The shift from 3D body scanned data to the physical world

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Abstract

This paper highlights the technological relationship and opportunities to combine 3D body scan and 3D print technologies for consideration within the fashion sector. Three dimensional (3D) human body scanning technology has been available for more than 20 years; fashion along with a number of other industries such as entertainment, security and medical have successfully extracted computational scanned data to obtain specific body measurement to gain a picture of body shape, proportion and posture. This information can provide valuable insight when dealing with the complexity of the human form, particularly in the context of lifestyle, age, ethnicity and location. Predominately this empirical data has been gathered to develop size/measurement averages for large population studies (11,000 participants were scanned, providing 130 body separate body measurements, in recent commissions in both SizeUK and SizeUSA).

In a fashion context, the information provided by these large studies has tended to reflect the mass apparel market, in particular sizing measurements for targeted groups, while customization of 3D body scan data for individuals within the fashion and textile industries has been limited. To date the most prominent examples have come from the niche market arena of men's suiting and specialized sportswear to aid fit, comfort and performance.

Over a similar period of time, 3D printing technology has also grown to the point that commercially available equipment has helped to shift a design approach for modelling and rapid prototyping applications. This technological transformation is having a profound effect on existing industries, for instance engineering, while also providing a fresh platform for emerging designers from many sectors to communicate design ideas as a physical reality. For example, bespoke fashion accessories developed by UK designer Catherine Wales in her 2013 work "Project DNA" illustrates that the fashion and textiles industries can also take part in this industrial transformation.

Using a technology focused design thinking framework, the research explores the opportunity for combining both these technologies; in other words utilizing individual 3D body scan data in the form of a point cloud to produce physical 3D modelling for customization purposes. At this stage there is little documentation of the reflective practice to empower designers with the techniques to connect these technologies, or indeed the exploration of creative possibilities and human centred outcomes. This paper documents early stage development of the conversion process from a Symcad 3D body scanner to outputs obtained from a Formiga P100 3D laser sintering system housed within the Design & Creative Technologies Faculty at AUT University, New Zealand. The physical prototype outputs are based on actual body scan data to produce a scaled mannequin. Key research findings and insight clusters are evaluated within a summary framework which highlights potential applications and uses for the fashion sector to engage with such technology to personalize and enrich human engagement.

Keywords: fashion, 3D body scanning, 3D printing, rapid prototyping, customization

Introduction

This paper explores the use of 3D digital technology for consideration within the fashion sector; in particular the technological relationship to combine 3D body scan and 3D print technologies and the opportunities this could present for designers wishing to enter this emerging field. In broad terms a 3D body scanner could be regarded as a technological input device for gathering digital information about the human body, whereas 3D printing technology provides the capability to produce an output in the form of a physical object. The understandings of both technologies in terms of inputs and outputs are complex and to date rely heavily on a skill base not normally associated with fashion design. Consequently, early adopters working within the fashion 3D digital design space tend to have come from backgrounds such as architecture or industrial design, where working in 3D digital modelling is more of an accepted practice. This point is significant and may partially explain why there has been a limited uptake from the fashion sector thus far. Additionally there is little documentation of the reflective practice needed to empower fashion designers with

the techniques to connect these technologies or explore creative possibilities.
This particular research does not try to predict exactly how or if the fashion sector will embrace 3D digital technologies, but poses the question of "How might fashion designers engage with both 3D body scan and 3D printing technologies?" to frame the research project. The main objective of this work is to document current contextual 3D digital design practice relative to the fashion sector and highlight reflective personal insights of early stage practice-based project development, essentially trying to highlight some of the issues a newcomer from a more traditional fashion background should be aware of before embarking on a creative 3D technology project. The project work involves utilizing individual 3D body scan data in the form of a point cloud to produce physical 3D modelling for individualized customization purposes. Developments are discussed in terms of formulating understandings for practical engagement with both of the 3D technologies.
The paper is structured to include contextual discussion and research findings within the following sections:

- An introduction to the area of 3D printing and 3D body scanning
- A discussion of contextual work currently being done internationally in this area
- An outline of research project engagement
- Conclusion and reflections.

Outline of 3D human body scanning for fashion

Three dimensional (3D) human body scanning technology has been available for more than 20 years. Technological methods for the extraction of human body digital information can be broken intofour main categories: laser scanning, white light scanning, passive methods such photogrammetry and sensor based technology including millimetre-wave radar (D'Apuzzo 2009). In each case computational scanned data can be extracted as a digital point cloud, providing both mathematical and visual information for specific uses. The technology is utilized in a number of specialist fields, such as healthcare for monitoring and diagnosis uses, entertainment for gaming or animation, as well as security in the form of airport scanners.

Generally speaking, in a fashion context, 3D body scanners have tended to be used more as an input device to obtain specific body measurements to gain a picture of body shape, proportion and posture. This information can provide valuable insight when dealing with the complexity of the human form, particularly in the context of lifestyle, age, and ethnicity, for example. Such empirical data has been gathered to develop size/measurement evaluation for large population studies. For example, 11,000 participants were scanned for the Size UK project (Bougourd, & Treleaven, 2002), each 3D body scan providing 130 separate body measurements, although height, hip, waist and chest measurements were used as the main indicators in assessing average body sizing compared to a previous manually measured study from 1951. The survey identified proportional size changes relative to age and modern lifestyle. The results provided the UK fashion industry with an anthropometric database that reflects body size and shape, improved knowledge of the customer for targeted products, and the potential to offer better fitting clothes. Advances in 3D body scanning technology and associated costs were the key drivers for government, tertiary and industry involvement for this venture.

Moving away from the mass market sector there is a growing interest in the more personalized applications for 3D body scan data, particularly for customization and fit for individuals. However, to date the most prominent examples are limited to the niche market arenas of men's suiting and specialized sportswear to aid fit, comfort and performance. While we may not normally associate tailoring with high performance sportswear, both areas place a particular emphasis on accurate fit. Tailormade London (2012) and Speedo, for their Fastskin 3 line (Science Illustrated, 2012), have successfully extracted individualized 3D body scan information to work in conjunction with appropriate fabrication and construction techniques to provide customized fitted garments specific to their specialized market, providing both comfort and performance. This highlights how 3D body scan technology can be utilized in a qualitative manner to create a deeper, more personalized experience for the customer.

Outline of 3D printing technology

A simple analogy of the 3D printing process would be to compare it to inkjet printing; instead of ink, the process known as selective laser sintering (SLS) involves the deposit of powder or chosen material in successive layers on top of each other, building up a physical structure. 3D printing technology first came to prominence in 1984 and has grown to the point that commercially available equipment is now accessible; indeed predictions are made that 3D printers will be in 40 per cent of the households in the USA by 2020 (Krassenstein, 2014).

The broad field of use is more extensive than 3D body scanning, ranging from medicine, aerospace, automotive, manufacturing, and even the emerging intersection with fashion design. However it is in the shift from the existing industry focused manufacturing model to that of home enthusiasts and designers that may prove most significant. Hod Lipson and Melba Kuman, authors of the book *Fabricated: the new world of 3D printing* (2013), describe the speed of rapid innovation and technological advances in this topic as difficult to capture. The authors position 3D printing as “a machine that can make almost anything” and hint at the notion of a world where “everything is becoming science fiction” is not so far away. Rifkin (2012) shares similar sentiments, describing technological shifts as the start of “the Third Industrial Revolution …In the new era, everyone can potentially be their own manufacturer as well as their own internet site and power company. The process is called 3-D printing.”

Contextual discussion of 3D printed fashion

The relationship we have with clothing, in particular the physiological sensations of touch, feel, warmth and smell we obtain from fabrics with natural fibres, is a very human experience and as such places a degree of doubt into how 3D printing might replicate this experience in a clothing context. Recent examples such as Stitch Fabric (Magic, 2012) show how a 3D printed mesh creation can simulate knit structure properties to react to the physical movement of with the body. However, early stage fabrication structures seem to be more technology driven rather than comfort focused; 3D printing that looks like a fabric structure but lacks the tactile sensation against the skin. Consequently, ready to wear 3D printed clothing may be some way off. Despite this comment, it could be argued that the fashion and textiles areas already have their own 3D printers in the form of digital knitting technology which uses a needle carriage instead of print head, and of course has the advantage that the fibres feel more natural to wear than the plastic, nylon and rubber structures that one would associate with current 3D print (Sher, 2014).

Perhaps as a result of this, there is more emphasis placed on the small but growing area of 3D printed fashion lifestyle products, such as purses, bags, jewellery, glasses or non-worn accessories. Rifkin's notion of "The Third Industrial Revolution" is exemplified by innovative companies Shapeways, Ponoko and I Materialise who each provide a commercial business platform utilizing the proposition to digital design technology and rapid prototyping, allowing independent designers without capability or access to expensive manufacturing equipment to make, sell and distribute product on a global level. Essentially any designer capable of creating a digital 3D object file could upload a design file for commercial or open source sharing purposes and have the product 3D printed at a location convenient to the client with access to a 3D printer. Could fashion designers be part of this movement?

Design focused wearable 3D printed fashion.

In a less commercial manner, a small number of inspirational designers have lifted the profile of computational fashion design through their innovative design approaches to 3D scanning and printing as a creative tool. The first example of 3D printed clothing was created as far back as 2000 by Jiri Evenhuis and Janne Kyttanen from the pioneering Dutch company Freedom of Creation. The piece *Black Drape Dress* is on permanent display in the Museum of Modern Art in New York. While it has taken some time for the 3D printed fashion movement to gain traction, future focused designers Catherine Wales, in her 2013 work "Project DNA", and Iris Van Herpen have pushed boundaries in fashion digital design, Van Herpen having used 3D printing in each of her international fashion collections since 2010.

The most high profile example of 3D printed clothing has been the collaboration between New York designer Michael Schmidt and architect Francis Bitonti (2013) who created a 3D printed dress for burlesque dancer Dita VonTeese. The dress is remarkable for its complexity, with over 3000 articulated moveable parts to link sections; this method ensures that the dress is capable of responding naturally to the movement of the wearer. Following on from the Von Teese project, the Francis Bitonti Studio launched a series of international workshops entitled "New Skins

Computational Design for fashion" (Bitonti, 2013, 2014), attracting collaboration by participants from a variety of disciplines beyond the fashion sector. Bitonti suggested that the focus be on total immersion with technology and experimentation through the medium of the computer, as a means for creative design expression and a method of problem solving. "I want to give the fashion industry the opportunity to see how computation can be more than a means of execution," says Bitonti (2013). He effectively places more value on the design approach than the physical outputs, suggesting "It's a medium for design, a fresh way to think and as much about aesthetics and culture as it is about production and performance."

In a similar vein, Madeline Gannon's (2013) highly innovative project "Reverberating across the divide", marries 3D body scanning, gesture controlled 3D modelling, animation and 3D printing to produce a range of uniquely personalized wearable pieces. The work has come through the Computational Design Lab at Carnegie Mellon University, USA, which is described as a multidisciplinary collaborative formed to address the complex issues at the intersection of art, design, architecture and engineering.

A pattern emerges, namely that the leaders in this field: Evenhuis, Kyttanen, Bitonti and Gannon, do not come from fashion backgrounds. From the highlighted examples, only Van Herpen, renowned for her experimentation and collaboration with others, can be said to be a fashion designer. Perhaps this suggests that fashion designers with traditional fashion skill sets, wishing to engage in 3D computational design, should consider collaboration with other digital specialists in order to develop the conceptual and technological skills necessary to enter this creative new field.

Project engagement

The initial research plan was to explore the opportunities to combine 3D scan and 3D print technologies, in other words utilizing individual 3D body scan data to produce physical 3D modelling for customization purposes. Early stage developments for this project are discussed in terms of formulating understandings for practical engagement with both technologies. The focus was not so much on the creation of a finished object or wearable piece but more to develop an understanding of process and issues. The experimental project was partly inspired by the

CopyMe3D project (Sturm, Bylow, Kahl, & Cremers, 2013). The researchers combined 3D scan and print to produce miniature figurines, representations of the human form; this prompted the question, “could it be possible to 3D scan and print full scale human representation?” or torso representation in the form of a dress mannequin. On reflection the work was a starting point that was more driven by curiosity about the technology itself rather than an intended design outcome; even if a full scale mannequin could be produced, was there a need for it? Nevertheless the project provided a platform to get involved with the technology, the challenge was to gain confidence with the specific software, the Formiga P100 3D laser sintering system and Symcad 3D body scanner equipment available (Figure 1).

Figure1. Symcad 3D body scanner and Formiga P100 3D laser sintering system housed within the Design & Creative Technologies Faculty at AUT University, New Zealand.

Project 3D body scanning

Four volunteers were invited to take part in the initial 3D body scanning phase; all were competitive male gymnasts and personally motivated by the prospect of accessing data relative to their personal body shape, size and posture (Figure 2).

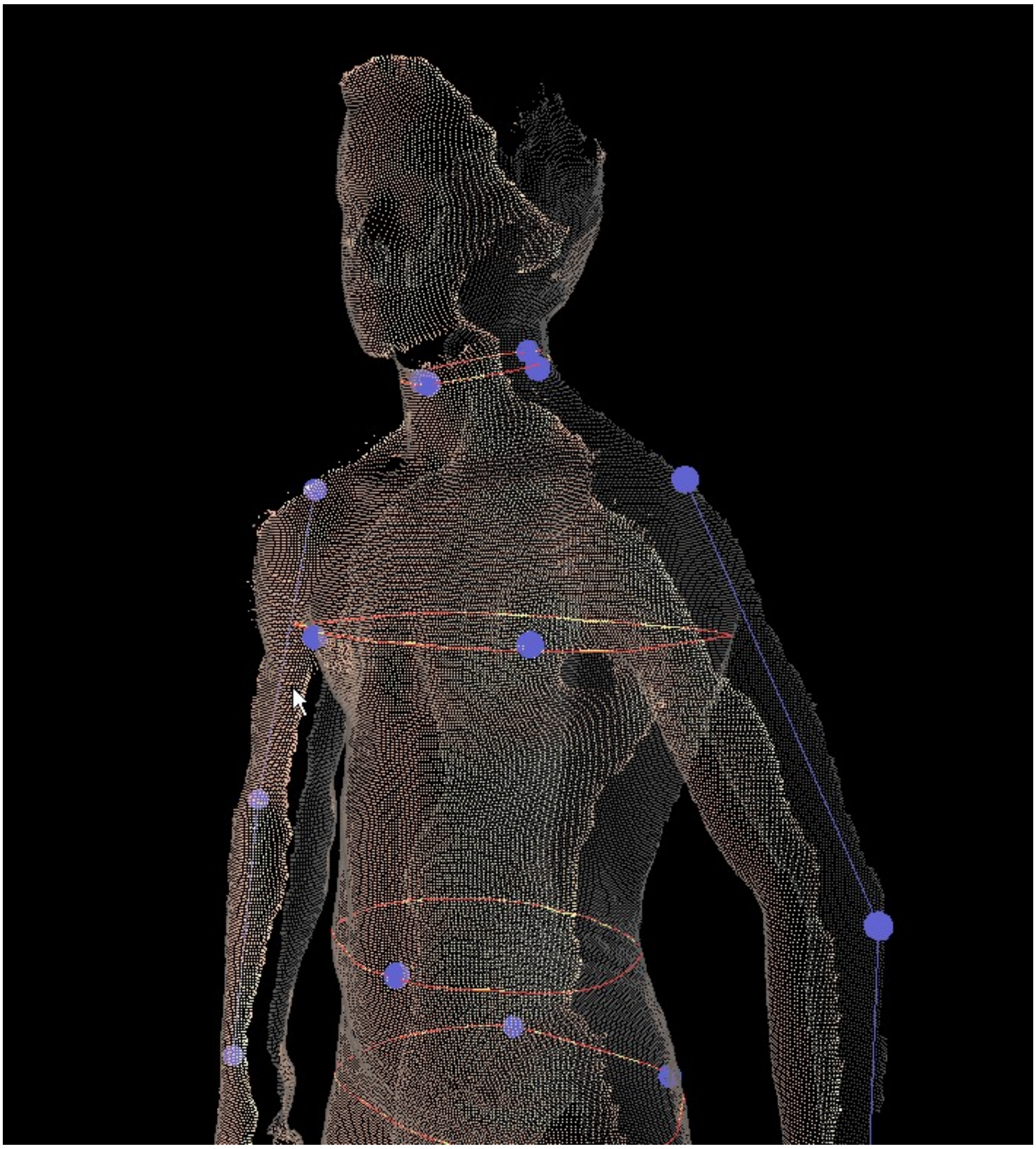

Figure 2. Manual and body scan measurements compared at 30 body locations.

The gymnasts were manually measured at 30 separate body locations and then 3D scanned. Both sets of measurements were cross referenced, and while there were a few discrepancies relating to interpretation of measurement locations, the results were found to be accurate. The purpose of this exercise was firstly to validate the reliability of the scanner accuracy and secondly to establish that the 3D body scan files would be a reliable file source on which to develop design work.

The particular Symcad body scanner used was designed with physical body measurement as the main feature; this aspect is accurate but has limitations for computer generated resolution of the extracted surface area mesh, in particular holes or dead angles where the scanner was unable to pick up enough information to complete the mesh surface (Figure 3).

Figure 3. Extracted 3D body scan showing holes or dead angles within surface mesh.

This is due to the fact that only two camera positions (front and back) are used, so it fails to recognize full 360 degree information such as sides of legs and arms. This may be okay when only extracting measurement data but presents some issues when a more detailed point cloud for design development purposes is required.

(Wang, Li, & Li, 2011) have proposed a set of algorithms to correct this issue; alternatively blending secondary scan files of side-on positions could be an option but would require 3D software expertise to do so. Further limitations included extracting accurate measurements when the subject is not in the prescribed standing position. A solution to this may be attaching body land mark recognition sensors when working with alternative positioning such as sitting, stretching, and activities. These points may be unique to the Symcad system itself, other commercially available scanning equipment may be considered for specific purposes.

Project development.

Conceptual and spatial understandings are important for engagement with 3D modelling and are crucial for learning new computer software such as Rhino, 3D Max, Maya, Solidworks, Grasshopper and Blender. Essentially the computer becomes your design translation tool and the only way to move forward. Stewart (2013) states that "Digital skills are pretty essential in order to explore 3D printing, you can't engage fully with the process if you lack the ability to communicate within the digital environment." My unfamiliarity and limited ability in 3D digital design software was supplemented by online tutorials and workshops to learn essential digital tools for my favoured platform of Rhino software.

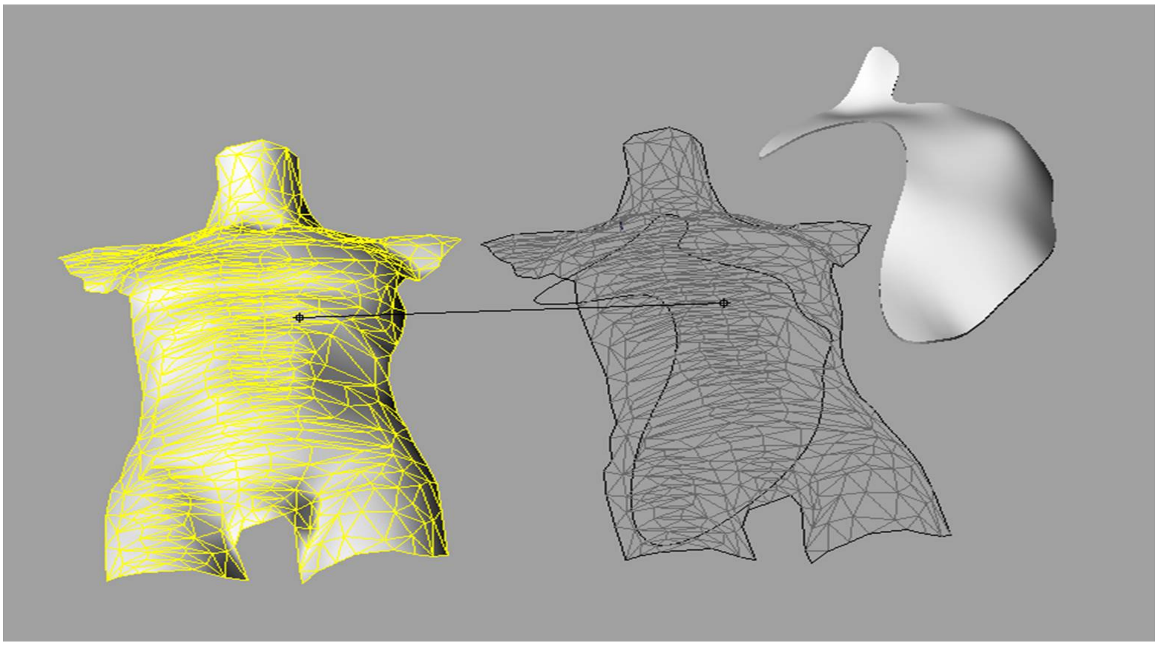

Figure 4. Rhino design development showing reduction of polygon shapes to simplify model surface.

Not surprisingly, the amount of information captured within a full 3D body scan acquisition equates to a large file size so, after importing the WRL/VRML (virtual reality/ open exchange modelling language) into the Rhino software platform, some file simplification is recommended to reduce the amount of polygon shapes that make up a model surface; this helps to simplify design developments (Figure 4).

Transferable fashion skills to 3D digital environment

The art of pattern making requires the ability to translate design detail to work with fabrication and the human body, therefore the pattern maker must have knowledge of body proportion and how the body moves before the subtle translation skills of design interpretation can occur. Utilizing both manual and computer pattern making experience and understandings proved conceptually valuable, transferable skills could be translated into a 3D environment. In particular, drawing design or contour lines directly on to a torso surface that could then be lifted and extracted as sections from the torso scan; this is similar in principle to the manner in which a pattern maker would draw and trace from a pattern block before cutting a pattern shape (Figure 5).

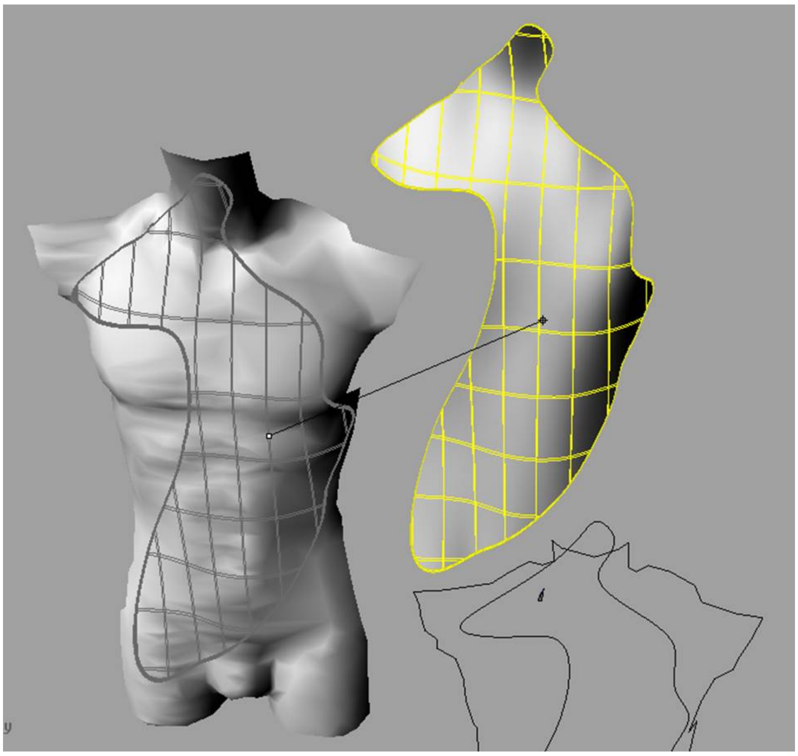

Figure 5. Design lines extraction from 3D torso surface, similar in principle to fashion pattern making process.

This was a significant finding from the perspective of design development of personalized close fitting clothing, the ability to work directly with a 3D body scan surface provides the designer with an extremely accurate and intuitive platform in contrast to the traditional fashion industry approach of development from 2D or flat pattern making blocks.

To date the fashion industry's favoured computerized 3D approach focuses on visual communication based on virtual garment assembly of imported 2D patterns and fabrications that are then dressed on virtual mannequins. This 2D to 3D approach is used by V-stitcher by Browzwear, Modaris 3D fit by Lectra, Haute Couture by PAD and 3D Runway by Optitex. (Power, Apeagyei, & Jefferson, 2011). The 2D to 3D approach is commercially driven and follows traditional protocols of sample making and fit testing, while placing emphasis on the perceived cost savings of virtual prototyping and benefits of visual communication. It could be argued that actual fashion design or the development of garments using 3D virtual environment or more specifically the 3D body scan as the starting point is still to fully emerge.

Project 3D print considerations.

Understanding the capabilities of the technological process is vitally important when considering larger scale 3D printing such as a full scale mannequin. In particular the maximum physical dimension of any single piece is influenced by the build volume of the printer For most machines this is no larger than 20 to 30cm in any direction, so larger scale coverage needs to include multiple panels no greater in size than perhaps an A4 sheet. The depth or thickness of each section should also be considered along with the height and width dimensions. The pieces for the full scale mannequin were planned at approximately 150mm x 150mm and 2mm thick.
3D printing is currently quite expensive so another consideration for the physical output is the best use of additive manufacturing powder within the build volume; the principle is similar to the process used for fabric utilization to minimize wastage. Instead of interlocking pattern shapes to improve fabric efficiency as one would in a 2D fabric lay plan, the 3D printer bed is more akin to stacking a dishwasher, fitting shapes within the 360 degree space.

With some of these considerations in mind initial design development involved the notion of producing multiple jigsaw like pieces based on the torso surface that could then be connected to create a 3D mannequin. Full engagement with the physical 3D printing of the work is yet to begin and will need a series of experiments and prototypes to test whether the proposition is fully feasible; in particular whether the irregular contours of the human form will present difficulty for connecting the jigsaw pieces. A secondary experiment and possibly simpler solution is underway inspired by tessellation, essentially the use of repeat geometric pattern shapes to form a three dimensional object like a football. Despite the fact that there is significant work still to be done to complete the project, there is satisfaction in knowing that preparation processes to get to this stage have resulted in a stronger knowledge base for design engagement with 3D body scan and 3D printing. The project process itself has helped formulate a clearer understanding of how to progress further.

Key research findings and insight clusters

Drawing from contextual 3D digital design practice and highlighted project insights, this section outlines some reflection and issues that should be considered prior to embarking on a fashion related creative 3D technology project.

Engagement with 3D digital technology

The most obvious limitation is availability and access to the technology itself, in part due to the relatively high costs; direct public access to a 3D body scanner outside of tertiary institutions and research centres may prove difficult in some countries. One low cost solution and possible entry point might be using a Microsoft Xbox 360 Kinect converted to perform as a 3D scanner; perhaps not as accurate as purpose built body scanners but it will provide a useable resolution mesh to base subsequent design work on.

Conversely, access to 3D printing equipment is somewhat easier on a commercial basis; certainly prices have dropped from tens of thousands to hundreds of dollars for basic models for domestic use, meaning greater access to modelling and rapid prototyping applications. It should be pointed out that, similar to other technologies, there are distinct quality differences between the personal, professional and production scale options. At the moment the costs involved for commercial quality rapid prototyping are relatively high, so should be taken into consideration.

It would be fair to say that before people will even begin to consider wearing 3D printed objects there is a sense that greater material research is required so that comfort and flexibility can be factored in accordance with the movement of the body. Progress is being made in the form of the Objet Connex multi material printer, which has the technical capacity to mix material compounds such as silicone and rubber, suitable for footwear developments.

Conceptual approach

“The use of new technology forces designers to expand their understanding of the design process and alter their methods for designing, thus potentially generating new products” (Parsons & Campbell, 2004). This point is extremely relevant as it hints that new design processes can result in new thinking that leads to new outcomes. While standard size dress mannequins are readily available, the approach to design and develop directly from an individual 3D body surface to produce a customized mannequin made from interlocking pieces is somewhat unique and could not be made using conventional manufacturing methods. This technology, placed in the hands of innovative design thinkers, can provide a fresh creative space to conceptualize and create artefacts that don’t already exist or alternatively can only be made because of the specific technology.

Importance of digital design skills

The highlighted scanning and printing devices themselves may be seen as the tools at the beginning and end of the technological process, while the space in between is where the main computational design development occurs. The emphasis for conceptual and 3D software skills cannot be underestimated for full process engagement to occur; simply put, if an individual wants to create a 3D printed object then they will have to learn to model in 3D CAD. They will have to learn how to manipulate the software to create the form that they are looking for. This can be a slow process and requires persistence. Alternatively, the question could be asked: do fashion designers need these 3D modelling skills? Or should they simply outsource or collaborate with others? Certainly outsourcing of design work to 3D specialists is a viable solution, but assumes that the designer has a firm idea of what the finished object should be and is able to communicate this. But this option fails to recognise that a design concept could be developed in an unconventional manner within the 3D interface; as Bitonti (2013) suggests, “computation can be more than a means of execution." If possible, a more viable option would be collaboration with other digital designers to fully utilize different skill sets to problem solve, develop and dissect the object you want to create and be able to build it up from the basics.

Conclusion

The paper set out to explore 3D digital technologies in relation to the area of fashion and posed the question of “How might fashion designers engage with both 3D body scan and 3D printing technologies?” The question itself is responded to within the documented research project process and reflections on technologies, skill base and conceptual understandings, but it is fair to say that further exploration and engagement is required to fully respond to this complex topic. While the identified technologies themselves are not new, the exploration of them being applied to fashion design is new, consequently the majority of related creative projects and research outputs identified in this paper are very recent and tend to support the claim that this is indeed an emerging area of research.

The prospect of using 3D body scanning technology to personalize and enrich human engagement is a very tangible proposition, using body scan files as an individualized reference point offers customization possibilities for fashion designers seeking a unique design premium. In contrast, the current state of fashion related 3D printing leading to complete wearable items is still in its infancy and may be more of a longer term proposition; however it is expected that this will change as technological and material advances capable of responding to the complex movement of the human form are developed. The future for this exciting area is unpredictable and should not be underestimated by the fashion community. Whether we see incremental uses of 3D printing working in unison with fashion fabrications or more radical applications, it presents an opportunity to develop a design premium that is not offered using existing processes.

Thus far, there has been a limited uptake from designers from a fashion background who have combined 3D body scan and 3D print technologies in a creative manner. It is hoped that the highlighted project reflections, and technical and conceptual insights identified in the paper, will add to the body of research for fashion engagement with the related 3D digital technologies.

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