Virtual Sewing System for Apparel Design

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Abstract

An apparel CAD system capable of 3D simulation of clothes is reported. The system works on personal computers, has graphical user interface and requires minimal input to indicate how to sew and put on the dress. The system automatically generates triangular mesh and calculates the mechanically stable state (i.e. no dynamics) of the dress put on the designated body. Pattern of the cloth can be mapped on the 3D shape and the distribution of stress can be also displayed. Fast simulation is achieved by our original method for function minimization.

1. Introduction

In the last decade, researches on the simulation of fabrics are flourished[1-6], even though it is still a small field. Beginning our study as early as 1983[3], we also have kept developing a simulation system that can predict the three dimensional shape of a garment from its paper pattern, mechanical properties of cloth and three dimensional data about the wearer's body. The main purpose of our project is to construct a CAD system with which apparel designers can work in 3D space as well as in 2D plane, with easy operation and quick response.

First, seam lines in the paper pattern are assigned and lines corresponding to the waist, neck hole and armholes are specified. Then, within 10 minutes or a little more on a personal computer, the garment is auto-meshed, assigned the mechanical properties of a particular cloth, given the 3D shape of the wearer and displayed as a 3D object texture-mapped with the pattern of the cloth.

2. Outline of the system

Fig.1 shows the outline of the system.

3. Mechanical model

The mechanical elements considered in the simulation are expressed by the following energy terms: E = Ea + Eb + Eg + Ec + Ep, where Ea is the energy for the first order distortion (i.e. elongation and shearing), Eb that for the second order distortion (i.e. bending and twisting), Eg for gravity, Ec for a potential function expressing the repulsion against the self collision of the cloth and Ep for the repulsion of the body against the cloth. Actually, the spatial derivatives of these energies (i.e. forces) are calculated in the simulation.

Let us denote the 2D space for the paper pattern by u,v-coordinates and the 3D space where the garment takes its form by x,y,z-coordinates. Then, since the garment is expressed by triangulated finite elements, the energy E is a function of the u,v-coordinates and x,y,z-coordinates of the vertices of the triangles Em(**U**,**X**), where **U** and **X** stand for the vectors of all u,v-coordinates of vertices and all x,y,z-coordinates, respectively (suffix m is to denote that the function form of E is dependent on the topological structure of mesh and sewing).

Values expressing mechanical properties of the cloth are obtained by KES fabric measurement system. Since nonlinearity is clear in Ea and Eb, cubic functions are adopted as the stress (force)-strain response for these terms and Poisson ratio is also considered. The body (or hanger) is also expressed as a collection of triangles and the interaction between body and garment is calculated so that each vertex of the garment is repelled when it penetrates into the triangles of the body. The repulsive force is again a cubic function of the depth of penetration. The treatment for collisions among the triangles constituting the garment is more complicated. The detection and treatment of collisions is executed for small volumes (guard zones) enveloping each triangle, so that true penetrations among triangles never occur.

To reduce time for the evaluation of collisions within the garment and against the body, a cell sorting algorithm (such that used in molecular dynamics or stellar simulations) is adopted. However, we found that in modern apparel design, collisions within a garment are not apparent except in special parts (collar and pocket). Therefore, in the personal computer version of our system, self collisions are neglected and special treatment is given to these parts.

4. Numerical analysis

The aim of our simulation is to obtain the minimum point of the energy function Em(**U**,**X**), where **U** is constant vector determined by the garment design and **X** is the variable in the simulation. To solve this problem, we have developed an adaptively controlled gradient method where each component X*i* of the 3D shape vector **X** is decreased by K*i* (ΔEm/ΔX*i*) at

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each time step. Ki is a function of the history of the value of ΔEm/ΔXi and is also controlled so that |Ki (ΔEm/ΔXi)| will not exceed a certain value Vmax. This upper limit ensures the evaluation and treatment of collisions work correctly except with very intricate multiple collisions. Our method does not follow the mechanical dynamics of the model, instead, it approaches the energy minimum in a more efficient and robust manner.

5. Graphical user interface

In current project, we aimed at an actual application that average users can use on their personal computers. Therefore, as much effort is spared to develop the graphical user interface to help entering and editing information about sewing and wearing, as to implement and optimize calculation programs. Also, to reduce the labor for data entry, we have developed a program which converts a paper pattern file of DXF data format into a paper pattern file based on long lines as the units of sewing and wearing indication.

6. Concluding remarks

In real clothing design, garments include many elements which are not supported by the current version of our system, for example, various kinds of sewing and folding. We are aware that they are indispensable for a CAD system in practical use and have designed our system so that such elements may be easily added. However, much study will be required for mechanical formulation of these elements.

We are proposing a data format for paper patterns including all information on how the garment is sewn and how it will be worn. Such “complete” data is required, not only by our system but also by automated sewing factories.

The expansion of 3D body surface to 2D shape is also requested by apparel designers, because it corresponds to their draping method. It is rather interesting to see that this problem is just the conjugate of the 2D to 3D simulation. When a 3D shape **X** is given, then the value of **U** that minimizes the energy function Em(**U**,**X**) gives the shape of the paper pattern with least strain energy when it is sewn up and forced to take the form given by **X**. (Actually, the true meaning of this interpretation is quite difficult). We have already shown that this problem is also effectively solved by our minimization method[6] and it will also be implemented in the personal computer version.

We may conclude that 3D simulation of garments involves many new aspects and problems in apparel science and is also a challenge for computer science. Would it be too much to say that we have observed another meeting of arts and science?

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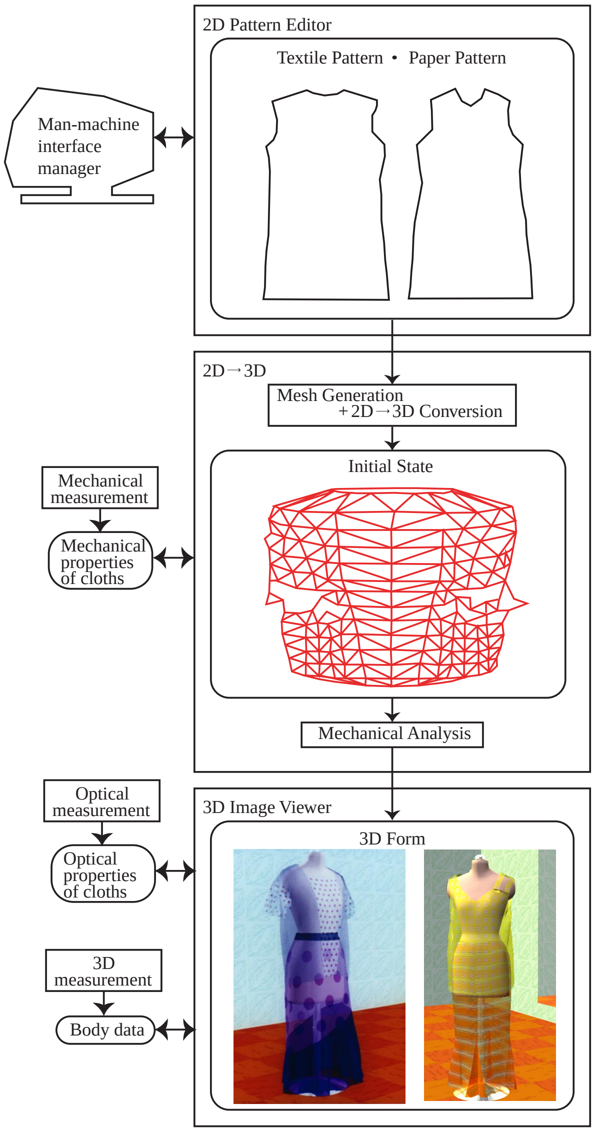

Figure 1 Outline of the Virtual Sewing System