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Can 3D CAD Revolutionise the fashion design process? A longitudinal survey of UK fashion companies

Abstract

3D CAD for modelling virtual garments offers the potential to revolutionise the fashion design process. Most research into 3D CAD's potential concentrates on technical application, the development of parametric body models, and cloth simulation and drape. However, there is little research regarding how fashion designers are reacting to, or using the technology. This research investigates how 3D CAD systems may impact on the designer and the design process, particularly in relation to skills and competencies. A longitudinal survey methodology collected data from four UK based fashion companies over a four-year period. The survey examined aspects of change over time, designer's attitudes and opinions, and the extent to which new forms of CAD systems were introduced and used. Findings show that 2D CAD systems have been successfully exploited as a creative tool to speed up design and communication within the supply chain allowing companies to gain the competitive edge. The evidence suggests the design process is significantly influenced by the application and quality of 2D CAD garment images. CAD tools facilitate accurate detailed artwork and provide photorealistic visuals as alternatives to physical samples, which assist

faster decision making and reduce iteration in the design process. In contrast 3D CAD systems have yet to be effectively adopted by the UK fashion industry.

Introduction

3D CAD is widely used in disciplines that require conceptual data representation. In architectural design practice 3D models have successfully replaced traditional depictions as a means to realise and evaluate ideas, reduce iteration and understand the consequences of the materials and methods (Schodek et al 2005). The entertainment industry's desire for virtual reality characters, animation and clothing has driven the boundaries of 3D and computer graphics imagery (CGI) and heightened awareness through games and films (Bermudez 2003).

Mainstream fashion industry designers use 2D CAD tools as a means to speed up the design process, enhance professional presentation, and reduce iteration, thus save costs. However 3D CAD systems, now available to the clothing industry, offer the potential to improve communication and reduce garment iteration through simulated clothing draped on an avatar to evaluate design, fit and cloth properties. While there are many examples of 2D CAD in the design process, there are few descriptive or empirical investigations about fashion designers utilising 3D CAD despite the availability of commercial systems.

Research aims and objectives

This research was motivated by the need to understand how 3D CAD impacts on the designer and the design process. The aim of the research is to:

- Examine 2D CAD for fashion design, attitudes and opinions towards 3D CAD, and provide evidence to make recommendations for skills requirements.

The research objectives will be to:

- Establish from the literature review the background knowledge of 2D/3D CAD;
- Provide an understanding of opinions and attitudes towards CAD within the design process, specifically 3D CAD;
- Draw conclusions from the research in relation to the impact of new forms of CAD on fashion design skills and competencies.

Research methods

This research was situated in a period of UK clothing industry downturn due to international competition and economic global perspectives. The research used multi-case, longitudinal studies carried out in two phases over a four-year period, as shown in table 1. The 1st phase was completed during 1999-2000 and the 2nd phase was completed during 2003-2004.

Table 1: Case study interview calendar

	1st phase				2nd phase	
	1999	2000	2001	2002	2003	2004
Case A	May/July				14 July	
Case B	June/Sept				0ctober	February
Case C		March			July	
Case D		May			April/May	

Table 2: Longitudinal case studies

1st phase	2nd phase	Location
Case A: The Fielding Group ▪ A: Design director ▪ B: Senior men's wear designer ▪ C: Senior children's wear designer	**Case A: The Fielding Group** ▪ A: Design director ▪ B: Senior men's wear designer ▪ C: Senior children's wear designer	Bedfordshire
Case B: Bhs ▪ A: Children's wear design manager ▪ B: Freelance children's wear developer ▪ C: CAD coordinator	**Case B: Bhs** ▪ A: Lingerie design manager ▪ B: CAD designer	London
Case C: Reebok UK	**Case C: Reebok UK**	Manchester

▪ A: Design manager & men's wear designer ▪ B: Technical sports wear designer ▪ C: Women's sports wear designer	▪ A: Product category controller & head of women's wear ▪ B: Women's wear designer & team leader ▪ C: Men's wear designer	
Case D: Coats Viyella ▪ A: Senior design executive with CAD responsibility ▪ B: Ladies outerwear designer ▪ C: Lingerie designer ▪ D: CAD manager/textile specialist ▪ E: CAD and printing/digital print specialist	**Case D: Quantum Design Group** ▪ A: CAD manager/digital print specialist ▪ B: Digital print technician ▪ C: Senior CAD designer/print & graphics specialist ▪ D: Lingerie designer	Nottinghamshire

Data collection followed a fixed structure using open-ended questions. Cases (table 2) were 'typical instances' (Denscombe 2003) of UK mass-manufacturing companies producing mainstream fashion/clothing, designed in-house for different market areas (e.g. children's, women's wear etc) using CAD in the design process. A design manager and two designers were considered a satisfactory sample from each case. Designers produced their own CAD work, but textile/CAD specialists were also interviewed where necessary.

During the period between phases economic constraints affected the structure and ownership of companies resulting in sample cohort 'mortality' (Cohen et al 2005); consequently suitable respondents were substitutes where possible, as table 2 illustrates. Interviews carried out during 2004 with three design experts using 3D technology, and three CAD companies developing 3D clothing software, supplemented the primary research (table 3). Respondents' expert knowledge, attitudes and opinions towards 3D and the skills and competencies required to use the technology provided additional rich data to formulate recommendations.

Table 3: Additional primary research

Expert designers	CAD company experts
• **Expert A**: is a textile artist using 3D CG and kinetics for digital installations • **Expert B**: is a fine artist using 3D/haptics to map surfaces • **Expert C**: is a 3D clothing CAD specialist	• PAD System Technologies • Browzwear • Tukatech

2D CAD and fashion design

The literature describes fashion design as a highly skilled multidisciplinary process requiring a systematic and analytical approach, technical expertise, creative design synthesis, evaluation and heuristic knowledge (Le Pechoux et al 2002, Sinha 2002). 2D CAD is used to provide commercial advantages, such as faster design-to-market and better connectivity between designers, suppliers, retailers, and manufacturers in different geographic locations (Burns and Bryant 2002).

2D CAD is portrayed as a powerful medium to express the fashion ‘look’ or trend (Mckelvey and Munslow 2007), and to present range ideas to clients. Numerous benefits are associated with accurate 2D CAD imagery as a means to reduce sample misinterpretation, which leads to costly re-sampling and creates barriers between technical and design functions (Burns and Bryant 2002). Jones (2005) argues that 2D CAD strengthens the design process through realistic imagery, and facilitates range approval prior to physical sampling, thereby reducing sample iteration, while Eckert and Bez (2000) claim 2D CAD allows designers to be in control of the design process. Internationally it is recognised as a visual language within the supply chain and an important communication channel (Stacey and Eckert 2003)

Brown and Rice (2001) argue 2D CAD supports and strengthens design communication, impacts the designer processing ideas, and the general design process. The main benefits can be summarised as follows:

- Scan garments and fabrics swatches
- Colour garment designs
- Experiment endlessly with designs

- Communicate with other locations
- Allow buyers approval online
- Provide digital images for adverts /catalogues
- Aids garment selection and reduces iteration

However despite these numerous advantages conventional 2D CAD may be destined for obsolescence because it has limited visual facility (Rodel et al 2001) hence cannot replicate fabric characteristics and lacks realism. 3D CAD will therefore supersede 2D CAD by providing verisimilitude, increased usability, speed, graphics, intelligence and automation (Eckert and Bez 2000, Stacey and Eckert 2003).

3D CAD for fashion

The scope of this area encompasses many technologies, including mass-customisation (MC), made-to-measure (MTM), e-retailing and scanning technologies; developing a parametric avatar and cloth characteristics; the interaction and layering of cloth with the avatar, garment virtual modelling (GVM), and animation and garment movement. Prominent institutions, such as the University of Geneva and Miralab, the Hong Kong Polytechnic University, the University of Belfast, together with leading clothing CAD providers are developing these innovative technologies.

Commercial 2D-to-3D clothing systems mirror traditional garment manufacture methods (Volino and Magnenat-Thalmann 2000) and are linked to a PDS, which requires the skills of the pattern technologist. Patterns draped onto the 3D avatar, which represents the fit model, are used to evaluate garment fit problems, fabric characteristics and design issues before physical prototypes are made (Kwong 2004, Volino et al 2005).

Commercial 3D solutions claim to improve garment productivity, particularly for high-cost economies competing with low-cost countries (Keenan et al 2004). Unlike 2D drawings, 3D visualisations are not “interpreted”, potentially improving design quality, enhancing product accuracy, and reducing iteration (Siodmok 2007), thus fewer physical samples present substantial cost savings (Burns and Bryant 2002). While 3D CAD is promoted for design evaluation and fit analysis its position within the design process is unclear. Bruner (in DesMarteau and Speer, 2004) argues the complexity and challenge of using 3D CAD presents competency issues for users who will require new skills to interact with 3D tools.

Contemporary initiatives

Recent EU initiatives (e.g. E-tailor, FashionMe, and Leapfrog) have supported the development and implementation of 3D CAD to overcome challenges facing the garment industry. These include the drive for faster accurate design-to-market; improving communication and collaboration with global supply networks; reducing the physical sample manufacture process; and improving the physical sample review process, which is expensive and has a low sample acceptance rate (see http://www.leapfrog-eu-org). Exploiting 3D real-time clothing simulation and visualisation for effective/profitable MC and MTM activities aimed to address such problems (Cordier et al 2003).

E-tailor for example combined 3D technologies for MTM (see www.ist-world.org/ProjectDetails). FashionMe developed a portal for animated avatars and services for MC (see http://www.fashion-me.com), confirming that virtual reality offers successful retail application (Miller and Mueller 2000). Leapfrog addressed effective garment design, prototyping and business organisation through high-tech production, virtual prototyping tools, and organisation concepts for MTM and MC e-retailing (see http://www.leapfrog-eu.org). However, while 3D potentially benefits the industry, one of the major problems for implementation is the industry itself, which prefers to outsource production to off-shore counties rather than adopt new technologies (Kiekens in De Coster 2006). Touch-enabled interaction technologies such as the Haptex system (Magnenat-Thalmann et al, 2007) are also promising to support scenarios where fabrics play a key role. However significant advances in existing technology are necessary before such research can be integrated successfully into 3D developments (IST 2006).

Results of case studies

Over time all cases experienced transformation in varying degrees, driven by difficult economic developments, increased supplier and product competitiveness, and the necessity for overseas partners. Recruitment as a designer generally required a creative portfolio underpinned by core design skills, previous experience, knowledge of markets, and CAD expertise. Cases identified a range of personal qualities and creative and technical skills necessary to work as a designer in the fashion industry. Problem solving, team work and effective communication were key capabilities identified in the 1^{st} phase.

In addition self-motivation, adaptability, reliability and discipline, management skills, self-confidence and language skills were considered essential by the 2^{nd} phase. Important creative skills included traditional artistic competencies, core design skills, effective trend research and the ability to expertly interpret trends and concepts, and to creatively apply CAD, colour and textiles. Key technical capabilities included CAD user skills, accurate CAD drawings, knowledge of pattern construction, garment manufacturing, and textiles.

Respondents' opinions of 2D CAD in the design process

As a design tool 2D CAD was fully integrated into the design process to gain the competitive advantage and to enhance communication within the supply chain.

> "2D CAD enables you to do any design, weave, print or graphic design you require in a very short space of time…I don't think the industry could not do without CAD any more… it is now an integral part of a designer's job". (2nd phase case D, 2004)

Cases combined commercial and proprietary software to gain maximum benefit for the design process. 1st phase proprietary 2D systems included Eneas Designer by CAD for CAD, and Lectra's U4ria, but these were considered difficult to use, costly to install and required expensive specialist training. While 1st phase cases invested heavily in professional CAD training for designers, 2nd phase cost-cutting strategies included utilising design staff for in-house training and replacing complex systems for off-the-shelf software, such as Adobe Illustrator, since designers favoured the user-friendly interface.

Case D however deemed specialist training and proprietary software as essential for the business. All cases reported issues with compatibility, colour values and large file formats, which were limited by processor power. 1st phase designers reported aesthetic and technical difficulties with the CAD software they used, but 2nd phase issues focused on the technical limitations of hardware rather than software problems. Off-the-shelf 2D CAD software was favoured for several reasons; it is cheap and connects well to other software, its user-friendly interface has the capacity to create sophisticated design responses, and it generates confidence in the designer to achieve design outcomes.

2nd phase design roles were influenced by faster design-to-market and a shorter less flexible design cycle. As products were more price-driven there was less scope for error within the design process; therefore emphasis was placed on accurate trend research and better knowledge of client requirements. The increased workload in the 2nd phase required designers to maximise expertise to improve 2D CAD outcomes. 2D CAD significantly influenced the design process by facilitating professional artwork effectively and cheaply, thus quality CAD sketches and accurate details reduced error and misinterpretation in product development.

Unambiguous 2D CAD design sketches and photorealistic images of textile work and colour representation could therefore substitute for garment samples, necessitating fewer design presentations and physical samples, consequently saving costs through reduced iteration. While quality CAD visuals provided on-screen evaluation without the need for physical CAD worksheets, it was generally believed the expectation of 2D CAD as a technology was beyond its capabilities.

Respondents' opinions of 3D CAD technology

Whereas 2D CAD technology was used to gain the competitive advantage, unexpectedly the exploitation of 3D CAD has not been seen as a dominant response to change; therefore not evident as a tool for design or product development. However 2nd phase case D was testing a Beta version of Lectra's desktop 3D Visual

Merchant software for visualising retail store layout, populated with two-dimensional hanging garments. But as its format lacked the detail and 360° view of clothing 3D CAD systems; therefore not considered a viable solution for visual merchandising.

Although 2nd phase respondents had awareness of 3D technology they had no user experience of 3D clothing CAD. Most respondents regarded the technology as a tool for simulating complex high-fashion garments, rather than the uncomplicated mass-produced products associated with the case studies. Opinion therefore suggested that for investment to take place 3D CAD should offer added value to the design process, such as specialist sportswear systems. Further barriers to 3D CAD implementation concerned the lack of touch and feel and realistic fabric characteristics, which virtual simulations cannot replicate, and which respondents regarded as key elements of design evaluation and product development. However, 3D CAD was regarded as a feasible concept for marketing departments, since buyers lacked design knowledge to interpret 2D CAD presentations.

Generally respondents perceived 3D as difficult to apply, complex to use, and time-consuming; consequently would constrain designer's efforts to manage the tight deadlines and faster design-to-market. While 2D provided a sophisticated and successful format to gain the completive edge, implementing 3D CAD as a design tool would require a new mind-set and modify the designers' role. Implementing 3D CAD into practice was an important cost issue, and would require intensive staff training for 3D. However diverting core skills to the new technology would leave a gap in the existing staff, which could be resolved by employing new staff for the 3D CAD area, but would necessitate extra expenditure.

Additional primary data

The findings from the comparison of CAD companies outlined in table 5 illustrate the advantages of 3D CAD, barriers that impede implementation, and core training and skills issues. According to the CAD companies the main issues for 3D technology users are acquiring a new skill set, gaining the skills to interpret a digital image, and learning a new software package. Expert designers regarded 3D's potential in terms of its impact on the design process, the skills and training needed to use the technology, and barriers and advantages to implementation, which are outlined in table 6.

Expert designers believed that 3D computer graphics offer the potential to explore, create and understand the limits of digital language. However they argue 3D for fashion/textiles will require the expertise and collaboration of other professionals. While 3D represents a unique visual language commercial 3D software may impose limitations on the artist or designer. Interpreting digital visual language would also require users to have specialist knowledge and skills in order to evaluate reality against the virtual simulation.

Table 5: CAD company issues regarding 3D user and implementation

Technology advantages	3D CAD will integrate design with technology & enhance communication between technology departments
	3D CAD will streamline design, pattern technology, & the sample verification process
	3D CAD offers the potential to enhance profits, reduce costs and iteration; increase design opportunities, improve communication within the supply chain and enhance competitiveness.
Integration Barriers	Lack of affordable high-powered high-resolution desktop systems with advanced micro-processors; hence the quality and viability of 3D is restricted by technology limitations
	Lack of tactile presence (touch/feel of garments/fabrics) to support visual appearance;

	3D CAD cannot match affordability, efficiency, and effectiveness of windows based, off-the-shelf 2D CAD software
	2D CAD is a universal communication tool capable of producing high quality images
	Designers' and buyers' negative attitudes towards new technology
	The preference of buyers for real sample garments rather than interpreting digital imagery
	The fact that pattern cutting skill is central to its use
	Software costs, installation and training
	The lack of evidence that performance and profitability can be enhanced with the technology
Core skills	User skills must be underpinned by practical design, pattern, and garment knowledge
	Users will require knowledge of fabric properties and fabric handling expertise
	Users will need to acquire analytical, evaluation, and interpretation expertise
	Users will require skills to translate appearance and quality the new digital language and will require expertise to predict digital outcomes & discern deviations from the real and virtual.

Table 6: Expert design issues regarding 3D user and implementation

The impact of 3D on design	3D is the gateway to innovative design concepts and novel perceptions of representation
	3D will have a broad application across commerce and ecommerce and a wide spectrum of design work in a variety of circumstances
	3D will transform the designer's role within the design process
	3D CAD presents a new layer of expertise within the design process
	3D CAD has the potential to streamline the design process and improve competitiveness
	A fast and easy to use interface will encourage investment.
	Accurate representations key to ascertain detail, fabric properties and drape, and garment fit.
3D skills and training	Requires skill of many disciplines to achieve an outcomes
	3D competencies are underpinned by 2D CAD skills;
	3D CAD requires prior material skills and practical knowledge.
Barriers	Software and hardware costs are barriers for investment;
	3D will not make garment manufacture cheaper or more accessible;
	3D will not make consumers more interested in buying clothing;
	3D will not evolve into a satisfactory option for designers;
	Lack of verisimilitude is a barrier for investment in 3D.
	Haptics and animation requires greater processing power and better software
	Lack of processing power limits the nature and aesthetic of 3D design work
	Lack of evidence of return on investment (ROI) and market utilisation
Advantages	3D offers the potential to explore visual and tangible perceptions and interfaces
	Creating and understanding of the boundaries of digital language
	Greater potential to explore the notion of VR textiles;
	3D is a conduit for melding art and design and science and technology;
	3D technology is challenging the nature and the role of the computer interface;
	The incorporation of haptics and animation will require a paradigm shift;
	In future 3D will allow designers to convey spatial ideas in 3D space;

Conclusions

The value of 3D CAD in fashion design is not clear. There is no specific evidence of designers' use of 3D CAD within the design process and the technology has yet to be adopted in any significant way by the fashion industry. However it appears that garment virtual modelling (GVM) has the potential to achieve better designed products and garment fit, and it is likely that it will reduce sample iteration and costly fit sessions. But competitiveness and profits will only be increased if 3D CAD evolves into an affordable, efficient and easy-to-use solution, with evidence of market application and return on investment. Advanced systems provide animated avatars that offer kinetics and more reality for fit sessions, but the approximation of touch and feel through haptics is not commercially available for the clothing CAD systems. Such new developments will be of little benefit to the fashion industry without a change in culture and more importantly improved processing power.

3D technology has the potential to integrate design and technology departments and improve communication to realise effective outcomes, but the ramifications of using the technology may present problems for skills, training, cost, and implementation. The feasibility of implementing 3D CAD should be evaluated against economic and resource implications, such as restructuring the design process, technology and product development; introducing new software; the reappraisal of hardware provision; streamlining design teams, repositioning staff or developing a new post.

3D CAD and 2D CAD will work concurrently, but used for different purposes and at different times in the design cycle.

3D will unite design and technology however the 3D designer role should be clearly defined and integrated within the design team. While the 3D designer may not design garments or make the patterns, they will require core design skills in order to interpret and closely represent the garment designer’s intention (the design sketch) through the simulation of the GVM. However both fashion designer and 3D designer will need to collaborate through the design evaluation process as the 3D designer will be able to manipulate detail, style and proportion to gain a realistic representation of the designer’s intention.

As GVM creates a digital language this will need to be translated, and will require specialist knowledge and skills to enable the 3D designer to compare and contrast virtual reality fabric representations against real fabrics. But gaining enough knowledge of digital language will be a significant obstacle for designers to overcome, which will require significant technical skills and knowledge of fabric characteristics to support understanding. The interval between gaining essential skills and efficient utilisation of 3D CAD might be a key issue for implementation therefore present new problems, such as a reduction or loss of income that may result in the short term. The many variables mentioned above will have a significant impact on its utilisation and optimisation within the design process.

Recommendations

While recent EC initiatives have addressed the sectors growth and competitiveness issues by taking advantage of 3D technology for MC and MTM, further initiatives are needed to bring the technology into mainstream fashion design. 3D CAD has the potential to provide an extra layer of technical design skills that are important for the modern fashion industry. But 3D CAD tools demands new skills and competencies for users. The literature did not adequately address the level and types of skills for fashion designers using a 3D system, nor did it explicate the designer's role and interaction within the 3D evaluation process.

To improve the use of 3D CAD, skills and training are the main issues to be addressed for designers, the industry, and education. Awareness and understanding of the technology's potential for the fashion industry is a key issue to be addressed by educational institutions and governments bodies. The provision of flexible vocational fashion design related courses in the education sector is essential to deliver advanced practical knowledge and application of 3D CAD for fashion design. The CAD industry itself must also be accountable for providing specific 3D training and development opportunities, in partnership with HE and FE. To encourage designers' use of 3D CAD, the technology must have the quality, user-friendliness and effectiveness of 2D CAD software.

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