EAI Endorsed Transactions
on Pervasive Health and Technology
Research Article EAI.EU

On the Extraction of Anthropometric Parameters by Visual and Non-Visual Means

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Abstract

In this paper the system for collection and recording of anthropometric data is presented, along with the novel techniques for extraction of such data. The very system is built on selected open-source platform having developed various plugins as a part of the project. Means for the extraction follow two approaches: visual and non-visual. The first presumes the acquiring of data from static 2D image, the latter gets data through the direct measurement. Visual approach utilizes several principles following the image processing and related face detection algorithms. Moreover, known anthropometric relations are utilized to estimate other human body proportions. As for the non-visual approach, the hardware for direct measurement of human body parameters is designed, implemented and tested in the real environment. The output in the form of data of individual user may serve for statistical comparison with other users. Further, data of all users is to be used for correlation studies with several diseases and changes of overall health condition. In addition, the extracted data follow the concept of newly proposed Human body description language (HBDL) that may be used in various scientific fields and applications or various programming languages. Thus providing the standardized and structured form of data entry.

Keywords: anthropometer, computer vision, description language, image processing, skeleton model, static image, structural anthropometry, human body.

Received on 20 October 2016, accepted on 05 September 2017, published on 07 September 2017

doi: 10.4108/eai.7-9-2017.153064

1. Introduction

Measurement of specific parts of human body has been carried out way before the advent of computer machines, this part of the medical science is referred to as anthropometry – specifically structural anthropometry, where the human body movement is not the concern of measurement. Knowledge of these measurements may be helpful in diagnosis of growth disorders or uncover correlation with other forms of health problems. Other uses of this data is in the field of ergonomics, where the information is used to help designers to predict and correctly adjust the products.

The principal focus in this research is the extraction of human body dimensional parameters and proposal of suitable structural form for storing of such data. Traditional form of estimation utilized specific devices directly designed for this purpose, e.g. GPM or Harpenden anthropometer. The recent advance in computer science and related technologies allowed partial replacement of these devices. The following sections present novel visual techniques that enable estimation of several selected human body dimensions. To check correctness of estimation and provide exact values, the developed hardware anthropometric device for data collection is utilized. Both, the visual approach and hardware device are storing the data in a structural form, i.e. prototype of Human body description language (HBDL).

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2. Human Face Anthropometry and its Detection

In the following section the anthropometry of human face is introduced and further we will focus on the face and its segmentation and detection processes.

2.1. Anthropometry of Face

One of the common human body features is the structure of a human face, i.e. set of two eyes and ears, one mouth and nose. All of these are set symmetrically in a bilateral symmetry. Similarities in this structure allow its utilization in the field of anthropometry.

Anthropometry, as defined by [1], is the "science of measurement and the art of application that establishes the physical geometry, mass properties, and strength capabilities of the human body". There are many uses of anthropometry, e.g. the same authors note: posture evaluation, clearances definition, separation of person from hazards etc. Authors in [2] use this field of science to estimate the length of the prosthetic hand. [3] define face anthropometry as a branch of research dealing with measurement and analysis of absolute quantities and proportion related to human head and face. Further authors note that these measurements are to be done by medical personnel using tools for measurement (ruler, tape etc.). Landmarks, help to find the relations in proportions and may be used for statistical purposes, e.g. age progression.

More information on the face and its parameterization and morphing is described in [4]. Same authors also point out that the anthropometry may be used as a solution for artifacts presence or occlusion using laser scanning or stereo images. In [5] authors used anthropometry to reconstruct face model. Worth of mentioning is also FACS, short for Facial Action Coding System, term originally comes from 1978 as defined by [6] to describe facial activity, e.g. used in recognition systems [7].

One of the relations existing in the nature, which also may be found in human being is the golden ratio or π. This ratio is useful in the face detection, authors in [8] used it to estimate the position of eyes, also research by [9] utilized the golden ratio for finding the location of face. Another form of implementing ratio onto a human face is its division to thirds.

2.2. Face Segmentation and Detection

Techniques used in image processing for allocation of groups in digital image based on specified criteria are called segmentation. On the other hand, the detection of objects in the image is generally a complex process, which requires implementation of various techniques. In [10] the detection is defined as a tool for identifying the location of specific object such as face. One of the requirements set within this paper is also research in the field of face detection. Definition of term 'detection' represents for us only localization of face in the image. Recognition in this case is not being taken into account, i.e. categorization of object into categories or subcategories.

Authors in [11] classify detection of faces into four categories:

Skin color model-based technique - color of human face is used as a feature for human face detection, advantage is its invariance towards rotation, however lightning conditions are crucial. Research on skin color technique was carried out by [12] and [13], the latter declares HSV color model to have the best performance, yet no specific data on efficiency of the solution is provided. Skin color detection together with AdaBoost algorithm was used by [14] with detection rate of 92.86 percent. Another research by [15] used mixed color model of YCbCr and RGB in their framework, detection rate was over 99 percent.

Template matching-based approach - predefine template is used to locate the face in the image, in this case the template is not invariant to rotation and also scaling. In [16] the authors used image pyramids to achieve scale invariance. This technique was used in the framework described by [17] for the identification of person.

Feature-based approach - selected features of face are used for its detection, e.g. eyes, ears etc. Research in [18] used combination of skin color model and feature model, allowing enhanced generalization for the detection. As the facial features were selected eyes, mouth, authors do not provide information about efficiency of proposed solution. Similar approach was taken by [19], in this care authors estimated the location of eyes, accuracy of the testing proved to be slightly over 90 percent. The last research we present is [20], which also uses skin color model and feature-based model, which is being employed after skin segmentation. Lip color model and search for eyes based on geometry textures proves solution to have accuracy over 98 percent.

Statistical model-based approach - statistical methods are employed to achieve the face detection. Such approach together with skin color model was utilized by [21], authors created face and non-face model as a product of multidimensional histograms. Aim of the project was to achieve detection and subsequent tracking of face, authors achieved detection rate of 90.5 percent, very similar research [22] deals also with face detection in video. More recent research is presented by [23] developed probabilistic method for face detection from multiple views. In [24] authors developed statistical model for face detection based on extracted multi-resolution image features. In model the illumination, pose and face variations are resolved. Authors claim approach to be significantly better compared to other approaches.

The broad review on human face detection and slightly different approach to division of approaches is presented in [25]. From the above described we can conclude that the most often employed technique is the skin color model approach used together with some other approach.

3. Face Detection in Parameters Estimation

The crucial part of the whole process is the face detection, which is being carried out as the first processing step. The input image may be acquired in two ways. In the first, only the face, is being used primarily to enhance the future calculations. In the second, the image of the person standing is the input to the system. In both cases, the system presumes persons in the input images to be facing the camera directly.

The first case, presumes only image of a face to be provided to a system. Further the face and eyes are being detected using the Haar-like features. Onto this image is applied the mask which divides the face into the five equal parts in vertical and three equal parts in horizontal direction. Note that this mask is only for future purposes and is being stored in database. In the future research these images are to be used to validate the presumption of dividing the face to thirds/fifths.

Detection of eyes is utilizing the Hough transform. Once the eyes are detected the constant of 65 mm is applied as a reference value, marking the distance between the eyes. This value was estimated based on several tests on a larger number of tests subjects. Value is then used to acquire the length and width of the head, i.e. limits that delimit the head itself. The same very process may be applied of the second image, however using close-up proved to be more accurate. Detected face with the mask is shown in the Figure 1.

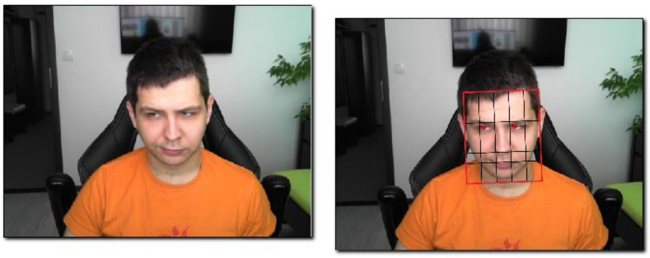

Figure 1. Face detection and eyes detection with masking operation

Analogous process is carried out for the second image, i.e. image of the whole body, providing the first image, i.e. image of the head, is not available. If the image is available, the height and the width of head is not calculated but extracted from a prior image.

Having the detailed image of human head, as an input image, another type of operation is carried out. In this case the mask is not the principal concern, only the detected head. This operation is the extraction of dimensions between the several facial features – eyes, nose and mouth. Hough transform is being utilized for the eyes. Eyes and nose form a triangle that is connected to a mouth. In the Figure 2 the extraction of above described features is depicted – blue rectangle marks the eyes, green marks the nose and orange marks the mouth, orange rectangle in this care is showing the detected face in the image. Knowing the reference value of one pixel we are able to calculate the distances. These are being extracted and stored as the input parameters in Human body description language (HBDL). They form one entity together with the other parameters, such as height or arm length. HBDL is adapted to process both parameters from the visual input and hardware devices while maintaining the same structure.

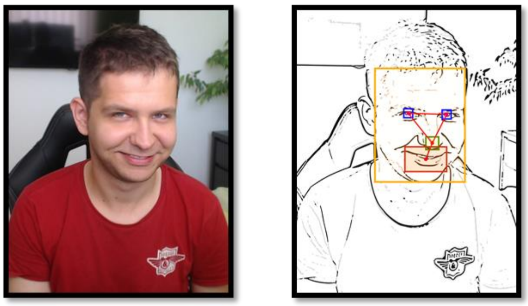

Figure 2. Specific facial parameters extraction

4. Skeleton Model Mapping and Parameters Extraction

Human body model mapping is following the concept of a skeleton model consisted of edges and vertices. Vertices are primarily of synovial joints type and edges are connection between vertices, mostly representing real bone structures. In our research another step of parameters extraction is mapping of this model onto an image of a full body. Such mapping is possible due to constant and symmetrical properties of human body and the fact that it may be located in the one vertical plane, i.e. no special poses are being taken into account in this phase of a project. This presumption allows mapping of several vertices, in total were selected twelve. Automatic detection of border nodes is fairly easy; however, six joints require semiautomatic approach. Once the skeleton model is mapped the extracted information of distance between the eyes is compensated to a second image, together with the information about the head height and width. Compensated distances are then used to extract the individual information of the edges length. To measure the person's height, the marginal points (upper and lower extremes) are being used, however for case of lower extreme the node of heel bone is being taken into account. This measurement also utilizes the information about person's head height and width with relation to human eyes. In the Figure 3 is depicted the mapping of vertices being connected be the edges, each vertex is numbered and considered as sole node that may be connected only with particular node. Hands (carpal bones), shoulders (humeral head) and heel bones are detected automatically and adjusted manually if required, the rest is using the semiautomatic detection, i.e. elbows, hip joints and knees (patella). When taking the image as a whole body certain presumptions have to be met considering the angle and camera height. Tests were carried out in the laboratory environment, however pose reconstruction and compensation is to allow omit these using the developed mobile application.

Testing of approach on several testing subjects (20 in total) proved to be success in the measurement of height, with total deviation of 20 millimeters. The precision of the other skeleton model parameters is rather inferior, with the average deviation of 50 millimeters, having the worst results for distance between hip joints and heel bones. Principal cause may be in the nature of skeleton model and reference value. Overall mapping of 2D skeleton model onto 3D scene is possible and provides promising results, however optionally complex 3D skeleton model might provide superior outputs. In the future research we plan to utilize such model and implement composite reference values in combination with the ratios existing in the human body. This will enable the pose to be in various positions. Extracted values were compared with those as measured by developed device for body proportions measurement.

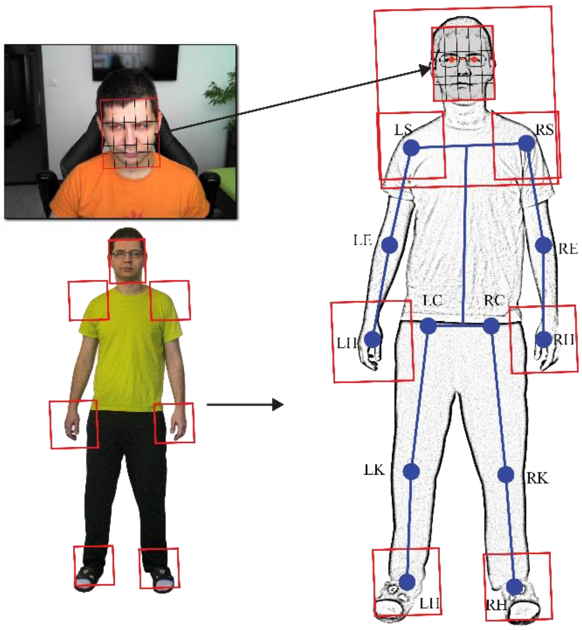

Figure 3. Skeleton model mapping (first L is for left, vice versa R for right, LH – hand, LE – elbow, LS – shoulder, LC – hip or coxa, LK – knee, LH – heel).

Same as in the case of the parameters extracted from the human head, the equivalent process is being applied, i.e. the extracted values are being stored in the HBDL format. These parameters are actually added to the information previously extracted, however for each individual is created new file.

5. Non-visual Parameters Extraction

The device for the direct measurements of distance units so called 'anthropometer' was developed as a part of this research project. Device itself is built on open-source hardware called Arduino. Separate module (Figure 4) for the measurement was developed, allowing to measure several parameters of human body. Measured are two aspects, circumference and distance. The first is done by hardware loop, that serves as a meter, and the second by gyroscope and accelerometer, having as a reference point the LH (0,0,0 for X,Y,Z axis). Note that LC and RC are in this case considered as one node. The measurement consists of placing the device node by node, having the direct contact with human body, until the skeleton-like model is created, providing the required values. Precision of device was estimated to be up to 3 millimeters.

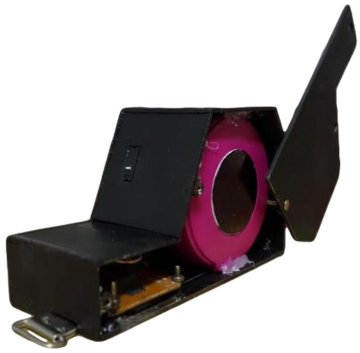

Figure 4. Anthropometer for manual extraction of human body parameters.

In Fig. 5 is shown the actual measurement using developed hardware 'anthropometer' wirelessly connected to microcontroller.

Figure 5. Manual extraction of human body parameters using developed hardware device.

Non-visual extraction was developed for two reasons, i.e. comparison and evaluation with the values as proposed above and creation of skeleton model with the exact dimensions. The principal advantage of this device lies in the ability to create a 3D model of a human body with the exact dimensions.

Novelty in the approach, which combines visual and non-visual measurements is in this field unique and enables various utilizations. Extracted values are to be used in the future medical-based projects and also for recognition enhancements. As for the non-visual approach, proposed HBDL language is used as output format, enabling the easy comparison with the values extracted from the photography.

Table 1 compares selected extraction results as acquired by visual and non-visual approach. Comparison of parameters is also enabled via created web interface, separate for every user, e.g. height to total average of the heights for specific gender and age. Skeleton model parameters may be put into a ratio with a group of other parameters and their tracking over specific duration of time is possible.

Table 1. Selected parameters: extraction technique (IET) vs. anthropometer (ANT). Testing subject: male, 25 years old.

Parameter	Measured IET (in mm)	Measured ANT (in mm)	Total mean ANT (20 subjects) (in mm)
Height	1900	1880	1855
LH-LK	530	570	542
LK-LC	460	500	454
LS-RS	550	510	510
LS-LE	300	320	291
LE-LH	270	300	264

6. Human Body Description Language

The Human body description language, or for short HBDL, is description language proposed by the authors. Principal idea and drive for creation of such language is the standardization of human body parameters entry. This language is to provide the standardized way of handling human body in the Internet of Things concept but also other fields that process human body parameters, e.g. anthopometry or statistics.

Such data in the very processing is to be structured in standardized manner and usable across many platforms and applications, due to set rules for formatting of parameters. File format for storing data is *.hbdl*, using Unicode standard. Please note that the language is currently under development and specific technical details are to be result of future research.

7. Conclusion

In this research we introduced two techniques for extraction of human body parameters. The first was visual computer-based extraction that utilized image processing algorithms and enabled extraction of dimensional parameters from the static 2D image containing human body in one plane. The latter technique is based on direct measurement of body parameters via developed device, so called 'anthropometer'. This device, as well as visual approach, allow to develop skeleton model of a human body with the exact dimensional units. Visual approach proved success rate in estimation to be over 85 percent, while utilizing reference distance between the eyes and semi-automatic skeleton model mapping. Non-visual approach has success rate of 100 percent, proving the proper conditions for measurement are met. Values acquired were used as a reference for the further comparison. Another analysis, enabled using created web interface, was between the set of total extracted values to a single user. Due to nature of testing set mostly the male subjects of the age from 20 to 30 were considered. This set is to be expanded in the future research, moreover multiple reference values or ratios will be used in the visual technique to enhance the overall output. One of the major outputs of the research presented in this paper is rudimental proposal of Human body description language (HBDL), all of the data were stored in this new format. This language proposes standardization of human body parameters entry.

Acknowledgements.
We support research activities in Slovakia/This project is being co-financed by the European Union. Paper is the result of the Project implementation: University Science Park TECHNICOM for Innovation Applications Supported by Knowledge Technology, supported by the Research & Development Operational Programme funded by the ERDF.

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