

Dynamic Anthropometry – Defining Protocols for Automatic Body Measurement

Dinamična antropometrija – opredelitev protokola za samodejno merjenje telesa

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Abstract

The paper presents the research on possibilities of protocol development for automatic computer-based determination of measurements on a 3D body model in defined dynamic positions. Initially, two dynamic body positions were defined for the research on dimensional changes of targeted body lengths and surface segments during body movement from basic static position into a selected dynamic body position. The assumption was that during body movement, specific length and surface dimensions would change significantly from the aspect of clothing construction and functionality of a garment model. 3D body scanning of a female test sample was performed in basic static and two defined dynamic positions. 3D body models were processed and measurement points were defined as a starting point for the determination of characteristic body measurements. The protocol for automatic computer measurement was defined for every dynamic body position by the systematic set of activities based on determined measurement points. The verification of developed protocols was performed by automatic determination of defined measurements on the test sample and by comparing the results with the conventional manual measurement.

Keywords: dynamic anthropometry, 3D body scanning, measurement protocol

Izvleček

Prispevek predstavlja raziskavo možnosti razvoja protokola za samodejno računalniško določanje meritev na 3D modelu telesa v definiranih dinamičnih položajih. Sprva sta bili določeni dve dinamični poziciji telesa za raziskave dimenzijskih sprememb ciljanih dolžin telesa in površinskih segmentov med premikanjem telesa od osnovnega statičnega položaja v izbrani dinamični položaj telesa. Pričakovano je bilo, da se bodo med gibanjem telesa določene dolžine in površine, ki so pomembne za konstrukcijo oblačil in funkcionalnost oblačilnega modela, znatno spremenile. 3D skeniranje telesa ženskega testnega subjekta je potekalo v osnovnih statičnih in dveh definiranih dinamičnih položajih. 3D-modeli telesa so bili obdelani in merilne točke so bile opredeljene kot izhodišče za določanje karakterističnih meritev teles. Protokol za samodejno računalniško merjenje je bil določen za vsak dinamični položaj telesa s sistematičnim naborom aktivnosti na podlagi določenih merilnih mest. Preverjanje razvitih protokolov smo izvedli s samodejnim določanjem meritev na testnem subjektu in s primerjavo rezultatov s klasičnim ročnim merjenjem.

Ključne besede: dinamična antropometrija, 3D skeniranje človeškega telesa, protokol merjenja

1 Introduction

Anthropometric human body measurement is the basis for obtaining accurate data on human body measures which are necessary for the construction of clothing block patterns [1]. Body measurements using conventional measuring instruments have been increasingly replaced by the use of modern computer technologies, such as various types of 3D body scanners [2, 3]. In addition to the determination of linear body measures, as the most commonly used data in the garment industry and on which the conventional garment construction is based, 3D scans are used to obtain body shape data, anthropometric relationships of individual body parts, deviations from normal proportions, and body posture [4, 5]. This enables the relevant data, necessary for the computer construction and the adjustment of garment patterns according to the individual anthropometric body characteristics of a particular subject [6, 7].

3D scanning technology can also be used for obtaining data on dynamic anthropometry, which is especially important when developing clothing for special purposes with high demands on functionality and fit [8]. Depending on the body position and motion, body surface areas are deforming and body measurements are changing, which demands additional ease allowances on correspondent segments of the garment [9, 10].

The international standard ISO 20685 has been developed to ensure the comparability of body measurements that are determined by standard ISO 7250 (Basic human body measurements of technological design) and ISO 8559 (Garment construction and anthropometric survey-body dimensions), obtained by using different types of 3D body scanners [11]. However, the accompanying computer programs applied for measurement on the obtained 3D point clouds at the end of the scanning process at this point enable automatic measurement procedure only in the basic standing body position.

If it is necessary to determine body measurements in any of the dynamic positions, it is performed interactively, with precision measurement being largely dependent on the user/measurer. Such a measurement method is not appropriate for serial measurements of test subjects since the positioning of the measurement points has to be repeated for each subject in the same way in order to determine measurements. During manual interactive positioning it is

very difficult to achieve the measurement precision and comparability of the measurement results for a sample of test subjects. In that sense, the paper presents the method of defining the protocols for body measurement in two dynamic body positions as a starting point for the improvement of the clothing construction methods as well as the design and development of functional garment models.

2 Methodology

2.1 Defining dynamic positions and 3D body scanning of female test subjects

Since the main objective of the research was to perform the analysis of the targeted lengths dimensions and body surface segments in the static and dynamic positions, two dynamic body positions were initially selected for 3D body scanning of female test subjects, together with standard static position, Figure 1.

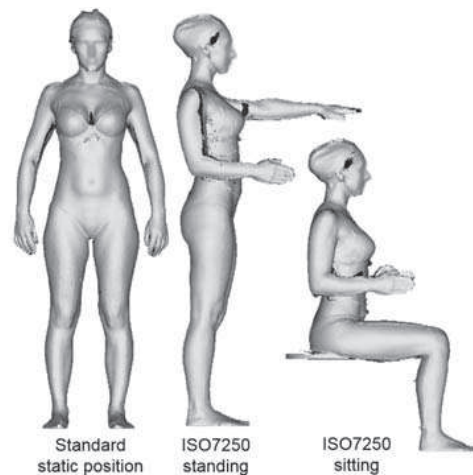


Figure 1: Scanned body models of female test subject in standard static and selected dynamic body positions

The test subjects were scanned with precisely positioned markers on the body at defined measurement points. Total of 80 female test subjects aged 20 to 30 years were scanned for the study using the laser 3D body scanner Vitus Smart developed by Human Solutions. After the performed 3D body scanning, an automatic measurement procedure was performed, with the control of the anthropometric points and measurements on every scanned model. Within the standard, 152 body measurements were determined for every test subject in the basic static body position according to ISO 20685: 2010.

2.2 3D models computer processing

Every particular 3D point cloud, i.e. body model of every test subject in static and dynamic positions was computer processed using the software Anthroscan 2016 (3.4.0.). Processing included closing body models surfaces and creating one-layered closed polygonal model.

2.3 Defining of measurement points and characteristic body dimensions

Measurement points were defined at the positions of recorded markers on the body as a starting point for the development of measurement protocols in dynamic positions. A total of 14 measurement points was defined for the dynamic Position 1, and 22 measuring points for the dynamic Position 2. The selected measurement points were specifically targeted for the purpose of determining the measurements that are from the aspect of achieving functionality of the garment model in dynamic conditions significant for clothing construction, Figure 2.

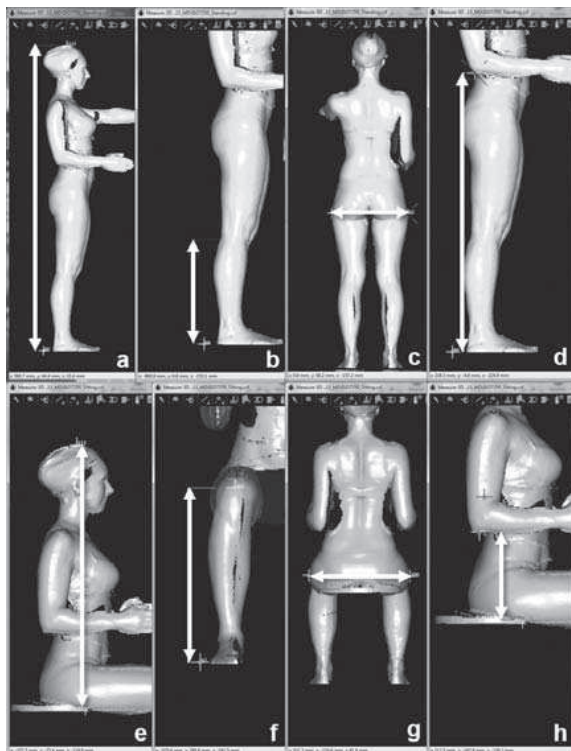


Figure 2: Positions 1 and 2 with selection of defined measurements

The measurements in dynamic positions were also selected to be correspondent with the measurements in static position and to enable comparison

of targeted dimensions based on the body dynamics. The protocol defines 11 measurements for position 1, Table 1, and 22 measurements for position 2, Table 2.

Table 1: Defined measurements for position 1

Position 1	
No.	Measurement
1.	Body height, Figure 2a
2.	Eye height
3.	Shoulder height
4.	Elbow height, Figure 2d
5.	Iliac spine height
6.	Crotch height
7.	Tibial height, Figure 2b
8.	Chest depth
9.	Body depth
10.	Chest width
11.	Hip width, Figure 2c

Table 2: Defined measurements for position 2

Position 2	
No.	Measurement
1.	Sitting height, Figure 2e
2.	Eye height
3.	Cervical height
4.	Shoulder height
5.	Elbow height, Figure 2h
6.	Shoulder-elbow length
7.	Elbow-wrist length
8.	Shoulder biacromial length
9.	Shoulder bideltoid width
10.	Elbow width
11.	Hip width, Figure 2g
12.	Lower leg length
13.	Thigh width
14.	Knee height, Figure 2f
15.	Abdominal depth
16.	Thorax depth
17.	Buttock-abdomen depth
18.	Elbow length
19.	Forearm-fingertip length
20.	Buttock/Seat depth
21.	Buttock-knee length
22.	Neck circumference

2.4 Defining protocol for automatic measurement of body in dynamic position

When defining a protocol for automatic measurement, it is primarily necessary to load each scanned 3D body model in dynamic position into the same file with the appropriate 3D model in the static position, Figure 3. A created combined scans file needs to be stored as a protocol configuration within the Anthroscan program.

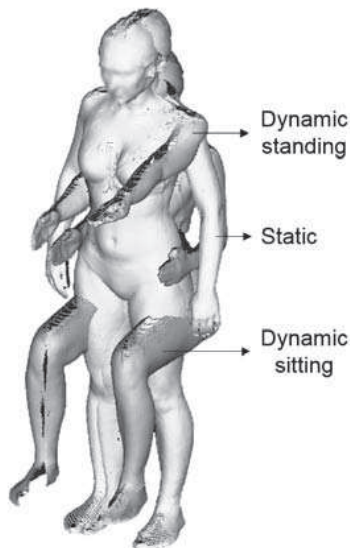


Figure 3: Combined scans data file

In this way, the connection between the scanned models in the dynamic positions and the anthropometric points defined by the ISO 7520 standard is achieved. Loading of the created file into the program enables defining of target dimensions in the dynamic position, whereby the coordinates of anthropometric points between which the measurement will be performed are defined directly on the 3D model.

The positions of the defined anthropometric points are stored as a file of measurements within the defined protocol. The protocol must be defined separately for each selected dynamic position, after which the automatic measurement of scanned body models in dynamic positions is enabled by selecting the desired protocol within the program menu.

A combination of protocols can be achieved by proper naming of the scanned model files within the particular group with the protocol as a name prefix of the group. Based on the name prefix, the system will automatically apply a targeted protocol without the need to select it. In this case, it is necessary to create bmp image files of the targeted positions

based on which the system will recognize which scan model within the combined scans file is appropriate for the application of each protocol. This also enables the application of multiple protocols in the same measurement procedure. Despite the fact that the protocols for measurement in dynamic positions are defined separately based on group naming, the system will link proper scan model with the targeted protocol.

The protocol also enables automatic creation of a measurement table, i.e. html file with measurements and coordinates of anthropometric points. It is also possible to create a specific measurement menu only with the selection of the measurements that will be included in further analysis, Figure 4.

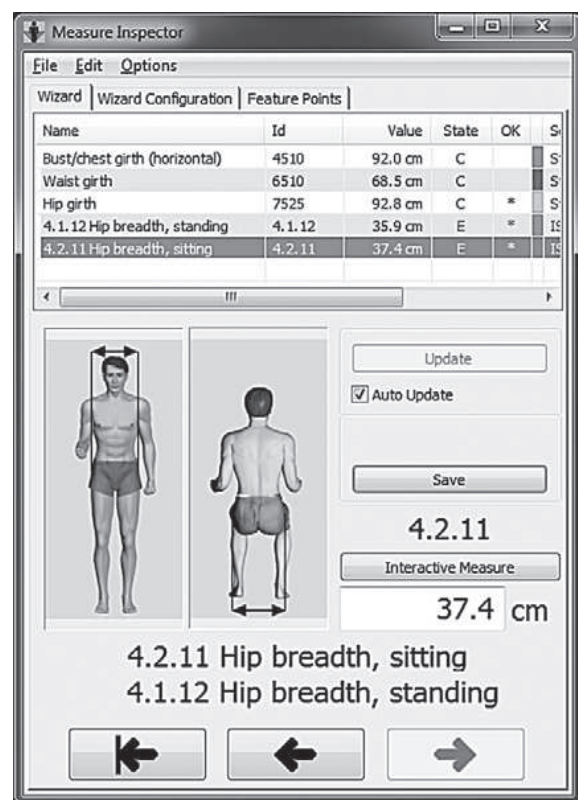


Figure 4: Menu with selection of measurements for analysis of hip width differences between positions 1 and 2

3 Results and discussion

Defined protocols for automatic body measurement in selected dynamic positions were applied on a sample of 80 female test subjects, aged 20–30 years. The measurement was performed on the files with the combined static and dynamic scan models.

Table 3: Definitions of position 1 measurement points with examples of points positions on body model




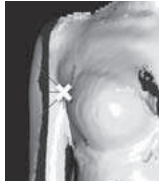





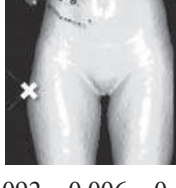


























Definition of point	Position of point	Definition of point	Position of point
Acromion – most lateral point of the lateral edge of the scapula spine	 (0.515, -0.078, -0.164)	Axilla left – most lateral point on the left side of the torso at mesosternal level	 (0.448, 0.041, 0.127)
Crotch – distal part of the inferior ramus of the pubic bone	 (-0.100, 0.031, 0.001)	Axilla right – most lateral point on the right side of the torso at mesosternal level	 (0.401, -0.010, -0.159)
Scapula – the most dorsal protuberance of the torso	 (0.404, -0.136, 0.081)	Elbow – lowest bony point of the bent elbow	 (0.159, -0.077, -0.185)
Eye – other corner of the eye	 (0.689, 0.066, -0.035)	Hip left – the most lateral point on the left side of the hip	 (-0.076, 0.004, 0.186)
Ilium – anterosuperior iliac spine	 (0.031, 0.082, -0.104)	Hip right – the most lateral point on the right side of the hip	 (-0.092, -0.006, -0.191)
Sternum – point on the union of the third and fourth sternebrae	 (0.304, 0.108, -0.058)	Tibia – point on the upper inside edge on the proximal end of the tibial bone	 (-0.451, -0.039, -0.043)
Venter – the most ventral protuberance of the torso	 (0.379, 0.135, 0.065)	Vertex – highest level of the head in the midsagittal plane	 (0.820, -0.026, 0.014)

Table 4: Definitions of position 2 measurement points with examples of points positions on body model

Definition of point	Position of point	Definition of point	Position of point	Definition of point	Position of point
Abdomen – front point at maximum depth of the abdomen		Patella – highest point of the superior border of the patella		Hip sitting left / right – lateral point of the widest portion of the hips, outer point in back view	
Buttock – maximum posterior protrusion of the buttock		Sitting surface level		Elbow lateral left / right – lateral point of the elbow region, outer point in back view	
Deltoid left / right – maximum lateral protrusion of deltoid muscle		Wrist – wrist point on the little finger side		Breast point	
Elbow bottom – lowest bony point of the bent elbow		Acromion left / right – most lateral point of the lateral edge of the scapula spine		Neck left / right – point between neck and shoulder, lies on neck girth	
Fingertip – middle finger		Cervicale – prominent bone at the base of the neck (c7 vertebra)		Popliteus – lower surface of the thigh immediately behind the knee	
Knee cap – foremost point of the knee cap		Elbow dorsal left / right – back of the upper arm at the elbow		Thigh top – highest point on thigh	
Loin – back point at the maximum depth of the abdomen		Eye, sitting – outer corner of the eye		Vertex sitting – highest level of the head in the midsagittal plane	
Neck ventral – point just below the bulge at the thyroid cartilage					

Using the defined protocols, the coordinates of 14 characteristic measurement points on position 1, and 22 points coordinates of position 2 were obtained for every test subject and saved as a measurement .bmf file, Table 3 and Table 4. The measurement file enabled automatic measurement procedure between defined points according to the measurement list or in this case the customized measurement menu.

For this purpose, measurements selection was performed and a new measurements menu was created for analysis of the hip widths values between

posture 1 and 2, Figure 4. Beside the hip width measurements in dynamic postures defined by the new protocols, the menu included basic body circumferences according to Standard. That way, testing of possibilities for combined measurements in both static and dynamic conditions was performed. Test subjects were grouped according to garment size, which was based on the breast girth measurement, to test the correlation between hip width changes and body size. The determined changes in hip widths are in the range from the 0.7 to 6.0 cm, Table 5.

Table 5: Measurements of hip widths with calculation of differences in values between position 1 and 2 and correlation of differences with garment size (breast girth) and hip girth value

GS	TS	BG	HG	HW 1	HW 2	Δ HW
38	F_219	87.2	85.8	32.9	36.5	3.6
	F_223	87.0	90.0	34.4	37.1	2.7
	F_207	88.0	95.4	37.4	40.6	3.2
	F_229	86.9	97.5	36.5	37.6	1.1
	F_210	86.8	100.2	38.3	42.8	4.5
	F_216	88.3	102.8	39.0	42.8	3.8
40	F_236	92.0	92.8	35.9	37.4	1.5
	F_221	90.6	93.1	34.4	36.8	2.4
	F_230	91.5	93.6	36.3	39.9	3.6
	F_226	91.2	95.1	35.2	39.7	4.5
	F_217	90.5	97.9	37.9	38.6	0.7
	F_237	90.3	98.1	37.0	40.9	3.9
	F_201	90.9	99.1	35.6	39.9	4.3
	F_304	93.7	100.1	37.9	41.8	3.9
	F_225	90.2	100.9	37.9	43.3	5.4
	F_214	90.4	100.9	38.0	39.9	1.9
	F_305	92.4	102.2	40.0	42.4	2.4
	F_208	93.1	103.3	39.4	43.5	4.1
	F_233	93.6	104.3	39.4	43.4	4.0
	F_228	92.9	106.5	40.8	44.1	3.3
42	F_209	94.6	93.8	36.4	42.4	6.0
	F_213	95.5	97.5	38.0	42.4	4.4
	F_227	94.2	101.1	40.3	41.3	1.0
	F_301	97.1	103.3	38.5	43.8	5.3
	F_232	94.8	105.0	40.7	43.7	3.0
	r	0.253	0.087			

Legend: GS – garment size, TS – test subject, BG – breast girth, HG – hip girth, HW1 – hip width on position 1, HW2 – hip width on position 2, Δ HW – difference in hip widths measurements on position 1 and position 2, r – correlation coefficient

The correlation analysis of the determined changes in hip width measurement showed very low correlation with breast girth, i.e. garment size and no correlation with hip girth, Figure 5 and Figure 6. This implies that hip measurement changes on different dynamic body positions cannot be predicted and classified using body size and body girths measurements, but the body morphology must be included in the analysis.

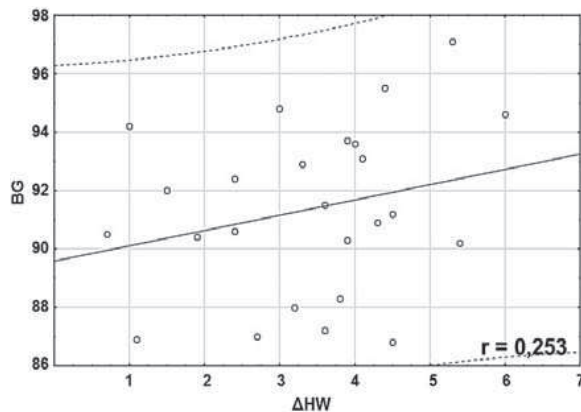


Figure 5: Correlation analysis between changes in hip girth measurements in positions 1 and 2 and breast girth (garment size)

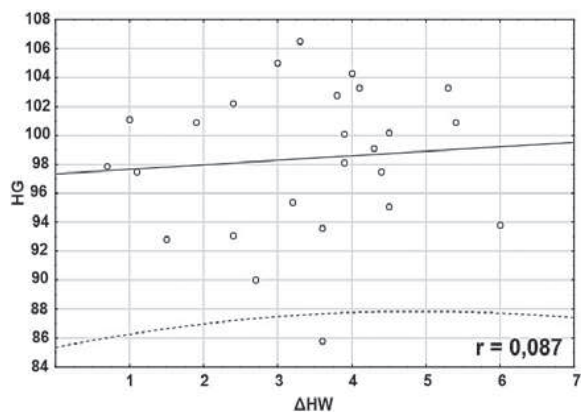


Figure 6: Correlation analysis between changes in hip girth measurements in positions 1 and 2 and hip girth

4 Conclusion

The determined measurement values in dynamic positions are the starting point for the analysis of changes on characteristic body measurements which are affecting the clothing functionality and

fit. Dimensional body changes must be taken into consideration while designing and constructing a garment with high criteria for functionality such as protective and sports garments.

A dimensional change of body in dynamic positions is a complex issue that cannot be considered only from the aspect of basic anthropometric measurement, but the body morphology parameters must be taken into consideration.

Creating automatic measurement protocols for dynamic positions provides greater precision in defining positions of anthropometric points compared to manual processing of individual models. It reduces a measurer's mistake and is repeatable since the points are always positioned in the same way according to the measurement file defined within the protocol. This enables comparison of the obtained measurement results since the measurements are always taken in the same manner, providing the possibilities for complex studies of body dimensional changes in dynamic conditions.

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