Image-Based Cloth Capture and Cloth Simulation Used for Estimation Cloth Draping Parameters

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Over the past few years, interest in computer simulated cloth algorithms has grown steadily. Recent advances in simulation algorithms allow complex and realistic looking cloth. Unfortunately, it remains quite difficult to adjust the parameters of these simulations to match a given realistic fabric.

The goals of modelling cloth and cloth structures for needs of textile industry and for computer graphics use are very different. Although the Kawabata Evaluation System can provide accurate measurements they are problematic for computer graphics cloth simulation problems because it does not evidently result a direct and simple mapping between particular cloth model parameters and the Kawabata parameters.

In this paper, we present a method for measuring the draping characteristics of static cloth, captured from photo images. Stretching, shearing and bending parameters could be estimated from the data we measure using a cloth simulator.

Keywords: Computer Graphics, Modelling Cloth, Draping Characteristic

1. Introduction

The goals of modelling cloth and cloth structures for needs of textile industry and for computer graphics use are very different. If you come to your – real or virtual – tailor, choose a fabric and – before making any decision – would like to see how a ready suit or skirt would fit your body, you will not wait long before the precisely modelled dress will appear on the screen at least in terms of mechanical engineering. In case of such applications we are generally interested in creating the simplest possible model that will produce realistic or acceptable results to the average observer.

Producing physically accurate and predictive models plays the least (if any) role; the main goal is to make computer-generated images and animations to “look right”. Nevertheless, your tailor should be able not only to measure your body and create your personal virtual mannequin, but also to measure some parameters of real cloths needed for 3D visualisation.

Although the Kawabata Evaluation System (KES) can provide accurate measurements, your tailor will hardly possess it: it is expensive and for special-purpose. The measurements made by the KES are also problematic for computer graphics cloth simulation because there might not be a direct and simple mapping between the parameters for a particular cloth model and the Kawabata parameters.

In many cases it would be more convenient to determine parameters for simulation system using conventional equipment such as photo/video capture devices. In our case we will fit parameters of a particle-based cloth model to fit the geometry of real cloth in a static rest configuration, draped over a round table (Drapemeter), estimating parameters from photo images of the cloth.

2. Photo Based Measuring System

Like Kawabata Evaluation System we have used ∅30 cm round samples of fabric. The dimension of the circular table of the measuring equipment was ∅15 cm. Draping properties of the sample are typical of mechanical parameters.

We have used a special 3D scanner for defining geometry of samples. There are four line-laser beams illuminating the sample through mirrors. Illuminated cross-section curves are recorded on digital photos. Regressing Fourier series characterize the geometry of cross-section curves in an analytical way. A spline surface interpolates the positioned cross-section curves. The interpolating surface reconstructs the original 3D geometry of the sample.

1.1 Structure of the Equipment

The computer controlled equipment (Fig. 1.) is mounted in a black box. Computer moves the round table positioned in the centre providing the natural pleating of fabric for the measuring. The core part of the equipment is computer moved a frame. There are laser-beams lighting the sample through mirrors. There are four cameras on the frame taking the pictures of cross section curves in different levels.

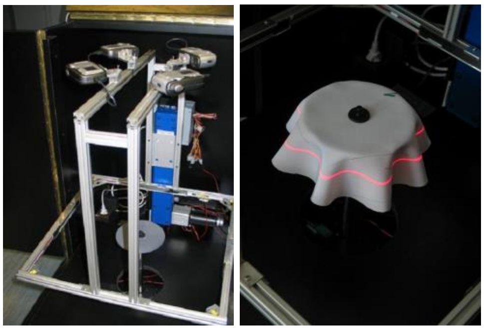

Fig. 1. The 3D drape scanner

1.2 Measuring process

Before fixing cross section curves by four cameras, a calibration is needed. Cross section curves are interpolated upon the calibrated photos.

1.2.1 The calibration process

There is a created target with defined dimensions. Upon the photos of the target created by the equipment, the software calculates and stores the distortion and the needed rotation of four quarters.

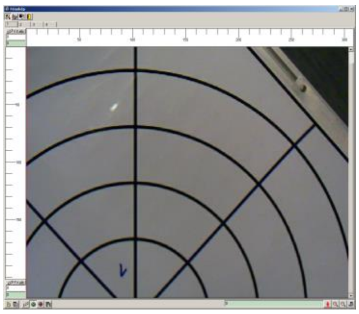

Fig. 2. Quarter of the Calibrating Target

1.2.2 Picture processing

Four pictures are stored by the software (Fig. 3.). Points of the cross-section curves are defined by picture processing methods. Considering the distortion and rotation cross-section points are placed in one picture (coloured points of Fig. 4.).

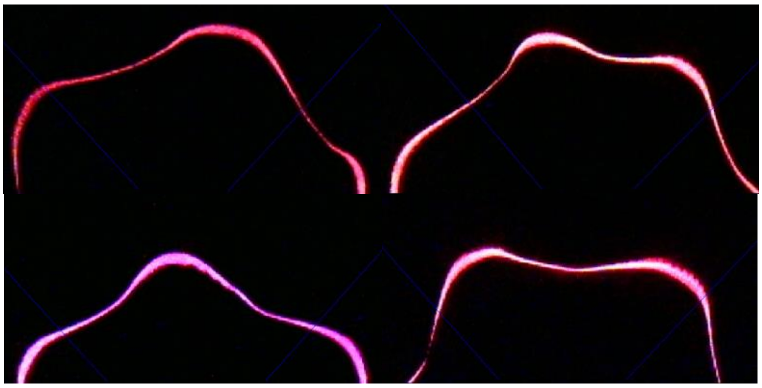

Fig. 3. Four pictures of a cross section curves

Cross-section curves are approached by a slice of Fourier series in the polar coordinate system (1). Size of the slice (n) can be defined by the software.

$$R(\varphi) = \frac{1}{2}a_0 + \sum_{i=1}^{n} a_i \cos(i\varphi) + \sum_{i=1}^{n} b_i \sin(i\varphi) \qquad (1)$$

Fourier coefficients are defined by least square method. If the N measured cross-section points of the actual level are (R_k, φ_k) then the a_i, b_i coefficients are defined by the minimum of a function (2).

$$\sum_{k=1}^{N} \left\{ R_k - \left[\frac{1}{2}a_0 + \sum_{i=1}^{n} a_i \cos(i\varphi_k) + \sum_{i=1}^{n} b_i \sin(i\varphi_k) \right] \right\}^2 = minimum \qquad (2)$$

Approaching curve coloured black in Fig. 4.

Fig. 4. Reconstructed cross section curves

1.3 3D Reconstruction

Geometry of the sample is modelled by Bezier surface patches. Shape of the patches are defined by $P_{i,j}$ vertices.

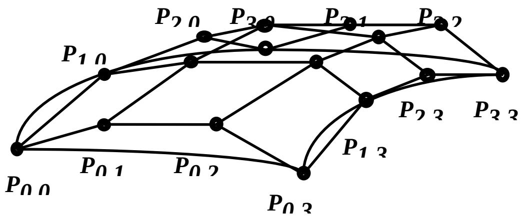

Fig. 5. Bezier patches

Patches are connected to each other continuously in first order by the Catmull-Romm model. Edge slopes are defined by the vertices of the actual element, too.

Vertices of the 3D geometry are defined by the approximating curves (1) on different levels.

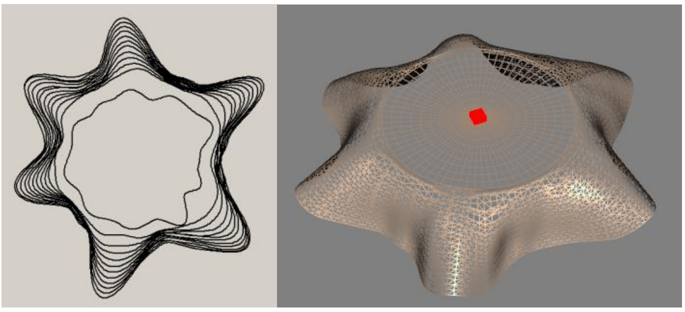

Fig. 6. 3D Reconstruction

3D reconstruction is appropriate for calculation of Drape Coefficient D defined as

$$D = \frac{A - \pi R_2^2}{\pi R_1^2 - \pi R_2^2} \times 100\% \tag{3}$$

where R_1 is radius of the cloth, R_2 is radius of the disc holding the cloth, and A is the area of the projected shadow. The shape of the sample however has more information, e.g. mechanical properties. A mechanical model is needed to determine mechanical properties.

3. Mechanical Simulation Model

The fabric is modelled by the mass and spring system, where mass particles, arranged in a rectilinear grid are connected to the three types of springs shown in Fig. 7.

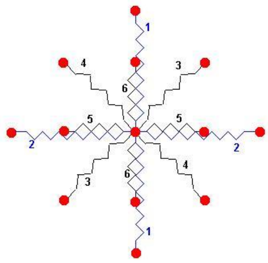

Fig. 7. Spring and Mass Points

There are: 1) structural springs that connect nearest-neighbour particles along thread lines (5, 6), 2) shear springs that connect nearest-neighbour particles along diagonals (3, 4), and 3) flexion springs that connect a particle with its second neighbour along thread lines (1, 2). Each spring shown in Fig. 7 includes a damping element. Springs are assumed to be linear, while damps are proportional to velocity. The basic mathematical model is based on the Lagrangian equation:

$$\underline{\underline{M}}\,\underline{\ddot{q}} + \underline{\underline{K}}\,\underline{\dot{q}} + \underline{\underline{S}}\,\underline{q} = F(t) \tag{4}$$

The main idea is to is to determine the position of each point vertex/mass of the cloth at a time t by integrating Newton’s second law of motion.

In addition, the system detects collisions with collision objects (array of spheres and/or planes, Fig. 8.).

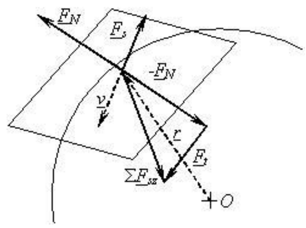

Fig. 8. Forces in effect during collision

The integration of Newton's second law of motion is performed by numerical method.

The more similar simulated and measured geometry is, the closer mechanical parameters are to reality.

If parameters of the mechanical model had chosen that the shape of the simulation result approaches the measured geometry then we have found the mechanical properties of the actual material.

4. Parameter Estimation

Let us define the difference measured shape and the simulated shape (*D*) as a function of material properties ($\underline{p}$) (5). The minimum position of the function defines the actual properties.

$$D(\underline{p}) = minimum \tag{5}$$

It is better to define the difference between shapes as the difference between the Fourier coefficients in a defined level then as the difference between the drape coefficients (3). If equation 6 the a_i^M and b_i^M indicates the Fourier coefficients of the measured shape and $a_i^S(\underline{p})$ and $b_i^S(\underline{p})$ indicates the Fourier coefficients of the simulated shape as functions of the mechanical properties.

$$D(\underline{p}) = \left[\frac{1}{2}a_0^M - \frac{1}{2}a_0^S(\underline{p})\right]^2 + \sum_{i=1}^{n}\left[a_i^M - a_i^S(\underline{p})\right]^2 + \sum_{i=1}^{n}\left[b_i^M - b_i^S(\underline{p})\right]^2 \tag{6}$$

The optimum place can be found by an iterative simulation process.

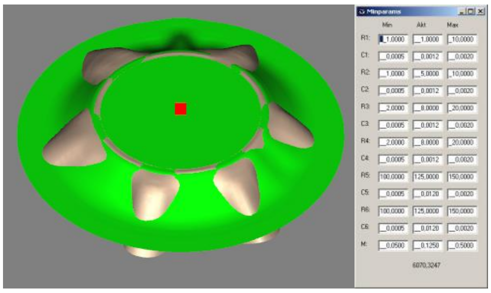

Fig. 9. The iterative simulation process

Conclusions

Presented method is appropriate to measure draping parameters of clothes as well as virtual fitting on.

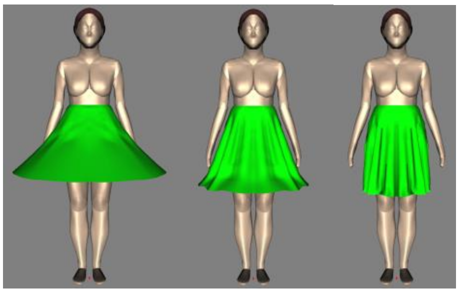

Fig. 10. Virtual Fitting On

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