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DEPARTMENT OF MECHATRONICS, OPTICS AND INFORMATION ENGINEERING

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IN THE FIELD OF

3D DRESS DESIGN

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1. Preliminaries

Manufacturing preparation systems appeared in the eighties. The objective was mass tailoring. Systems stored the digitized 2D model of middle size cloth part geometry of designed basic patterns. Typical points of geometry were moved upon rules based on body sizes defining the cloth parts of different sizes.

I have been dealing with rag-trading computer systems since 1985 as a member of research group of informatics and rag-trade at Budapest University of Technology and Economics [Halász M. and Co., 1988]. *CAT for Windows* system was was elaborated primarily for training purposes [Halász M.,1994], [Halász M.; Kiss Z.; Tamás P.; Tóth B.,1995], and even now it is still a continuously developing commercial product.

Designing ready made cloth products is a natural research objective too. We developed a pilot system for manufacturing ready-made gents' shirts with developers of *CAT for Windows* at the beginning of the nineties. In this framework I have elaborated an automated photo digitizing method based on picture processing and I have interpolated grading rules of different points (*pt.def*) as a linear function (with ax_i, ay_i coefficients) of different body sizes ($bodysize_i$, $basesize_i$) (1).

$$[x,y]^T = \sum_{i\in bodysizes} \left[ax_i(pt.def), ay_i(pt.def)\right]^T * (bodysize_i - basesize_i) \qquad (1)$$

The manufacturing system of gents' shirts was a market success for more then ten years too [Halász M.; Tamás P.; Kiss Z.; Tóth B., 1998].

Due to the fast growth of computer capacity 3D cloths design became feasible at the turn of century. The starting point in every development process is always a stored model of human body. Initially, when the aims of computer games were dominant data of the model were defined by photos. With the spreading of 3D scanners point-clouds have become the dominant way.

There are two basic directions of research there. Followers of the first direction try the traditionally prepared cloth parts on the virtual mannequin with mechanical simulation. Others design the cloths' surfaces from the point-clouds with the help of construction rules and loose function, and then the surfaces are laid out by special methods. The first direction is called virtual tying on. Nowadays these results are integrated in the commercial CAD systems [Schofield N.A.; LaBat K.L., 2005], [*Pattern_maker,* 2006], [*TC^2*, 2006], [*Tukatech*, 2006], [*Browzwear*, 2006].

The other direction is the real 3D cloth design. Developments are concentrated in three research workshops.

Miralab used H-Anim model [*H-Anim*, 2006] originally prepared for computer games and other industrial aims. The model was excellent for virtual trying on of sewn cloths parts by defined geometry even in moving. It is crucial to define the function between the body sizes and the body surfaces, in order to create geometrical features [Magnenat-Thalmann N.; Seo H.; Cordier F., 2003], [Magnenat-Thalmann N.; Cordier F.; Seo H.; Papagiannakis G., 2004]. Activities of eTailor project, usage of hard mathematical and informatical weapons (sizing survey, artificial intelligence based methods discovering functionality between body sizes and body shape and 3D scanners) [*e-Tailor Project*, 1999-2002] and aims of LeapFrog project [*LeapFrog Project*, 2002-2006] do not show insuperable contradictions between the demands of rag-trade and H-Anim model. Cloths are the set of sewn patterns designed in 2D and the model only tries it on whereas the functionality between the 3D model of body and 2D patterns is strongly researched. There may be interests of project partners, big European software houses in the background of this seeming logical error.

There is no information about the background of scientific ideas of pattern designer of American *(TC)*^{2} [*TC*^{2}*,* 2006] because it is a commercial product. The puritan principle behind is "measure by scanner, lay the sections out, draw around and the pattern is ready". Usage of expensive scanners shows that the target costumers are not small and medium enterprises.

The method chosen by the *Hong Kong University Science and Technology* seems to be closest to the ideal 3D design. They could base their research on results published in Europe and in America. According to HKUST researcher the key of ready-making is stored feature based cloths pattern [Wang C.C.L.; Wang Y.; Yuen M.M.F, 2003]. Feature based geometry of cloths patterns is derived from the vertexes surface curves and surface patches of parametric body model by loose functions [Wang C. C. L., 2005]. The basis of the cloths pattern points can be selected interactively and the moves perpendicular to the body surface are stored [Wang C. C. L.; Wang Y.; Yuen M. M. F., 2005]. This design method seems to be the way of future.

There are more research projects at Budapest University of Technology and Economics with my participation in subject of 3D design of cloths [*MKM FKFP*, 2000], [*OM ALK*, 2002], [*GVOP-3.1.1*, 2004].

2. Objectives

The basic aim has been to elaborate a new method for 3D cloths design. The focus was to prepare a body data defined model that describes the human body according to accuracy demands of rag-trade and applicable for visualization on computers.

The elaborated individual body model defined by photos or 3D scanners was meant to be suitable both for ready made cloths design and for virtual trying on.

The basic aim of sizing research is clustering body shapes and discovering unknown relationship between body sizes.

As a consequence of discovered relationships between body sizes and measured data I planned to find a method as an alternative of sizing research.

The final goal was to develop a new cloth design principle, methods and software based on functionality between body shape and cloths geometry. Developments are topical due to the crisis of both Hungarian and European rag-trade which has lost market against inexpensive labor force and low quality. There is only field to win and this is the field of qualitative products both in material and in model. Computers have broken in the rag-trade in the last two or three decades. In case we only buy western products and run only cloths assembler factories than the competition is hopeless again and we lose the competition again. We have chance against eastern and western opponents only in the field of development and ready making.

Elaboration and development of 3D rag-trade systems are in the focus of international research and development. Computer aided designing of ready made textile products represents a set of knowledge certainly usable in other fields of mechanical engineering, too.

3. New Scientific Results

1. Thesis

I have proven that object-oriented, parametric feature based models built on tubes and half tubes like elements cut along axis, consisting of Bezier patches continuously connected in first order, realized by the generalized two-dimensional Catmull-Romm spline describes the human body with appropriate accuracy according to the demands of rag-trade and is suitable for computer visualization (Fig. 2).

- The shape of the Bezier patches (Fig. 1) is defined by 16 vertexes ($P_{i,j}$ where $i=0...3$ and $j=0...3$) while points of the surface are determined by function of u and v parameters (2).

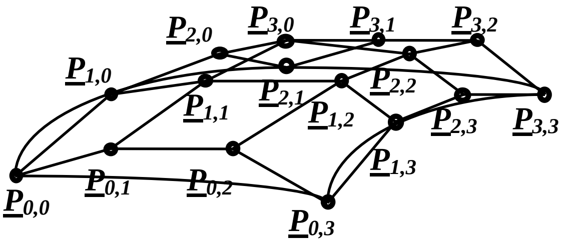
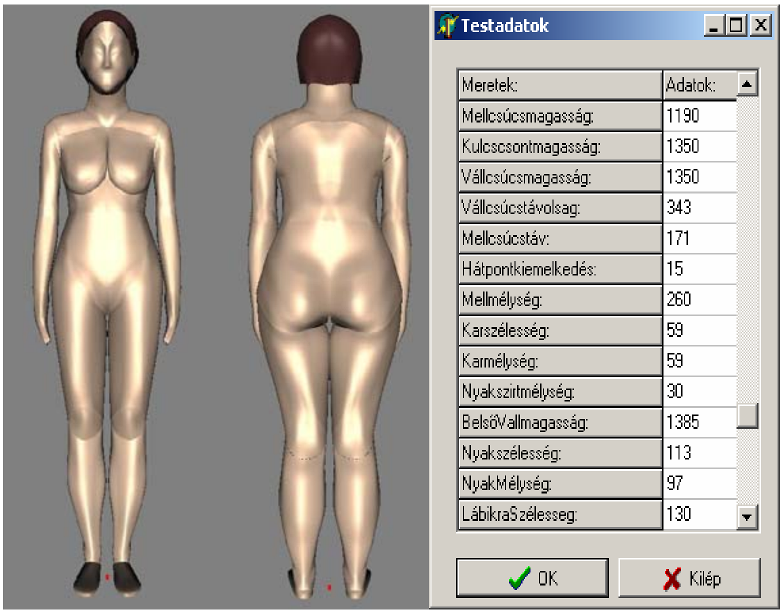


Fig.1. Vertexes of Bezier patch

$$\underline{P}(u,v) = \sum_{i=0}^{3}\sum_{j=0}^{3}\binom{3}{i} * u^i * (1-u)^{3-i} * \binom{3}{j} * v^j * (1-v)^{3-j} * \underline{P}_{i,j} \qquad (2)$$

where u,v $\in [0,1]$



Meretek:	Adatok:
Mellcsúcsmagasság:	1190
Kulcscsontmagasság:	1350
Vállcsúcsmagasság:	1350
Vállcsúcstávolsag:	343
Mellcsúcstáv:	171
Hátpontkiemelkedés:	15
Mellmélység:	260
Karszélesség:	59
Karmélység:	59
Nyakszirtmélység:	30
BelsőVallmagasság:	1385
Nyakszélesség:	113
NyakMélység:	97
LábikraSzélesseg:	130

Fig. 2. Body shapes with different parameters

The four corner points (*i=0 or i=3* and *j=0 or j=3*) lay on the surface. If inner points are defined accordingly $\underline{P}_{0,1}$ point in eq. (3) (*left* upper index means the neighbor in the left side)

$$\underline{P}_{0,1} = \underline{P}_{0,0} + \left(\underline{P}_{0,3} - \underline{P}_{0,0}^{left}\right)/6 \qquad (3)$$

and inner point of eq. (4) comes from the terminal points

$$\underline{P}_{1,1} = \underline{P}_{0,0} + \left(\underline{P}_{1,0} - \underline{P}_{0,0}\right) + \left(\underline{P}_{0,1} - \underline{P}_{0,0}\right) \qquad (4)$$

and the tangent perpendicular to the sides are also defined by the vertexes like eq. (5)

$$\underline{P}_{1,0} = \underline{P}_{0,0} + \left(\underline{P}_{3,0} - \underline{P}_{0,0}\right)/3 \qquad (5)$$

then we get the generalized body modeler Catmull-Romm spline.

- Corner points of surface patches are defined as functions of measured parameters because the used 66 body parameters are the squared linear (measuring position depended) combination of vertex coordinates.

Publication related to the thesis [1], [2].

2. Thesis

I have proven by measurements and experiments that the difference between the model outlines projected on the view plane and contours defined in the front and left view photos is a function of body parameters and the minimum place of this function defines a virtual mannequin well approximating the real body shape according to the rag-trade demands, so it is good both for designing ready made clothes and as virtual trying on (Fig. 3).

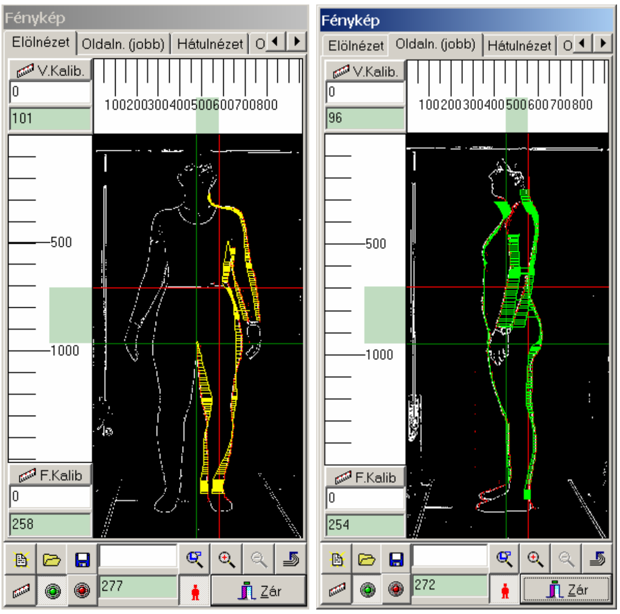


Fig. 3. Difference between profile curves

Publication related to the thesis [3], [4].

3. Thesis

I have shown by measurements and experiments that vertexes of measuring features for rag-trade can be defined by automatically calibrated 3D scanner produced points of the human body if the approximating point-cloud is processed by 3D noise filtering, statistical clustering upon body parts, and surface curves are approximated Fourier based trigonometrical regression (Fig. 4).

- The scanner lights the surface by line-lasers, and there is an angle between the picture plane and the plane of the surface curves. A table with known dimensions was used to the calibration process. The x_S

minimum of (6) function as a regression with broken lines gives the positions of corner points (x_i and y_i are picture points, a and b are the coefficients of regression).

$$H(x_s) = \sum_{x_i < x_s} (y_i - (a_{x<x_s} x_i + b_{x<x_s}))^2 + \sum_{x_i \geq x_s} (y_i - (a_{x>x_s} x_i + b_{x>x_s}))^2 \tag{6}$$

Space position of every picture point can be determined because calibration defines an isometric perspective mapping between the plane of measuring and the plane of the picture.

- Point-clouds in the space can be approximated by trigonometric regression with slices of Fourier series in body-part dependent order if the measured points were characterized by polar coordinates (φ, R) and coefficients a_i and b_i were defined by eq. (7), and they meet accuracy needs of rag-trade.

$$\sum_{k=1}^{N} \left\{ R_k - \left[\frac{1}{2} a_0 + \sum_{i=1}^{n} a_i \cos(i\varphi_k) + \sum_{i=1}^{n} b_i \sin(i\varphi_k) \right] \right\}^2 = \text{minimum} \tag{7}$$

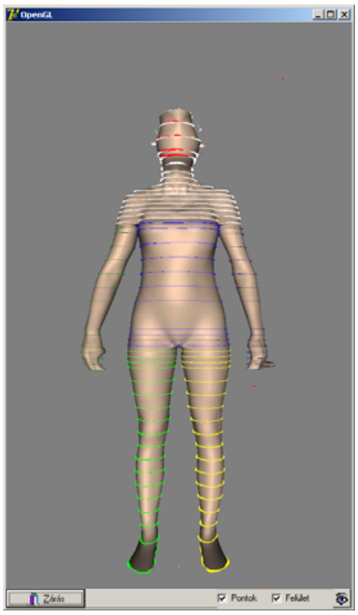


Fig. 4. Approximated body by measuring feature

Publication related to the thesis [5], [6].

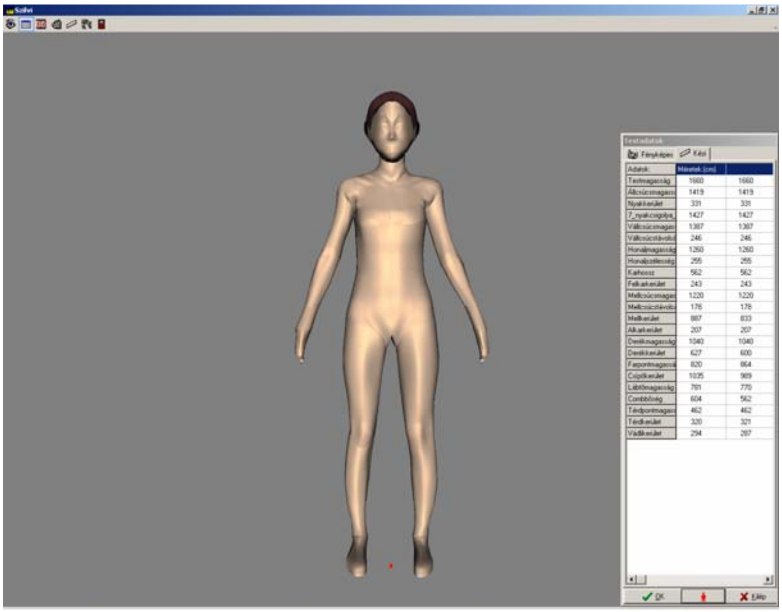
4. Thesis

I have demonstrated that the relationship between basic body sizes and modeling features of body can be explored by procedures based on data mining methods (Fig. 5).

- A reduced set of basic body parameters used by tailors and dressmakers can be defined by distances of model-points and numerically computed length of rectified surface curves.

- The (8) *ф* function between basic parameters and modeling feature parameters which maps the *SP* set of basic tailoring parameter vectors into *CRP* set of Cattmull-Romm vertex coordinate vectors can be determined by interpolation of *k*-closest neighbors.

$$\phi: SP \rightarrow CRP;\ \phi(\underline{sp}) = \underline{crp}; \qquad \underline{sp} \in SP \text{ és } \underline{crp} \in CRP \tag{8}$$



Adatok	Méretek (cm)	
Testmagasság	1660	1660
Állcsúcsmagass	1419	1419
Nyakkerület	331	331
7_nyakcsigolya_	1427	1427
Vállcsúcsmagas	1387	1387
Vállcsúcstávolsá	246	246
Hónaljmagasság	1260	1260
Hónaljszélesség	255	255
Karhossz	562	562
Felkarkerület	243	243
Mellcsúcsmagas	1220	1220
Mellcsúcstávols	176	176
Mellkerület	887	833
Alkarkerület	207	207
Derékmagasság	1040	1040
Derékkerület	627	600
Farpontmagassá	820	864
Csípőkerület	1035	989
Lábtőmagasság	781	770
Combbőség	604	562
Térdpontmagass	462	462
Térdkerület	320	321
Vádlikerület	294	287

Fig. 5. Model based on tailors' and dressmakers' data

Publication related to the thesis [6].

5. Thesis

With the help of my computer system based on newly developed cloths design principles I have proven the following statements: Ready made cloth geometry derived from body part models inherits shapes and data automatically. Geometry can be designed by 3D methods upon draft of profile curves and can be modified by linearly interpolated moving of vertexes in normal direction. Shape of patterns depending on deformation can be computed by the numeric approximation of isometric lay out mapping.

- Type depended formation of basic dresses uses parameter curves distributed evenly upon the curve length.
- If deformation of lay out is minimal then data of cuts are optimal that is when the (9) approximation of *E* is minimal (R_i the length of patch diagonal before the layout and R_i' after).

$$E = \frac{|R_1' - R_1|}{R_1} + \frac{|R_2' - R_2|}{R_2} \tag{9}$$

- Integration simulation of dresses and visualization of material textures result an adaptable system for virtual trying on (Fig. 6).
- If the geometry of test-pieces defined by simulation with different material parameters is compared with 3D measured draping model then the minimum of difference is at the actual material parameter values.

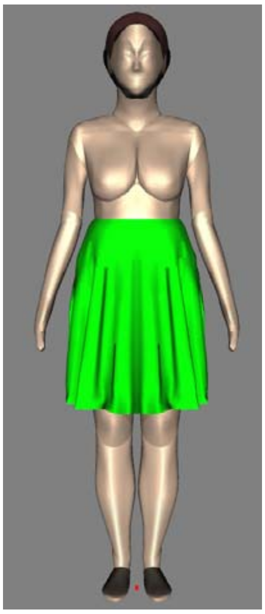


Fig. 6. Shirt draping simulation

Publication related to the thesis [4], [7], [8], [9], [10], [11].

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