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Development of a Platform for Realistic Garment Drape Simulation

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Abstract: An integrated platform for garment drape simulation system has been developed. In this system, garment patterns from conventional two-dimensional CAD systems can be assembled into a three-dimensional garment on a parametrically resizable realistic human body model. A fast and robust particle-based physical calculation engine has been developed for garment shape generation. Then a series of geometric and graphical techniques were applied to create realistic impressions on simulated garments. This system can be used as the rapid prototyping tool for garments in the future quick-response system.

Keywords: Garment drape simulation, Particle-based drape simulation, Realistic garment representation, Rapid garment prototyping, Quick-response system

Introduction

Computer-aided design and manufacturing has become a common phenomenon in most modern industries thanks to the remarkable advancement in computer technology. It has long been very difficult to find any design process that is not aided by computer systems in traditional manufacturing processes of machinery, aircraft, and watercraft and most engineers think it as a matter of course nowadays. Although the computer-aided processes have been applied to some extent in apparel industry so far, the progress of automation seems to be rather slow compared to those of other industries. In fact, two-dimensional CAD systems are prevalent in apparel engineering, while three-dimensional CAD systems are widely used in other manufacturing industries. It is probably because of the difference in the nature of material used in each industry that, basic material for apparel have non-linear large deformation properties that cannot be dealt with easily, while the material for other industries usually have linear elastic properties and solid forms. Moreover, a garment may have infinite number of variations according to the designers' creativity because there are no regulations, standards, and restrictions on its shape and size. For this reason, a three-dimensional garment CAD system cannot be made by one researcher and therefore an interdisciplinary research among apparel science, textile engineering and computer science is necessary [1-3].

The core technology of three-dimensional garment design is said to be the drape simulation of flat fabric pieces. Many researchers have been studying on this topic and the particle-based physical method is widely accepted for this purpose [4-9]. Although the continuum-based approach may produce more realistic appearance of draped fabric, particle-based approach is mainly used for the CAD oriented drape simulation because it can produce acceptable result quite quickly compared with the former method. There are many factors to be considered in garment drape simulation including the generation of a realistic body model, collision resolution between the body and garment, and the proper spatial arrangement of patterns around the body [10-13]. In our previous study, a garment drape simulation system had been developed including the functions mentioned above [11].

In this study, an integrated platform for three-dimensional garment CAD system has been developed by upgrading the previous system through the implementation of a new drape engine and a series of rendering techniques. A platform system is very important in this field of research because a fully functional preprocessor, a main drape engine, and a postprocessor are indispensable even for the development of a small single function required for the entire drape simulation. In this study, a new drape engine has been designed based on the particle physics and a new parametric body model has been developed to facilitate the complex spatial arrangement of many pattern pieces. Finally, a series of geometric and graphical techniques were integrated into the system to enable the designers to manipulate the sophisticated aesthetic appearance of garments realistically.

Preparatory Processes for Garment Drape Simulation

Importing Garment Patterns from other CAD Systems

As the drape simulation system developed in this study features only the basic flat pattern manipulation functions, complex flat garment patterns must be imported from the results of other general-purpose two-dimensional garment CAD system. Most garment CAD systems support the DXF (Drawing Exchange Format) file for mutual compatibility. Although there is a standard format such as AAMA (American Apparel Manufacturers Association), DXF files from various CAD systems are not perfectly exchangeable due to minor differences among the systems. In this study, a versatile DXF conversion algorithm was developed to import the DXF files from most commercial CAD systems as shown in Figure 1

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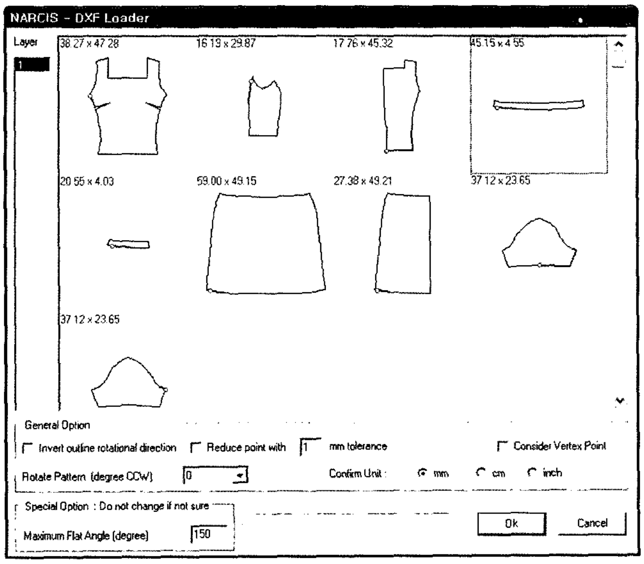


Figure 1. DXF converter.

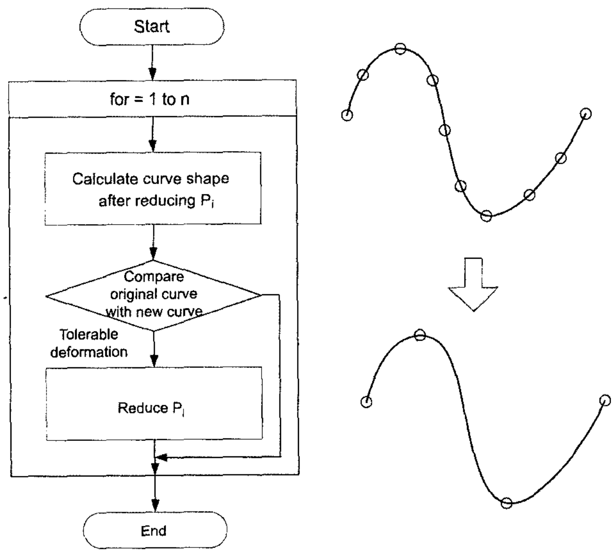


Figure 2. Schematic diagram of control point reduction.

to enable the users to use various garment patterns for drape simulation.

Generally, a large-scale digitizer is used to input the paper patterns to a two-dimensional CAD system. In some cases, users tend to pick more points than are needed to uselessly complicate the geometry of patterns, which may cause not only the long calculation time but also some numerical errors. In this study, a control point reduction algorithm was developed based on the B-Spline interpolation technique to remove the excessive control points on the pattern outlines while preserving their original shapes as shown in Figure 2.

In many cases, patterns from 2-D CAD systems cannot be used directly for the drape simulation. One reason is that

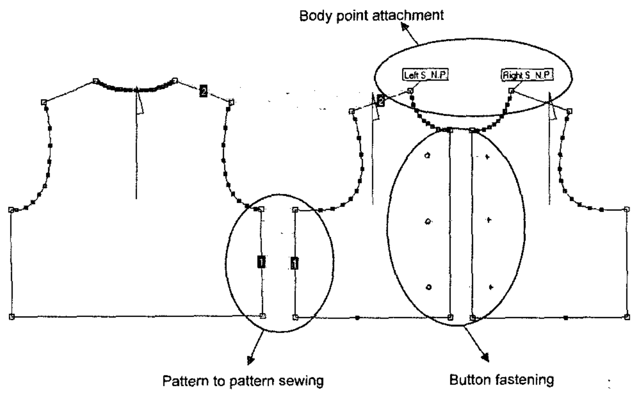


Figure 3. Definition of various sewing conditions.

some seam allowances are usually added along the outline of them, which must be removed before the virtual sewing process. Another reason is that usually only the halves of symmetric patterns are drawn by 2-D CAD systems to facilitate the cutting process. In this study, a series of basic interactive geometry manipulation functions were developed to modify such patterns into the appropriate ones for subsequent drape simulation process. Such functions can be used to modify the pattern geometry even after the simulation to get a better shape or fit of the garments.

Sewing conditions must be defined to turn the pattern pieces into an assembled garment. Three kinds of sewing conditions are available as shown in Figure 3. One is the sewing between two patterns, another is the attachment of a pattern onto the body, and the third is the button fastening between two patterns. Pattern to pattern sewing can be defined by selecting a series of lines to be sewn together. A point attachment condition can be defined by selecting a vertex on the pattern and a point landmark on the body. A line attachment condition can be defined by selecting a line on the pattern and a line landmark on the body, which can be used to simulate skirts and slacks that are to be fixed around the waistline. A button fastening condition can be defined by selecting a button and a buttonhole from two different patterns to be fastened.

Once all the sewing conditions are defined, patterns are subdivided into fine triangular mesh structure. Then users can arrange the patterns with respect to the flattened bounding volumes and the patterns are arranged around the body model automatically by the inverse mapping of the flattened bounding volumes as shown in Figure 4. The shape and size of each bounding volume can be changed freely and the overall formation of bounding volumes is managed by a database system that user can recall an appropriate formation from the database according to the shape of the garment to speed up the pattern arrangement process.

Drape Simulation Engine

A particle system must be organized for each pattern for

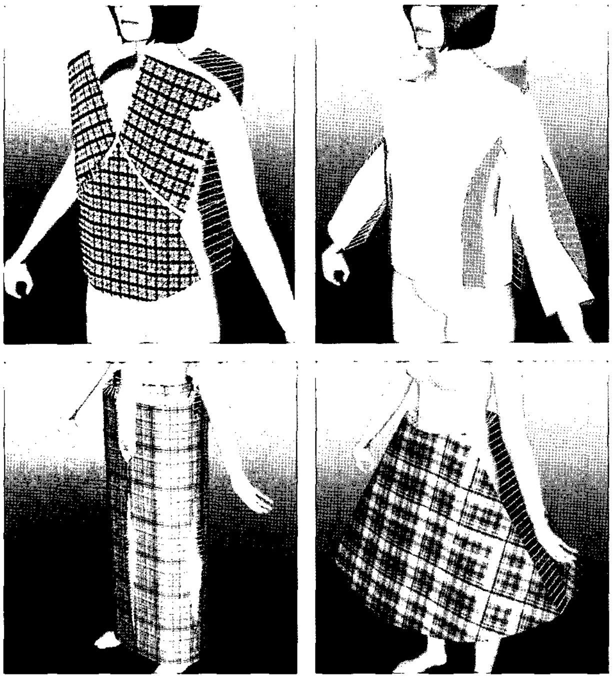
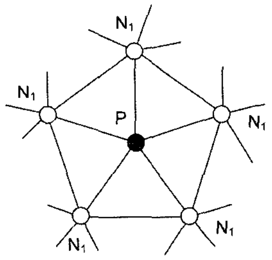


Figure 4. Spatial arrangement of garment patterns.

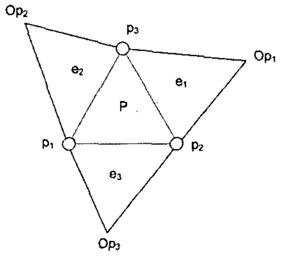


$$\vec{F} = \sum_{i=1}^{n} \frac{r}{e^r} \cdot M_i \cdot m_p \cdot \overrightarrow{PN_i}$$

where, $r = \dfrac{\overrightarrow{PN}_{i3D}}{\overrightarrow{PN}_{i2D}}$

M_i = tensile modulus between P and N_i

Figure 5. Calculation of tensile force acting on a particle.



$$\vec{v_i} = \overline{p_i Op_i}$$
$$k_i = \vec{v_i} \cdot \left(\vec{N_p} \times \vec{N_{e_i}}\right)$$
$$\vec{F} = \sum_{i=1}^{n} \vec{N_p} \cdot k \cdot \frac{1}{e^k} \cdot B_i$$

where, N = normal vector of an element

B_i = out of plane bending rigidity between P and e_i

Op_i = opposite node of p_i

Figure 6. Calculation of bending force acting on a particle.

the drape simulation. In the case of a rectangular mesh structure, the formation of a particle system is rather easy because the neighboring particles of a particle can be referred easily. However, it is difficult for a triangular mesh structure and some preparatory process are necessary to enhance the performance of simulation. For example, the lists of the neighboring particles of each particle and the neighboring triangular elements of each triangular element must be made prior to the simulation to accelerate the massive calculation. To reflect the anisotropy of fabric material, physical properties of fabric must be assigned to each particle considering the direction of the grain line defined on each pattern.

The trajectory of each particle after a time step dt can be calculated using equation (1).

$$P_{next} = P_{previous} + \left(\frac{dP}{dt}\right)\Delta t + \frac{1}{2}\left(\frac{d^2P}{dt^2}\right)\Delta t^2$$

$$\left(\frac{d^2P}{dt^2}\right) = \frac{F}{m}, \quad \left(\frac{dP}{dt}\right) = \left(\frac{dP}{dt}\right)_{previous} + \left(\frac{d^2P}{dt^2}\right)\Delta t \qquad (1)$$

Where, P: position of a particle, F: force acting on a particle, m: mass of a particle.

In this study, forces acting on a particle were limited to the gravitational forces, tensile force, and bending force. The gravitational force can be calculated easily by considering the gravitational acceleration. Tensile force acting on a particle can be calculated as shown in Figure 5.

In this study, normalized tensile modulus values were used, which were stabilized over a series of experiments, instead of the real tensile modulus of the fabric because the calculated results tended to diverge when the real values were used. The relationship between the real values and normalized ones will further be revealed through experiments. The bending force acting on a particle can be calculated as described in Figure 6.

Bending force is calculated based on the angle between two neighboring triangular elements. In a triangular mesh based particle system, bending forces can act on a particle in many directions. In that case, it is assumed that the sum of each bending force is acting on the particle in the average direction. Bending rigidities used in this study were also the normalized values, which will be tuned to the real values afterwards.

To get the draped shape of a garment, various boundary conditions must be considered during the simulation such as sewing, attachment, and collision resolution between the body and the garment. Sewing and attachment condition can be resolved easily by restricting the positions of related particles. Collision detection and resolution takes almost all the simulation time and thus can be regarded as the rate-determining step. In this study, a spatial partitioning algorithm was used to accelerate the collision related calculation. In our previous research, user must stop the simulation at a certain step or the simulation continued forever [5]. In this study, a self-terminating simulation algorithm was developed to stop the simulation automatically after a stabilized garment shape is obtained. For this, the value of total tensile force, bending force, and areal difference between two-dimensional and three-dimensional patterns with respect to the simulation step were traced. Then the results showed that the tensile force and areal difference are stabilized quickly after a few

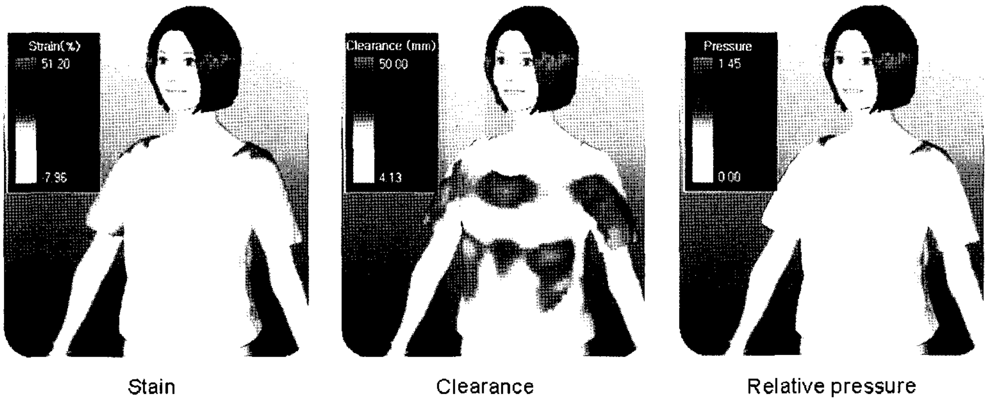


Figure 7. Visualization of physical status of garment.

simulation steps while the bending force takes considerable time before it is stabilized. In this study, the simulation is terminated after the rate of change in total bending force gets smaller than a predefined tolerance.

Visualization of Simulated Garments

Once the simulation is terminated, some physical information can be visualized on the simulated garment three-dimensionally including the strain distribution on each pattern, clearance between garment and body, and relative garment pressure distribution as shown in Figure 7.

Cross-sectional observation on the simulated result can be made in every direction as shown in Figure 8. Useful information for garment design and evaluation such as the clearance between garment and body can be obtained by the cross-sectional analysis.

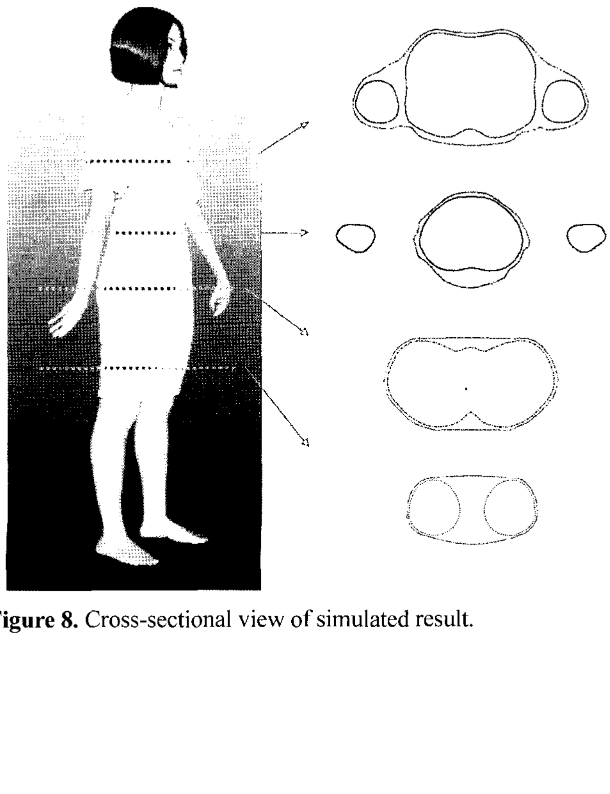


Figure 8. Cross-sectional view of simulated result.

In our previous research, the realistic visualization of garments was difficult because only the garment patterns themselves were involved in the drape simulation. In this study, various fashion features were included in the visualization of garment such as the fancy stitch lines, decoration tapes, buttons, buttonholes, and seam lines, as shown in Figure 9 to enhance the realism of simulated results.

To express the fine surface detail of the fabric, the state-of-the-art real-time bump mapping was implemented. Bump mapping is a graphical technique used to visualize the finely rugged surface structure without increasing the geometric complexity of the surface as shown in Figure 10. Different surface detail and luster can be assigned to each pattern for

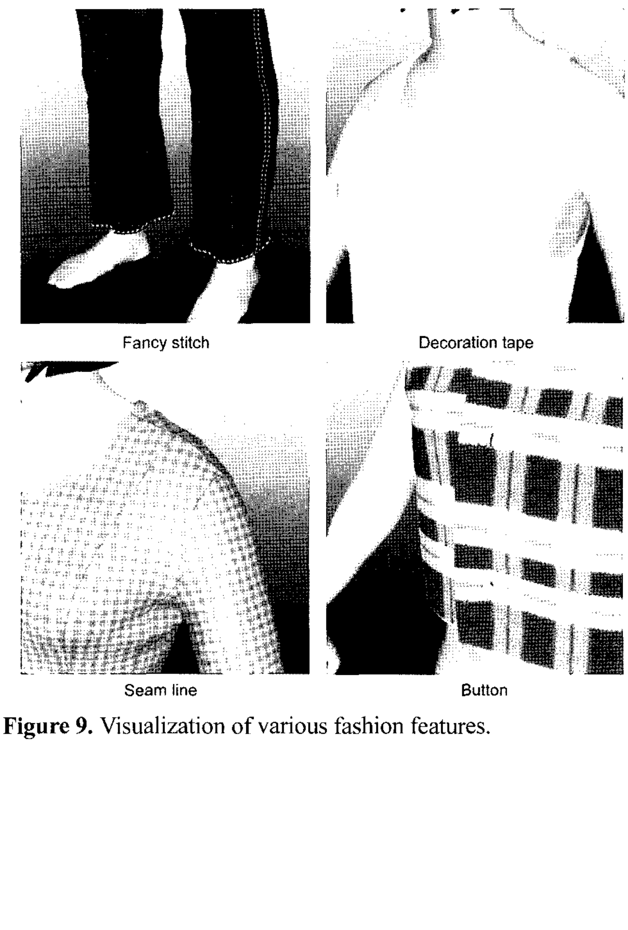


Figure 9. Visualization of various fashion features.

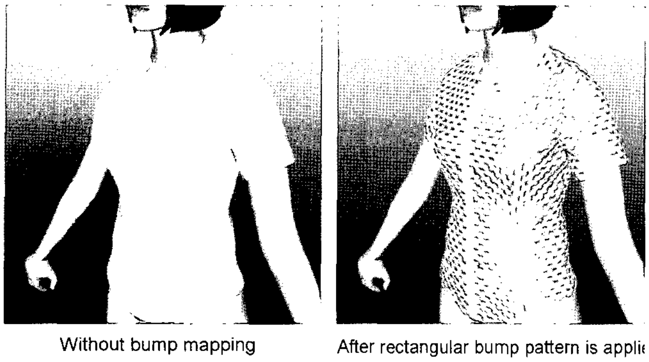


Figure 10. Examples of texture mapping with bump effect.

the realistic visualization of the garments.

The size and rotation angle of applied fabric texture can be changed directly on the three-dimensional garment. The information regarding the relative placement of each pattern piece on the patterned fabric can be used in the nesting process of the garment.

Results and Discussion

Examples of Simulated Garments are Shown in Figure 11.

Conclusion

In this study, an integrated platform for the three-dimensional garment CAD system has been developed. It consists of four major modules including a realistic as well as functional body model generation system, a basic two-dimensional pattern manipulator, a particle-based physical drape simulation engine, and a graphical rendering engine. As all the essential functions required for a garment CAD system have been developed, further improvements on each module for better-quality results will be easier than before. Of course, there still remain a number of problems to be solved for an ultimate true-to-life drape simulation system, the platform developed in this study will surely be a cornerstone for subsequent research.

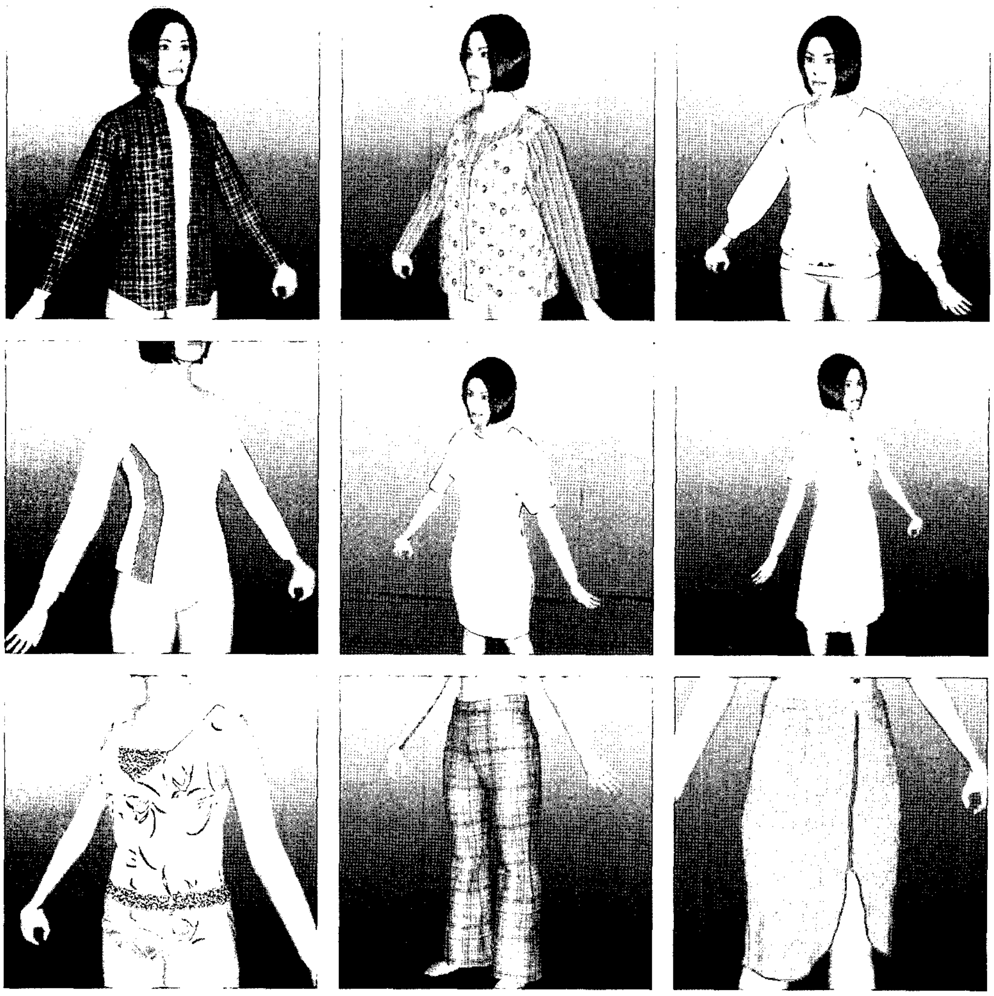


Figure 11. Examples of simulated garments.

References

1. D. House and D. Breen, "Cloth Modeling and Animation", A. K. Peters, Natick, Messachusetts, 2000.
2. P. Volino and N. Thalmann, "Virtual Clothing", Springer-Verlag, Berlin, 2000.
3. B. Hinds and J. McCarteney, *Visual Comput.*, **6**, 53 (1990).
4. J. Plath, *Comput. Graphics*, **24**(6), 897 (2000).
5. B. Eberhardt and A. Weber, *Comput. Graphics in Textiles and Apparel, IEEE Comput. Grapics and Appl.,* **16**(5), 52 (1996).
6. P. Volino, N. Thalmann, S. Jianhua, and D. Thalmann, *Comput. Graphics in Textiles and Apparel, IEEE Comput. Graphics and Appl.*, **16**(5), 42 (1996).
7. D. Breen, D. House, and M. J. Wozny, *Text. Res. J.*, **64**(11), 663 (1994).
8. D. Breen, D. House, and M. J. Wozny, *Text. Res. J.*, **64**(11), 663 (1994).
9. M. Carignan, Y. Yang, N. Thalmann, and D. Thalmann, *Comput. Graphics*, **26**(2), 99 (1992).
10. C. Choi and H. Kim, *J. Korean Soc. Clothing and Text.*, **27**(9), 1015 (2003).
11. S. Kim and C. Park, *Fibers and Polymers*, **4**(4), 169 (2003).
12. A. Fuhrmann, C. Grob, V. Luckas, and A. Weber, *Comput. Graphics*, **27**(1), 71 (2003) .
13. S. Kim and C. Park, *Fibers and Polymers*, **5**(1), 12 (2004).