth of demand from better educated consumers, mass customization, e-commerce, advances in virtual reality applications, the virtual garment development is strongly desired in order to optimize apparel industry's design and development processes. Although this is now commonplace in the aeronautical, automotive, furniture and shoe sectors, development in the apparel industry has been slow and complex; mainly due to the dropping and stretching properties inherent in fabric, which are not only radically different between different fabric types and constructions, but also in the direction off weave or knit within the piece [3].

This research investigated the level of the technology implementation in the early adopters, the vision of the big corporations, entrepreneurs and professional users for the global clothing and fashion industry as well as the challenges, opportunities and barriers that need to be overcome in order for digital prototype to accelerate business processes on an integrated basis. During the process of identifying everyone affected by a change initiative, we grouped the areas that will be impacted by the new involved technology implementation like 3D prototyping and

visualization or PLM and according to their roles and relationships with the industry we divided them in 4 groups:

1. Technology providers-vendors
2. Managers-executives-professional users
3. Entrepreneurs-independent user
4. Academics

The research has been conducted using a combination of primary and secondary sources. First hand interviews with the previously mentioned categories were used; interviewees were called to share their experiences, answer questions, examine and criticize the existing tools and help the investigation study to dig deeper into the characteristics of these technologies, the way they affect the apparel product development process and see if the hypothesis stated by the vendor side (3D design and visualization features is now an important part of the revolution in digital design and production technology for apparel manufacturers) is established by the experienced users of 3D, the independent consultants of the industry and the academic researchers. The software NVivo was chosen as a state-of-the-art analysis tool for qualitative and mixed methods research.

Virtualization as an Integral Part of Fashion Product Development

The 3D concept is an important development in the design process. It allows designers to unleash their creativity in a real-life visualization of designs that could previously only be imagined through 2D sketches. It is clearly visible that the world is going digital. 3D virtualization plays

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a leading part in this. According to Dassault System though, many processes still do not live up to their full potential. Creative 3D materials have always been painful whereas vendor software companies claim that with 3D virtualization is a fantastic way of starting the process of apparel product development. If it is so, then why is the industry using 2D tools to design products that are fundamentally 3D objects? If 3D virtualization has so many benefits and potential for the business why hasn't it been adopted in a large scale yet?

The clothing industry has been transformed from a traditional labour-intensive industry into a highly automated and computer-aided one. However, the primary drawback for the most of the existing commercial CAD systems in the last decade, was, that they relied on mere geometrical modelling and did not provide virtual simulation tools (with few exceptions) [2]. 3D technology started to get in that market but needed technology advancements to get there [4]. The first developed sewing and draping tools gave the designers the ability to evaluate their design on the screen but the proposed approaches [5], were generally computationally intensive. Later, Wang et al. [6], developed a 3D sketch input method for the design of the garment pattern to fit the 3D human model but still, they were not effective in supporting design modifications. Updated algorithms, Luo et al. [7] provided 3D garment fitting simulation the ability to react to the 2D pattern modification efficiently and speedily without the need to repeat the entire simulation for every modification. Others used parametric curves to control the silhouette of garment's shape more easily. Lately, Meng et al. [8] tried to solve the problem to generate customized apparel products for individuals with variant body shapes with a flexible shape control technique. Even recently, Vitali et al. [9] presented a virtual environment to emulate tailor's work based on mixed reality, permitting to take measures for clothing design as traditionally done by tailors. In sum, 3D garment design makes it possible to adjust garments to fit potential customers who might not conform to the target group's normal size and shape [10].

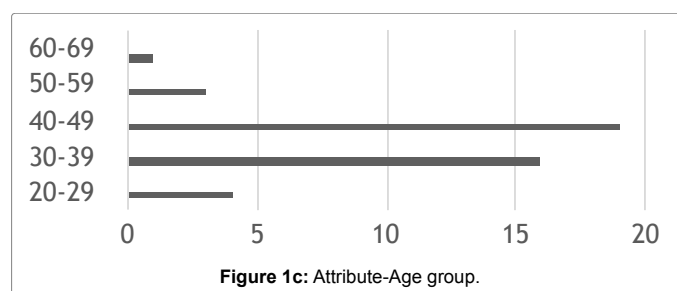
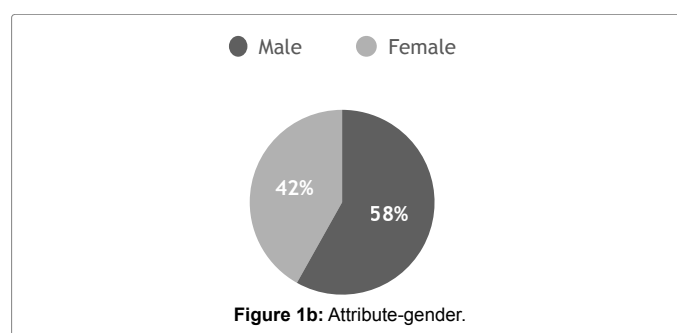
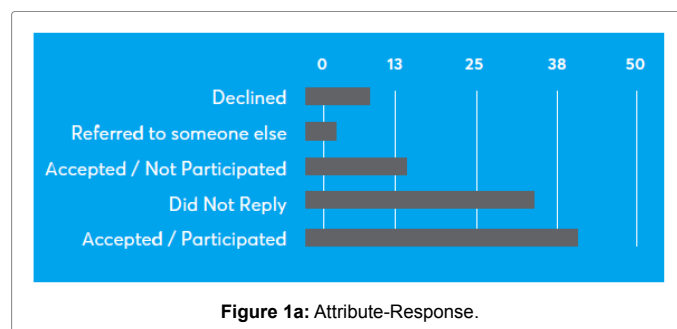
Three-dimensional (3D) technology-while well established and a powerful tool in many other industrial sectors like aerospace, architecture and industrial design-is still relatively new to the fashion industry which has started to adopt it in order to optimize the design and fabrication processes [11]. In particular, the area we are focused on, design and product development will make use of 3D tools that allow for garments to be created in 3D and converted automatically to 2D for traditional manufacturing methods. Digital body models can be created by 3D body-scanning systems, which will allow the digital products to be draped over them. The simulation of these digital products on the body can be obtained from the fiber and fabric characteristics. These data can be shared digitally and monitored through the product development process without the need for the development of a physical fabric or garment sample [12]. Using existing technology it is possible to conduct fit sessions on a variety of shapes, within each size category, within virtual environments. This data can provide quantitative details of fit and highlight potential fit issues [13].

Gerber states that 3D design and visualization features integrated into every aspect of the apparel process, from design, pattern making, production, and manufacturing, is now an important part of the revolution in digital design and production technology for apparel manufacturers [14]. New software development like Lotta [15] and Clo3D [16], provide direct 3D apparel design on the 3D human model to simulate the effect of the apparel on the human body; it also, as argued in the previous chapter, allows design change under the 3D environment to avoid repetitive fitting by the real model in

the traditional apparel design process and the repetitive manual changes. The fact is that 3D visualization is now much more embraced and embedded in the fashion industry than in the past. Interviewees were called to share their experiences, answer questions, examine and criticize the existing tools and help the investigation study to dig deeper into the characteristics of these technologies, the way they affect the apparel product development process and see if the hypothesis stated by the vendor side is established by the experienced users of 3D, the independent consultants of the industry and the academic researchers.

Materials and Methods

The research project gathered the opinions and experiences of experts with direct contact and use of technology solutions for the product development process like 3D and virtual prototype or PLM (Product Lifecycle Management); the selection of the sample was purposive rather than random. 100 Experts from four different backgrounds of the fashion industry were selected to participate in this survey contacting personal interviews. As Figure 1a shows, 43 "relatively unstructured" personal interviews were carried out; some of them in typing due to lack of time on their behalf or the time difference between countries 34 didn't respond at all, although they have been contacted with a coming-up e-mail twice. In Figures 1b-1e, participants are categorized in some demographics; Gender, Age Group, Country of Work and Occupation.



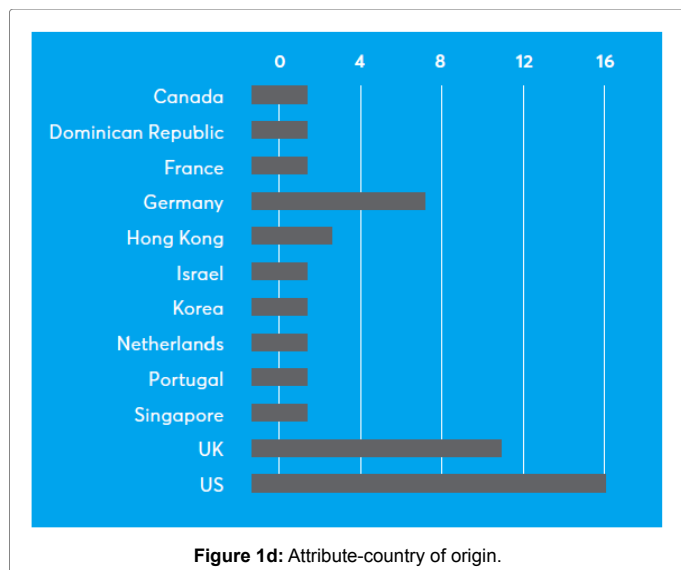


Figure 1d: Attribute-country of origin.

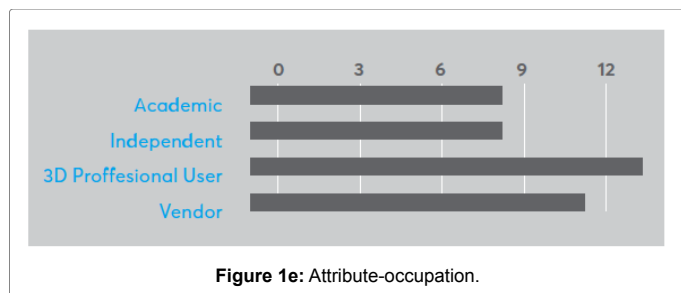


Figure 1e: Attribute-occupation.

The collection of primary data was not only relied on personal interviews but on surveys, notes, fieldwork and a combination of information types. The software NVivo was chosen as a state-of-the-art analysis tool for qualitative and mixed methods research.

The software enables the researcher to develop tree nodes which show relationships between and within nodes, and consequently between and within data sets. It must be noted that software programs such as NVivo do not do the intellectual work for the researcher, nor do they assume context free analysis; rather they facilitate creative management of multiple data sources and enable researchers to make visible their methodological processes for a more 'trustworthy' study [17].

Results

Interviewees were called to share their experiences, answer questions, examine and criticize the existing tools and help the investigation study to dig deeper into the characteristics of these technologies, the way they affect the apparel product development process and see if the hypothesis stated by the vendor side is established by the experienced users of 3D, the independent consultants of the industry and the academic researchers.

a) Advantages/Benefits

Some of the benefits the 3D digital product offer to the product development is less samples, faster prototypes, much higher quality earlier-on in the cycle, and ability to make decisions based on that [18]. Moreover, designers are able to understand the technical aspects more when they are working alongside the pattern makers as 3D design seamlessly integrate 3D models with pattern design. Pattern makers on the other hand, can visualize entire size ranges on screen, from the

smallest to the largest sizes. At any time whatsoever, it is possible to pass over immediately from 2D visualization to the three-dimensional one and vice versa, and all the amendments made appear in both. This possibility is not insignificant and represents a truly incredible advantage [11]. Other 3D prototyping options like Clo3D [16] provide the collision detection - an effect used in realistic 3D video games-allowing designers to create a garment's layering effect - the biggest component missing from virtual garments. Designers can create puffs, pleats, and padding that they would consider in real life. A virtual product development is one that not only simulates the human being but virtualizes the cut and the fabric in extremely high quality. The cut quality is exact and the fabric display is totally realistic when the parameters are known [19,20].

Participants were drawn to discuss the advantages of this new technology. Again, we are going to divide the answers in the categories of vendors, 3D expert users employed in apparel companies, independents in use of 3D and academics. What is one advantage for one user maybe a different advantage for another (Tables 1-4).

1	Speed of conception/Reduces time to develop
2	Reactions in sampling
3	Reduction in cost
4	Increases time to experiment/Allow more designs
5	Encourages communication
6	Eases communication
7	Better visualization-helps in presentation
8	Reduce physical samples
9	Reduces Errors when integrated with 2D and PLM
10	Streamlines the process; keeps it more efficient
11	Better collaboration

Table 1: Advantages of 3D-vendors.

1	Affordable method of testing micro changes in prototypes
2	Instant Tech Pack and BOM (in Lotta/Browzwear)
3	Not only about reducing samples
4	Speed in making a physical sooner enhances the quality of the physical
5	More flexible visual to show your merchandising team, your sales team, retail team
6	Rapid prototype let the companies spend time in what they want to pursue right away
7	Right decisions; Silent decisions
8	Photorealistic products can be used in photoshoots
9	Integration with PLM and design
10	Reduces carbon footprint

Table 2: Advantages of 3D-independents.

1	Better work balance
2	Less iteration
3	Lower rate of misinterpretation (3D better than 2D flat sketch)
4	Direct collaboration and usage by everyone; mutual language for different categories
5	Faster decision making
6	Visual communication
7	Accuracy
8	Reducing waste
9	Earlier decisions
10	3D Digital much faster than physical
11	Reducing time for the design development and prototyping process
12	Much quicker feedback
13	Reduces defectuous products
14	Has the potential to reduce samples on the long run (hard to prove)

Table 3: Advantages of 3D-3D user experts.

1	Short lead time
2	Less cost
3	Better visualisation of design concepts
4	Enhances decision making
5	Saving sources
6	Quick integrated controls over the garment
7	Maintains the linearity between 3D changes and the 2D pattern
8	Speed

Table 4: Advantages of 3D-academics.

As we can see in the previous tables, speed and fastness is one of the advantages mentioned in all categories. For this reason, we decided to ask the participants some quantifying questions. We later split independents in two categories (entrepreneurs and independents separately) due to significant different answers. Among managers and academics it is alike, it is widely accepted that three main factors impact NPD success: time, quality, and expense. Moreover, these three factors are not independent: changes to one factor impact the other two. Therefore, we asked the participants to quantify 3D prototyping technology in terms of development time (1 to 10; 1-very poor and 10-excellent):

- Question 1: Time to customize product per design specifications;
- Question 2: Time to produce more variety in designs;
- Question 3: Time to change the design easily;
- Question 4: Overall design speed;
- Question 5: Time to introduce new products into production;
- Question 6: Speed in introducing new information.

The results and the evaluation for each question regarding 3D technology in clothing NPD in terms of development time are shown in the following (Figures 2a-2f).

Although the collected data from participants is very limited, it is interesting to see the responses between the categories and the average evaluation for every question.

With an average of almost seven (7) and a significant difference between the entrepreneurs' and the academics' quantification it is obvious that the time to customize product per design specifications depends on the product. The simpler the garment, the higher the number, Lanninger explains [21]. This explains the high number in the UX (User Experience) professionals. If a designer gives a basic T-shirt/block and the avatar/dress form is the right one, then the process can be fast. Entrepreneurs state that the technology needs to be much faster to be most productive, especially for outwear, suits and multi-layer garments that need a significant added time comparing to a basic T-shirt (Figure 2a).

Question 2: Time to produce more variety in designs; vendors are the ones who believe more that 3D can accomplish that. UX Professionals score 8, 38 in average, stating that it depends on the software tool; it depends on the preparation. According to a Strategy and Project Brand Operations manager of a global sportswear company [22], if all these are already done then the developer can produce new design variations quite fast. Entrepreneurs still are very skeptical and not convinced yet. If design means changing colors, material, appearance (not folds/silhouette or patterns) the number is between 1 and 4. If it is a pattern, then also depending on the change it could be 1-4 but often also is 5-10.

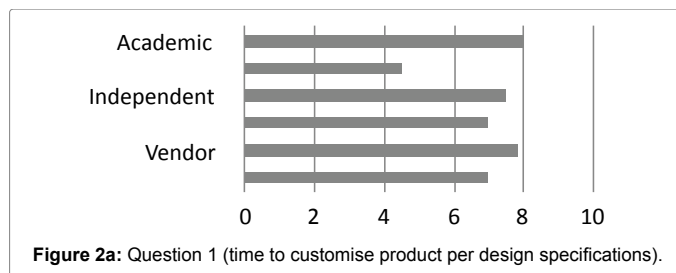


Figure 2a: Question 1 (time to customize product per design specifications).

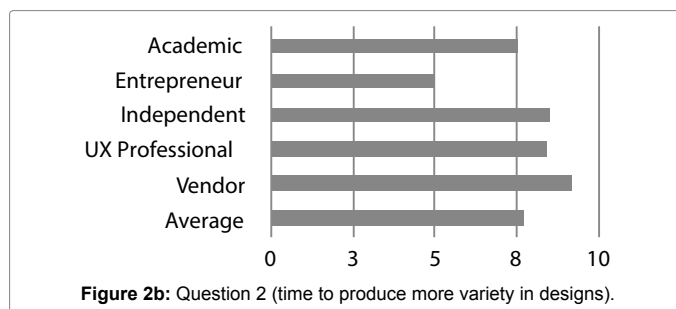


Figure 2b: Question 2 (time to produce more variety in designs).

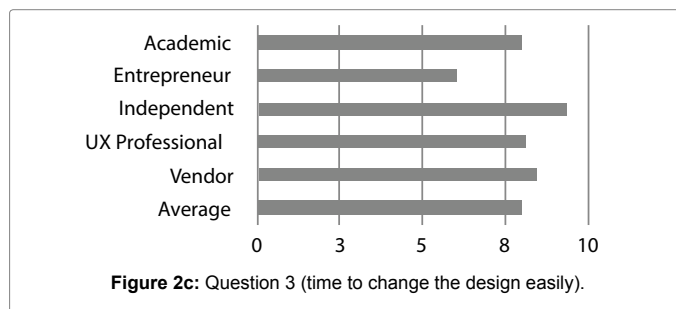


Figure 2c: Question 3 (time to change the design easily).

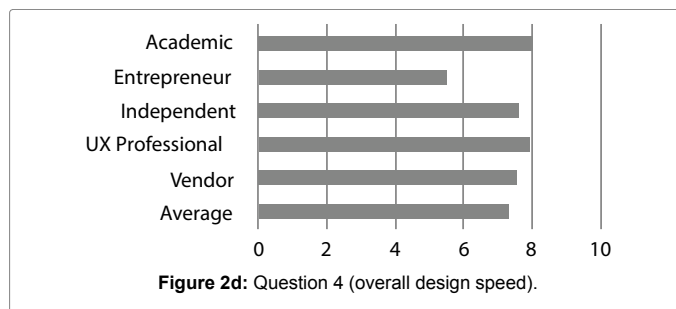


Figure 2d: Question 4 (overall design speed).

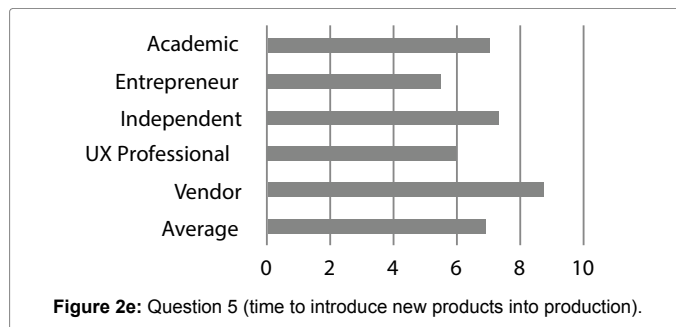


Figure 2e: Question 5 (time to introduce new products into production).

There was a vendor who could not generalize it and wasn't specific in giving a number in this question (Figure 2b).

Question 3 was about time to change the design easily. In this question the category of the independents scored the highest average

followed by the vendors (as expected) and the academics. In general again, it depends on the user. Some 3D experts stated that it is excellent (10) for an experienced user but they would put 7 (seven) for a non-experienced designer (Figure 2c).

In the question that the participants had to evaluate then overall design speed (Figure 2d), again there were answers that mentioned the dependence of time to the 3D user efficiency as well the process behind it. Independents believe it will get increasingly faster like non specialized software design tools (i.e., Adobe Illustrator) [23].

Question 5: Time to introduce new products into production, scored the lowest of all with an average of 6.89. In this question even 3D experienced users argue that unfortunately the technology is not there yet, with the whole production depending still in 2D tools. Pattern is a big problem and at the same time always needed even in 3D environments. A design can be conceptualized in 3D space but in order to be finalized it requires a pattern with the appropriate grading on it (Figure 2e).

The last question (6) showed an average of 7, 93 (almost 8) with 4/5 categories scoring high but again not excellent (Figure 2f).

b) Disadvantages

3D in fashion is evolving slowly and will speed up, although it should and could have been years now. It is interesting to see how each category replied to the questions: “What are the disadvantages of 3D virtualization?”

From the vendor’s point of view, it has nothing to do with the technology of the software they provide. On the contrary, vendors believe in their products and claim that the technology is far more advanced, becoming more powerful and cheaper as opposed to the business situation which is becoming tougher and tougher. For the needed change, vendors give most of the credit to the factories. The problem to them is not the type of garment or how difficult and complex it is but the type of pilot of people would dedicate time and effort in adopting the new technology. According to CEO of Browzwear, it takes persistence and perseverance [24]. Some companies go into pilot stage and never grow out of this and some others start from difficult types like all the winter clothes. So to them, the most important factor is the difficulty to implement and the adoption.

Independent users of the technology don’t see adaptation as a problem. As believers in the technology themselves, state that the software is improved in a much faster rate than it was ever before. Now the industry with leaders like Adidas, Nike, Under Armour with experience behind 3D and Target, Coach etc., all these big corporations are applying pressure on the vendors to produce things that work. To them, ROI is of great importance [25]. Other independent participants reported the accuracy of the solutions that is not at the wanted level for

the industry; that is the reason why many companies have moved it to Digital Prototyping solutions as being more of a concept and design tool [26].

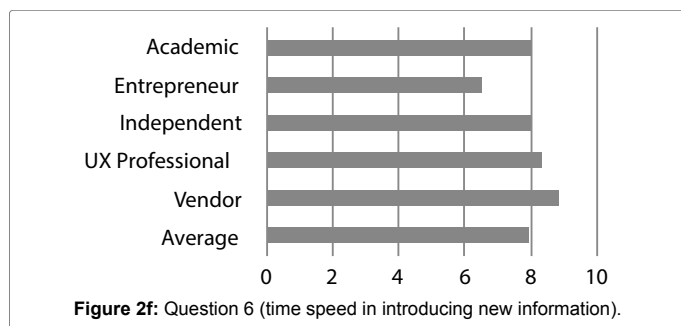
Academics report the biggest disadvantage as being the lack of experienced users with technical knowledge. All the academic participants had one thing in mind; the time it takes to learn this new technology, and how insufficient the tool can become when comparing a skillful simple technician with an amateur 3D user. Even so, these needed skills were ignored by many fashion courses in higher education run by non-technologists, and ineffectively developed by those inexperienced practitioners who focus on design only and are generally fearful of change.

The actual every day users and managers of the previous mentioned pilot projects in implementing 3D technology, make a list of disadvantages depending on how the company is fragmented, how many samples they produce, of what type the garments are, who is doing the 3D job and so on. For the project managers everything starts with the libraries. Certain materials and certain content like buttons, zippers and so on need to be available in 3D. This is a huge workload for the project team. The next obstacle is fabric properties related to the feel, drape and reaction on the body. The foundation of doing great things in 3D depends on understanding the complicity the relationship between the individual threads of the fabric. “That is why the other industries have implemented 3D quicker, because the materials are so much different than woven and knitted fabrics” [27]. The next huge problem for companies who interact with their factories in Asia is the lack of communication between different 3D software tools. If the headquarters have one solution and the factory has another one, the exchanged file between them loses stitching information and the physical parameters used. Although the communication has been improved and the development team can do virtual iterations before visiting the factories, dxf, the exchange format, is still missing a lot of information as with the CAD Systems” [28].

Fit also was mentioned as a problem by many. Virtual fitting is not that easy. This is the reason that a physical sample is needed; to check the feel of it, how the avatar reacts and moves with the virtual garment on. 3D avatar for many is not there yet as a fitting tool; “Fit was not as straightforward as what the demonstration was” [29]. Fabric properties as a disadvantage are remarked in the academic research of Behera [30]. More specifically, analysis of the tailoring process reveals that mechanical properties such as tensile, bending, shear, compression and surface are equally important in the making-up process of the garment. The shape and size of the garment relative to the shape of the body, known as the fit, will be strongly influenced by physical and mechanical properties such as tendency of the fabric to stretch, shrink, distort, and drape due to stresses induced during use under static and dynamic situations.

To draw a conclusion, all people involved in 3D projects, from managers to end users, are optimistic about this technology. They want it to succeed. They employ designers, 3D artists, pattern makers, developers, technical people to make the process faster and they try to reduce the number of steps that are not giving feedback on the result of the user’s task.

3D is certainly gathering real momentum and, according too many participants in the research, not before time. Early adopters of the technology like Adidas, Nike, Under Armour, Target, Coach and many others who have already adopted 3D, have experimented for years with this new technology and are applying pressure on the vendors to



produce solutions that work. According to 3D User experts, if the tools are going to be used in the industry then they need to solve problems that people have. The above mentioned “change teams” are pressured to deliver results. Some problems are still there, needed solving and the managers cannot predict how long it will take to solve them. Internal integration with existing systems plays an important role in this.

Further research could be conducted to identify the current provided solutions by the vendor companies and the improvement needs by the early adopters of the technology.

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