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Virtual 3D Garment Draping as a Service

Abstract

This research details a collaborative project jointly funded by Numerion Software and a Future Fashion Factory innovation challenge grant. The aim was to develop a pioneering, virtual 3D garment draping, cloud hosted service that was fit for fashion industry needs and could be leveraged with ease. A focus group consisting of leading fashion designers, brands, manufacturers, educationalists and fashion students, were sent a link to Numerion's initial prototype together with a questionnaire. This asked participants how the software could be developed; how valuable the proposed service would be, exactly how would individual designers, brands and educationalists use the service; how they would prefer to interact with it and how would it integrate with their current workflow etc. The data was used to improve and develop the prototype with the intention to trial this in real time with the focus group. The outcomes identified the challenges facing the fashion industry as they seek to embrace live 3D simulation. This influenced the development work required to address any concerns around functionality and frictionless operability to the software as well as to identify a solid path to commercialization for a 3D garment draping service.

Key Words: virtual; 3D; garment; draping; fashion; industry

Figure 1. Future Fashion Factory exhibition and logo, 2019. Courtesy of Future Fashion Factory.

Introduction

The paper is structured to begin with a description of the research problem in order to set the stage for the aims of the study. Further context is provided in a section that introduces the work of both Numerion and Future Fashion Factory. The significance of the research is explained in relation to a review of relevant literature and is followed by the methodology section. The mixed methods approach is described and justified alongside an overview of the data collection techniques. The findings provide an in-

depth analysis of the questionnaire results and the research decisions made from these results in order to develop the 3D garment draping technology. The conclusion considers how the research aims have been addressed and identifies the future steps for the 3D garment draping service in relation to its expansion, commercialisation and lasting influence within the global fashion industry.

The research has four principal aims. To give a context to the research the literature review explores the background to cloud hosted, virtual 3D garment draping software in the global fashion industry. Essentially 3D draping technology allows the fashion professional to see a design virtually on an animated avatar in a way that accurately replicates its realistic counterpart. Companies developing the technology have worked hard to create results that define the different characteristics of numerous materials and how they react on the body. Avatars can move to show how a fabric hangs and reacts to movement. Fabrics can be simulated in an exact 3D environment, which gives the designer an excellent understanding of the fit and drape of the design they have created on a variety of different body shapes and sizes.

An overview of the collaboration between Numerion Software and Future Fashion Factory (FFF) on an FFF innovation challenge grant is described. The aims of the joint research project were to explore the background to cloud hosted, virtual 3D garment draping software in the fashion industry and education. The endeavour also aimed to gather feedback from a fashion industry and education focus group in order to develop the prototype for Numerion's Virtual 3D Garment Draping, cloud hosted service. This considered features the fashion industry wanted to see in the software in order to meet specific industry and educational needs. The group contributed forward thinking and insightful ideas for how the service could be successfully adapted, which allowed Numerion to identify the further development work needed to create a solid path to commercialization for a 3D garment draping service.

Figure 2. Cloud hosted, 3D virtual garment draping technology from the Promotional film by Numerion Software, 2021. Courtesy of Numerion Software.

Background to Numerion and Future Fashion Factory

Numerion Software is a boutique dynamics consultancy based in Milford, UK. It was set up by Dr. J C. Leprevost - Chief Scientist and Dr. Mike King – Chief Executive Officer in 2009 (Leprovost and King 2021: n.pag.). The company aims to leverage their carbon dynamics library in order to deliver both cutting edge interactive and concurrent simulation solutions. Numerion's initial application for carbon was for artist plug-ins for Maya and Houdini tools. These plug-ins have been used on most major movies in the last seven years for hero character clothing and flesh simulation for animated films and digi-double work. More recently, Numerion has been moving this technology into a cloud hosted simulation platform for interactive and real-time AR/VR character simulation. The aim of this platform is to deliver high (movie) fidelity simulation in the cloud and deliver back to the consumer high fidelity media, as required by the application. Be that high-resolution images, video or pixel streamed interactive content or even in geometric meshes. The aim of the project with Future Fashion Factory was to adapt and be able to deliver virtual 3D garment draping as a service that worked for both the fashion industry and education as well as Numerion. This needed to be a frictionless prototype that was easy to access, as no matter how good the service, if it is hard to use and requires deep technical knowledge, then adoption is likely to be very limited.

In order to secure funding for the project, Numerion made an application to the Call 3, Responsive Research and Development, Proof of Concept (POC) funding from Future Fashion Factory. This is a UK, Arts and Humanities Research Council funded project, housed at University of Leeds. The initiative is a £5.4 million research and development partnership, 'Exploring and developing new digital and advanced textile technologies to boost the design of high-value creative products' (Future Fashion Factory 2021: n.pag.). It is designed to harness and support innovation in the UK textile and fashion industry. Several funding calls for projects have been advertised and these needed to be developed with an academic partner from one of the three universities involved in Future Fashion Factory: University of Huddersfield - UK, Royal College of Art – London, UK or University of Leeds - UK. The Numerion application was successful and the company was able to provide match funding to the sum awarded. A University of Leeds academic was assigned as principal investigator on the project.

Literature Review

An overview of literature explored how the digital revolution in fashion is changing the way clothes are designed, made, sold and used. The Digital Fashion Group, which is a European led initiative between the fashion industry and fashion academics, aims to equip industry professionals and educationalists with appropriate levels of expertise, outlook and approach for tomorrow's workplace (Revolution: The Digital Fashion Group 2021: n.pag.). As they advocate, 'Digital is not just an add on it's a different way

of thinking both creatively and strategically' (Revolution: The Digital Fashion Group, 2021: n.pag.). The digitisation of fashion has been explored in a variety of works that have documented computer-aided design and manufacture (Grice 2018; Pimcore 2021; Stott 2012; Sikarskie 2020; Tallon 2008; Tallon 2013; Weiss Chase 1996). The pattern cutter, Winifred Aldrich produced a series of manuals that have formed the mainstay of pattern cutting instruction for garments in many universities and colleges worldwide (Aldrich 2002; Aldrich 2007; Aldrich 2011; Aldrich 2015). She was also one of the first to embrace the use of CAD in pattern cutting and as well as digitising the traditional approaches to cut, she had pioneered (Aldrich 1994). This was made accessible through a series of workshops Aldrich delivered to international fashion schools. The designer and author, Sandra Burke initiated a series of books that aimed to integrate the use of CAD successfully within the design and technical process of fashion design (Burke 2006). Useful surveys on CAD methods in 3D design and 3D, interactive garment pattern making technology contribute to the body of literature (Liu, Zhang, and Yuen 2010 and Liu, Bruniaux, Tao, Yao, Li and Wang 2018). In addition to this exploratory research that investigates methods of advancing garment prototypes from draping techniques have been studied by investigators (Yong-Jin, Zhang and Yuen 2010; Xuyuan and Bruniaux 2013). Research has also being conducted that considers the reproduction of historic costumes using 3D apparel CAD (Kang 2016).

Within the above context, virtual 3D garment draping is an exciting development in digital fashion and its progression has been explored in various studies (Kang and Min Kim, 2000a; Kang and Min Kim 2000b; Kenkare 2005; Kenkare, Lamar, Pandurangan and Eischen 2008; Miguel, Lucas, Melo, Pereira, Fernandes, Barata, Reis and Silva 2020). 3D draping technology can speed up both the design and technological process of fashion design. Some of the activities developed through software companies such as Clo3D and Lectra allow a greater reduction in design preparation time (Clo 2021; Lectra 2021). Design ideas can be sketched onto an avatar and pattern pieces can be automatically generated. Any amendments to 2D patterns, textures, finishes or colours can be quickly simulated therefore the quality of designs can be improved faster in their initial process and the subsequent development of patterns and garment samples. The technology can successfully match the drape sensitivities of fabrics, ranging from wovens, non-wovens and jersey. There are limitless possibilities available to create graphic ideas, prints and colours that can immediately be viewed on a 3D avatar and avoid the need to see changes on physical samples therefore improving lead times (Clo 2021).

A further body of literature has considered the technical implications of using 3D garment draping. This assigns an in-depth background to what has already been achieved and gives a context to ways in which Numerion Software could develop its own cloud hosted, 3D garment draping technology after consideration of the focus group feedback. Areas such as improving the speed of drape simulation on avatars utilising constrained fabric collision have been investigated (Sul and Kang 2004). The geometric, nonlinear rotation-free triangle and its applications to drape simulation

(Zhou and Sze 2012) and cloth simulation parameters from static drape using neural networks (Ju and Choi 2020), have also been considered in relation to the diversity of applications for use of the technology.

Methodology

The research approach utilized a mixed methodology. This type of research combines both qualitative and quantitative methods in the collection of viewpoints and data and their subsequent analysis. The academics, Schoonenboom and Burke Johnson said, 'A mixed methods design is characterized by the combination of at least one qualitative and one quantitative research component' (2017: 107). The amalgamation of these approaches gives a broad depth of perception and verification when analysing a research problem. The qualitative approach taken in this study was summarised by the writers Corbin and Strauss who described how, 'Qualitative research allows researchers to get at the inner experience of participants, to determine how meanings are formed through and in culture, and to discover rather than test variables' (2008: 12). In this research, it was necessary to gather the thoughts and opinions of a group of selected fashion specialists. Their views related to virtual 3D garment draping software in the fashion industry and education and were utilised to identify the development work needed for Numerion to commercialise it successfully. Quantitative research collects data that is numerical, for instance that found in percentages. This data is analysed to identify results that are balanced and impartial and can be generalised in relation to the aims of the research. The sociologist Yuniya Kawamura, considered how many researchers believe that human experiences cannot be analysed quantitatively therefore the assimilation of both quantitative and qualitative methods can be a more effective approach (Kawamura 2011). The quantitative data gathered in this research came from the percentages gathered from some of the closed questions in the focus group questionnaire.

Data Collection Techniques

The two data collection techniques utilised in the research were focus groups and questionnaires. Responses to the questionnaires were examined using content analysis and inductive thematic analysis. In discussion with Numerion, these techniques were considered to be the most appropriate and valid way to address the research aims. Semi-structured interviews were considered however it was recognised that the use of open-ended questions within the questionnaire would allow respondents to freely write down their thoughts and would enable a wider geographic of participants to contribute to the research within a restricted timescale. This would result in a similar collection of data to that collected through semi-structured interviews. In order to process the data collected through the questionnaires, content, discourse and thematic analysis were considered. Discourse analysis was felt to be too closely related to the use of language in order to define ideas. Content analysis was therefore selected as appropriate because it enabled the researchers to conduct a thorough review of the questionnaire responses. Inductive thematic analysis was adopted to identify issues of importance and new issues related to the development of the 3D garment draping technology.

Focus group research is where selected individuals or groups of people are brought together in order to gather information about their ideas or views on a certain topic. The FFF innovation challenge grant permitted Numerion and the academics to work together to amalgamate their joint contacts in industry and education in order to create a strong network. An initial invitation was sent out to this combined network inviting them to join the focus group. This consisted of students, academics, brands and designers who were all professionally involved in the fashion industry in a variety of different roles. The demographic of the network varied in age group, gender and geographical location as Numerion considered it important to gather a set of opinions from a diversity of fashion specialists in order to inform the development work needed for the garment draping service.

The second data collection technique adopted was the questionnaire. This is a research tool that comprises of a group of questions that collects information from those who participate in it. A questionnaire would usually comprise of a series of set questions that follow a format. These can either be open-ended or closed questions or combinations of both. Open-ended questions allow the respondent to give their own answer be that long or short. Closed-ended questions usually ask a respondent to select an answer such as a yes or no or from another set of options. As the geographical location of the focus group was wide and the research took place during the Covid 19 pandemic it was decided that a questionnaire was the most appropriate means to gather data as the respondent could answer in their own time. The focus group was also large and geographically situated in different time zones so it was recognised that it would be difficult to gather the participants together as an online group to ask the questions and record and transcribe these answers. It was therefore decided to issue the questionnaire through a Google Docs format. This permitted an accurate system for documenting and recording the answers and subsequent data.

The questionnaire was designed to gather both qualitative and quantitative data, which depended on the nature of the questions. The qualitative approach consisted of the open-ended questions. These were designed to get close to the heart of the subject by encouraging the participants to respond with answers that recorded their thoughts and feelings about 3D garment draping technology. The quantitative approach consisted of the closed questions with options for multiple answers. These results are detailed as descriptive summaries in the pie charts within the questionnaire section of the findings. This groups the nature of the different companies in which participants worked as percentages as well as the percentages of those businesses who used an asset management system. The responses to all questions were critically analysed by Numerion and the academics working as a team and used to inform their decisions on how to develop the draping technology.

Content analysis was employed to examine the replies to the questionnaires. This is a qualitative methodology used to analyse images, film, audio and in the case of this

research, text. Within the social sciences it is employed to examine patterns or systems in communication. Both Numerion and the academics considered this to be a valid method within the research as it was important to analyse the respondents thoughts about 3D garment draping technology in the fashion industry and how this could develop as well as their reactions to the existing Numerion software and how the company could improve it. The content analysis of questionnaire responses, 'Can be undertaken to understand remarks that may explain the responses, provide illustrative examples of issues raised in the questionnaire, define new issues or issues of importance that were not covered in the questionnaire and inform the design of new questions in future surveys' (Griffiths 2016: n.pag.). The answers were subsequently examined using inductive thematic analysis. This approach is used within qualitative research to identify themes and patterns within the data that has been gathered. In this study it was used to categorise answers in terms of their relevance to the research aims and the future direction for the 3D garment draping technology.

Data Analysis

The literature review enabled the development of the questionnaire. When data from the questionnaire came back, Numerion and the academics scrutinized this using content then thematic analysis. Following analysis, triangulation of the data took place through six fashion industry colleagues not involved in the research. They were approached individually to validate the overall analysis. This aided triangulation of the data as informed individuals who were not participants in the research were able to provide 'sense checking' with their experience as well as comparing this with the literature reviewed (Vaughan 1992). In this sense, triangulation took place as a means to ensure methodological integrity with a reliable set of data as a convincing means to make concrete decisions from the findings. This approach was supported by sociologist Uwe Flick who said, 'In social research the term 'triangulation' is used to refer to the observation of the research issue from (at least) two different points' (2004: 178). The intention for further development of the research is to trial the improvements to the software in real time with the focus group. This will again be tested through a written survey of results to a questionnaire and will be triangulated by asking individual respondents to validate the collated survey. These results would be used to develop and refine the prototype even further.

Findings

The first stage of the project was led by the University of Leeds lecturers. The combined network consisting of fashion designers, brands, manufacturers, students and academics were approached in order to gauge interest in being part of the focus group. This was compiled using the collective industrial and educational contacts of Numerion and the academics and included many former fashion graduates placed in a wide variety of national and international companies. The affiliation list of Future Fashion Factory, which at that point worked with 231 fashion industry and 23 fashion educational members was also used to establish contacts. Further contact was made with the Association of Suppliers to the British Clothing Industry (ASBCI) who gave permission

for their member companies to be contacted. The initial email invited people to be part of the focus group to help conduct research in order to facilitate the launch of *Virtual 3D Carbon, Garment Draping Software* to the fashion market. Some background was given that related to the project. Numerion's position as a boutique dynamics consultancy who deliver both cutting edge interactive and real-time simulation solutions was explained as well as the key challenges involved in being able to represent physical fashion products within the digital world.

The initial email included a link to Numerion's existing, draping software, which the recipients were invited to watch. It was also emphasized how the focus group would have the opportunity to see the development of the exciting new system (figure 3). The link explained how the company were building on ten years of movie hero garment simulation. Live simulation can be achieved in fashion, movie production, architecture, product design and presentation and medical training etc. The link also detailed how fast, accurate multi-layer draping could be achieved at approximately one second per garment including rendering and unlimited close up detail. This was illustrated by an avatar of a female in lycra gymnastic wear and included close images of the garments (figure 4). The same figure was shown in a virtual try on with the size of the body wearing the garments, increasing and decreasing to demonstrate how the avatar could be changed to accommodate different body shapes. The first section of the link culminated by advertising what would be coming soon with technological developments, including: accurate multi-level drape, virtual try on, soft avatar simulation, animate, interact and accessories. This was followed by short demonstrations of the following activities: untangling a skirt mesh using Carbon; introduction to velocity reducer for cloth and morph; using a texture to select binding points; stiffening cloth with actor and rigid welding.

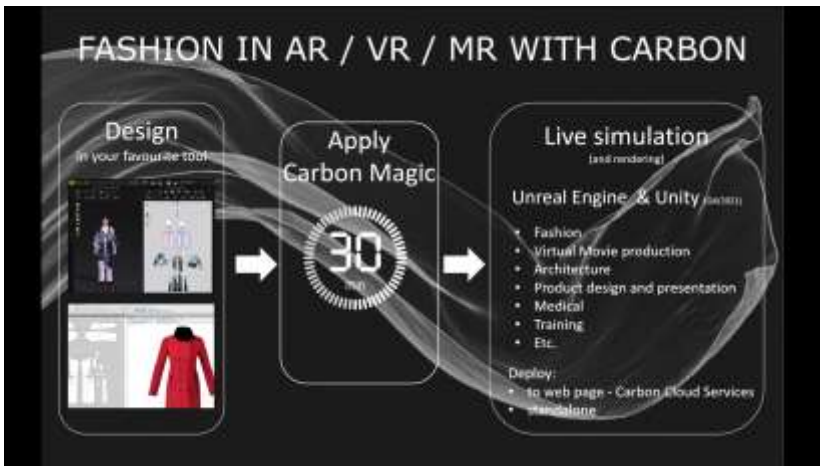


Figure 3. Detail from the link sent to the focus group, detailing Numerion's virtual 3D garment draping service, 2021. Courtesy of Numerion Software.

Figure 4. Avatar of a female in lycra gymnastic wear that includes close up images of the garments, from the link to Numerion's virtual 3D garment draping service, 2021. Courtesy of Numerion Software.

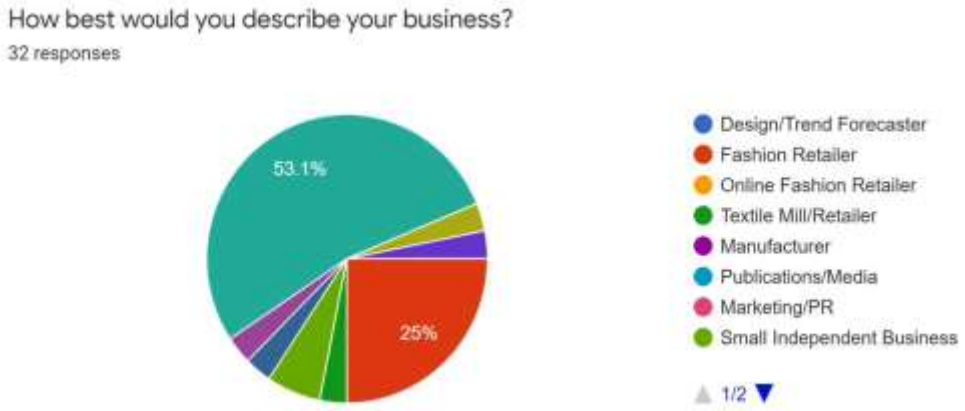
The replies to the email resulted in a shortlist of the following international businesses and institutions who were keen to form the focus group (Table 1). Several of the respondents belonged to one business or institution. In total 42 individuals formed the focus group.

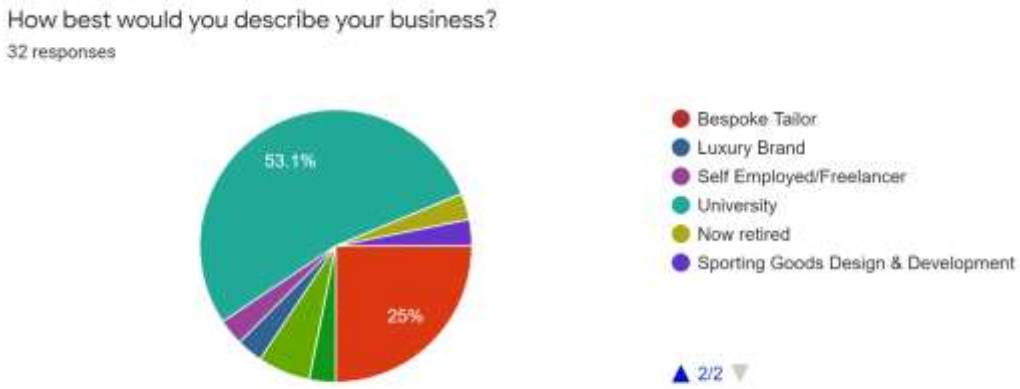
Yorkshire Textiles	The Digital Fashion Group
Hainsworth	Wallis
Joshua Ellis	Mint Velvet
Sil Group	Inspire Intimates
University of Leeds	Joe Brown Ltd
University of Technology, Sydney	French Connection
Royal College of Art	Burberry
University of Huddersfield	Worme
California College of Arts	Tu Sainsburys
Staffordshire University	Raeburn Design
Cornell University, New York	Asos
Independent Fashion Designers	Pentland Group
Independent Knitwear Designers	ASBCI

Table 1. Shortlist of companies and institutions in the focus group, 2021.

The Questionnaire

Each member of the focus group were sent the online questionnaire through Google Docs. The initial question sought to identify the role of the company or the individuals. The percentages of the different business roles from the focus group are identified in the pie charts (figure 5 and 6). Not all the listed businesses types are represented as 32 individuals responded to this question out of 42.





Figures 5 and 6. The percentages of the different business roles from the members of the focus group, 2021.

The first questions were designed to explore what the existing digital environment of the participants was like and if they were currently using a 3D package within their business or design practice? If the answer was no, how ready were they to adopt 3D technology and what would it take to get them there? Those already using or having access to 3D packages were asked what these were and what they were used for as well as what the benefits were to their work or business from their use. They were also asked if there were any specific features they felt were missing and if their current package was user friendly and compatible with existing software. The second set of questions explored the participant's reactions to the existing software demonstrated in the link sent with the initial email such as; where they as a brand, business or individual saw the value in Numerion's Carbon virtual 3D draping innovation software and what fashion companies or individuals were looking for in terms of virtual 3D draping. Participants were also asked how they saw the technology enhancing the development of 3D fashion design and garment realization, whether they would pay for the technology and if it would enhance the sales and marketing of their products.

Content and Thematic Analyses of Questionnaire

The content analysis methodology was employed to systematically explore the replies to the questionnaire. The responses reflected how the participants were ambitious for the technology to do many things related to the different areas of design, pattern cutting and garment manufacture. These responses were filtered by Numerion and the academics using inductive thematic analysis to identify clear and forward thinking solutions for its future development. A summary of the main responses are discussed beneath each question. Each question is highlighted in italics. Quotations from participant responses have been kept anonymous to deflect from any bias towards a company, educational institute or individual. The quotations are all cited, (Anon. 2021) however they are numbered to empasise how different people have been quoted, for instance Anon 1. Anon 2. etc. This summary was then returned to the six fashion industry colleagues not involved in the research to validate the analysis in order balance out some of the subjective replies from different individuals.

What are Fashion Companies/Individuals looking for in terms of Virtual 3D Draping?
Many respondents explained that they wanted to see designs more directly and that a 3D virtual presentation would better explain ideas and allow others to see designs from multiple angles. This would enhance a more accurate way of displaying and engaging potential buyers and existing customers for garments and textiles. One respondent felt that, 'Virtual representation is as good as or better than a physical prototype fitting, for identifying fit and balance issues in a pattern' (Anon 1. 2021). This means designers would not need to see many samples to make small styling changes that could be seen and decided on virtually. It also saves time and supports the use of digital garments in the visualization and selling process, utilising physical garments from virtual show rooms to virtual try-on and customisation, through to full marketing campaigns. It was clearly stressed that getting an accurate representation of fabric properties is very important to virtual 3D draping as this enables designers to visualise the pattern and fabric as a garment and gain an understanding of fit and movement in the garment design. The technology also enhances the ability to be playful or ridiculous and not constrained by mannequin, block pattern or matrix rules.

What features of Carbon Virtual 3D Garment Draping would you be interested in?
The main responses to this question emphasised a need for the technology to show the fit of garments on various body shapes as a true simulation so customers could see how a specific fabric would drape and react within a particular design before sampling. Retailers and e-commerce could offer the service as a virtual try on with 360 degree or at least multiple viewpoints, with the ability to zoom in and out and hover. This would also give the consumer the ability to change the size of the avatar and garments. It could also be sent to customers as a video, complete with zooming, rotating or catwalk movement. The designer or customer could upload pattern pieces to create a virtual garment and mix and match outfits and accessories online in order to fully style the ensemble.

Where do you as a brand/business/individual see the value in Numerion's Software Carbon Virtual 3D Draping Service?

The majority agreed that the technology would be useful in the pattern development and toiling stage of fashion design if pattern pieces could be seen alongside a virtual garment to ensure that first time, fit samples are as near perfect as they can be before being made in real life. This would reduce the need for in person fittings and the amount of time spent on creating patterns and allow for better communication between designers and pattern makers. It would also permit fashion designers to understand the weight of fabrics, which is difficult to convey without physical visualisation. One respondent commented that, 'For designers, being proficient in such skills will also make them more competitive in the job market' (Anon 2. 2021). In fashion retail, respondents felt the software could be used in online stores, where access to physical garments is limited. This would show the viewer exactly what they want to see and replicate the handle and trying on of the clothes. From a sustainable perspective, it could eliminate the need to purchase clothing when the goal could be to experience dressing digitally. This would help prevent over consumption and waste of the earth's resources.

How do you see this service enhancing the development of 3D Fashion Design and the garment realization/design process?

Within the fashion design process respondents felt that being able to determine the fit and fall of garments before actually cutting them out or making them up could help reduce waste in fabric and other materials. Virtual draping could decrease the back and forth communications with mills and factories when discussing fabrics and finishes and their effect on completed garments. It would reduce the waste of materials as the designer would know patterns are accurate and cut to the desired fit after using the software. It lets the designer experiment more with shapes and draping with ease. One respondent felt the rendering quality of the virtual garments on the video was quite basic. More lifelike visualisation and accurate drape simulation would be needed to provide enhanced 3D fashion design development. Another respondent commented, 'I think the nature of the programme allows you to visualise true ideas and create conclusions without going through the full design, sample construction and production process' (Anon 3. 2021). It was also suggested that the software could be used as an experimental design tool in a wildly imaginative way that could show realistic simulations of strange, complex and currently (near) impossible trials or tests, which open up new directions for fashion innovation.

Responses to those who answered – NO – to - how ready are you to go there and what would it take to get you there?

One of the respondents, who is a garment technologist commented, 'We are researching into this currently. I think the responsibility of the software knowledge and usage will be in the supplier's hands, but we are ready to see what they can achieve to make our development process more streamline. We are looking to run small projects, to see their capability and to then present this to our directors' (Anon 4. 2021). Cost was generally

considered important as for manufacturers, the wholesale market could be slow to adopt the software. Training packages were also held to be integral to the adoption of the technology as this would ensure competence in its use. It was considered that initial training packages developed by Numerion, should comprise of very clear explanations of how to use the software and include details of access to an operator or help desk to trouble shoot questions.

What are the benefits to you/your business from using this package?
The majority of respondents agreed that adoption of the software would save money, time and resources, which would be both positive and sustainable. It would also mean garments could be approved without multiple mock ups or samples being made. This would enhance, 'Speed to market, reduction in samples, enhanced assets for selling especially when people can't travel and enhanced communication with vendors' (Anon 5. 2021). Building virtual outfits would also allow designers to understand the drape and shading of garments on the human form so when they need to be illustrated it can be seen how the fabric would react on the body. This would encourage designers to explore the design process in a different way. They could engage with digital technology to advance existing skillsets and encourage the development of innovation in fashion design and education along with input to the future of the software packages with the ultimate aim of creating a seamless technological suite.

Are there any specific features you feel are missing?
The development of virtual fabrics was deemed essential by many respondents. Digital fabric properties were not considered accurate enough and different ways of viewing them on garment and body representation was essential although they needed to be realistic in terms of parameters and functional effects. It was also noted that users need to be able to lift garments and resettle them on the body to check the balance of the fabrics and clothes. It would however be beneficial to see the garment move and be able to manipulate the virtual image. The notion of mistakes and happy accidents were stressed as essential to draping and garment innovation. Therefore, it was suggested that a greater sense of play and serendipity be designed into the software so a novice could get going faster, whilst a more experienced designer could switch to a more refined palette of tools and processes. It was also suggested that the software includes basic shapes and basic blocks already uploaded to the system, so the user can adapt these blocks, rather than having to start from scratch. This could be achieved through building an asset management system that could be used in conjunction with the 3D draping technology.

Are You Using an Asset Management System?
An asset management system is a process or inventory that a company utilises to record all the equipment and tools essential to the daily operation of the business. The rationale for this question in relation to the survey, was to gain an idea of how the business, organisation or individual would catalogue the essential equipment such as garments, patterns or 2D images needed to create designs, patterns and garment samples. The idea

for asset management is that the 3D draping technology could take what it needed from the system to create the prototype. There were 28 responses (figure 6) to the question that were mainly in the negative apart from two who used a system related to FlexPLM, which is a product lifecycle management device from a PTC company for retail footwear (FlexPLM V12 Retail PLM Solution 2021).

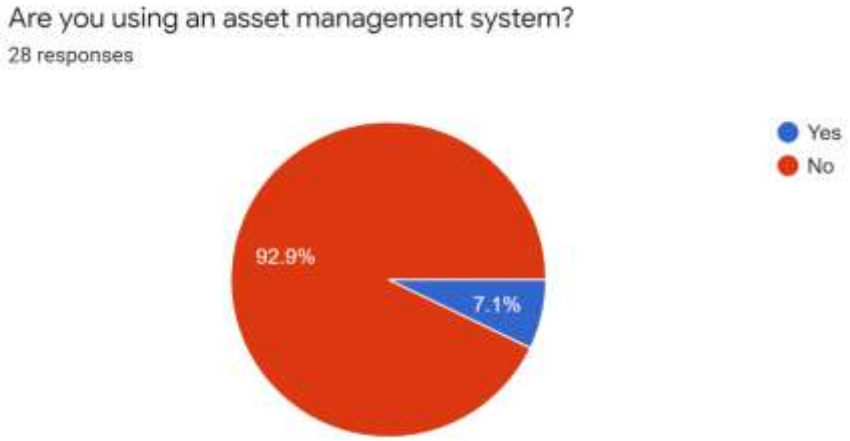


Figure 6. Responses to the question about use of the asset management system. 2021.

Please have your say, we would like to welcome you to add any additional information or ideas below.

This section offered respondents the opportunity to add further thoughts about the development of the software. It was strongly felt that the chance to show cloth and virtual garment draping would fulfil a gap around current global manufacturing issues. As with any new technology, the technology itself is not enough therefore, a new way to provide well-designed and fitted clothing, as well as incorporating virtual reality would also be needed. One respondent said, 'I think virtual 3D draping is an amazing idea and very exciting for the education of fashion design. A lot more jobs are requesting experience in this software, so it is essential that it continues to be taught in the education system as it is so useful in understanding each stage of the design process' (Anon 6. 2021). The importance of training was echoed by most respondents as the key to marketing and gaining new customers for the software. It was observed that many professionals don't have time to read through large manuals and do not need to know everything at once therefore bite sized training on different aspects of the software would be useful.

Decisions made from the Questionnaire Results

Before receiving the results from the questionnaire, no concrete ideas were expected from the focus group responses. Inductive thematic analysis permitted the identification, interpretation and evaluation of the responses. The feedback was that the participants mainly wanted the 3D draping technology to do a lot of the things

that the researchers felt could have been anticipated in terms of design, garment creation and aesthetics. The comments were therefore an important validation of improvements that needed to be made to the draping technology all of which Numerion decided to action in its subsequent development. Due to the acknowledgement that very few were using a digital asset management system (DAM), the conclusion was that this essential capability was missing and was therefore the glue to making the 3D draping technology work (Resource Space 2021: n.pag.). As this was relatively new to the fashion industry, Numerion, felt few were using asset management because there was a lack of understanding of these systems and how they could connect to 3D draping. Govisetech described the use of DAM in the fashion industry within their website. This described how it, 'Involves tools for storing, organizing, and retrieving all digital assets. As the fashion industry is all about viewing the sampling designs right before their release, it is important to manage all the data pertaining to visualization in a more structured way' (Govistech 2021: n.pag.). Dr Mike King, CEO of Numerion Software commented, 'Sometimes you don't know what you want until you are presented with it' (King 2021: n.pag.).

It was recognised that building a DAM from scratch would be very expensive and well beyond the budget Numerion had available. It was therefore decided to use some of the Future Fashion Factory funding to develop it and create a comprehensive asset management system that would engage with the way customers wanted to use it with the 3D draping technology. Further support could be sought from one of several solid Open Source solutions available that already assist the basics of image and video handling, for instance, from companies such as, *Resource Space* and *Pimcore*. The first steps would be to put together a data base consisting of 3D objects, 2D images, video and 2D patterns to act as a user interface and workflow for the draping (table 2). The idea being that 3D draping could take from the asset management system to create what was needed on a particular project. In response to the final question asking for further thoughts on the 3D draping technology, Numerion verified the importance of training packages to teach users how to merge asset management with the draping technology as well as operators or help desks to approach with any issues. The digital assets that would be included but not be limited to are detailed in table 2.

Patterns	Avatars
Fabric Shaders	Scenarios
Physics properties	Avatar animations
Mapping between simulation and render panels	Restrictions on what can and can't be mixed and match, size fits etc
Images	Videos
3D assets in various packages	Fashion illustrations

Table 2. List of initial assets to be held in the DAM data base, 2021.

Numerion deduced that without asset management it would be difficult to arrive at a sophisticated use of the 3D draping technology. Therefore, the challenge would be making it accessible and understandable to those who would use the system. It was anticipated that assets could be put into a database and the user could pull up a window to view them. The draping could then be used internally to view assets or externally to develop and show customer requirements. This system would be used to educate the industry who could move from distributing folders on a share-point to using a digital asset management system. Once created the DAM could be trialled through the focus group to gain further feedback on its effectiveness. Numerion considered this to be an exciting and educational move and a major initiative to promote through Future Fashion Factory as well as its adoption in the global fashion industry, considerably expanding the use and application of the technology.

Conclusion

The literature review explored the digital environment in fashion and gave an overview to the background of cloud hosted, virtual 3D garment draping software within the industry. The responses from the fashion industry and education focus group provided important feedback to further develop the prototype for Numerion's virtual 3D garment draping service. This was an opportunity to consider the key features fashion companies want to see in the software that meet specific industry needs and is therefore an important point of reference of lasting influence. The majority of feedback confirmed what had been anticipated by Numerion and will be applied to the development of the software. In summary, this will include, advancing the technology to show the fit of garments on various body shapes as a true simulation so customers could see how a specific fabric would drape and react within a particular design, before sampling. Identifying how pattern pieces could be seen alongside a virtual garment to ensure that first time fit samples are as near perfect as they can be, before being made in real life. Being able to determine the fit and fall of garments before cutting them out or making them up will also reduce waste in fabric and other materials and is sustainable, saving money, time and resources. The accuracy of virtual fabrics and their digital properties and the different ways they could be viewed on garments was also deemed essential although they need to be realistic in terms of parameters and functional effects.

The catalyst for the most important development to the technology was the low response to the question that asked if respondents were using an asset management system. Numerion concluded this crucial facet as missing and was therefore essential to making the 3D draping technology work. The plans to create a digital asset management system (DAM) are the next steps to the research and this will be trialled with the existing focus group. The DAM will be set up with the digital assets suggested in the findings in table 2 and the trial will be used to identify what further assets users would need to make the 3D garment draping system work for their business needs. It is anticipated that these developments to the technology will significantly expand the range and depth of virtual 3D garment draping by making it

more user friendly and create a solid path to commercialization for a 3D garment draping service. Numerion would want to be credited for supporting the development of the DAM, however consider the best outcome for all would be for the DAM to be branded - *Future Fashion Factory created by Numerion Software*. Companies could also use the DAM for other purposes in the business, such as managing their website assets etc. Therefore, this technology would have far wider implications and global impact beyond its use with the Carbon draper.

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