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3D VIRTUAL MEASURING OF HUMAN BODY SIZES

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Abstract:

The main purpose is to establish a method of gathering anthropometric measurement data based on the technology of 3D scanning human body, as a tool for automated recording of anthropometric bodily measures. The concept will be based on determining the position of individual anthropometric points on human body, while special attention will be given to studying virtual anthropometric points. Anthropometric points are divided into fixed ones and virtual ones, which shift with the position of the body. Object-oriented, parametric feature based model describes the human body with appropriate accuracy. Vertexes of modelling features for rag-trade or medical aims are defined by automatically calibrated 3D scanner produced points of the human body. 3D model helps to measure the different body sizes virtually. The relationship between basic body sizes and modelling features of body can be explored by procedures based on data mining methods.

Keywords:

human body modelling, 3D body scanner, data mining

1 INTRODUCTION

Since 1983 the researchers at BME (Budapest University of Technology and Economics) have been engaged in the development of computer-aided modelling and 3D body scanning systems for the clothing industry and medical purpose, resulting in a number of patents, PhD dissertations, and some applications for industrial and educational purposes. The researchers at University of Maribor have been engaged in the research, modelling and simulation of garments, designing a especial garments and thermo-physiological measurements resulting in a number of publications, research reports, and PhD theses.

2 CONCEPT OF 3D SCANNAING

The essence of the method is that the laser line emitters illuminate the sections created with horizontal planes of the body surface. The body contour obtained this way is recorded with cameras positioned at a given distance above the plane of lasers and focus on the intersection of the vertical centroid line and the plane defined by the lasers (Figure 1). The spatial position of the points of the contour can be determined from the height of the contour plane by processing the photograph.

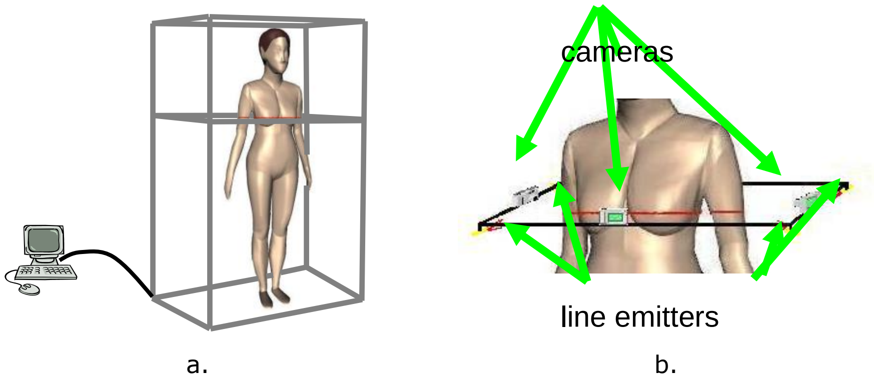

Figure 1: Principle of the scanner

2.1 Calibration

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 analyse errors.

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 [1, 2] projecting quadrangle to quadrangle. The matrix of transformation (1) has eight independent coordinates (p_0, p_1,…p_8).

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

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

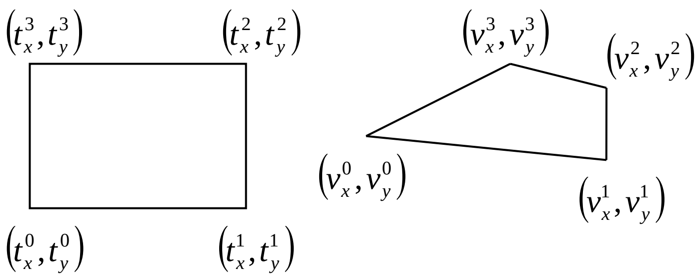

Figure 2: Planar perspective projection

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 equation (2).

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

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

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

Determination of corner coordinates [3] 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_i point coordinates and the $a*x_i+b$ lines [4] with unknown parameters (x_i are point coordinates) in front of the corner and behind the corner (Eq. 4).

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

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).

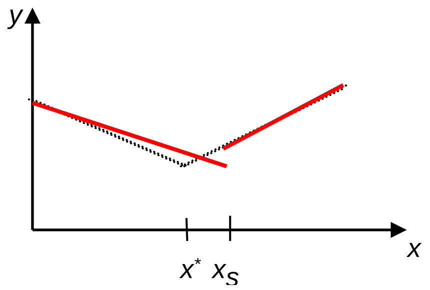

Figure 3: Corner point definition

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.

The planar section points of the body surface supplemented with the actual height data of the measuring frame result in a spatial point set. The height (z) coordinate of the surface points is provided by the height data of the frame drive, and coordinates x and y can be determined with image processing (Figure 5).

The structure of the human body is characterized by the fact that the number of body parts that can be characterized with closed contours on the ground, at the end of the hand, and at the height of the crotch, armpit and crown changes step-like (Figure 6).

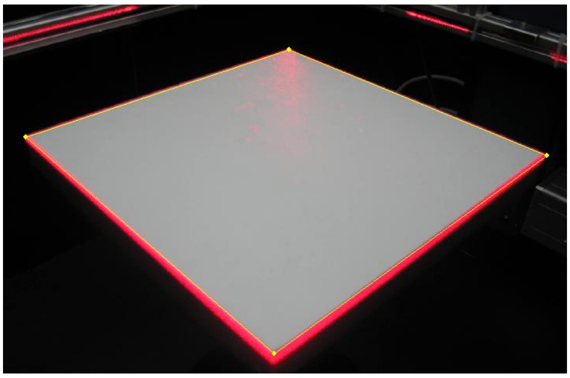

Figure 4: Quadrangle of the calibration

Figure 5: Point cloud

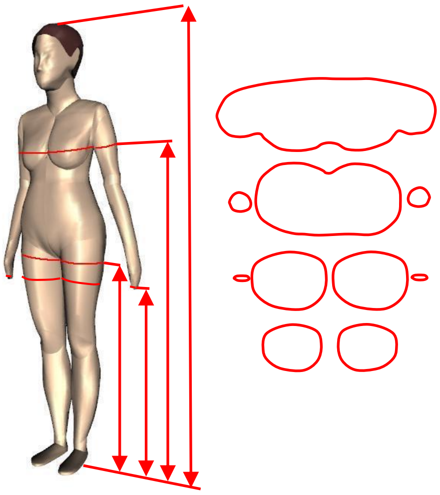

Figure 6: Base dimensions of the body

2.2 Separation of the Bodyparts

The points recorded by the cameras of the measuring frame are used for the automatic separation of the body parts. Based on the calibration the real *x* and *y* coordinates of the planar section points can be determined from the image points and together with *z* coordinate provide the points of the body surface in 3D (Figure 5). Examining the set of points level by level the first step is to determine the centroid of all points at the given level; this will be the origin of the coordinate system. The direction of *x* and *y* coordinate axes in plane is the same as the axes defined during calibration.

A histogram [5] can be prepared based on the number of coordinates with the given *x* coordinate – by dividing the interval of axis *x* visible in the image into parts (Figure 7).

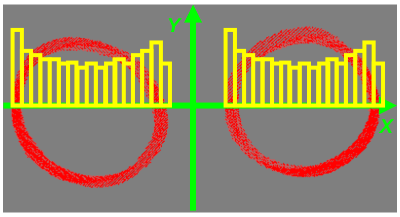

Figure 7: Histogram of the number of surface points as a function of x coordinate at a given level

The not zero areas of the histogram usually separate from each other and create groups. The following cases might arise:

- There are two groups near the legs.
- Below the crotch, near it the arms (hands) also create a group, hence there are three or even four groups since it is not sure that the arms have the same length and even the position may cause a deviation.
- The number of groups above the crotch until the armpit height is three.
- The number of groups above the armpit is one.

It is not always possible to use the method mentioned above to separate the body parts. The body can rotate compared to the calibrated axis, and the body parts might touch each other near the crotch and the armpit. Therefore, the centroid inertia axes of the points of the given plane can be determined at the critical heights, and the approximate step function of the average distance measured from the axis can be created in the coordinate system determined this way along axis *x* (Figure 8). The step function will have a local minimum near the armpits and the crotch, on the basis of which the armpit height on the left and right side as well as the crotch height can be determined.

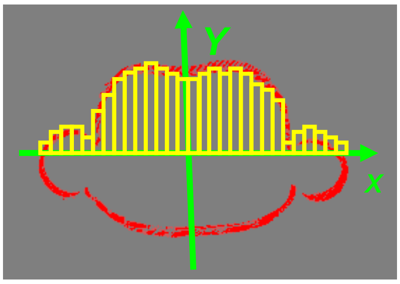

Figure 8: Histogram of the distance of the surface points from the centroid axis x as a function of the x coordinate at a given level

The groups formed this way determine which points belong to which body parts. Figure 9 shows the classification of points of the measurement illustrated in Figure 5 according to body parts.

Furthermore, image processing like activities can be carried out on the grouped body points in order to filter disturbing light effects coming from the environment.

In the first step only those spatial points are considered the distance of which from the axis of the body (the vertical centroid axis of all points) do not exceed 0.75 m. Attention has to be paid to this when positioning the person to be measured.

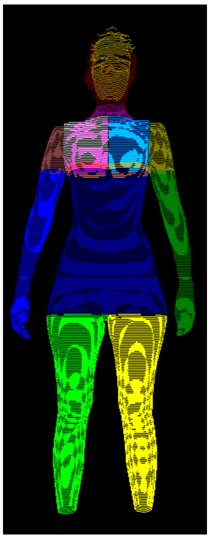

Figure 9: Classification of surface points according to body parts

2.3 3D Filtering

After the determination which point belongs to which body part image processing activity continues in the space the aim of which is to filter wrong points. The centroid (*S*), the expected value of the distance (*M*) and the deviation (*D*) of the points from the centroid of each group at each level is determined. Only those points are considered at the body parts the deviation of the distance from centroid *S* of which does not exceed expected distance M with more than a given multiple of deviation *D* (Figure 10). The value of the multiple (*szor*) changes from body part to body part based on experimental calculations.

As the strongly enlarged image in Figure 10 shows, the width of illuminated surface curves is 6 to 8 pixels depending on the resolution applied.

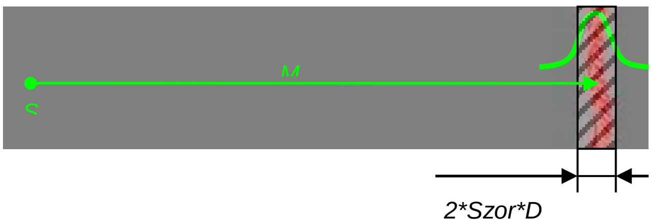

Figure 10: Filtering of body parts

Figure 11: Enlargement of the illuminated surface

The points of the curve could be determined with conventional image processing methods; however the surface curves were approximated with trigonometric regression, sections of Fourier series [6]. The independent variable of the approximating function is angle φ belonging to the point. φ is the angle between the line defined by the centroid of the point and the point array and axis x. This angle can be calculated directly from the centroid of the point array and the actual point. This way the image can be filtered further and the surface curve can be approximated as well. Figure 12 shows the approximating curve defined this way in the cross section of the thigh. The question how large the error of the regression approximation of the 6 to 8 pixel wide laser line is arises.

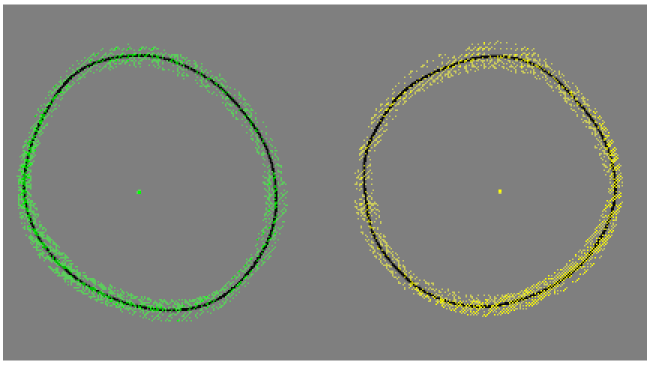

Figure 12: Fourier approximation of thigh cross sections

3 MEASURING ON THE MODEL

There are different types of dimensions to be measured on the body model. The easiest dimension type is the height of a defined point of the body e.g. tarsus on Figure 13. The position of the tarsus point is defined automatically by separation. The value of z coordinate is the same as the higher points of leg or length of legs (Figure 9). The other types of dimensions are perimeter sizes at a defined body position. Such dimensions are perimeter of thigh at the tarsus or perimeter of body at the armpit (Figure 14). The perimeters are measured with numeric integral of the rectified curve the cross section of the actual body parts. Program has to search of special point of body the define the third type of dimensions (Fig. 15). Perimeter of knee can be measured only after searching for the knee joint. There is an angle different of shin and thigh and can be determined similarly as the calibration corner (4). Determination of perimeter of hip and perimeter of waist should be defined an interval and the maximum value will be the perimeter of the hip and the minimum will be the perimeter of waist.

Figure 13: Length of legs

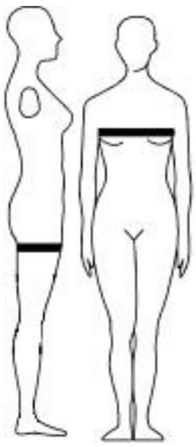

Figure 14: Perimeter of thigh and perimeter of body

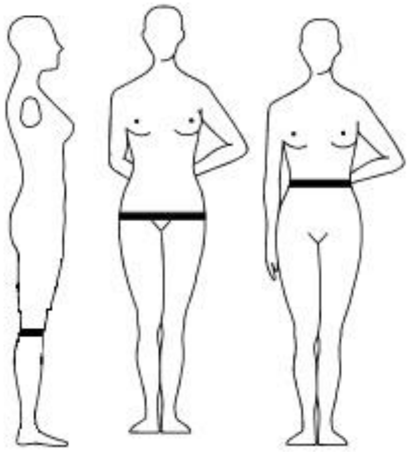

Figure 15: Perimeters at special positions

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