COMPARISON OF CONVENTIONAL AND COMPUTERISED HUMAN BODY MEASUREMENT METHODS

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Abstract: *There is research cooperation between the Mechanical Engineering Faculty of Budapest University of Technology and Economics and the Faculty of Textile Technology of University of Zagreb. The subject of the study is the comparative research between anthropometric sizes measured by conventional equipment and data measured by two different 3D scanners. We have used the set of anthropometric dimensions defined at the Faculty of Textile Technology of University of Zagreb and we have created a 3D computer model of the human body based on NURBS surfaces in order to develop correlating methods. We have developed special software for measuring the distance between the points of body surface and measuring the length of surface curves of conventional anthropometric dimensions. In order to elaborate the correlating method we have chosen 30-30 girls from Zagreb and from Budapest of the same age group. They were between 21 and 25.*
Keywords: *anthropometric measurement, 3D body scanner, virtual human body, avatar, human body model*

1. Introduction

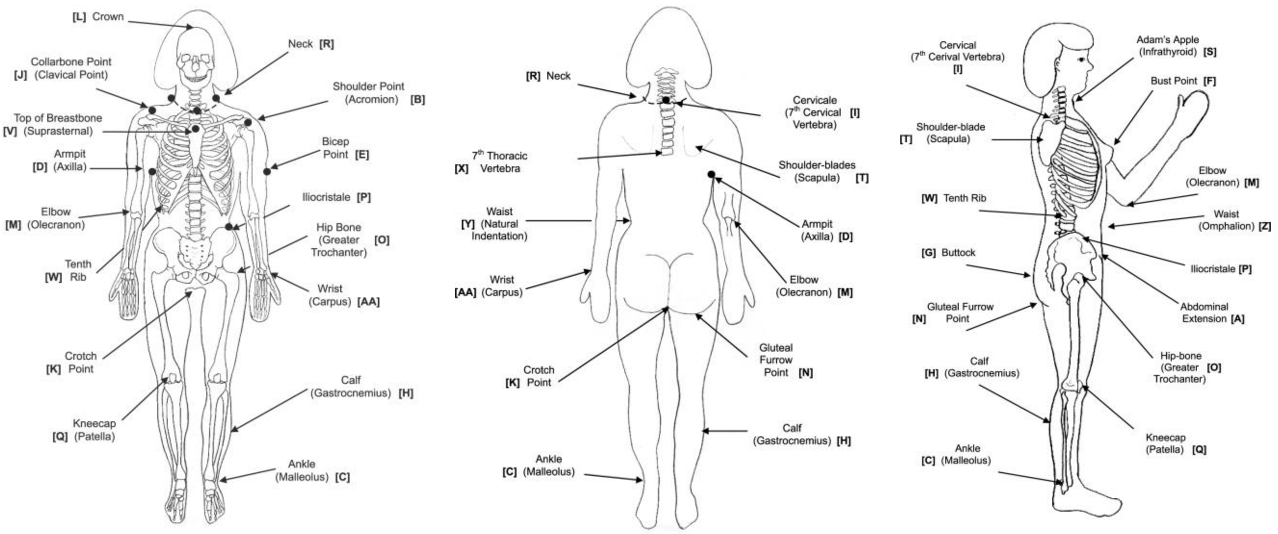
The purpose of the study is to the determinig influence of application different methods and measuring equipment on the anthropometric dimensions of the body. The technological process of clothing and footwear manufacture uses anthropometric measurements in design, modeling and transformation, and they are obtained through anthropometric measurements of a representative sample of a given population. To define a system for clothing and footwear, it is necessary to make anthropometric measurements of the population. Before the 19th century, there is little evidence of attempting to systematize body measurements and their applications. Pattern drafts from the first half of the 19th century represent the foundations for later more sophisticated methods, which have ensured the mass production of clothing. Slowly measuring tools began to develop and inventions for taking measurements were patented. Since 1901 systematic anthropometric surveys have been performed in order to develop and to improve footwear and garment sizing systems [1,2]. Over the last decade modern technologies have been increasingly used for the purposes of anthropometric measurements. In this direction the investigation described in the paper was done. Within the scope of the research, measurements of a selected sample of the female population of Croatia and Hungary were carried out using conventional methods of measuring and two types of 3D body scanner.

2. Anthropometry and standardization

Anthropometry can be defined as the science of measurement of humans. Pheasant has extended this definition to "applied anthropometry" which included numerical data concerning the size, shape and other physical characteristics of people and can be used in the context of clothing design. Joint Clothing Council first published the classic terminology and methods of taking body measurements for the clothing area. Later standard instructions for measuring the body became available. Body measurements were divided into four categories: height, segment length, body width and circumference. In 1996 Beazley proposed a procedure for determining the survey of sizes according to ISO 8559 (E), which included the natural sequence of measurements of the body including three data types: horizontal, vertical etc [3,4]. Standard is the basic document, which for common and repeated use provides rules, guidelines or characteristics for activities and their results, and it guarantees the best level of regulation in the given circumstances. For garment construction the most important standard is ISO 8559 on the basis of which the basic foundations for the unified definition of human body measurements for the apparel industry were laid as well as for the way of taking anthropometric measurements, while the ISO 3635 standard established the basis of labeling garment sizes.

2.1 Anthropometric measurements using conventional methods and 3D body scanner

The proportions of the human body are determined on the basis of anatomy that studies the shape and arrangement of certain parts of the body. Proportions are used to determine the regularity of the relationship between individual body sizes, deviations of the physique from the average physique, i.e. the possibility of a deformation important for the construction of cuts is determined. The results of anthropometric measurements are used in a wide range of industries, from apparel, footwear to furniture industry.



a. b. c.

Figure 1: Anatomical points using in locating body landmarks; a) on the front of the body, b) on the back of the body, c) on the side of the body

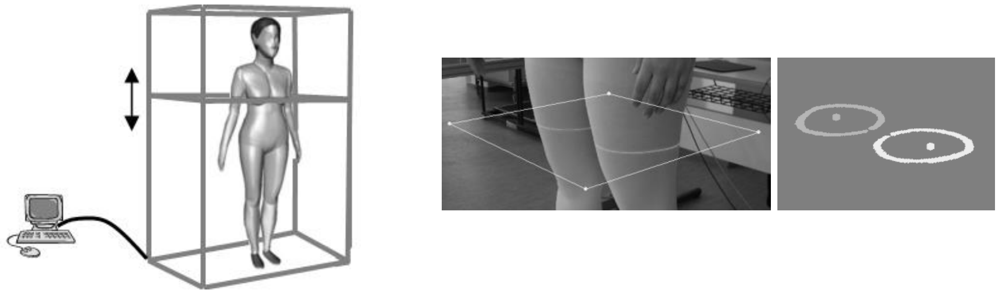
Garment construction is based on the main and auxiliary physical measurements that are determined by measuring on the specific anthropometric landmarks on the body, Figure 1. For conventional or classical measurements of the population and in order to adopt national standards the following instruments are used [5]: one-arm anthropmeter, two-arm anthropometer, tape measure, sliding caliper, special goniometer and digital scales. Over the last decade modern technologies, such as various types of 3D body scanners, have been increasingly used for the purposes of anthropometric measurements. The advantage of using 3D scanners in comparison to conventional measurements is in non-contact scanning procedure and in the precise computer determination of anthropometric measurements, whereby a large number of measurements is determined in a short time. The lack of implementation of these systems is usually reflected in the time of scanning, whereby the body can be shifted, thus causing measurement errors. Furthermore, 3D scanners developed by different manufacturers do not determine individual measurements identically, i.e. there are deviations in positioning anthropometric landmarks on the model body. Also, body posture during scanning is of great importance for the accuracy of measurements, including proper selection of clothing and headgear. In order to facilitate the comparison of measurement results using various 3D scanners, the international standard ISO 20685 was adopted in 2005 [6]. The main purpose of this standard is to ensure the comparability of body measurements that are actually determined by the ISO 7250 (1996 - Basic human body measurements for technological design) and ISO 8559 (1989 Garment construction and anthropometric surveys - Body dimensions), but measured using a 3D body scanner rather than traditional anthropometric instruments [7]. In the meantime, a new version of ISO 20685 (May, 2010) was published considering these problems; it replaced and abolished the first edition of ISO 20685: 2005. The purpose of ISO 20685 is to ensure the comparability of the measurements defined by ISO 7250-1, and measured using a 3D body scanner.

3. Experimental

Within the scope of the research, measurements of a selected sample of the female population of Croatia and Hungary were carried out using conventional methods of measuring and two types of 3D body scanner. A sample of 30 girls aged between 21 and 25 years in each country was selected. For the conventional measurement the same measuring equipment referred to in item 2.1. was used. For the contactless measurement of the Hungarian population the Sylvie 3D system was used, which was developed at Faculty of Mechanical Engineering, Budapest University of Technology and Economics. The Vitus Smart 3D body scanner made by Human Solutions was used for the measurements of the Croatian population [8].

3.1 The Sylvie system - 3D scanning and body modelling

Sylvie system developed at Budapest University of Technology and Economics uses a feature based body model [9]. The developed integrated robot-scanner equipment is able definite of geometry of bodies more accurate. This presentation is about the background of the measuring process. There is a computer controlled moving frame. Line lasers installed on the frame scan along the body while cameras rigged on the frame store pictures of the illuminated body surface. The stored pictures are sent to the controlling computer. The machine processes pictures and defines the points of the body surface, Figure 2a.



a. b.

Figure 2: a) The scanner structure; b) One shot and the reconstructed point set from four side shot

As we want to achieve necessary accuracy, we had to calibrate photos of parallel cameras, in order to develop measuring methods as well as to analyze errors. The task of the frame is the definition of the points on a two-dimensional curve based on photos. Points of the curves are defined by picture-processing methods. Points of body surface lit by laser beams are stored on camera shots. Coordinates of lit points are derived from the calibrating points and the altitude of the frame Figure 2b. Points should be defined by picture processing methods, but the result will be better, if regressed curves are searched. Surface curves on body parts are approached by Fourier series [10]. The angles as the independent variable of the curves are determined from the centre of gravity of point set and the position of points on actual level. Approximating function (R) is the distance from centre of gravity as the function of the angle from x-axis (φ). Only the first $2*n+1$ members of Fourier series are considered where the n is defined differently on different body parts.

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

Unknown Fourier coefficients are determined by least square method. If there are N points on the actual level where the distance and the angle of k-the point is (R_k,φ_k), then a_i, b_i coefficients are defined by the minimum of (2).

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

In order to find the minimum, a system of linear equations should be solved. Measured 3D points and the Fourier series are used to define the body model. Similarly to the parameterised model [1] body surface sectioned measuring features (Leg, trunk arm, shoulder, neck, head), Figure 3. Surface of features interpolated NURBS. Vertexes of surfaces are defined by the measured points.

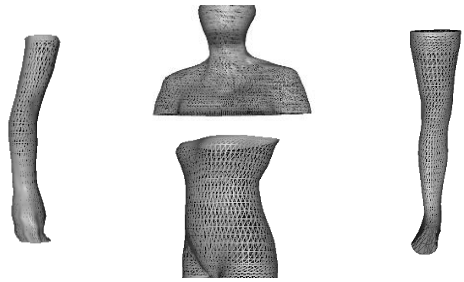


Figure 3: Body part features

3.2 Body scanning and measuring using the Vitus Smart Laser 3D scanner

The principle of laser scanners is based on the measurement of the polar coordinates or the horizontal and vertical angle and the distance to each space point. The instrument emits the sequence of laser pulses according to the predefined interval. Registering the overall shift of the system in relation to its initial position and the measured length, the spatial coordinates of each point are calculated. A 3D cloud of points is arranged in parallel, horizontally positioned planes, with a resolution of points which is about 1 mm in the horizontal plane and about 2 mm in the vertical plane. Each camera captures body segments and processes the data of the captured segment in the computer. Individual segments are connected to a 3D point cloud using a computer. This point cloud describes the body shape. Data processing takes about 40 seconds, and thereafter using the software package ScanWorx V 2.7.2. anthropometric body measurements are extracted. A total of 30 female subjects were measured with a total of 85 body measurements. 25 measurements, which were also determined by the conventional method in order to compare the results, were extracted. Table 1 shows the measurements of three female subjects, with a description of each measurement.

Table 1: Anthropometric measures for three female subjects determined by using 3D scanner Vitus Smart

Codif	Name of measurement	Description of measurement	Model I [cm]	Model II [cm]	Model III [cm]
10	Body hight	Height vertically measured between the top of the skull and the bottom of the feet.	164,1	160,2	172,1
20	Waist hight	Height vertically measured between the rear point at waist and floor line.	104,1	98,2	106,6
30	Crotch hight	Height vertically measured between the groin and the floor.	75,6	67,7	78,1
40	Mid neck girth	Measurement determined as neck girth, in "neck centre". It is measured approximately vertically in relation to the neck central axis.	32,6	31,0	30,0
50	Neck girth	Measurement determined as neck base girth. It is measured over the 7th cervical vertebrae, left neck point, front and right neck point.	37,3	35,2	32,8
60	Cross shoulder over neck	Measurement determined as shoulder width measured over neck. The tape measure runs from the shoulder left point over the 7th cervical vertebrae, left neck point, front and right neck point .	38,9	37,6	36,6
70	Shoulder width - right	Length determined as distance from right neck point to right shoulder point	12,4	12,5	12,3
80	Shoulder angle - right	Angle between the imaginary horizontal line and shoulder line defined by the right neck point and the right shoulder point.	23,1	26,0	25,0
90	Bust points width	Measurement determined as a distance between left bust point to right bust point.	19,5	17,4	17,7
100	Bust point to neck - right	Measurement determined as a distance between right neck point to right bust point	28,0	26,4	26,6
110	Breast girth	Measurement determined as bust girth. It is measured horizontally over bust points, under armpit, and on the shoulder over scapula.	100,7	91,3	88,0
120	Midriff girth	Measurement determined as underbust girth. It is measured horizontally, under the bust.	84,0	75,6	70,9
130	Back width	Measurement determined as shoulder width. The distance from the left armpit point to the right armpit point on the shoulder is measured.	34,2	32,5	32,7
140	Back length	Measurement determined as a distance from the 7th cervical vertebrae and the back point at waist line. The tape measure traces the shoulder line.	38,1	38,7	39,9
150	Waist girth	Measurement determined as waist girth. It is measured horizontally over the narrowest waist part.	77,6	67,5	64,9
160	Waist to hip - right	Measurement determined as a distance from the right point at waist line to the right point at hip girth line.	25,6	22,3	21,1
170	Maximum hip girth	Measurement determined as maximum hip girth. It is measured horizontally over the curve of the greatest girth in the hip area.	105,7	96,2	95,3
180	Arm length to neck back - right	Measurement determined in such a way that it is measured from the 7th cervical vertebrae, over shoulder tip and elbow point to the wrist point on the right arm.	78,6	72,8	77,4
190	Arm length - right	Measurement determined in such a way that it is measured from shoulder tip, over elbow point to wrist point on the right arm.	59,8	54,2	59,1
200	Upper arm girth - right	Measurement determined in such a way that it is measured vertically in relation to the central axis of the upper arm over the biceps area of the right arm.	28,4	25,7	24,0
210	Wrist girth - right	Measurement determined in such a way that it is measured vertically in relation to the central axis of the forearm after the wrist point and before the hand of the right arm.	14,9	15,6	14,4

220	Sideseam at waist - right	Measurement determined in such a way that the distance between the right point at waist line and the floor measured on the outside of the right leg.	106,1	99,9	107,9
230	Thigh girth - right	Measurement determined as right thigh girth. It is measured horizontally in the area of the thigh of the right leg.	59,2	55,2	52,0
240	Knee girth - right	Measurement determined as right knee girth. It is measured horizontally in the area of the right leg knee.	40,9	37,2	34,3
250	Ankle girth - right	Measurement determined as the girth of the right ankle joint. It is measured horizontally in the area of the ankle joint of the right leg.	26,8	22,0	23,2

Measurements determined for each of female subjects were implemented in the computer program Runway made by Optitex, and the transformation of the parametric model of the body or avatar was carried out. Thus, the obtained avatars for each subject, which can be further used in the process of the customization of clothes made to measure, using the 2D/3D CAD system of the construction preparation of clothing.

4. Results

By use of the three previously described methods of anthropometric body measurements the results for 30 Croatian and 30 Hungarian female subjects were determined. The comparison of measurement results between conventional measurement methods and using a 3D scanner was performed, with no evidence of significant deviations. The use of the Sylvie 3D system and the accompanying computer program allows the adjustment of the parametric body model in the program and determining measurements on the adapted model upon scanning, Figure 4. Avatars for three female subjects reshaped on the basis of the measurements determined by use of Vitus Smart 3D body scanner are presents on Figure 5. On the body models all of the measured sizes can be defined and virtually measured.

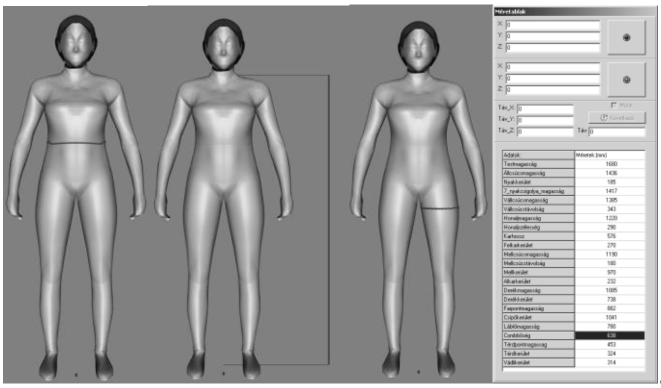
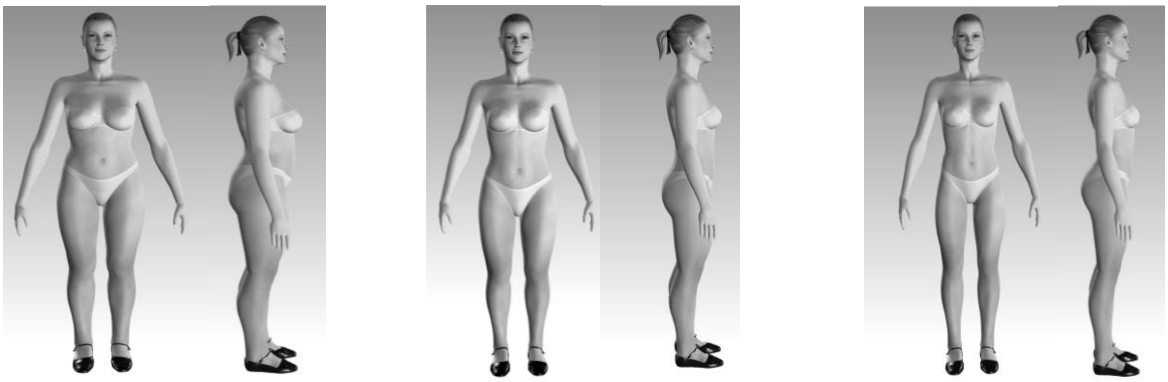


Figure 4: Virtual measuring process



a. b. c.

Figure 5: Avatars for three female subjects reshaped on the basis of the measurements determined by use of Vitus Smart 3D body scanner; a) Model I, b) Model II, c) Model III

5. Conclusion

The paper presents the first results achieved in the joint project between the Mechanical Engineering Faculty of Budapest University of Technology and Economics and the Faculty of Textile Technology of University of

Zagreb. Within the scope of the project a comprehensive investigation will be carried out in the future in order to find the differences between the Croatian and Hungarian population of selected age groups. Within the scope of this work initial measurements of samples of 30 Croatian and 30 Hungarian girls aged between 21 and 25 years were made. In fact, both groups were measured in the same way by conventional measurements according to ISO 8559 and additionally each group was measured by a type of the 3D body scanner in accordance with the instructions in the standard ISO 20685. The use of this comparative measurement allows the determination of differences between the conventional method and the use of 3D body scanners, and between two different scanners. The adaptation of the computer body model or avatars to the anthropometric characteristics determined using a 3D body scanner allows a clear visualization of body shape and the implementation of the same in the CAD system for 2D/3D garment design. The obtained results prove not only the permeability between the two methods, but it is also suitable to relate typical sizes of the two nations. It shows chance in many different fields like reg-trade, sport and hygiene.

Acknowledgement

The paper was written within the scope of the the international bilateral project between University of Zagreb, Faculty of Textile Technology, Department of Clothing Technology and Budapest University of Technology and Economics, Faculty of Mechanical Engineering, Department of Polymer Engineering.

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