

Computer Aided Measuring of Textile-mechanical Parameters

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Abstract. A new equipment for measuring the draping characteristics of static cloth is presented in the paper. In contrast with Kawabata Evaluation System 3D geometrical data of the sample are captured from photo images. Based on a mathematical reconstruction of geometry, and 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. The sample is scanned by laser-beams. 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 the cloth simulator. Springs are assumed to be linear, while dampers are proportional to the velocity. The physics engine running the simulator calculates vertex positions at a time 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.

To evaluate the influence of the individual parameters, a series of simulations was 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.

1. Introduction

The goals of modelling cloth and cloth structures for needs of textile industry and for computer graphics use are very different. If one comes to the – real or virtual – tailor, choose a fabric and – before making any decision – would like to see how a ready suit or skirt would fit the body, he 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 the general interest is 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, the tailor should be able not only to measure the body and create a personal virtual mannequin, but also to measure some parameters of real cloths needed for 3D visualization.

Although the Kawabata Evaluation System (KES) can provide accurate measurements, the 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. Another approach is to fit parameters of a particle-based cloth model in order of fitting the geometry of real cloth in a static rest configuration, draped over a round table (Drape meter), estimating parameters from photo images of the cloth. An integrated robot-scanner equipment has been developed for more accurate

definition of geometry of test pieces. Background of the measuring process is presented in the chapters as follows.

2. Structure of the equipment

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

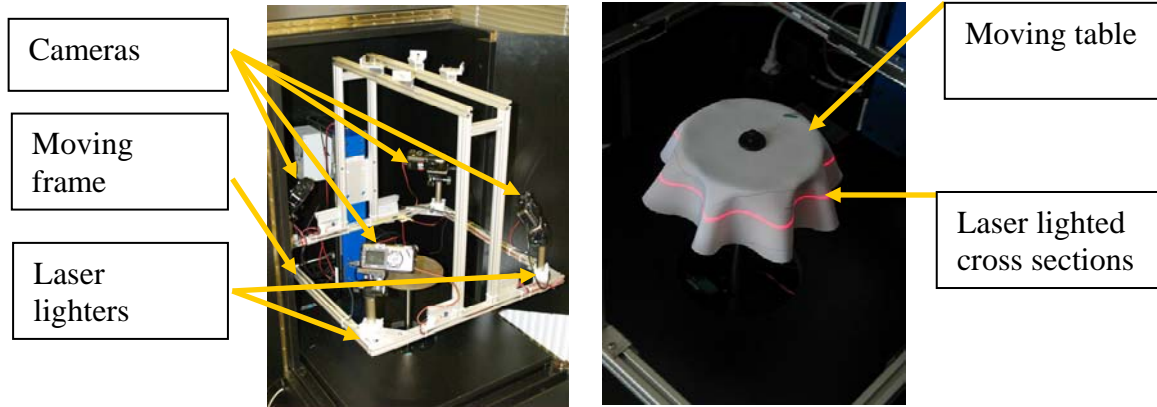


Fig. 1. The 3D drape scanner

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. Frame is programmed on serial port. The controlling programs have been developed using Borland Delphi [1], Alkenius' Cam Remote components [2] are used to program the Canon firmware [3].

3. Measuring by the Equipment

In order to achieve the necessary accuracy for garment trade, it is necessary 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. Points of curve are defined by processing of four pictures. For 3D scanning the plane to plane perspective transformation is bijection. Perspective transformation by homogenous coordinates is a linear transformation [4] projecting quadrangle to quadrangle. The matrix of transformation (Eq. 1) has eight independent coordinates (p_0, p_1, \dots, p_8).

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

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

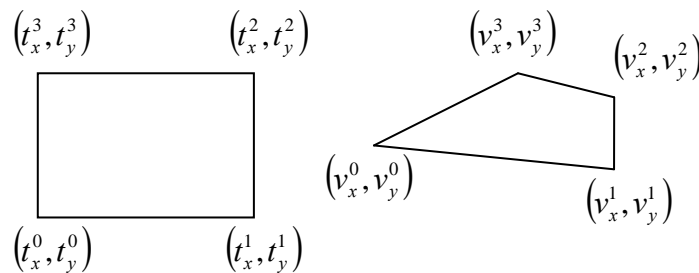


Fig. 2. Planar perspective projection

Corners of calibration equipment are (t_x^i, t_y^i) , and corners of its picture are (v_x^i, v_y^i) and in homogenous coordinates $(v_{xh}^i, v_{yh}^i, v_{zh}^i)$ ($i=0, 1, 2, 3$), then the transformation is shown in (Eq. 2)

$$\begin{bmatrix} v_{xh}^i \\ v_{yh}^i \\ v_{zh}^i \end{bmatrix} = \begin{bmatrix} p_0 & p_1 & p_2 \\ p_3 & p_4 & p_5 \\ p_6 & p_7 & 1 \end{bmatrix} \cdot \begin{bmatrix} t_x^i \\ t_y^i \\ 1 \end{bmatrix} \quad (2)$$

There are eight unknown p_i coordinates and eight equations (Eq. 3).

$$\begin{aligned} v_x^i &= \frac{v_{xh}^i}{v_{zh}^i} = \frac{p_0 \cdot t_x^i + p_1 \cdot t_y^i + p_2}{p_6 \cdot t_x^i + p_7 \cdot t_y^i + 1} \\ v_y^i &= \frac{v_{yh}^i}{v_{zh}^i} = \frac{p_3 \cdot t_x^i + p_4 \cdot t_y^i + p_5}{p_6 \cdot t_x^i + p_7 \cdot t_y^i + 1} \end{aligned} \quad i = 0, 1, 2, 3 \quad (3)$$

Determination of corner coordinates starts at the corner closest to the actual camera. Having defined the point of the edge image in the coordinate system connected to the left-bottom corner of the photo, the 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 is a function of x_s ! In other words $H(x_s)$ is the sum of the differences of y_j point coordinates and the $a \cdot x_j + b$ lines [5] with unknown parameters (x_j are point coordinates) in front of the corner and behind the corner (Eq. 4).

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

Minimum of $H(x)$ 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.).

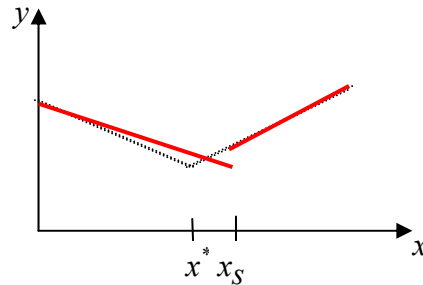


Fig. 3. Corner point definition

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

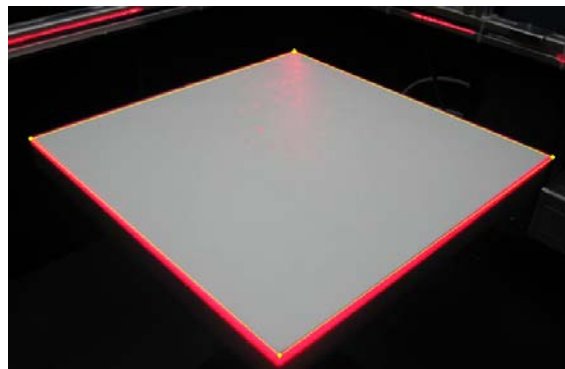


Fig. 4. Quadrangle of the calibration

3.2. Determination of laser lighted 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 (Eq. 5). Size of the slice (n) can be defined by the software.

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

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 (Eq. 6).

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

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



Fig. 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 are defined by $P_{i,j}$ vertices (Fig. 6.).

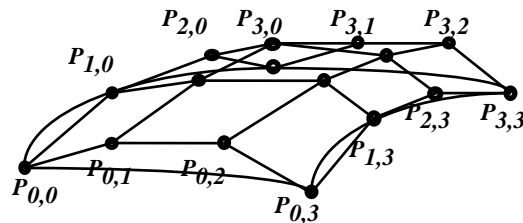


Fig. 6. Bezier patch

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, as well [6].

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

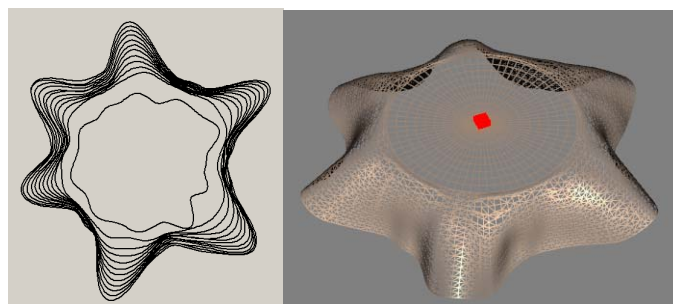


Fig. 7. The reconstructed geometry

4. Measuring Material Parameter by Simulation

The basic measuring idea is the simulation of material behaviour as a function of properties. If the right set of properties is chosen, the measured geometry will be obtained.

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] (Fig. 8.).

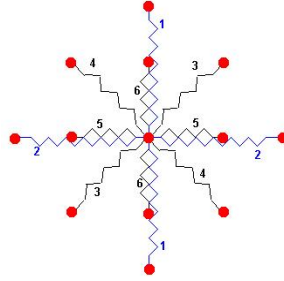


Fig. 8. Springs and Mass Points for fabric model

The basic mathematical model is based on the Lagrangian equation (Eq. 7) where \underline{M} , \underline{K} and \underline{S} are the matrices of mass, absorber and spring data. \underline{q} is the vector of coordinates:

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

4.2. Parameter Estimation. Let us define the difference measured shape and the simulated shape (D) as a function of material properties vector (\underline{p}) (Eq. 8). The minimum position of the function defines the actual properties. [9, 10]

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

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. If equation (Eq. 9.) 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.

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

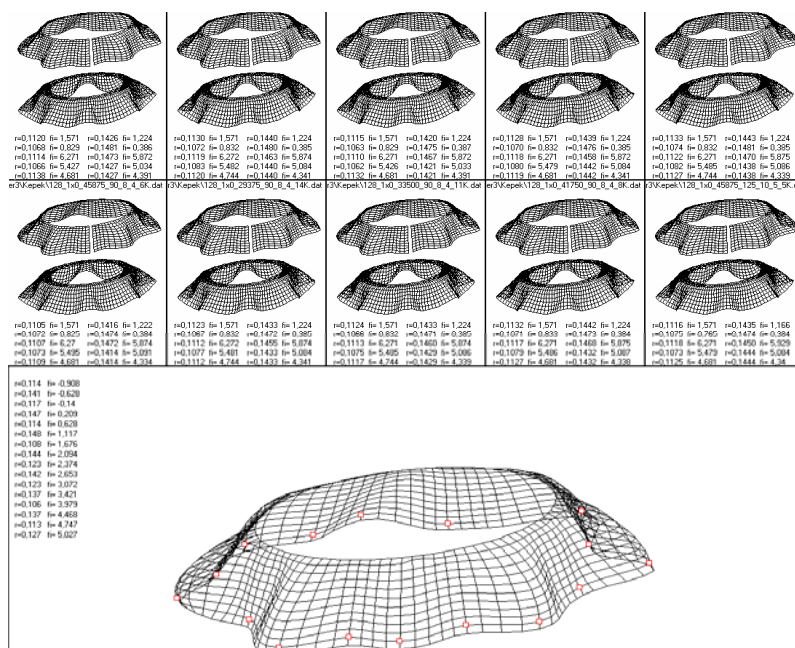


Fig. 9. The expert database

The optimum place can be found by an iterative simulation process. Starting position of minimum searching is aided by an expert system. There are 1100 simulation results stored in a database. The level curves are defined by the mass-point positions. Base of comparison is the Eq.10 norm where the h_{sz} is the wave-number, r_{max} the maximum radius and r_{min} is the minimum radius (Fig.9).

$$5|h_{sz} - h_{sz_m}| + \left(|r_{max_{sz}} - r_{max_m}| + 1 \right)^3 + \left(|r_{min_{sz}} - r_{min_m}| + 1 \right)^2 \quad (10)$$

5. Summary

It is possible to measure draping parameters more precise with picture processing based functions of the brand new measuring equipment Measuring is feasible in case of soft materials when the traditional equipments are not useable. Measuring the model parameters opens new perspective in cloths design. The equipment and method developed in the project are able to measure draping parameters of clothes as well as virtual fitting on [8] (Fig 10).

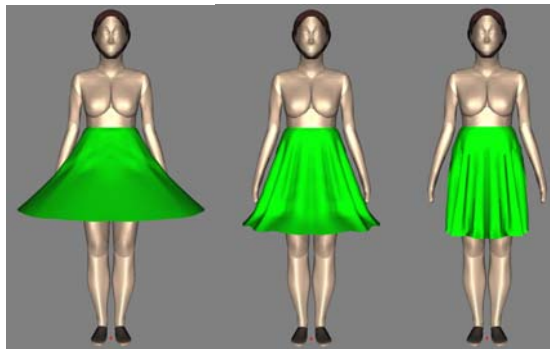


Fig. 10. Virtual Fitting On

6. Acknowledgement

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