NC STATE UNIVERSITY
COLLEGE OF Textiles NC STATE UNIVERSITY
JTATM
Journal of Textile and Apparel, Technology and Management

Volume 7, Issue 1, Spring2011

Computer Aided Technical Design

Jung Hyun Park
Department of Clothing and Textiles
Pusan National University
Pusan 609-735, Korea

Hoon Joo Lee
[2]Department of Textile and Apparel, Technology and Management
North Carolina State University
Raleigh, NC 27695-8301, U. S. A.

ABSTRACT

In this paper, we review the current apparel Computer Aided Design (CAD) system, three dimensional (3D) to two dimensional (2D technology. First, 3D virtual body was acquired from 3D body scan data. Meshing techniques were applied to the 3D virtual body. In order to create flattened (2D) patterns from 3D data, flattening methods such as dart generation algorithm which considers shear deformation, and wireframe transform model were presented. Virtual scissoring method and geometric draping modeling which imitate draping techniques were represented.

Keywords: Computer-aided design (CAD), 3D body scan, Flattened (2D) pattern, Meshing, Flattening.

Introduction

Body size and shape vary according to the individual. Even though some people have the same bust size, their girth of waist and hip probably differ. Even if they have the same measurement in the main parts of the body, the flat degree and the sectional cross area probably would be different. The obese and seniors especially show different body shapes with general body types. However, the conventional pattern making system is based on regression formulas indicating the average relationship between measurements and bust girth (Yang & Zhang, 2007). Therefore, mass production that maintains the conventional pattern system cannot satisfy customers, fit expectations. In the case of on-line purchase, problems about fitting occur at a high rate because customers cannot try cloths on. In the case of suits or tight-fitted garments, especially, pattern fit is a critical factor of evaluation. A 2 dimensional (2D) pattern generation system reflecting the curved surface information of a body by using individual 3 dimensional (3D) body scan data could be a solution to the problem.

After a technical designer generates garment patterns according to the design, samples are manufactured in order to identify the real shape of the garments in space and the final pattern is obtained by modifying faults. Such processes are time-consuming and expensive. If it was possible to simulate 2D into patterns a 3D garment, it would be a useful system. Connections between such simulation systems and current pattern computer-aided design (CAD) systems provide effective functions. Such systems can also be applied to a customized design system in which customers select design components by means of a database (Figure 1).

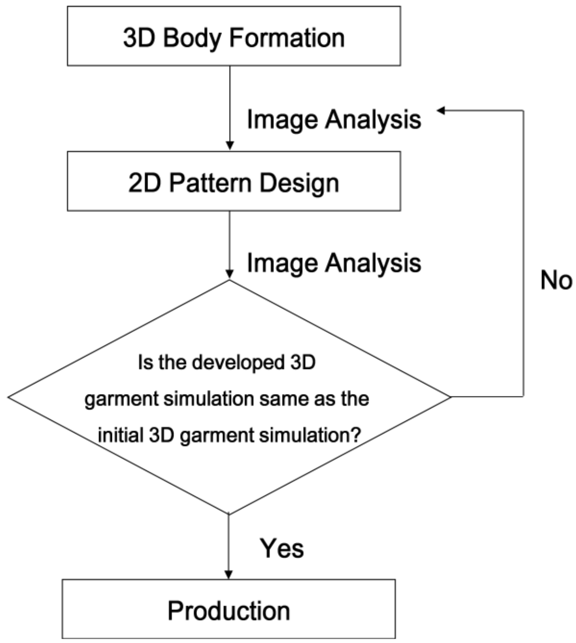

Figure 1. Computer-aided manufacturing (CAM) Algorithm

A 3D virtual individual body model is required in order to create patterns from body scan data. Cho *et al* (2005) created a *3D interactive body model* in which lengths and perimeters are adjusted according to individual body size (Cho *et al.*, 2005). Some researchers utilized information from the 3D scan data to construct patterns (Chan *et al.*, 2005; Griffey & Ashdown, 2006). Others used a mesh method in which triangular and quadrilateral mesh are used to flatten 3D surfaces onto a plane (Choi *et al.*, 2007; Daanen & Hong, 2008; Jeong, *et al.*, 2006; Kang & Kim, 2006b; Kim & Park, 2007; Kim & Kang, 2002). Kim and Kang developed a body model and a garment model, modifying the garment model on the body model by means of convex hull generation and multi-resolution (Kim & Kang, 2002). They proposed a projection algorithm based on the strain minimization technique. Jeong *et al* (2006) utilized Garland's method of triangle simplification for pattern design of tight-fitting garments of stretch fabric (Jeong *et al.*, 2006). Kim and Park (2007) introduced the fit zone and the fashion zone and showed various style variations using the fashion zone which is modified by shape parameters and is combined with the fit zone (Kim & Park, 2007). Yang and Zhang showed geometrical transformation of 3D surface into 2D pattern through constructing a 3D wireframe (Yang & Zhang, 2007). Sul & Kang (2006) developed a virtual scissoring method by NURBS cutting curve and a mesh cutting algorithm imitating draping techniques also brought draping techniques into their method in which shearing behavior of woven fabric was considered (Sul & Kang, 2006). Cho *et al.* (2006) also brought draping techniques into their method in which shearing behavior of woven fabric was considered (Cho *et al.*, 2006).

Objectives

We focus on technical CAD systems in today's use. In 3D to 2D technology, virtual body surface generation is required. 3D body scan data, B-Spline curve, and convex hull were used for body formation. The uniform mesh type such as quadrilateral mesh and triangular mesh and triangulation will be explained. In the image analysis sections, various flattening systems and virtual draping systems will be mainly dealt with. Accuracy is described in the evaluation section. The algorithm of technical Computer Aided Design (CAD) is shown in Figure 2.

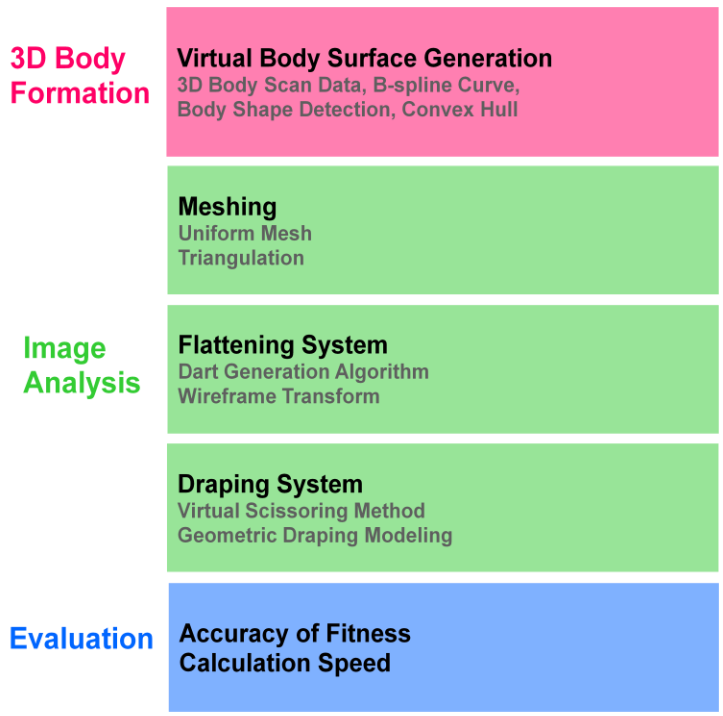

Figure 2. Computer Aided Technical Design

Body Generation

Cho *et al.* (2005) developed 'virtual interactive body model'. They made a body model made of 'cross-sectional lines' at regularly spaced intervals from scan data of dummy. They determined 9 perimeter parameters such as bust, waist, and hip and 3 length parameters such as bodice length in the body model. Therefore, if parameter values are inputted into the body model, body model is modified according to the individual body size. However, this method has limitation to represent each body curved shape because basic body's shape feature is reflected to body model and only perimeters and lengths are controlled.

Kang & Kim (2000); Kim & Kang (2002) adopted the way to create 'body model' and 'garment model'. After appropriate sorting of points obtained from 3D body scanner for data reduction or obtaining data from sliding gauge, they developed the body model composed of cross-sectional points in the cylindrical coordinate system. Landmarks such as neck points, shoulder points, and armhole points of body model which are located at the maximum, minimum, or extreme points and maximum curvature are determined using the Fourier series expansion. Because garments usually do not follow complex body surface directly and cover body smoothly, they generated garment model into convex shape using general dummy by stereoscopy. The body model and the garment model are matched and the garment model shape is transformed into convex shape covering body model.

Kim & Park (2007) offered the way to divide 'fit zone' and 'fashion zone'. 'Fit zone' means the parts fitting closely body shape such as the above part of bodice's bust level and the above part of skirt's hip level. 'Fit zone' is acquired by taking surface of a dummy and is expressed as B-Spline surface. To easily take the 'fit zones' without complicated formation process from each body scan data, the way to adjust parameters such as key lengths and angles in the initial 'fit zone' is used. 'Fashion zone' indicates the changeable parts according to various garment design. 'Fashion zones' also can be deformed using 'shape parameters' such as lengths, widths, and the number of folds. 'Fit zone' and 'fashion zone' are joined in order to compose entire shape of garment.

Transfer from 3D to 2D

Mesh Generation

To transform three dimensional surfaces into two dimensional flat patterns, a mesh generation method is generally adopted. The surface is divided as small pieces in space and the pieces are recombined on a plane. Two primary mesh generation methods have been used. In the pre-partition method, the surface is first separated into several zones by specified lines (center line, bust circumference line, princess line, shoulder line, etc.) and then each section is divided into tiny pieces (Choi *et al.*, 2007; Kang & Kim, 2000). In the other method, the surface is entirely divided into small pieces (S. Kim & Park, 2007; S. M. Kim & Kang, 2002). Of these two methods, the former does not cause darts and the latter generally does cause darts during the flattening process. In the pre-partition case, dividing lines can be used as dart lines (Kang & Kim, 2000) or design lines such as a princess line and a yoke line.

Uniform mesh generation methods keep the size and arrangement of meshes constantly. That is, the width and height of zones are separated at regular intervals (Choi *et al.*, 2007) and such processes generate quadrilateral elements or triangular elements taken diagonally from rectangles. The structure which is well aligned horizontally and vertically is related to the mesh size control. It is important to decide optimum size of elements in that high grid resolution has a tendency for many darts despite expression in detail (Kim & Kang, 2002). Too many darts is inappropriate not only for typical garment patterns, but also for sewing production.

Triangulation is a method to create meshes with the points from 3D scan data and to consider curvature. That is, large meshes are generated in low curved surfaces and comparatively small meshes are generated in high curved surfaces (Daanen & Hong, 2008). As the number of triangles increases, the curved surfaces can be refined more in detail. However, since it takes a long time to deal with data in the case of many triangles, it is important to decide the optimum size of triangles to hold shape well and to have minimum of data. The Garland simplification method makes it possible to reduce the number of triangles without strong deformation (Jeong *et al.*, 2006).

Flattening System

Each mesh element undergoes deformation during the flattening process from three dimensional surfaces into a two dimensional plane. Because the degree of deformation is related to accuracy, the key point is how to minimize deformation in the flattening process. Kang & Kim (2000) presented a pattern projection method considering the elastic and shear properties of the fabric. To minimize deformation of mesh structure obtained by projecting, the lengths of the quadrilateral mesh elements are adjusted. If the differences in the lengths and angles of quadrilateral elements between 3D and 2D as calculated in Equations (1) and (2) reach the specified elastic allowance and the shear allowance, the adjusting process of lengths is stopped (Kang & Kim, 2000).

$$A_{Modulus} = 100 \times \sum_{i=1}^{N} \sum_{j=1}^{4} \frac{\left| L_{ij}^{2D} - L_{ij}^{3D} \right|}{L_{ij}^{2D}} (\%) \quad \text{(Equation 1)}$$

$$A_{Shear} = 100 \times \sum_{i=1}^{N} \sum_{j=1}^{4} \frac{\left| \theta_{ij}^{2D} - \theta_{ij}^{3D} \right|}{\theta_{ij}^{2D}} (\%) \quad \text{(Equation 2)}$$

where N is the number of elements; L_{ij} is the length of j^{th} side on i^{th} element; Y_{ij} is the size of j^{th} angle on i^{th} element.

Kim & Kang (2002) introduced a dart generation algorithm using triangular elements derived from uniform rectangles split diagonally. Triangles are more determinative than rectangles because shape can be determined with merely three lengths. Therefore, when using a triangular structure, it is possible to reduce the number of control factors considered in order to develop an algorithm and to make an uncomplicated algorithm. When triangular elements are combined one by one, the subsequent element is forced to attach to neighboring elements until the difference between angles before and after distortion does not exceed the predefined shear tolerance value. If the angle difference exceeds the tolerance, a dart is formed by elements detaching (Figure 3). This algorithm creates darts in the perpendicular direction with boundary lines of the pattern and shows a tendency to have a smaller number of darts with larger shear angle allowance. Kim & Park (2007) compared patterns having user-defined darts with patterns having automatic darts. They showed that the former is more practical and more suitable than the latter was shown.

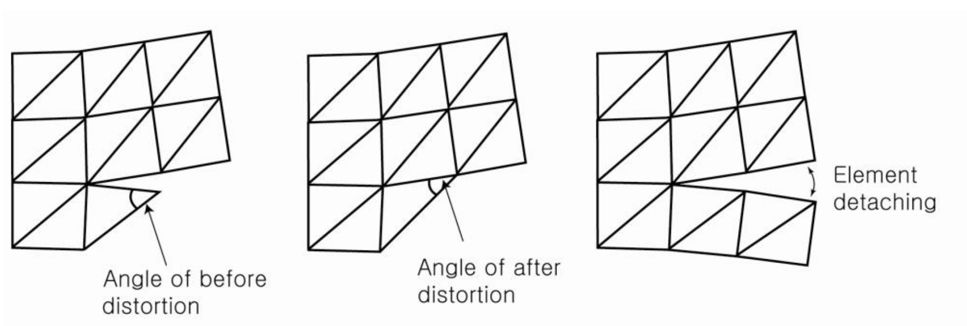

Figure 3. Dart generation algorithm (Source: Kim & Kang, 2002)

In the case of triangulation, there are flat triangles which are different from curved triangles requiring the flattening process in uniform mesh structure. Therefore, triangles are separately reflected on the plane with their original shape and connecting lines between triangles and then triangles are combined by application software. Gap and overlap exist between triangles in a merged pattern owing to the three-dimensional shape (Jeong *et al.*, 2006).

Yunchu & Weiyuan (2007) developed a geometric flattening method using a three dimensional wire-flame tool. First, the half bodice of the 3D body surface is divided into 10 zones in space according to the geometric features of the surface, referencing a structure of pattern prototype developed by Japanese Bunka Women's University. In order to transform the 3D surface into a 2D pattern, each zone was subdivided horizontally or vertically, mainly in a longish quadrilateral shape (Figure 4 (a)). The 3D wireframe which is composed of such structural lines is transformed into a 2D pattern by geometric means. Controlling direction and position of specific outer lines such as the center front line, center back line, and bust circumference line, each quadrilateral element is flattened in regular sequence. In the case of a quadrilateral, if positions of two neighboring lines are determined, intersection of arcs drawn by the two remaining lines becomes the final point of quadrilateral (Figure 4 (b)). Using the above rule, the final 2D flat pattern having similar structure to a conventional pattern prototype is obtained. This method has the possibility of application to various styles of garments due to such pattern construction.

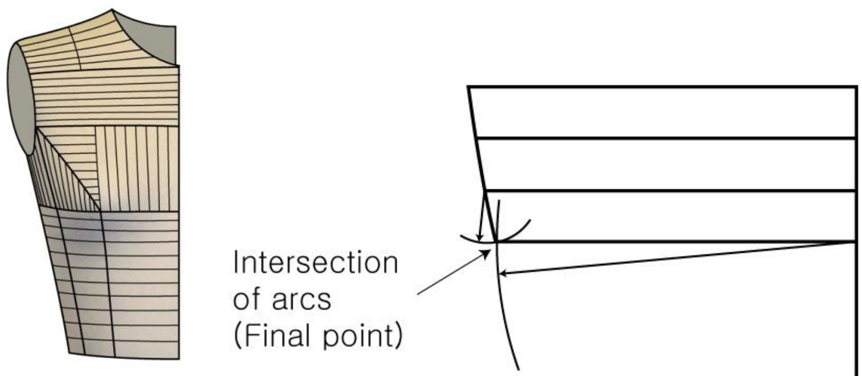

Figure 4. (a) 3D wire-frame; (b). The principles of geometric transformation (Source: Yang & Zhang, 2007)

Virtual Draping System

Sul & Kang (2006) developed a virtual scissoring method imitating draping technique, directly modeling garment shape on a dummy with pinning and cutting fabric. They constructed 3D triangular meshes. The 3D mesh is reflected on the 2D image surface and cutting lines are drawn on the 2D image plane showing the 3D mesh at the same time. Cutting lines such as dart lines, necklines, and hemlines are drawn on the fabric by NURBS curves obtained by connecting points located by mouse clicks. Fabric is cut according to cutting lines by detaching, deleting and recombining meshes associated with a cutting line. Intersection points of meshes and cutting lines are basic reference points for the cutting process. Since the 2D mesh and the 3D cloth mesh are transformed at the same time, the virtual scissoring method doesn’t require a flattening process to generate patterns (Figure 5). Sul & Kang (2006) also developed a mesh adding technique which is to add and connect a new mesh at the edge of an existing mesh. Fabric cannot be expanded or created in real draping, but fabric can be inserted in virtual draping by changing design lines. A new mesh’s node coordinates are estimated by surrounding meshes. A pinning technique is used to fix fabric at a specific position and to prevent falling down. Sul & Kang (2006) demonstrated the generation of garment patterns by using above the methods. A bodice pattern with under arm darts and waist darts is acquired by pinning and cutting lines and pattern pieces are virtually sewn together. Texture mapping is shown and it also allows users to predict final garment appearance closely.

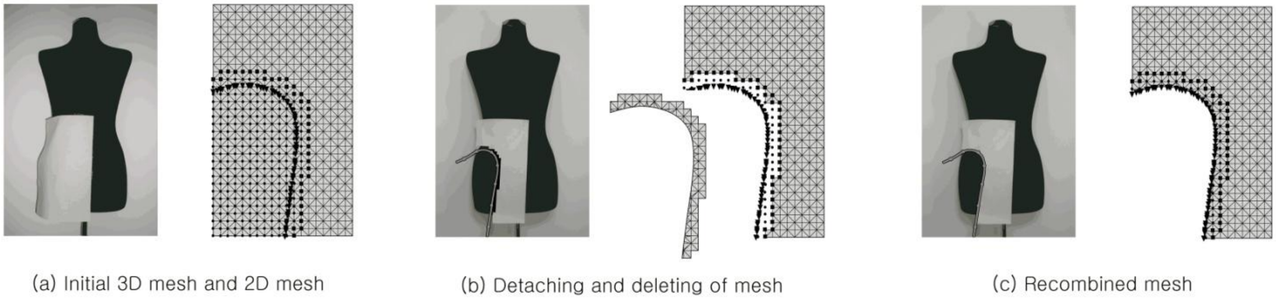

Figure 5. 3D mesh cutting algorithm (Source: Sul & Kang, 2006)

Cho et al. (2006) also presented a CAD pattern making method using draping principles and acquired tight skirt patterns. First, the 3D curved surface of a dummy is prepared with triangular patches and grain lines are drawn on the 3D surface to match with grain lines of fabric as in draping. Cross sections of waist and hip levels are superimposed and grain lines are placed at 15° intervals. Grain lines become dividing lines of 3D surfaces and grain lines can be applied to design lines or dart lines. Therefore, allocating some grain lines in high curvature to dart lines, they fitted a fabric lattice on the 3D surface while considering fabric shear angle. For example, if the shear angle is 64°, the fitting process proceeds only until a threshold of 64 degrees. The fabric lattice is cut according to reference lines of 3D surface and is spread on the 2D plane keeping the lattice at right angles. (Figure 6).

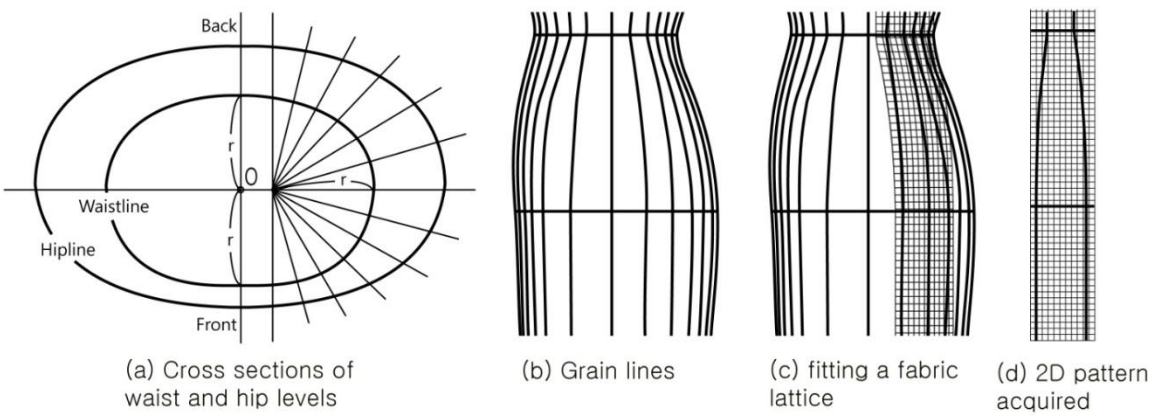

Figure 6. Geometric draping modeling process (Source: Cho *et al.*, 2006)

Evaluation

Accuracy of Fitness

To verify a pattern generation method reflecting 3 dimensional data, researchers use various ways that comparing lengths and areas, analysis of the space between clothing and body, analysis of virtual fit and self sensory-test. Jeong, Hong *et al*. (2006) compared areas of 2D pattern pieces developed from 3D data with original areas of 3D manikin and also showed differences in lengths of significant parts of a garment between the 2D pattern and 3D manikin. Nam *et al*. (2007) analyzed the space between clothing manufactured by 3 dimensional data and body form. Pictures by 3D scanner indicated the amount of space between clothing and body form by variation of color and the silhouette of vertical sections also indicated the fit of clothing. Daanen & Hong (2008) virtually sewed their made-to-measure patterns and showed virtual try-on images that illustrate strain, ease amount, and relative pressure in order to evaluate fitness. Hong *et al.* (2006) conducted self sensory-test indicating satisfaction of fit by numerical value about their tight-fitting garments by a participant after wearing for five days. However, it is difficult to present objective results in the case of too few participants.

Conclusions

In this paper our discussion was focused on the transfer from 3D to 2D patterns. Various methods such as meshing, wire-frame, and draping application methods are used for pattern making. Virtual scissoring method has a special advantage in that the designer can look and feel the garment appearance interactively during the design process because draping principles are used. Many researchers acquired basic blocks from 3D data, but tools to develop various designs are required in order to function in the apparel industry. Also, since the process is somewhat complicated and time-consuming, it would be useful to effectively improve process and data management. As patterns are changed according to materials, it is necessary to effectively develop ways that consider feature of the materials. Because accurate fitness is very important in pattern construction, verification of methods is required by more practical tests. These methods can be applied to garments for the obese, seniors, disabled people and tight-fitted sportswear. In the apparel industry quickly changing the above CAD system can also allow a company to response quickly to customers' needs and to reduce the cost and time.

References

Chan, A. P., Fan, J., & Yu, W. M. (2005). Prediction of men's shirt pattern based on 3D body measurements. *International Journal of Clothing Science and Technology*, *17*(2), 100-108.

Chiricota, Y. (2003). Three-dimensional garment modeling using attribute mapping. *International Journal of Clothing Science and Technology*, *15*(5), 346-358.

Chiricota, Y., Cochaux, O., & Provost, A. (2001). Geometrical modeling of garments. *International Journal of Clothing Science and Technology*, *13*(1), 38-52.

Cho, Y., Komatsu, T., Inui, S., Takatera, M., Shimizu, Y., & Park, H. (2006). Individual Pattern Making Using Computerized Draping Method for Clothing. *Textile Research Journal*, *76*(8), 646-654.

Cho, Y., Okada, N., Park, H., Takatera, M., Inui, S., & Shimizu, Y. (2005). An interactive body model for individual pattern making. *International Journal of Clothing Science and Technology*, *17*(2), 91-99.

Choi, Y. L., Nam, Y., Choi, K. M., & Cui, M. H. (2007). A Method for Garment Pattern Generation by Flattening 3D Body Scan Data. 803-812.

Cugini, U., & Rizzi, C. (2002). 3D design and simulation of men garments. *Journal of Winter School of Computer Graphics*

Daanen, H., & Hong, S.-A. (2008). Made-to-measure pattern development based on 3D whole body scans. *International Journal of Clothing Science and Technology*, *20*(1), 15-25.

Dai, X., Furukawa, T., Mitsui, S., Takatera, M., & Shimizu, Y. (2001). Drape formation based on geometric constraints and its application to skirt modeling. *International Journal of Clothing Science and Technology*, *13*(1), 23-37.

Gong, D. X., Hinds, B. K., & McCartney, J. (2001). Progress towards effective garment CAD. *International Journal of Clothing Science and Technology*, *13*(1), 12-22.

Griffey, J. V., & Ashdown, S. P. (2006). Development of an Automated Process for the Creation of a Basic Skirt Block Pattern from 3D Body Scan Data. *Clothing and Textiles Research Journal*, *24*(2), 112-120.

Jeong, Y., Hong, K., & Kim, S.-J. (2006). 3D Pattern Construction and Its Application to Tight-fitting Garments for Comfortable Pressure Sensation. *Fibers and Polymers, 7*(2), 195-202.

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

Kang, T. J., & Kim, S. M. (2000b). Optimized garment pattern generation based on three-dimensional anthropometric measurement. *International Journal of Clothing Science and Technology*, *12*(4), 240-254.

Kim, S., & Park, C. K. (2007). Basic garment pattern generation using geometric modeling method. *International Journal of Clothing Science and Technology*, *19*(1), 7-17.

Kim, S. M., & Kang, T. J. (2002). Garment pattern generation from body scan data. *Computer-Aided Design, 35*, 611-618.

Kim, S. M., & Park, C. K. (2003). Fast garment drape simulation using geometrically constrained particle system. *Fibers and Polymers, 4*(4), 169-175.

Kim, S. M., & Park, C. K. (2004). Parametric body model generation for garment drape simulation. *Fibers and Polymers, 4*(4), 12-18.

Liu, Y., & Geng, Z.-F. (2003). Three-Dimensional Garment Computer Aided Intelligent Design. *Journal of Industrial Textiles 33*(1), 43-54.

Sul, I. H., & Kang, T. J. (2004). Improvement of drape simulation speed using constrained fabric collision. *International Journal of Clothing Science and Technology, 16*(1/2), 43-50.

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

Volino, P., & Magnenat-Thalmann, N. (2005). Accurate Garment Prototyping and Simulation. *Computer-Aided Design & Applications*, *2*(5), 645-654.

Weil, J. (1986), “The synthesis of cloth objects” Proceedings, SIGGRAPH ’86, Computer Graphics, 20(4), pp. 44-54.

Lafleur, B., Magnenat-Thalmann, N., and Thalmann, D., (1991), “Cloth animation with self-collision detection”, in Kunii, T.L. (Ed.), Modeling in Computer Graphics, Tokyo, Japan: Springer-Verlag.

Yang, Y, & Zhang, W. (2007). Prototype garment pattern flattening based on individual 3D virtual dummy. *International Journal of Clothing Science and Technology*, *19*(5), 334-348.

Corresponding author:

Hoon Joo Lee, Ph.D.
Assistant Professor
Department of Textile and Apparel,
Technology and Management
North Carolina State University
Tel: 1-919-515-1528
Fax: 1-919-515-3733
Email: hoonjoo_lee@ncsu.edu