Advances in Virtual Prototyping: Opportunities for Clothing Manufacturers

*Abu Sadat Muhammad Sayem**
Department of Apparel, Hollings Faculty, Manchester Metropolitan University (MMU), UK
*Corresponding E-mail: asm.sayem@mmu.ac.uk

Abstract
This paper summarises the recent developments in 3D clothing design systems and discusses the features of available CAD systems. It also highlights the benefits of using such systems the clothing manufacturers can enjoy.

Key Words: Virtual Clothing, 3D CAD, Prototyping

1. Introduction

Significant advances have been made in the area of virtual clothing prototyping in the last few decades and a number of 3D clothing CAD systems are now available on the market. Several European and American design houses have started to adopt 3D systems while this technique is being incorporated in the fashion courses offered by the renown Universities around the world. It has also started to catches the eyes of the manufacturers due to the interesting features present in the available CAD systems.

2. Advances in Virtual Clothing Prototyping

Six distinct approaches to virtual clothing prototyping have been investigated in the research works carried out in the last two decades. They are: 1) 3D modelling and 2D pattern unwrapping; 2) 3D simulation of 2D patterns; 3) 2D-sketch-based 3D simulation; 4) combined techniques; 5) reactive 2D/3D design technique; and 6) digital draping. These various approaches will be considered systematically in the following sub-sections.

2.1 3D Modelling and 2D Pattern Unwrapping

Hinds et al. [1] and Okabe et al. [2] presented the pioneering concept of creating clothing designs directly on virtual mannequin. McCartney et al. [3], Kim and Kang [4], Wang et al. [5,6], Petrak and Rogale [7], Petrak et al. [8], Decaudin et al. [9], Kim and Petrak [10] and Fang et al. [11] demonstrated various ways of extracting flat pattern pieces from 3D designs. Their works provided a particularly useful resource for software developers, but will continue to be of little interest to end-users and designers until a suitable software package becomes available.

One of the early methods of 2D sketch-based 3D design using a virtual human model and subsequent pattern flattening and also including a concept of 3D grading was presented by Wang et al. [5,6]. For 3D grading, they proposed to construct the same garment repeatedly on different-sized virtual models, which is a time-consuming and repetitive process. A more efficient alternative would be to convert the virtual model from one size to another after designing a garment only once. This approach requires the use of a virtual model which has been parameterised with the size data. A process of developing such a parametric model was proposed by Sayem [12] but the model was only suitable for close-fitting garments. The research project 'AiF-1454 BG' from the German Federation of Industrial Research Associations which was concluded in 2007 also followed a similar approach for creating 3D designs of close-fitting garments on parametric virtual models and 2D pattern flattening [13]. Siegmund et al. [14] determined the distance between body and garments using scan data at different points over the surface area of garments to generate horizontal and vertical offset curves relative to a virtual body. Their process of ease definition by determining the distance of offset points is conceptually similar to that of McCartney et al. [3]. Considering the offset distances as parameters to define the size and shape of outerwear is dissimilar to the established practices within the industry, which consider ease over girth measurements. It is apparent that it requires a lot of distance parameters to define the shape of a garment accurately if the 3D design is to be based on offset curves. A combined technique of 3D design, 3D grading and extracting 2D patterns for loose-fitting garments has been demonstrated by Sayem et al. [15], which considered ease distribution over girth measurements. However, no customised CAD software packages for the 3D to 2D pattern unwrapping of outerwear products are available on the market.

2.2 3D Simulation of 2D Patterns

3D garment simulation from 2D pattern pieces using virtual sewing and drape simulation techniques is a "2D to 3D" approach to 3D clothing design. Notable work that has successfully implemented this design approach includes research presented by Fozzard and Rawling [17], Volino et al. [17], Kang and Kim [18,19], Chiricota [20], Fuhrmann et al. [21], Thalmann and Volino [22] and Luo and Yuen [23]. A fabric modelling technique plays a key role in the garment simulation scheme. Mathematical modelling of fabrics began in the 1930s with the pioneering work of Peirce [24]. Attempts at the computer-aided modelling of fabrics were initiated in the late 1980s [25, 26] and a number of modelling techniques have been presented in the last twenty years. However, not all the techniques have been developed targeting an application in clothing design and simulation systems. A review of the different fabric modelling techniques can be found in [25, 2, 28 & 29]. The prevailing cloth simulation techniques can be classified into three categories: geometrical, physical, and hybrid (a combination of geometrical and physical). Fabric models developed in the last two decades are characterised by their algorithms, nature of complexity and the computational times required. In-depth analysis of the algorithms is beyond the scope of this discussion. The static and dynamic models notable for the development of 3D CAD clothing systems are highlighted here. Stylios, Wan and Powell [30] presented a virtual fashion show by modelling the dynamic drape of garments on virtual mannequins. Volino et al. [17] described a system for cloth simulation and demonstrated the animation of dressed synthetic characters. The garment simulation software "MIRACloth", developed at MiraLab (Switzerland), offers the design of 2D patterns, interactive 3D pattern placement on virtual bodies, 3D garment construction, cloth simulation and animation [31]. A further development from MiraLab is an efficient tool for dynamic simulation and animation of virtual dressed humans, and it may be used to produce a virtual fashion show [22, 32-35]. This modeller is integrated into the virtual garment design and prototyping software "Fashionizer" which significantly advanced the techniques used for virtual fashion shows [22]. Kim [18,19] also demonstrated a clothing design system which had a module for drafting 2D flat patterns, a resizable virtual mannequin and a module for wrapping 2D patterns onto a 3D body. The "2D to 3D" approach to 3D clothing design has been successfully adopted in a significant number of clothing CAD systems that are available on the market.

2.3 2D-Sketch-based 3D Simulation

The 2D-sketch-based 3D simulation approach is another version of the "2D to "3D" design approach which works on a 2D sketch or design from the designers instead of 2D patterns pieces. The concept of utilising initial sketch from a clothing or fashion designer to generate virtual clothing is presented by Ito et al. [36][. They postulate a design system that would take an initial design sketch of clothing as its input and would intelligently deliver a set of 2D patterns and a virtual presentation of the 3D garment as its output. Decaudin et al. [9] and Turquin et al. [37,38] presented a design system that could directly convert an initial 2D sketch into a 3D object without the necessity of any 2D patterns.

2.4 Reactive 2D/3D Design Process

Luo and Yuen [23] presented a 3D system, which followed the "2D to 3D" design approach but which allowed the designer to modify the 2D pattern interactively. The interesting feature of their CAD system is that any interactive change in the 2D pattern pieces could make an automatic change in the corresponding 3D design; they termed the process as "reactive 2D/3D garment pattern design".

Table 1: **Available 3D Clothing CAD Systems**

Features \ Software	Modaris 3D	Vstitcher	TUKA3D	Vidya	3D Runway	TPC	Design-Concept
Wrapping 2D patterns on 3D body	√	√	√	√	√	-	-
Developing 3D design on 3D body	-	-	-	-	√	√	√
Flattening 2D patterns from 3D design	-	-	-	-	* √	-	√
Realistic fabric draping	√	√	√	√	√	-	-
Adjustable mannequin	√	√	√	√	√	-	-
Dynamic pose/ virtual fashion show	-	-	√	√	√	-	-

**for close-fitting garments only*

2.5 Digital Draping

Digital draping is the computerised version of physical draping, the "haute couture" process of pattern creation. It considers fabric as virtual rectangular sheet and drapes it onto a virtual body. The CAD system presented by Sul and Kang [39] has this characteristic feature. Their system offers virtual pinning and scissoring tools that allow the designer to fix virtual cloth on the mannequin and to remove the redundant cloth parts while digitally draping it onto the mannequin.

2.6 Combined Techniques

There are examples of combining both "2D to 3D" and "3D to 2D" approaches in a single CAD system to extract the benefit of both. Okabe et al. [2] gave an outline of such a CAD system. An energy-based modeller for static cloth simulation was incorporated into their 3D CAD. This modeller could accept the mechanical properties of fabrics measured by Kawabata Evaluation Systems for fabrics (KES-f). Okabe et al. [2] envisaged that their CAD system would be positioned at the centre of a textile information network so that the textile design and clothing design could be processed synchronously and in parallel. Other examples of combined CAD techniques for apparel were presented by McCartney et al. [3] Fontana, Rizzi and Cuguni [29] and Fang and Ding [11].

3. Available 3D Clothing CAD systems

Commercially available 3D CAD systems for 3D garment visualisation and virtual try-on software can be categorised into two groups, based on the underlying working procedure, to create 3D designs. One group, which includes software such as TPC Parametric Pattern Generator (TPC), allows designers to develop garment silhouettes and styles in a 3D environment according to their preference. Other types of 3D CAD system allow the importation of 2D pattern pieces from the appropriate 2D CAD software to wrap them onto a virtual model in order to visualise the virtual product and also to simulate fabric drape and fit. This group includes *Vstitcher*™ from Browzwear (Israel), *Accumark 3D* from Gerber (USA), *Modaris 3D* from Lectra (France), TUKA3D from Tukatech (USA), *3D Runway* from OptiTex International (Israel) and *Vidya* from Assyst (Germany). These are 3D virtual prototyping solutions which associate 2D patterns, fabric information and 3D virtual models. They enable simulation of 3D design from 2D pattern pieces developed by a wide range of 2D CAD software and helps the designer to validate fabrics, motifs and colours. They allow an on-site or remote review of the virtual prototypes in three dimensions and provides the opportunity to check garment fit in various fabrics and sizes. They usually come with a broad library of materials together with their mechanical characteristics. However, they also allow the users to input new fabric properties in order to view differential drape. The major features of the available 3D systems are summarised in Table 1.

4. Opportunities for Clothing Manufacturers

3D clothing design systems offer a number of benefits over 2D clothing CAD systems in use. Virtual prototyping results in fewer physical prototypes and a shorter product-development phase [40]. For decision-making on product selection and prior to the commencement of production, it is usual for at least two up to ten physical prototypes to be made when using existing traditional product-development systems [41]. Gray [42] mentioned that more than seven out of ten samples (prototypes) could be rejected through rigorous assessment by retail buyers in the United Kingdom (UK). This incurs a high cost involvement and time consumption. According to Lectra [43] and Tukatech [45] virtual prototyping and virtual try-on processes can significantly reduce the product-development time and cost. Virtual review and evaluation of fit with realistically simulated fabric behaviour can enable faster detection of errors and earlier corrections to design elements, material selection and assembly. At the same time, the virtual prototypes can be used as a marketing aid for online product presentation and internet-based retailing.

3D CAD systems have started to get industrial application in a slow pace. As reported by the suppliers such as Lectra, Gerber, Tukatech, Browzwear, Assyst and OptiTex, several European and American design houses have started to adopt 3D design systems. At the manufacturers' end it has also started to make it footprints. *Esquel*, a Honk Kong based company having manufacturing facilities in mainland China, whose customers include Ralph Lauren, Tommy Hilfiger, Nike, J. Crew and Brooks Brothers, started to use virtual prototyping technology since 2012 as reported in *Apparel Magazine* in June 2014 [46]. Using such technology, the virtual sample is jointly reviewed by its client and its design and product development team on an online platform for getting right time feedback and doing instant adjustment of the design if suggested by the client. After getting approval on the virtual sample from its client, it then manufactures a physical sample.

With 24 factories in Kolkata, *Amrit Exports* is a leading manufacturer of workwear in India. The company produces more than 250,000 garments each month in fabrics that include cotton, polyester cotton, polyester, nylon, acrylic, wool, Kevlar®, and antistatic. It is using 3D CAD system in its product development and marketing activities. Mr. Anil Buchasia, its sales & marketing Director, said in an online interview: "If two companies make the same shirt, how much different can the price be?...What makes the difference is the service. It's the same with any product." [44]. He also added "It is difficult for me to carry so many samples, I prefer having all of them on my iPad and show them to customers virtually"[44].

Indochine International, a China-based apparel company having over $500 million annual sales, has also integrated 3D CAD system in its production plant. Ms Janet Xu, its director of U.S. operations said in an interview: "We had grown to such an extent that we knew in order to connect with our clients, our factories, our development offices, we had to do better than what we were doing with emails, video conferencing and FedExing samples….the reduction of product development time allows us to do a lot more styles for more customers"[45].

Timex Garments is a leading apparel manufacturer and exporter in Sri Lanka for the EU and USA markets. Its managing director Mr. Arshad Sattar commented "...we are making 10 times more samples to see the print placements, different silhouettes, story boards etc. to make quick decisions, however all these are 3D virtual samples….we are developing over 1,000 new styles and about 5,000 iterations of different combinations per month. We could n't do that in the old conventional method of sample development and stay profitable" [47].

5. Conclusion

3D revolution in garments manufacturing is about to begin. From the examples of Esquel, Amrit Exports, Indochine International and Timex Garments, it is apparent that virtual clothing prototyping is bringing significant benefits to the apparel manufacturers. It will bring the manufacturers and retailers much more closer as business partners right from the design phase. It will also pave the way for the manufacturers to concentrate in design development and to wow their clients with design offers.

References

[1] Hinds, B.K.; McCartney, J.; Hadden, C. and Diamond, J. "3D CAD for Garment Design", *International Journal of Clothing Science and Technology,* 4 (4), pp. 6-14, 1992.

[2] Okabe, H.; Imaoka, H., Tomih, T. and Niwaya, H. "Three dimensional apparel CAD system", *Computer Graphics*, 26 (2) pp. 105-110, 1992

[3] McCartney, J.; Hinds, B.K.; Seow, B.L. and Gong, D. "Dedicated 3D CAD for garment modelling", *Journal of Materials Processing Technology*, 107, pp. 31-36, 2000.

[4] Kim, S.M. and Kang, T. J., "Garment pattern generation from body scan data", *Computer-Aided Design*, 35, pp. 611-618, 2002.

[5] Wang, C.C.L; Smith, S. S. and Yuen, M.M.F. (2002) Surface flattening based on energy model. *Computer-Aided Design,* 34, pp. 823-833, 2002.

[6] Wang, C.C.L.; Wang, Y. and Yuen, M.M.F., "Feature based 3D garment design through 2D sketches", *Computer-Aided Design*, 35, pp. 659–672.

[7] Petrak, S. and Rogale, D. "Systematic representation and application of a 3D computer-aided garment construction method, Part I: 3D garment basic cut construction on a virtual body model", *International Journal of Clothing Science and Technology*, 18 (3), pp. 179-187, 2006.

[8] Petrak, S.; Rogale, D. and Mandekic´-Botteri, V. "Systematic representation and application of a 3D computer-aided garment construction method Part II: spatial transformation of 3D garment cut segments", *International Journal of Clothing Science and Technology*, 18 (3), pp. 188-199, 2006.

[9] Decaudin, P.; Julius, D.; Wither, J.; Boissieux, L.; Sheffer, A. and Cani, M. "Virtual garments: A fully geometric approach for clothing design" *EUROGRAPHICS 2006*, 25 (3), pp. 625-634, 2006.

[10] Kim, S. and Park, C. K. "Basic garment pattern generation using geometric modelling method" *International Journal of Clothing Science and Technology*, 19 (1), pp.7-17, 2007.

[11] Fang, J. and Ding, Y. "Expert-based customized pattern-making automation: Part I. Basic patterns" *International Journal of Clothing Science and Technology*, 20 (1), pp. 26-40, 2008.

[12] Sayem, A.S.M. "Study on the development of parametric virtual female bodies for the three dimensional construction of close-fitting and foundation garments", Thesis (MSc.), *Masterarbeit Nr. 1275* Technische Universitaet Dresden (TU Dresden), Germany, 2004.

[13] Roedel, H. "Development of parametric virtual female bodies for the three dimensional construction of close-fitting and foundation garments". AiF-Forschungsproject Nr. 14540BG, Research Report, Dresden: Technishe Universitaet Dresden, 2008.

[14] Siegmund, J.; Krywinsky, S.; Paul, L. and Kleben, V. "3D design for protective workwear and men's outerwear", *Textile Network,* 11-12, 2010, available online at http://www.textile-network.com/11-12-2010-november-december/artikel_3d-design-for-protective-workwear-and-men%E2%80%99s-outerwear-_13772_9_924_en.html [Accessed 08 November 2011]

[15] Sayem, A. S. M., Kennon, R., and Clarke, N. "Resizable trouser template for virtual design and pattern flattening", *International Journal of Fashion Design, Technology and Education*, 2011, DOI:10.1080/17543266.2011.614963, [online] Available at http://www.tandfonline.com/doi/abs/10.1080/17543266.2011.614963 [Accessed 11 December 2014]

[16] Fozzard, G.J.W. and Rawling, A.J. "Simulation of dressing and drape for garment CAD", In: *Proceedings from the 6th International Forum on CAD*, pp. 157-162. 1991, (cited in Hardaker and Fozzard, 1998).

[17] Volino, P.; Thalmann, N.M.; Shen J. and Thalmann, D., "An evolving system for simulating clothes on virtual actors", *IEEE Computer Graphics and Applications*, 16 (5), pp. 42-51, 1996.

[18] Kang, T.J. and Kim, S. M., "Development of three dimensional apparel CAD system Part 1: flat garment pattern drafting system" *International Journal of Clothing Science and Technology*, 12 (1), pp. 26-38, 2000

[19] Kang, T.J. and Kim, S. M., "Development of three dimensional apparel CAD system, Part II: prediction of garment drape shape", *International Journal of Clothing Science and Technology*, 12 (1), pp. 39-49, 2000.

[20] Chiricota, Y., "Three-dimensional garment modelling using attribute mapping", *International Journal of Clothing Science and Technology*, 15 (5), pp. 346-358, 2003.

[21] Fuhrmann, A.; Gross, C.; Luckas, V. and Weber, A. "Interaction-free dressing of virtual humans", *Computers & Graphics*, 27, pp. 71–82, 2003.

[22] Thalmann, N. M. and Volino, P. "From early draping to haute couture models: 20 years of research", *Visual Computer*, 21, pp. 506-519, 2005.

[23] Luo, G. Z and Yuen, M.M.F. "Reactive 2D/3D garment pattern design modification" *Computer-Aided Design*, 37, pp. 623–630, 2005.

[24] Peirce, F. T. "The geometry of cloth structure", *Journal of the Textile Institute Transactions,* 28 (3), pp. T45-T96, 1937

[25] Ng, H. N. and Grimsdale, R., Computer graphics techniques for modeling cloth. *IEEE Computer Graphics and Application*, 16 (5), pp. 28-41, 1996.

[26] Choi, K. and Ko, H., "Research problems in clothing simulation", *Computer-Aided Design,* 37, pp. 585–592, 2005.

[27] Hardaker, C.H.M. and Fozzard, G.J.W., "Towards the virtual garment: three-dimensional computer environments for garment design", *International Journal of Clothing Science and Technology*, 10 (2), pp. 114-127, 1998.

[28] Breen, D. E., "A survey of cloth modeling methods". In: House, D. H. and Breen, D. E. *Cloth modeling and animation,* Massachusetts: A K Peters, pp. 19-53, 2000.

[29] Fontana, M.; C. Rizzi, C. and Cugini, U., "3D virtual apparel design for industrial applications", *Computer-Aided Design*, 37, pp. 609–622, 2005.

[30] Stylios, G. K; Wan, T. R. and Powell, N. J., "Modelling the dynamic drape of garments on synthetic humans in a virtual fashion show", *International Journal of Clothing Science and Technology,* 8 (3), pp. 95 – 112, 1996.

[31] Cordier, F. and Thalmann, N. "Real-time animation of dressed virtual humans". *EUROGRAPHICS 2002* (*Computer Graphics Forum*, *Blackwell Publishing)*, 21(3), pp. 327-336, 2002.

[32] Ito, I.; Kawauchi, K.; Odagaki, C. and TMSJ. M. "Three-dimensional computer system for automatic pattern making and simulation" *Journal of the Textile Machinery Society of Japan*, 38 (3), pp. 68-77, 1992.

[35] Volino, P.; Cordier, F. and Thalman, N.M. "From early virtual garments simulation to interactive fashion design", *Computer-Aided Design,* 37*,* pp. 593-608, 2005.

[37] Turquin, E.; Cani, M. and Hughes, J. F., "Sketching garments for virtual characters". *EUROGRAPHICS workshop on sketch-based interfaces and modelling,* 2004[online] Available at http://dl.acm.org/citation.cfm?id=1281539 [Accessed 30 December 2011]

[38] Turquin, E.; Wither, J.; Boissieux, L.; Cani, M. and Hughes, J. F., "A sketch-based Interface for Clothing Virtual Characters". *IEE Computer Graphics and Applications*, pp. 72-81, 2007.

[39] Sul, I.H. and Kang, T.J., Interactive garment pattern design using virtual scissoring method. *International Journal of Clothing Science and Technology*, 18 (1), pp. 31-42, 2006.

[40] Ernst, M., CAD/CAM Powerful. *Textile Network*, 4, pp. 20-21, 2009.

[41] Lectra Bylined Article (n.d.) The advantages of virtual 3D prototyping in the apparel industry. [online] available at

[42] Gray, S. (1998) Virtual reality in virtual fashion. *IEEE Spectrum,* February, pp. 19-25.

[43] Lectra, "Fit checking and design approving", [online] available at http://www.lectra.com/en/solutions/fashion-product-development/flat-3d-pattern-development/fit-checking-and-design-approving.html [Accessed 20 November 2011].

[44] OptiTex, "Optitex 3D Suite Keeps Amrit Exports Ahead of Competitors", [Online], available at: http://www.optitex.com/en/Amrit-Export-Success-Story [Accessed 14 December 2015].

[45] Tukatech, "Using Tukatech's Suite of Apparel Technologies, the 11-year-old Indochine International is Poised to Realize $1 Billion in Annual Sales**"** [online] available at http://www.tukatech.com/indochine-poized-one-billion-with-tukatech [Accessed 14 December 2015].

[46] Zager, M., "Concept to spec case study: Esquel shortens product development times with 3D samples", *Apparel Magazine, June 2014, pp. 40-42*

[47] Tukatech, "Russia's Modis to use TUKAcad & TUKA3D**",** n.d., [online] available at http://www.tukatech.com/russias-modis-tukacad-tuka3d [Accessed 14 December 2015].