DETERMINATION OF TEXTILE-MECHANICAL PROPERTIES USING IMAGE PROCESSING AND SIMULATION

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ABSTRACT

We are presenting a new equipment for measuring the draping characteristics of static cloth. In contrast with Kawabata Evaluation System 3D geometrical data of the sample are captured from photo images. There is a mathematical reconstruction of geometry, so drape coefficients and mechanical parameters are evaluated upon the geometrical model. The computer controlled equipment moves a round table, positioned in the centre providing the natural pleating of fabric for the measuring. The core part of the equipment is a computer moved frame. There are laser-beams lighting the sample. Lasers light the cross section curves of the sample on different levels. There are four cameras on the frame taking the pictures of cross section curves in different levels. 3D geometry is reconstructed upon the pictures.

A mass, spring and damping element system is the basis of our cloth simulator. Springs are assumed to be linear, while damps are proportional to the velocity. The simulator calculates vertex positions at a time t based on interaction forces with neighbouring vertices, including stretch, bend, and shear forces. Collision of the cloth model with the model of the underlying object is performed and handled in each time step.

In order to evaluate the influence of the individual parameters, a series of simulations are performed. For the real cloth samples, a range of cross-section curves is captured, digitalized and interpolated by Fourier series. The same Fourier coefficients are determined for the cloth model as a function of simulation parameters.

The actual simulation parameters are defined by the minimum of the difference between the modelled and the measured geometry.

Key Words: draping characteristics, 3D test piece modelling, 3D measuring, garment trade

1. INTRODUCTION

The objectives 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 have to wait long before the precisely modelled dress appears on the screen at least in terms of mechanical engineering. In case of such applications we want to create 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 objective 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 not really meant for the special purpose. The measurements made by the KES are also problematic for computer graphics cloth simulation because it does not guarantee 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 geometry of real cloth in a static rest configuration, draped over a round table (Drapemeter), estimating parameters from photo images of the cloth. We have developed an integrated robot-scanner to achieve a more accurate definition of geometry of test pieces. This presentation is about the background of the measuring process.

2. STRUCTURE OF THE EQUIPMENT

The computer controlled equipment (Fig. 1.) is mounted in a black box. The computer moves the round table positioned in the centre providing the natural pleating of fabric for the measuring.
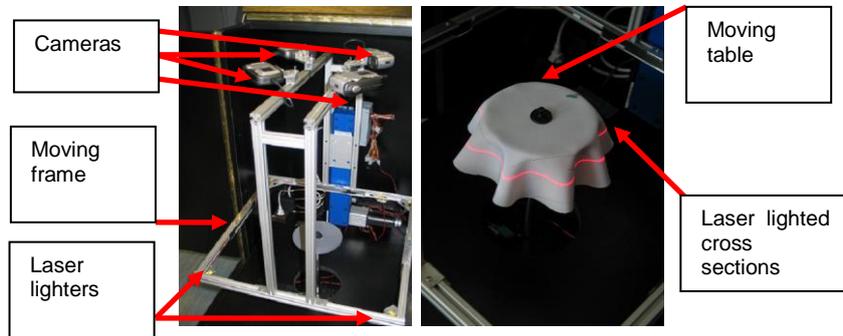

Figure 1. The 3D drape scanner

The core part of the equipment is a computer moved frame. There are laser-beams lighting the sample through mirrors. Lasers light the cross section curves of the sample on different levels. There are four cameras on the frame taking the pictures of cross section curves in different levels. The frame is programmed on serial a port. We have developed controlling programs by Borland Delphi [1], Alkenius' Cam Remote components [2] are used to program the Canon firmware [3].

3. MEASURING BY THE EQUIPMENT

As we want to achieve necessary accuracy for garment trade, we have to calibrate photos of parallel cameras, in order to develop measuring methods as well as to analyze errors.

3.1 Calibration Process

Laser beams light a planar curve in every position of the frame. Curve points are defined by processing four pictures. For 3D scanning the plane to plane perspective transformation is bijection.

Perspective transformation by homogenous coordinates is a linear transformation [4] that projects quadrangles to quadrangles. The matrix of transformation (1) has eight independent coordinates.

$$\underline{\underline{P}} = \begin{bmatrix} p_0 & p_1 & p_2 \\ p_3 & p_4 & p_5 \\ p_6 & p_7 & 1 \end{bmatrix} \tag{1}$$

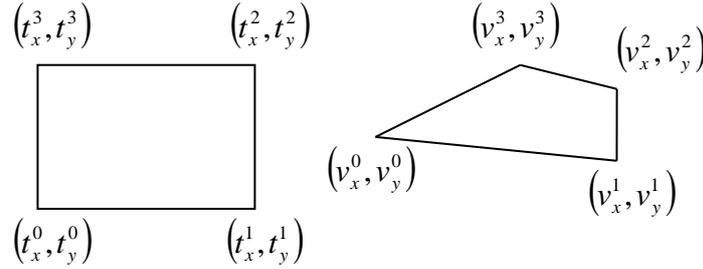Corners of a rectangular calibration element are appropriate to define matrix coordinates (Fig. 2).

Figure 2. Planar perspective projection

Corners of calibration equipment are $\left(t_x^i, t_y^i\right)$, and corners of its picture are $\left(v_x^i, v_y^i\right)$ (i = 0, 1, 2, 3) then the transformation is shown in (2)

$$\begin{bmatrix} v_x^i \\ v_y^i \\ 1 \end{bmatrix} = \begin{bmatrix} p_0 & p_1 & p_2 \\ p_3 & p_4 & p_5 \\ p_6 & p_7 & 1 \end{bmatrix} \cdot \begin{bmatrix} t_x^i \\ t_y^i \\ 1 \end{bmatrix} \tag{2}$$

There are eight unknown coordinates and eight equations there (3).

$$v_x^i = \frac{p_0 \cdot t_x^i + p_1 \cdot t_y^i + p_2}{p_6 \cdot t_x^i + p_7 \cdot t_y^i + 1}$$

$$v_y^i = \frac{p_3 \cdot t_x^i + p_4 \cdot t_y^i + p_5}{p_6 \cdot t_x^i + p_7 \cdot t_y^i + 1}$$

$$i = 0, 1, 2, 3 \tag{3}$$

The determination of corner coordinates starts at the corner closest to the actual camera. If we define the point of the edge image in the coordinate system connected to the left-bottom corner of the photo then regression lines can be defined for every x_s on section $x<x_s$ and $x>x_s$. Let the error of the regression H be a function of x_s! In other words $H(x_s)$ is the sum of the differences of y_i point coordinates and the $a*x_i+b$ lines [5] with unknown parameters (4).

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$$H(x_s) = \sum_{x_i < x_s}(y_i - (a_{x < x_s} * x_i + b_{x < x_s}))^2 + \sum_{x_i > x_s}(y_i - (a_{x > x_s} * x_i + b_{x > x_s}))^2 \qquad (4)$$

The minimum of $H(x_s)$ will be at the real position of the corner at x^*. Substituted back on $x<x_s$, or $x>x_s$ section y^* will be identifiable (Fig 3.).
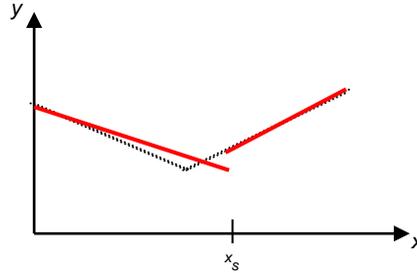

Figure 3. Corner point definition

The farthest away coordinates from the camera can be counted similarly. The only difference is that regression lines come to the edges of the square. Corner points on the left and right sides are derived as intersections of the defined regression lines. Fig 4. shows the defined regression lines and corners on calibrating square.
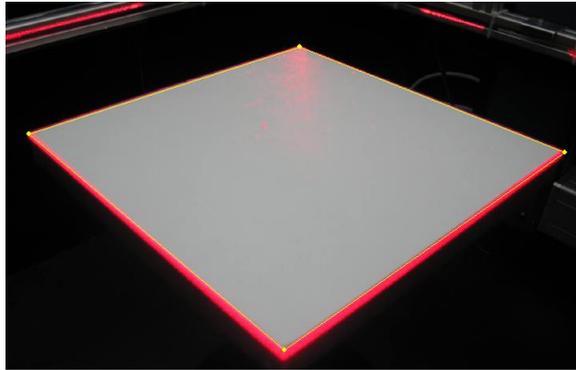

Figure 4. Calibration quadrangle

3.2 Determination of laser lit cross section point positions

Four pictures are stored by the newly developed software (left side on Fig. 5.). 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

Cross-section curves are approached by a slice of Fourier series [5] in the polar coordinate system (5). Size of the slice (n) can be defined by the software.

$$R(\varphi) = \frac{1}{2}a_0 + \sum_{i=1}^{n} a_i\, cos(i\varphi) + \sum_{i=1}^{n} b_i\, sin(i\varphi) \qquad (5)$$

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 (6).

$$\sum_{k=1}^{N}\left\{R_k - \left[\frac{1}{2}a_0 + \sum_{i=1}^{n}a_i\,cos(i\varphi_k) + \sum_{i=1}^{n}b_i\,sin(i\varphi_k)\right]\right\}^2 = minimum \quad (6)$$

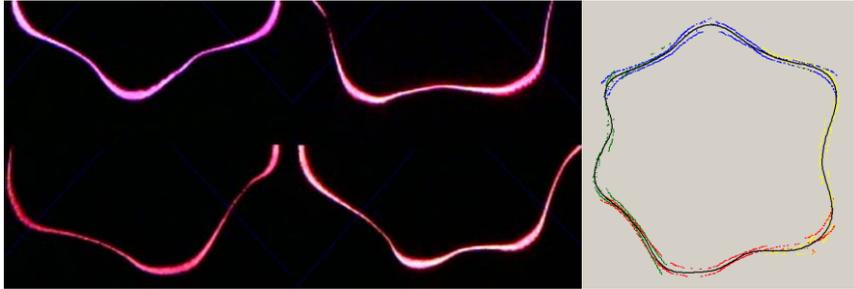The point cloud and the approaching curve of an actual level are shown on right side of Fig. 5.

Figure 5. Four pictures of a cross section curves
and the reconstructed cross section

3.3 3D Reconstruction

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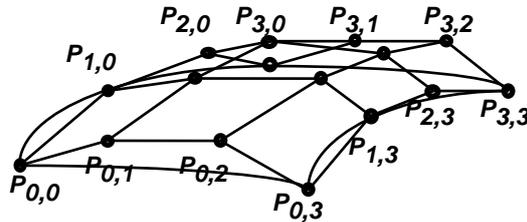

Figure 6. Bezier patch

Patches are connected to one another continuously in first order by the Catmull-Romm model. Edge slopes are defined by the vertices of the actual element, too [6].

Vertices of the 3D geometry are defined by approximating curves (5) on different levels (Fig. 7.).
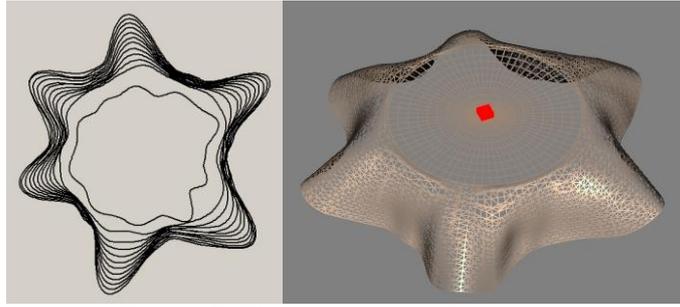
Figure 7. The reconstructed geometry

4. MEASURING MATERIAL PARAMETER BY SIMULATION

The basic measuring idea is simulating material behaviour as a function of properties. If the right set of properties is chosen, we get the measured geometry.

4.1 The Mechanical 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 [7] shown in Fig. 8.
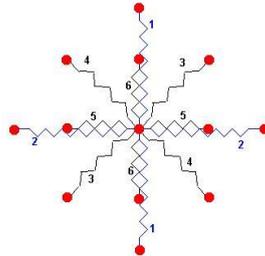

Figure 8. Springs and Mass Points for fabric model

The basic mathematical model is based on the Lagrangian equation (7):

$$\underline{\underline{M}}\ddot{\underline{q}} + \underline{\underline{K}}\dot{\underline{q}} + \underline{\underline{S}}\underline{q} = F(t) \tag{7}$$

4.2 Parameter Estimation

Let us define the difference of the measured shape and the simulated shape (*D*) as a function of material properties (*p*) (8). The minimum position of the function defines the actual properties. [9, 10]

$$D(\underline{p}) = minimum \tag{8}$$

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. In equation (5) 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.

$$D(\underline{p}) = \left[\frac{1}{2} a_0^M - \frac{1}{2} a_0^S(\underline{p}) \right]^2 + \sum_{i=1}^{n} \left[a_i^M - a_i^S(\underline{p}) \right]^2 + \sum_{i=1}^{n} \left[b_i^M - b_i^S(\underline{p}) \right]^2 \quad (9)$$

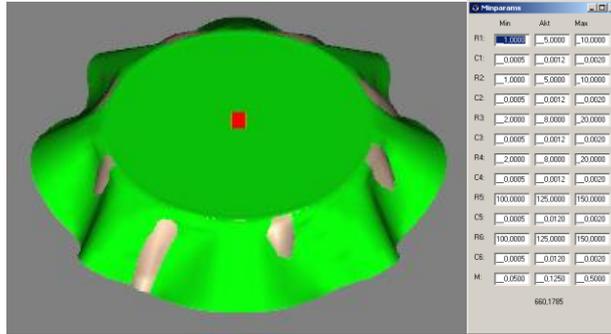The optimum place emerges from an iterative simulation process.

Figure 9. The iterative simulation process

4. CONCLUSIONS

The presented equipment and methods are appropriate to measure draping parameters of clothes as well as virtual fitting on [8] (Fig 10).

Figure 10. Virtual Fitting On

ACKNOWLEDGEMENTS

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