Method for Automatic Analysis of the Clothing Related Body Dimension Changes During Motion Using High-Speed (4D) Body Scanning

Yordan KYOSEV [1], Vanda TOMANOVA, Ann-Malin SCHMIDT
TU Dresden, ITM, Chair of Development and Assembly of Textile Products, Dresden, Germany;

https://doi.org/10.15221/22.24

Abstract

The high-speed (4D) body scanner MOVE4D provides the possibility to scan moving humans with high resolution and frequency. The large data set of point clouds has information about the body and clothing interaction, but requires new algorithms for its evaluation. The IBV team provides for the scanner a dedicated software, which includes algorithms to fit a body template to the scans. The scanned vertexes remain in this way consistent with the connected body parts and the mesh is homologous. This feature allows to track different distances and curves during the motion by following the same vertex between the frames without complex 3D image processing algorithms.

The current work presents a new developed specialized programming environment, which tracks curves marked on a human body surface during a motion. The curves are defined using the common file format "ini" and are based on the vertices. Then the coordinates of the vertices are extracted from the files with the consistent meshes. Finally, the curves and their lengths are analyzed and visualized. The method allows automatic processing of circumferences and lengths of the body and provide novel information about the body size during the motion. This information will provide qualitative new information for the design of clothing with better dynamic fit, for instance close to the body sportwear, workwear and others.

Keywords: 4D body scanning, body dimension changes, data processing, dynamic fit, clothing

1. Introduction

Nowadays the development of clothing is based on anthropometric data from static positions of the human body. The freedom of the motion is provided by additional allowances. These allowances are mainly based on the experience of the pattern creators. But, at different motion types the body deformations are different and vary significantly [1]. The pattern creators and designers work with these differences and are creating different types of pattern and/or using different types of material. In the last years, the use of elastane in the production of clothing increased. It is used in the production process of highly elastic knitted and woven structures and thus simplifies the fitting tasks.

However, it not solve the task of creating clothing with the best dynamic fit for certain types of motion completely. The only way for solving this task requires systematic analysis of the changes of the clothing related body dimensions during the motions and their consideration during the pattern creation. Especially for people with disabilities, people, who require body corrections or during a pregnancy, the analysis of the body deformation during motion can provide beneficial information to create significantly better fitting clothing [2,3]. This paper represents a method for automatic postprocessing and evaluation of the curve length changes from high speed body data of moving humans, scanned and processed with MOVE4D scanner and its software.

2. High speed body scanning with MOVE4D

2.1. Hardware

The high-speed body scanning is performed with the MOVE4D scanning system installed in the scan-lab of the chair of development and assembly of textile products, ITM, TU Dresden, Germany. The MOVE4D is produced by IBV, Valencia, Spain and contains in the current case 12 scanning modules, which allow scanning with a frequency of up to 178 frames per second with special resolution of 1 mm. Each module has a infrared projector which generates a mesh of points, two infrared cameras which are used to determine the vertex coordinates and one RGB camera for registering the color (texture)[4].

[1] Yordan.kyosev@tu-dresden.de, +49 (0) 351 463-39313, http://tu-dresden.de/mw/itm/mt

2.2. Homologous Mesh

Currently, one of the most important advantages related to clothing of the MOVE4D system [4], is the in the processing software integrated option to obtain homologous mesh. Homology [5,6] is coming from the ancient greek word ὁμός, homos, (femine ὁμή , neuter ὁμόν), which means similar, same or common. In the biology [5,6] homologous structures are body parts of organisms that have same anatomical features, while in the mathematical topology [7] the homology is a general way of association of sequences of objects. MOVE4D software can generate automatically homologous meshes during the processing of scanned data, if the human body is scanned with close to the body clothing. All approximate 50k vertices and its water tight mesh (Fig.1) are moving with the body between the frames, while remaining associated to the same body parts (Fig. 2). The remaining correspondence of each point to the same body part between the frames means that these can be considered as landmarks. According to this definition, the homologous processed data from the MOVE4D has always 49530 landmarks which can be used for analysis of the motion. This special feature is used in the current work.

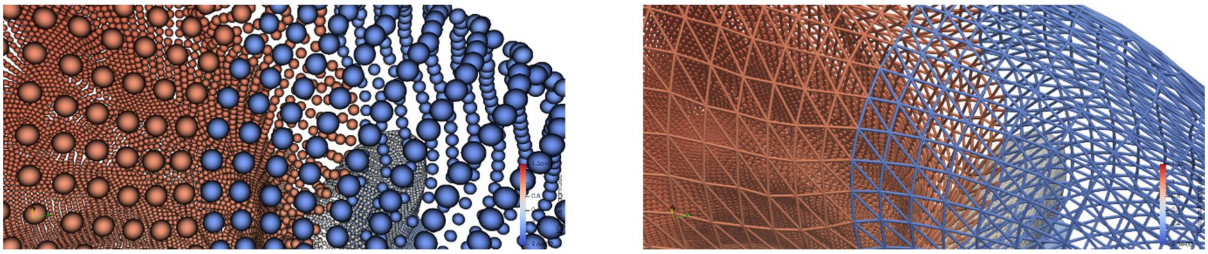

Fig. 1. Vertices of generated homologous processed mesh after the scanning (left hand side) and the corresponding homologous water tight mesh of a part of the body (right hand side)

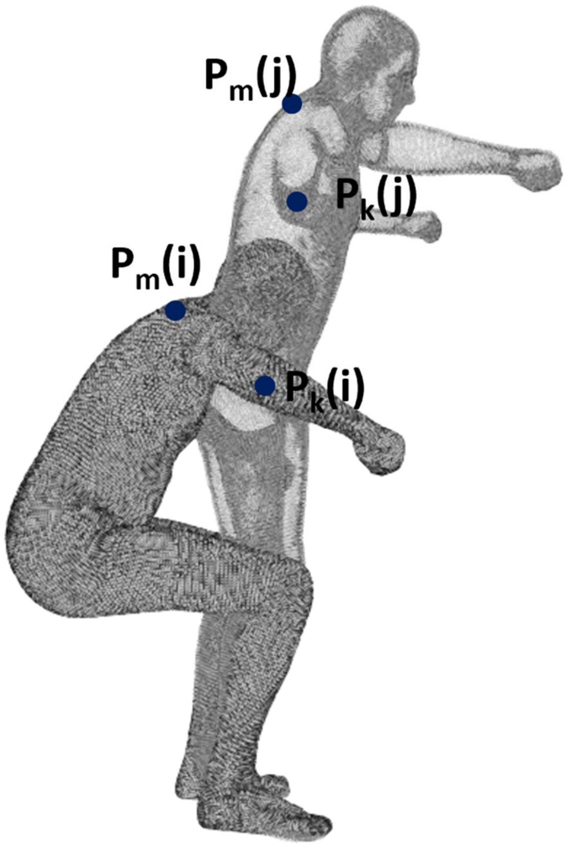

Fig. 2. Homologous mesh principle. Point P_k remains associated on the same body part during the frames i and j

2.3. Feature extraction tool

After the scanning and data processing, a large list of obj files with the body geometry, mtl files with the associated textures and light data, and png files with the texture maps are available. For their automatic analysis, a new tool was developed at the Chair of Development and Assembly of Textile Products, ITM, TU Dresden. As programming environment Matlab of the company MathWorks is used. The initial trials with Python libraries were at this point not very successful, because the most of the 3D libraries, available in python have troubles in the memory management of larger set of 3D data files. These libraries normally work with one or two 3D files and seems not to be able at the current point to clean the allocated memory properly. For later uses, independent on the Matlab licenses and for full control of the process on HPC computers the translation and development of a new version of the tool in pure C++ was started, but the principal of work remains the same as reported here.

In order to analyze the lengths of the important curves on the body surface, these curves have to be defined. In the current case, these curfes are saved as a list of vertex indices in a INI file. The INI files were initially used in Windows operation system for saving configuration settings and are pure text files, which are human readable and understandable. Each curve is defined by a separated field as for instance [bustcircumferance] (Fig. 3). Empty spaces in the curve names are not allowed, because these can not be processed from the Ini2struc library [8] for matlab currently. For the better readability and later for using of the ploting and labeling a separated field “name” is used, where any text, including empty spaces, can be used as curve description. All vertex numbers (IDs) are provided as semicolon-separated list in the variable points.

The INI file with the defined curves is read at the beginning of the process and the data is stored in a separate structure in the memory (Fig.4). The user selects a folder with saved OBJ files and then the program opens each of these files, extracts only the coordinates of the required vertices and saves these in the memory (or alternatively on file). After processing all files, the program saves all extracted data into one file, in order to avoid the need of re-reading the files. The discrete described curves from all selected frames can be then plotted or their length can be computed and visualized. Some other methods for processing the data for FEM analysis of clothing analysis are reported in [9] and [10], and the complete data management structures of MOVE4D system in more details in [11].

```
[bustcircumferance]
points=35644;36176;36166;39788;35577;35584;...
name=bust circumferance

[waistcircumference]
points=9257;23631;23632;9137;9068;9085;23356;...
name=waist circumference

[legrightback]
points=36149;36136;36138;36140;43825;...
name=leg right back
```

Fig. 3. INI File with the path definitions by vertex indicies

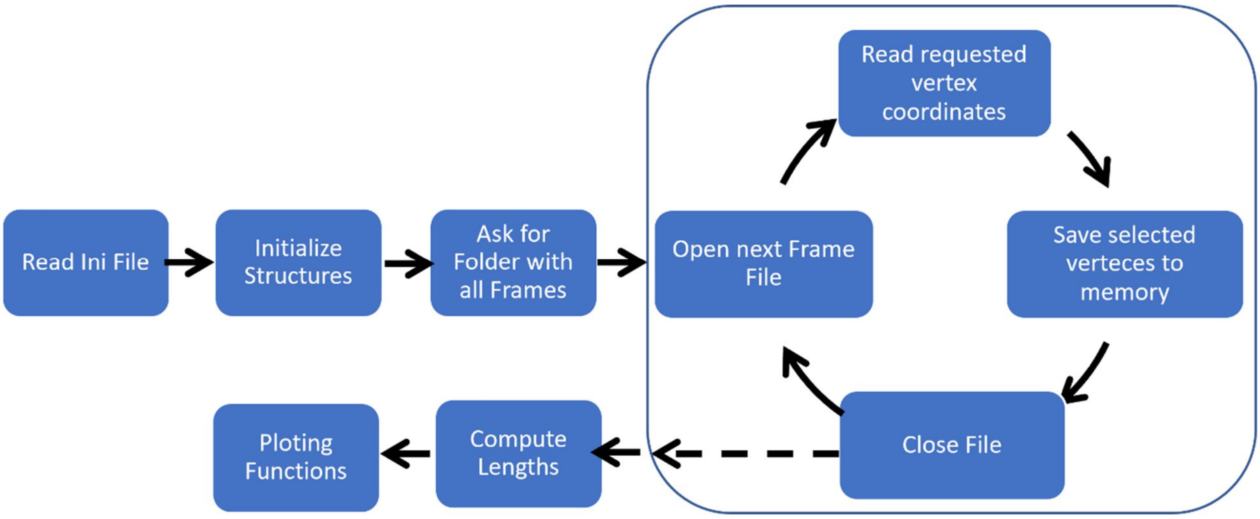

Fig. 4. Workflow for the postprocessing

3. Example results

One of the very common motions is the sitting and standing. The scanned sequence while sitting is analyzed with the prepared algorithm and two curves – one on the front side and one of the back side of the left legs are visualized in the Fig. 5 and Fig. 7, respectively.

The 3D curves are plotted together with the vertices from the starting position only, in order to keep the visibility of the data acceptable. The curve lengths of the both motions are visualized in Fig. 6 and 8, for the front and the back left leg curves, respectively. As well visible on the diagrams, the change of the marked curve on the front of the left leg changes from standing to sitting its length with 9 cm. The differences on the back are larger – from 76 to 91 cm and have a 15 cm difference. Both curves have smooth regions where the length increase or decrease clearly, and regions with fluctuations. The fluctuations are aused by different reasons. One reason is the method for receiving the homologous mesh – a prepared template of the human surface is numerically fitted to the scanned points. In this case some of the vertices have to jump around the surface in order to receive the best fit, and their positions then are not more on the straight curve selected by the user at the curve definition, but slightly on around it, building small "zick-zack" effect. The length of the zick-zack curve increases or decreases rapidly with the change of the distance of each point from the main curve, so any small fluctuation of the position cause already visible jump in the length. These fluctuations are not disturbing at the current time of the investigation, where the authors first like to identify the amplitude of the length differences. Their elimination is possible with an analysis of the point position and the authors are working on the automatic improvement of this issue.

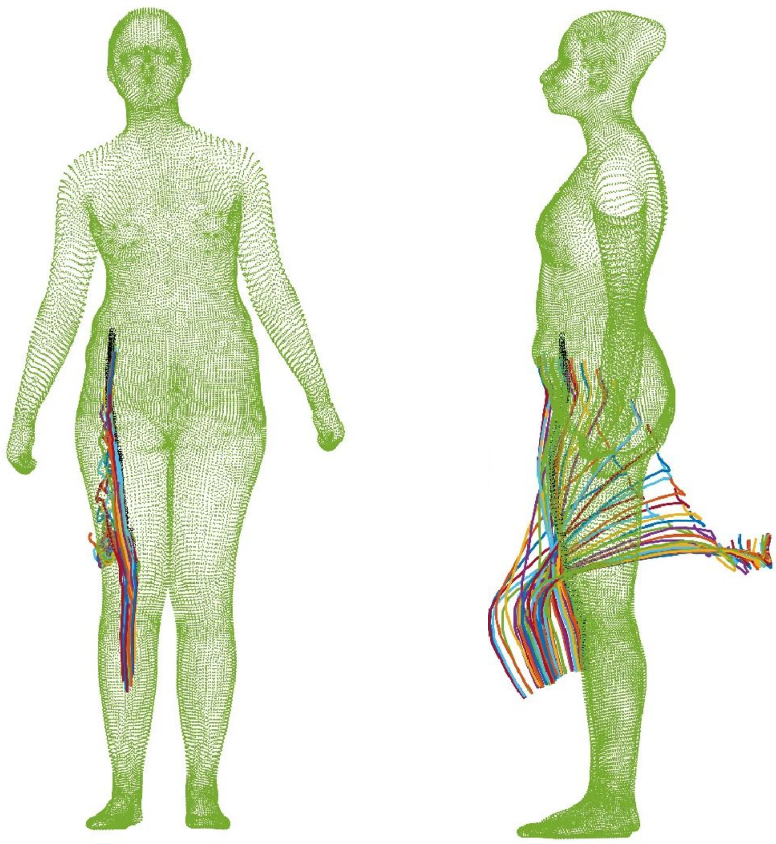

Fig. 5. Changes of the left leg front curve while sitting, the mesh shows the starting position only

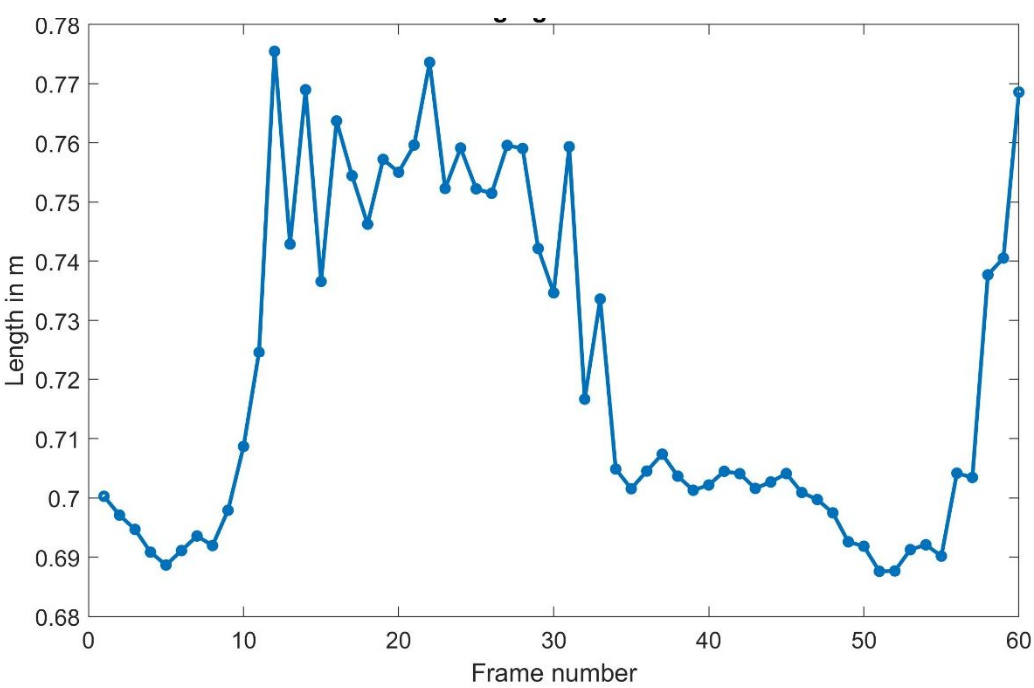

Fig. 6. Length of the defined left leg front curve while sitting

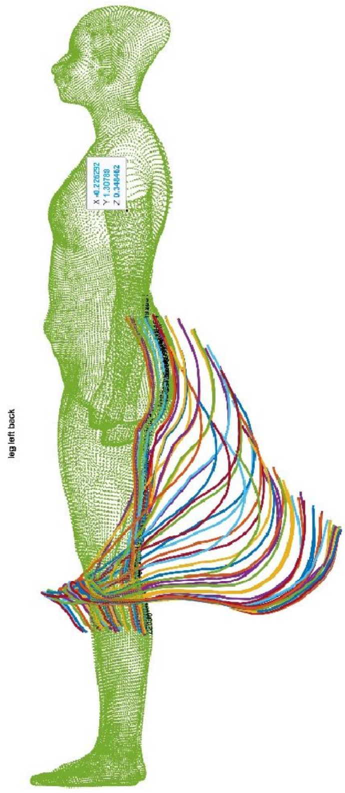

Fig. 7. Changes of the left leg back curve while sitting

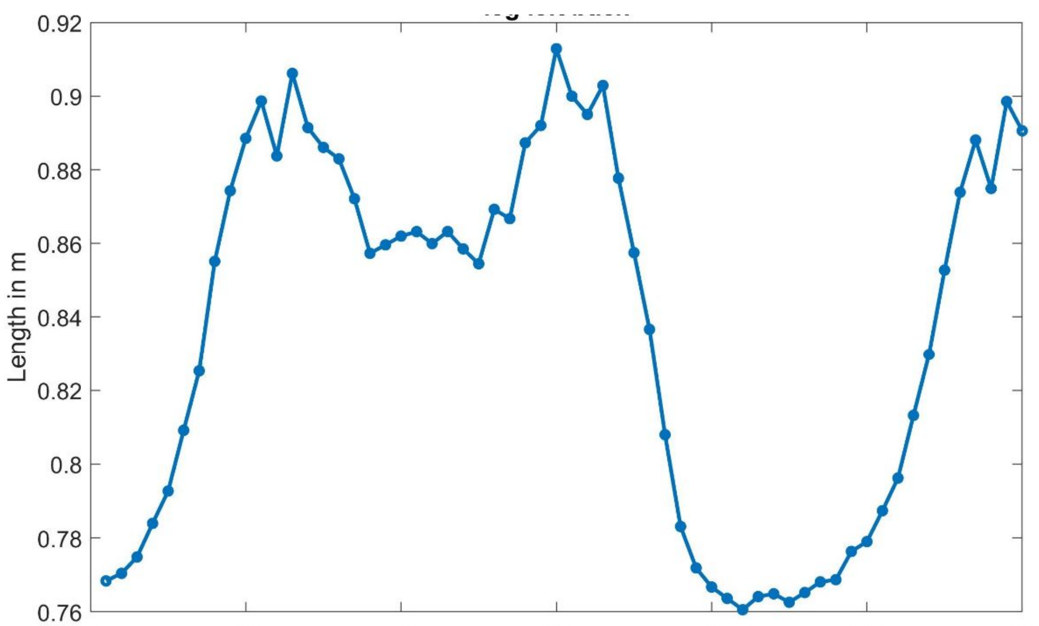

Fig. 8. Length of the left leg back curve while sitting

3. Open issues

One of the most time consuming operation is the selection of the vertices and the definition of the curves. Although a tool for automatic picking and saving of the vertex numbers in a INI file is in its final stage of the development, at the time of the preparation of this investigation, the curves were defined by the user manually. The OBJ file with the homologous mesh was opened in MeshLab (Fig.9). The curves, which are important for the current application, where painted on the body or the clothing and are visible from the texture (Fig.9). The user can then choose vertices along these curves and see and record their IDs.

One problem during this manual selection is that the user selects the coordinate on 2D projection (Fig. 10), where behind one point can be placed four different vertices. After some experience it is possible to minimize such by the user, but this is connected with more time for rotating the geometry and double checking the vertex id. For a quick check of the correctness of the selected vertices, a separated plotting function to a 3D graph was developed. The comparison of the measured lengths with the MOVE4D scanner and then calculated with the explained algorithm and real data was done only at the extreme positions. The comparison showed identical values with error less than 5mm, but the manual measurement was done after the scanning process. During the scanning it is not possible to stop and measure manually, because the visibility of the investigated body by the cameras gets lost. A detailed analysis of the accuracy of the method based on several quasi-static positions is currently running and will be reported in the near future, when finished completely.

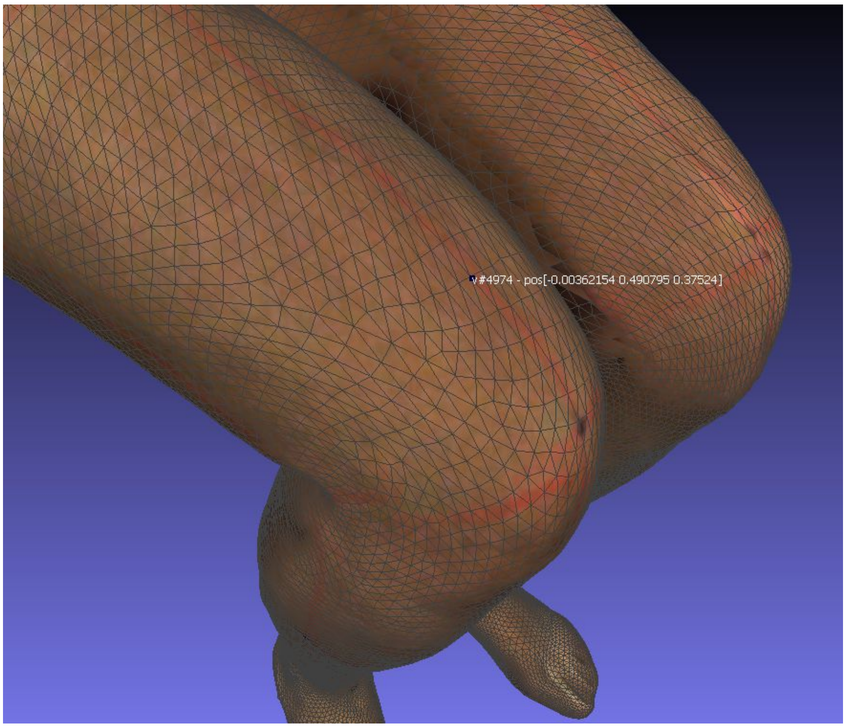

Fig. 9. Vertex selection of the vertex Index with MeshLab software, along the drawing path from the scan data

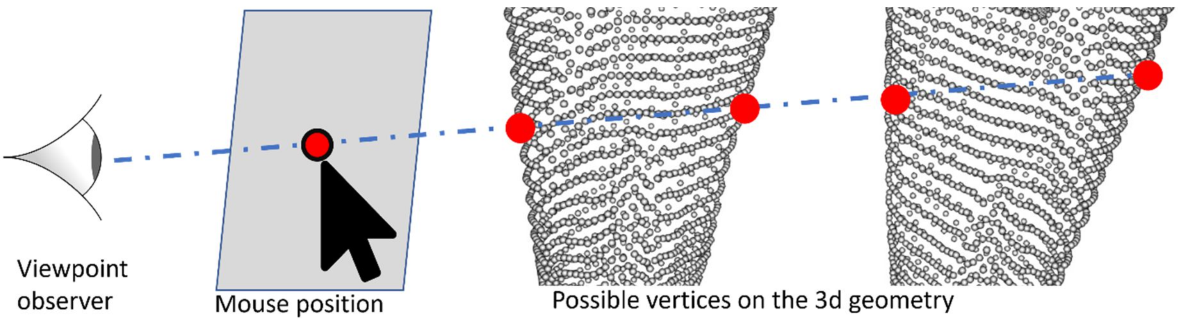

Fig. 10. Problem with multiple selections of vertices on 3D geometry. The observer can click and see the vertex ID of one of four points on the same 3D screen position in MeshLab.

4. Conclusions

The presented method for automatic post processing the homologous meshes, based on the description of the 3D curves on the body surface in INI files shows very promising results. The developed Matlab code allows quick analysis of large set of scanned data and extraction of multiple curves with their positions and lengths. The data can help in the development of clothing, where the dynamic fit can be significantly improved, because the knowledge of the required lengths of the textile material in the different direction will be available.

References

[1] S. Bragança, et.al. , "Effects of Different Body Postures on Anthropometric Measures," in Advances in Ergonomics in Design. Advances in Intelligent Systems and Computing.: Springer, Cham., 2016.

[2] K. Cieśla, I. Frydrych, S. Krzywinski, Y. Kyosev, Design workflow for virtual design of clothing for pregnant women. Communications in Development and Assembling of Textile Products, 1(2), 148-159. https://doi.org/10.25367/cdatp.2020.1.p148-159, 2020

[3] I. Dabolina, J. Fomina, E. Lapkovska, and L. Silina, "Selected dynamic anthropometrics and body characteristics for posture corrector fit", cdatp, vol. 1, no. 2, pp. 96-103, Nov. 2020.

[4] E. Parrilla, A. Ballester, F. Parra, and Ana V. Ruescas, "MOVE 4D: Accurate High-Speed 3D Body Models in Motion," in 10th Int. Conference and Exhibition on 3D Body Scanning and Processing Technologies, Lugano, Switzerland, 2019, pp. 30-32.

[5] I Brigandt, Homology and the origin of correspondence. Biology & Philosophy 17, 389–407 (2002). https://doi.org/10.1023/A:1020196124917

[6] R. Owen, Lectures on the Comparative Anatomy and Physiology of the Vertebrate Animals, Delivered at the Royal College of Surgeons, in 1843. London: Longman, Brown, Green, and Longmans, 1843

[7] P. Hilton, "A Brief, Subjective History of Homology and Homotopy Theory in This Century", Mathematics Magazine, Mathematical Association of America, 60 (5): 282–291, https://doi.org/10.1080/0025570X, 1988,

[8] A. Nych, Ini2Struc, https://de.mathworks.com/matlabcentral/fileexchange/17177-ini2struct, 2007

[9] Y. Kyosev and D. Zhang, "Algorithmic Issues During the FEM Mesh Preparation of Human Models Based on 3D body Scans", Proc. of 3DBODY.TECH 2020 - 11th Int. Conf. and Exh. on 3D Body Scanning and Processing Technologies, Online/Virtual, 17-18 Nov. 2020, #48, https://doi.org/10.15221/20.48.

[10] T. Kuehn and Y. Kyosev, "4D Scanning of Clothed Humans - Preliminary Results", Proc. of 3DBODY.TECH 2021 - 12th Int. Conf. and Exh. on 3D Body Scanning and Processing Technologies, Lugano, Switzerland, 19-20 Oct. 2021, #25, https://doi.org/10.15221/21.25.

[11] S. Alemany, A. Remon, et.al, Data management and processing of 3D body scans, in Norsaadah Zakaria (Ed.), Digital Manufacturing Technology for Sustainable Anthropometric Apparel,Woodhead Publishing,2022,Pages 97-116,https://doi.org/10.1016/B978-0-12-823969-8.00007-1.