Method for Evaluation of the Motion Comfort of the Clothing for Deaf People Using of High Speed (4D) Scanning

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Abstract

This paper presents a short survey about the situation and amount of deaf people and the way they communicate. During the motion of the hands, deaf people require significantly more freedom in their clothing compared to the people, which can hear the voice and do not have to describe their words with hands. Typical gesture movements are scanned with a high-performance 4D scanner MOVE4D and the data is processed to homologous mesh using the scanner software. After that, a newly developed post-processing tool is applied for automatic analysis of the length changes of selected segments. Based on the analysis of the length, the extreme gestures as language postures are detected and the required length changes compensation due to material elongation or slippage is calculated. The use of the obtained data in the design of clothing for the hearing impaired will allow optimizing the cut of clothing following the functional environment.

Keywords: clothing for deafs, sign language, gestures estimation

1. Introduction

Over 5% of the world’s population – or 430 million people – require rehabilitation to address their ‘disabling’ hearing loss (432 million adults and 34 million children). It is estimated that by 2050 over 700 million people – or one in every ten people – will have disabling hearing loss [1].
‘Disabling’ hearing loss refers to hearing loss greater than 35 decibels (dB) in the better hearing ear. The following types of disease are defined:

1) Hearing loss - a person who is not able to hear as well as someone with normal hearing – hearing thresholds of 20 dB or better in both ears;
2) 'Hard of hearing' refers to people with hearing loss ranging from mild to severe;
3) 'Deaf' people mostly have profound hearing loss, which implies very little or no hearing.

They often use sign language for communication [2].
To describe or identify anyone who has been deaf all their lives, or since before they started to learn to talk is used word Deaf with a capital D. These people are pre-lingually deaf. It is an important distinction because Deaf people tend to communicate in sign language as their first language. According to the World Federation of the Deaf, there are more than 70 million deaf people worldwide. More than 80% of them live in developing countries. Collectively, they use more than 300 different sign languages [3].
Interpreters from sign language have an important role to play to allow hearing, deaf, and hard of hearing people equal access to information and interactions. However, the complexities of the task, the types of visual interpreting, and the enormous range of qualifications brought by the interpreter make it anything but simple [4].
According to these trends, it is obvious why the Deaf community is winning more and more attention in modern society. A significant number of scientists are working in various research fields on problems related to the social adaptation of Deafs. At the same time, the apparel industry is low involved, because it is generally accepted, that hearing loss people have no special requirements in clothing, as they do not physiologically differ from hearing people. This statement is only partially correct because it does not take into account that the preferred method of communication for such people is sign language. Active manual articulation involves stress on the hands, which is significantly increased by the use of uncomfortable clothing. This is especially true for sign language interpreters, for which one work cycle duration can reach 4 hours. Since the use of sign language to communicate is the major functional environment for such people, clothing products in this category must be developed with the optimal solution. While also keeping in mind that the product must allow the wearer to perform repetitive movements of relatively constant amplitude for a certain amount without any stress to provide the wearer with a necessary degree of comfort. For this reason, clothing for the Deafs should be defined as functional clothing and for its design should be used an approach that accounts the peculiarities of the functional environment formed by communication in sign language.

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Signed languages (also known as sign languages) are languages that use the visual-gestural modality to convey meaning through manual articulations in combination with non-manual elements like the face and body. Similar to spoken languages, signed languages are natural languages governed by a set of linguistic rules [5]. One of the challenging aspects regarding the translation of signed languages compared to spoken languages is that while spoken languages usually have agreed-upon written forms, signed languages do not.
As signed languages are conveyed through the visual-gestural modality, the most straightforward way sign language notation is via video recording. Therefore, recent research on the study and classification of sign language characters has been conducted to create software applications for reading sign language and translating it into common forms of recording (audio or writing). They are based on the tracking the movement of every pixel on the human body from one frame to another, to gauge its movement vector [6, 7].
Video-to-Pose—commonly known as pose estimation—is the task to detect human figures in images and videos, so that one could determine, for example, where someone's elbow shows up in an image. This area has been thoroughly researched with objectives varying from predicting 2D / 3D poses to a selection of a small specific set of landmarks or a dense mesh of a person [8, 9]. The results obtained make it possible to improve existing sign language interpretation software or develop new ones focused on video conferencing, use as apps for smartphones, etc.
A different approach is needed to analyze sign language for the purpose of clothing design. Since the input data for clothes design are anthropometric measurements, it is necessary to make such an analysis, which would allow us to determine the major types of gestures, causing the maximal dynamic effects of a human body surface.
Quantitative assessment of the dynamic effect of body size using mathematical relationships to determine the surface dimensions of the product elements, as well as the optimal amounts of constructive additions in order to garment design is involved in dynamic anthropometry. Dynamic anthropometry is one of the most topical areas of research in the clothing industry in recent years [10]. It is especially relevant when providing dynamic conformity of working, sports, protective and other types of functional clothing. In the past, the assessment of body measurement alteration was only possible with measurement tape. This was time-consuming and could only be realized with great effort. With the development of 3D scanning systems, an appropriate analysis was feasible. Though, 3D body scanner technology enables only the capturing of static postures. Therefore, the scan shows the muscular system working to hold the position and not the interaction between agonist and antagonist in dynamic movement. The technological evolution from 3D to 4D scanning systems enables scanning in motion [11]. This has allowed significant advances in the development of functional clothing, taking into account dynamic measurements. In this case, more attention is paid to determining the typical positions for a particular field of functional activity, on which basis kinematic models for further virtual clothing design are developed.
The purpose of the study [12] was to develop an efficient way for creating ergonomic clothing for motorcycle riders according to the motorcyclist's typical body motions. Therefore, virtual, 3D human body models were developed in selected dynamic poses using kinematic analysis of a motorcycle rider to identify the typical poses. To obtain the typical posture for mounting a motorcycle rider the major steps were identified and images of each step were extracted from the video recording. The authors [11] to identify differences between static and dynamic body measurements have used the method of photogrammetry. Though, three meaningful work and sports-related movements were defined to assess body geometry alteration. During the research, the authors had to solve several problems that could have been simplified or avoided by using 4D body scan. High-speed (4D) scanning provides a large amount of data, which requires new algorithms for processing and analysis. The methods for evaluation of scans with close-to-the-body clothing and those for evaluation of people with free-moving clothing differ significantly. In [13] Kühn and Kyosev present some preliminary results of the application of 4D scans for clothed humans where the distance between the meshes is used to evaluate which regions are moving. In [14] the main steps in the preparation of FEM mesh are reported and in [15], a method for analysis of the deformation of the tight-fit clothing or the skin is evaluated. This paper represents an analysis of the motion data, where the evaluation method considers the useful knowledge of these previous works and its integration of a newly developed tool for postprocessing of the meshes from 4D scans. With this tool, the motion is analyzed automatically and the extreme postures from data, obtained with a high-speed MOVE4D scanner and its software are detected. The information from this analysis provides a good basis for the development of garments with dynamic conformity for deaf individuals.

2. Methods

2.1. Kinematic analysis

Ensuring dynamic conformity of clothing is based on the study of movements that are typical for a particular functional environment. In our case, the task comes down to the study and classification of gestural movements in order to take them into account when establishing dynamic allowances.
For this purpose, an interpreter with 30 years of experience was consulted. Also, methodological guidelines for training sign language interpreters and many videos using sign language were studied. Based on this, typical upper arm and lower arm movements commonly used for the majority of sign language gestures were identified.
For schematic representation and recording of the obtained data is used kinematic approach. Kinematics is the study of the motion of the body, limbs, and joints that occurs during a movement. The human body is considered as a biokinematic chain, each joint of which has its own numbering and can perform three types of movements, fixed in vector or coordinate form [16]. This method of analysis provides a non-invasive means of collecting objective information on the joint and limb movements of the participant. Using the above approach, typified diagrams of basic gestural language movements were developed and used in the following stages of research.

2.2. 4D Scanning

To analyze typical motions and develop their virtual prototypes, modern high-speed 4D-scanning technology is used. The scanning is performed with the MOVE4D scanner, installed in the scan-lab of the chair of development and assembly of textile products, ITM, TU Dresden, Germany. The scanner consists of 12 scanning modules, which are able to record motion with a special resolution of up to 1 mm and up to 180 frames per second. After the processing of the data by the MOVE4D software, various options for data processing and export are available [17]:

- the raw point clouds with coordinates and colors;
- non-homologous triangulated mesh of free-style clothing;
- template-based, homologous water-tight meshes of the human bodies.

This last option is used in this study. All 49530 vertices in the homologous mesh are moving with the body between the frames, remaining associated with the same body parts and they can be considered as landmarks.

2.3. Matlab analysis

After the scanning and data processing, a large list of files with the body geometry, associated textures, and light data are available. For their automatic analysis, a new tool was developed at the Chair of Development and Assembly of Textile Products, ITM, TU Dresden [17]. As a programming environment Matlab of the company MathWorks is used. To analyze the lengths of the important curves on the body surface, these curves were defined and saved as a list of vertex indices. 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 discrete described curves from all selected frames can be plotted or their length can be computed and visualized. The workflow for this processing in details and open issues were reported in [17].

3. Results

To identify the kinematic joints and enable valid measurements, on the testing model's torso and arms according to anthropometric landmarks positions were marked 20 points, 8 of which are symmetrical. The scanning process resulted in 298 individual images of the surface. Each of these frames can be interpreted as a separate pose, recorded at a time point in a given interval. The amount of the data is large, needs some cleaning in some areas, and requires time-consuming treatment in applications if done manually. Dynamic anthropometry is based on measurements taken in so-called extreme postures. Extreme postures are that cause the greatest changes in the measured surface. These changes can be reported in the form of length differences, coordinates replacement, as well as in vector form. The ratio of this delta to the starting value of the measured parameter is called the dynamic effect.

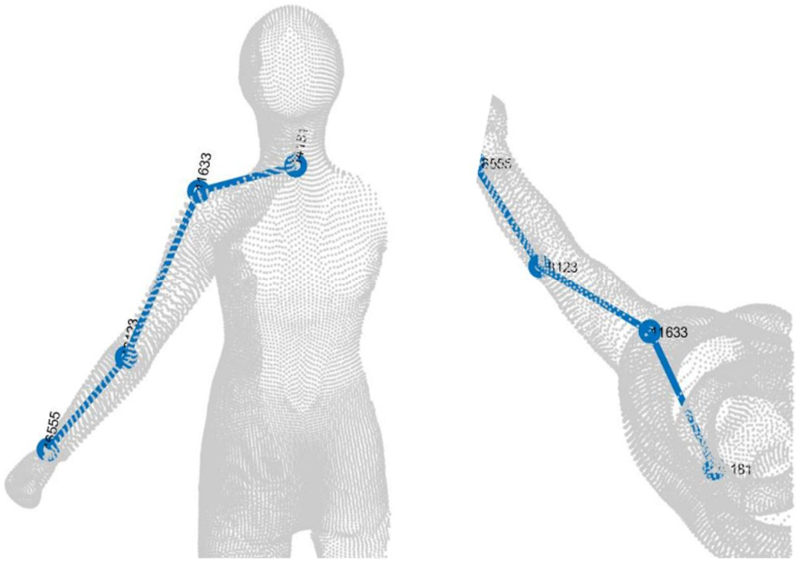

Fig. 1. Investigated chain, defined as a set of linear segments between the landmarks

Consequently, for this work is needed to identify from the dataset only frames, which provide the greatest dynamic effect and have a significant impact on the structural construction of garments designed for the selected group of consumers.

In the first step of the work, the relationship between the anthropometric landmarks and the vertexes of the homologous mesh was established. The vertices, which are used as landmarks for the investigated segments are demonstrated in Fig. 1. By processing the files with the homologous mesh with the Matlab-based tool reported in [17], the multisegment chains corresponding to certain anthropometric measurements were visualized on the triangulated surface at the initial position, as well as curves characterizing a whole kinematic chain. According to the changes that occurred during movement, the segments change their position (Fig. 2a,b). The Matlab-created program allows fixing the dynamics of changes in the position of kinematic joints in space and visualizes their extreme positions.

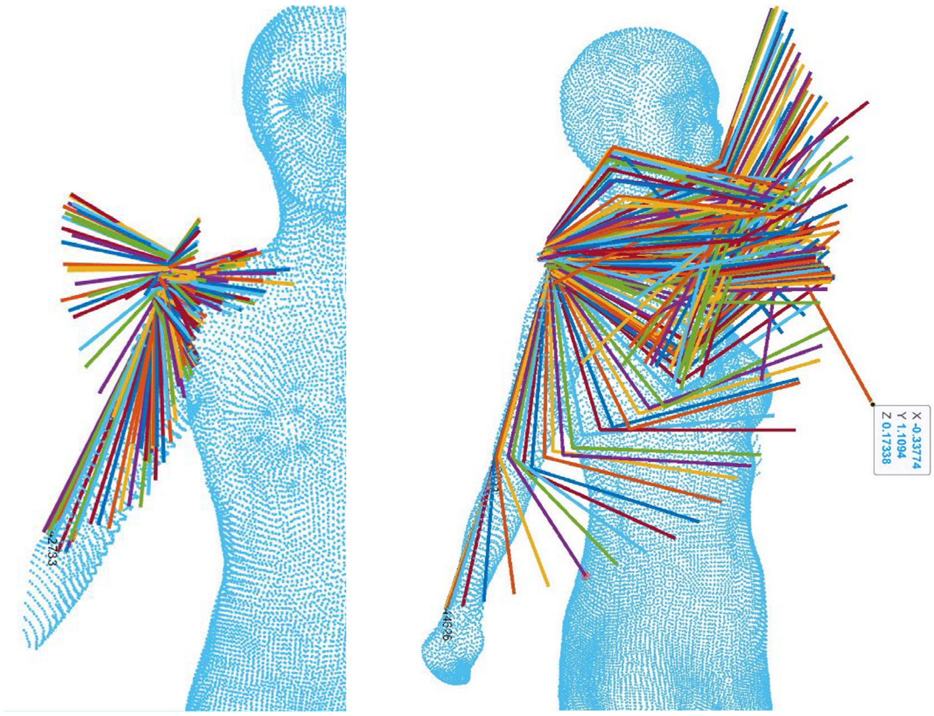

Fig. 2. Segments characterizing a movement of a single chain segment (a – shoulder movement), and a whole kinematic chain (b – right arm chain movement)

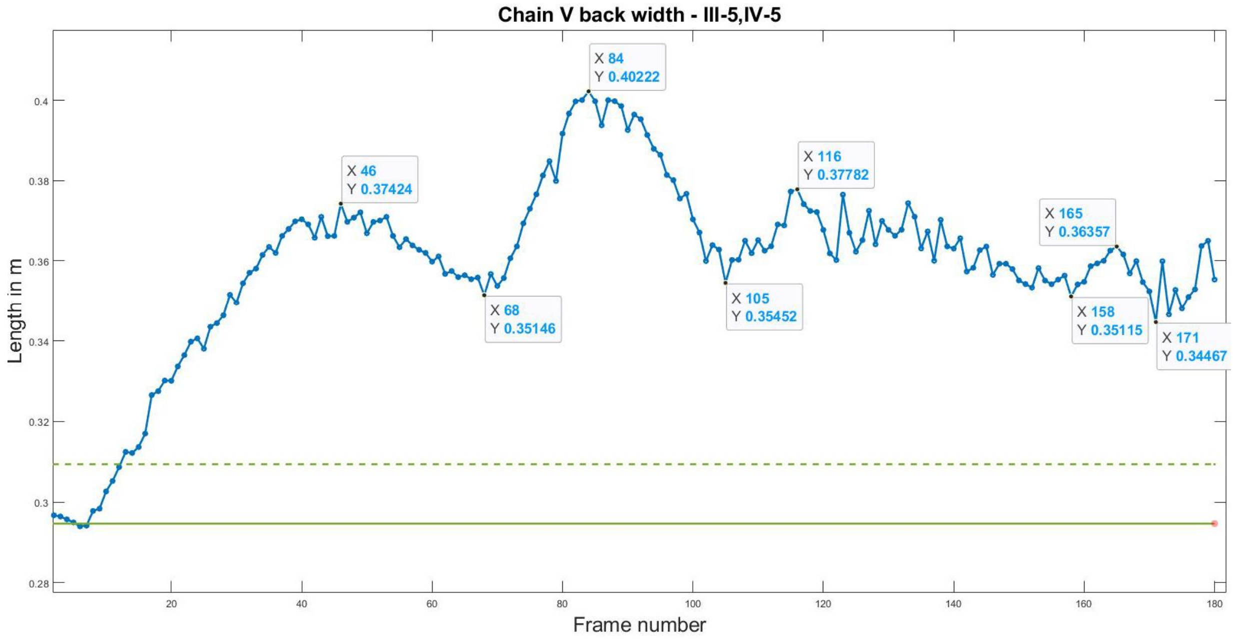

Fig.3 Length of the defined chain curve while motions with defined extrema point

However, given the asymmetry of sign language gestures, not always the extreme positions of the kinematic chain joints cause the maximum dynamic effect. To quantify the dynamic effects and to determine the lengths of the plotted on the surface of the virtual mannequin chains, an analysis of the chains associated with the extreme positions was performed (Fig. 3).

The green straight horizontal line (Fig. 3) indicates the level associated with the length of the selected segment at rest (A-Pose). The dash green horizontal line limits the interval in which the presence of the dynamic effect is considered to be insignificant, as length changes can be compensated by material properties and design allowances. This interval is defined as a neutral one. The value of the neutral interval is calculated as a quotient of the original line length.

The parts of the diagram outside the neutral interval were analyzed for extrema. Extrema were considered to be the points of minima and maxima where the curve changed its direction. Here a significant amplitude of data dispersion was found, which makes it difficult to approximate. One reason for the fluctuation is the method for receiving the homologous mesh. Some of the vertices of homologues mesh have to jump around the surface in order to receive the best numerical fit, and their positions then are not more on the straight curve, but slightly on around it [17]. Another reason is the availability of scanning “blind spots”, filled in automatically during data processing and distorted the real size and proportions. To ignore the effect of fluctuations the authors first like to identify the amplitude of the length differences, analyze the point position, and approximate the curves.

After approximating the data, extrema were identified manually by the nature of the change in the curves (Fig. 4). The points of the extrema on the Matlab diagrams correspond to the frames, which can be considered as extremes for the selected type of movement. It is clear that in order to ensure dynamic comfort in a constructive way only the maximums are important, while the minimums can have a negative impact on the esthetics of the external shape. For our future work, which involves the development of product designs for people who speak sign language, only maxima are considered. Based on the analysis, the most important poses, responsible which have to be considered during the development of clothing with better fit are detected and these are in the current case with numbers 46, 84, 116, and 165 (Fig 4). For these poses the length of the investigated segment is already known, so the garment developer can then decide if this length has to be reached by the elongation of the material; based on slipping between the body and the clothing, or by the combination of these.

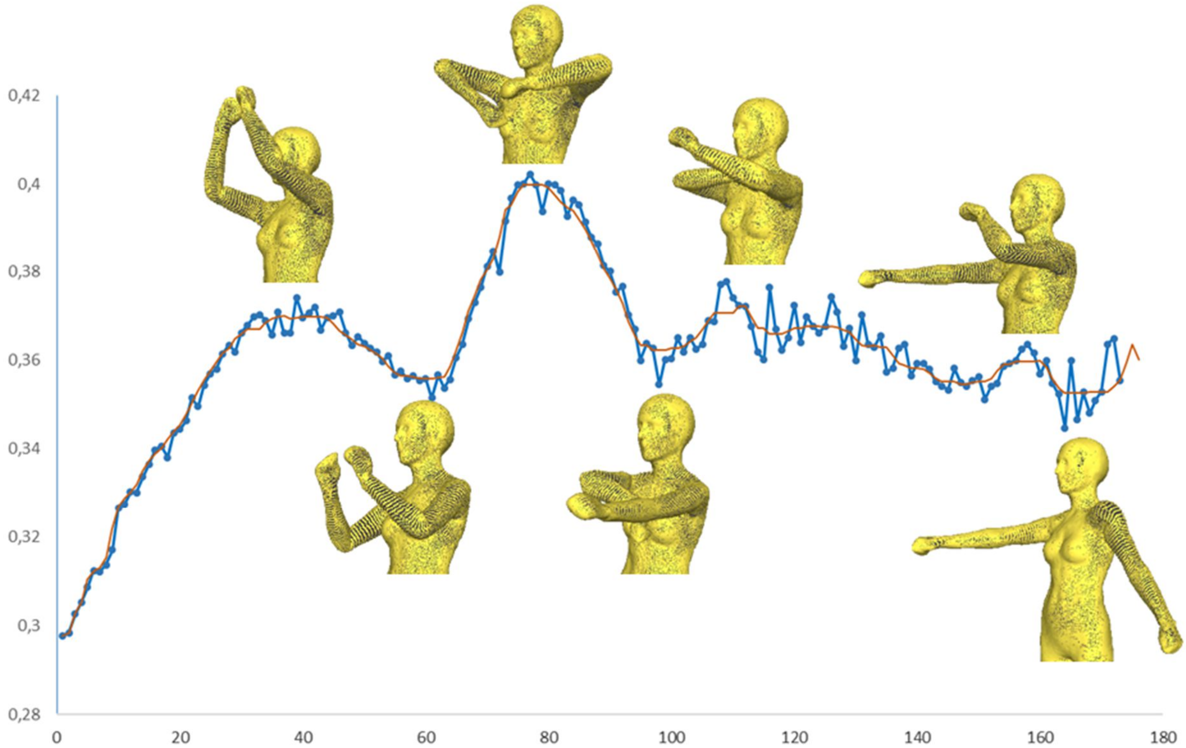

Fig. 4. The frames, considered as extremes for the selected type of movement

4. Conclusions

A method for automatic postprocessing of homologous meshes obtained from MOVE4D scans of deaf people is applied for analysis of the hand motion and the length of specific segments of the clothing during their communication. The application of the method allowed detection of the important poses within a very short time (few minutes), where the investigated segment has a longer length than the defined one as critical, based on the selected material. The obtained data provides a new engineering basis for clothing developers, which will allow the creation of clothing with significantly better comfort and less mechanical effort by communication of deaf people.

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