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

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Abstract. In this paper the system for collection of anthropometric data is presented, along with the novel techniques for extraction of such data. System is built on selected open-source platform having developed various plugins as a part of the project. Means for 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 recognition algorithms. Moreover known anthropometric relations are utilized to estimate other proportions. The output in the form of data of individual user may serve as for statistical comparison with other users. Further such data is to be used for correlation studies with several diseases and changes of overall health condition.

Keywords: Anthropometer · Computer vision · Image processing · Skeleton model · Static image · Structural anthropometry · Human body

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 to other forms of health problems. Other uses of this data is in the field of ergonomics, where the data 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. Traditional form of such estimation utilized specific devices directly designed for this purpose, e.g. GPM anthropometer. 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 human body dimensions. To check correctness of estimation, the developed hardware anthropometric device for data collection is utilized.

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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 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 present in the nature and which also may be found at 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 the face location. 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 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] categorize 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%. Another research by [15] used mixed color model of YCbCr and RGB in their framework, detection rate was over 99%.

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%. 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%.

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%, 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. Input image may be acquired in two ways. In the first, only the face, is being used only 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.

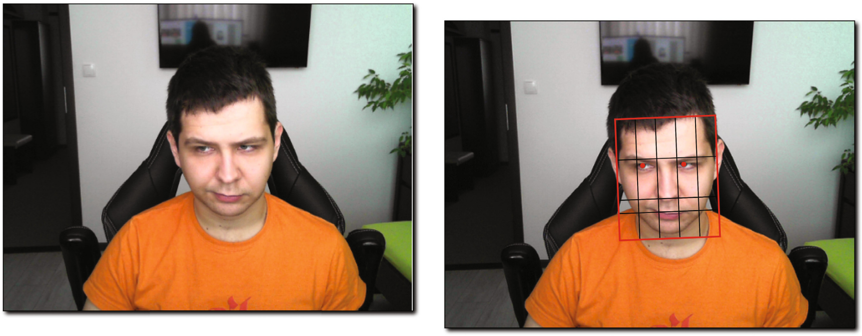

Fig. 1. Face and eyes detection with masking.

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 5 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.

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. Same process may be applied of the second image, however using close-up proved to be more accurate. Detected face with the mask is show in the Fig. 1.

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

4 Skeleton Model Mapping and Parameters Extraction

Human 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 human body 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)

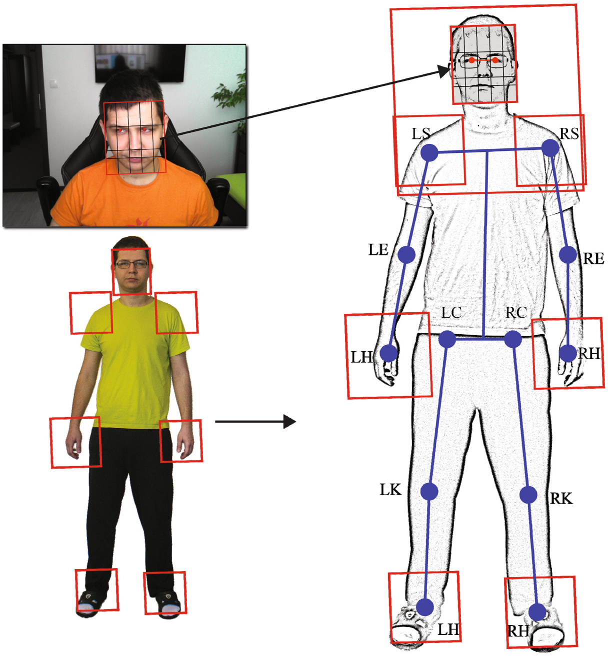

Fig. 2. Skeleton model mapping (first *L* is for *left*, vice versa *R* for *right*, *LH – hand*, *LE – elbow*, *LS – shoulder*, *LC – hip* or *coxa*, *LK – knee*, *LH – heel book*).

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 Fig. 2 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 mm. The precision of skeleton model parameters is rather inferior, with the average deviation of 50 mm, 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 3D complex 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 position.

Extracted values were compared with those as measured by developed device for body proportions measurement.

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 (Fig. 3) 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 mm.

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 enhancement.

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.

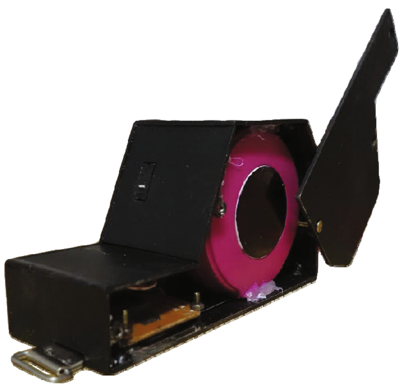

Fig. 3. Anthropometer for manual parameter extraction.

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

Parameter	Measured IET	Measured ANT	Total mean ANT (20 subjects)
Height	190 cm	188 cm	185.5 cm
LH-LK	53 cm	57 cm	54.2 cm
LK-LC	46 cm	50 cm	45.4 cm
LS-RS	55 cm	51 cm	51.0 cm
LS-LE	30 cm	32 cm	29.1 cm
LE-LH	27 cm	30 cm	26.4 cm

6 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 created device, so called anthropometer. This device, as well as visual approach allows to develop skeleton model of a human body with the exact dimensional units. Visual approach proved success rate in estimation to be over 85%, while utilizing reference distance between the eyes and semi-automatic skeleton model mapping. Non-visual approach has success rate of 100%, proving the proper conditions for measurement are met. Values acquired were used as a reference for the further comparison. Another analysis was between the set of total extracted values to single user. Due to nature of testing set only 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.

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