A Survey of Human Modelling in Computer Graphics

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ABSTRACT: *Human body modelling is a prospering research in computer graphics as the researchers face many issues. The complexity of the anthropology leads to the design of human shape. Many systems for the 3D human body processing have been outlined which range from identity-dependent body shapes and its various poses. We in this work reviewed the current methods for 3D human body modelling.*

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1. Introduction

The way people perceive the world around them and interact with each other change; the current communication technology involves the transmission of audio and visual data between objects. This way, users can interact with others at a distance. Undoubtedly, video communication tools such as Skype and Viber are useful for many applications and tasks. However, text, 2D image and voice are not sufficient enough to satisfy as an alternative to human interaction, because there is no personal contact between the interlocutors and there is a limited sense of presence (sharing the same space). For the user these facts create a feeling of incompleteness and dissatisfaction with the communication process.

Currently, although in an early stage of development, augmented reality (AR), mixed reality (MR) and virtual reality (VR) offer great potential to include the five human senses in the communication process to become more meaningful and natural to all participants.

To simulate the particular physical function in the virtual environments, on each element is applied numerous algorithms. More particularly, those algorithms are developed for the human body models. Building a model involves many issues, such as 3D body training dataset preparation, designing a proper body model, and training the model to fit the prepared data.

The rest of the paper is organized as follows: in Section 2, some of existing human body representations are briefly described. Some of free available databases are presented in Section 3. In Section 4, the human body shape modeling techniques can be found. The conclusion is given in Section 5.

2. Human Body Representation

To compare a population groups and to create an anthropometric dataset, the anthropometric measurements can be used as a basis. ISO 7250-1 gives such list of body measurement descriptions. A list of primary and secondary dimension indicators is given by ISO-8559 standard Part 2 [1]. Figure 1 represents some of the measurement landmarks that are used by the both standards.

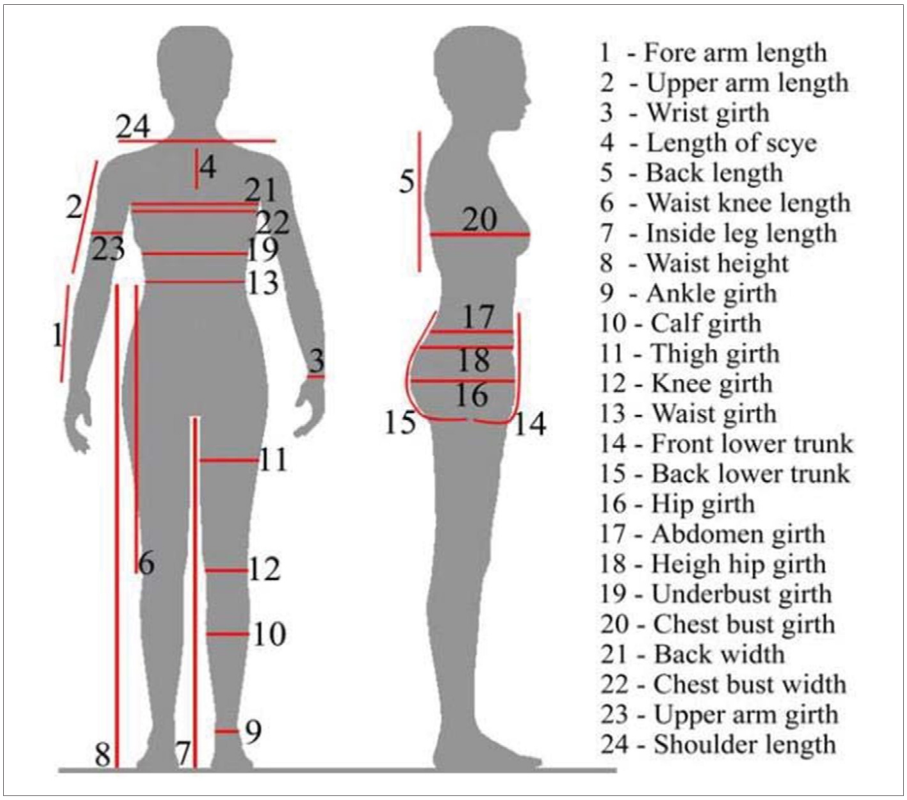

Figure 1. Some of the major body measurement landmarks extracted from ISO-7250 and ISO-8559 standards (issue from [2])

The anthropometric measurements are used to describe the human shape. They represent an estimation of the distances (linear and curvilinear) between anatomical landmarks or circumferences at particular regions of interests of the human body. For example, in medicine, in case of difficulty in determining the height of a patient, upper arm circumference is used for estimation of his body mass index [3]. Body mass index (BMI) is the ratio of the stature and the weight. The anthropometric measurements are widely used in many simulation systems [4].

Common anthropometric measurements include height (stature), weight (body mass), erect sitting height, triceps skinfold (upper arm girth), arm circumference (upper arm girth), abdominal circumference (waist circumference), calf circumference, knee height and elbow breadth [5].

Male (see Fig. 2) and female (see Fig. 3) bodies can be scaled by modifying standard anthropometric dimensions. Such examples are shown in Fig. 1 and Fig. 2, where height, weight and erect sitting height are used to represent a range of body sizes. Unfortunately, not all dimensions of the figures are adjusted, which sometimes leads to unrealistic shapes of these scaled figures [4].

3. Databases

Regarding 3D body shape datasets, we can mention several of them, freely available online [6], [7]:

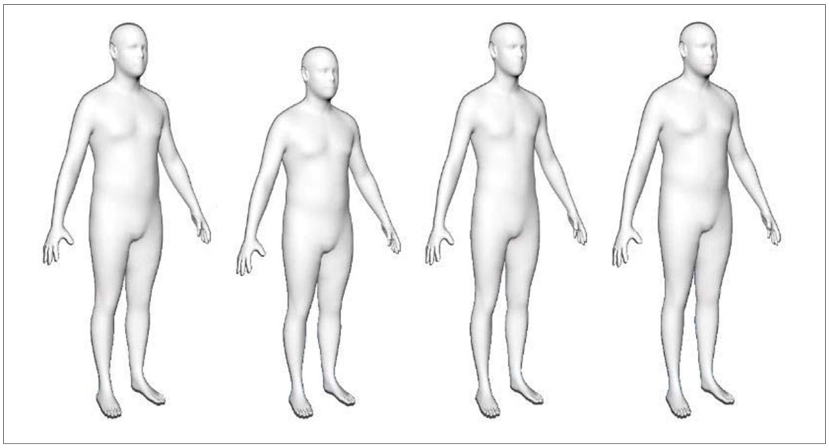

Figure 2. Editing tree anthropometric parameters of a men's body. Left to right: average shape, with height decreased by 10 cm, weight decreased by 20 kg and decreased the ratio erect sitting height (decreased by 5 cm) to the stature (unchanged from the initial)

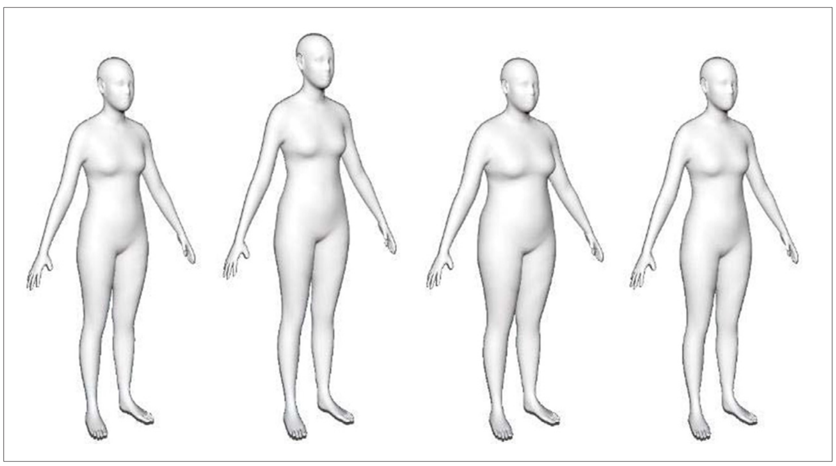

Figure 3. Editing tree anthropometric parameters of a women's body. Left to right: average shape, with height increased by 10 cm, weight increased by 20 kg and increased the ratio erect sitting height (increased by 5 cm) to the stature (unchanged from the initial)

• Civilian American and European Surface Anthropometry Resource (CAESAR) project is the earliest research on anthropometric surveys conducted by 3D scanners. This is the largest commercially dataset, which contains raw 3D colored meshes with missing regions. It contains approximately 4000 human bodies of different shapes (male and female bodies) [6]. An example is shown in Figure 3 a).

• Shape Completion and Animation for PEople (SCAPE) dataset is built by only one subject in different poses. As a result, 71 meshes using only geometric information, reconstructed from real data, are obtained [8]. In Figure 3 b), one of those registration is visualized.

• FAUST - This data set containing 300 real, high-resolution human scans of 10 subjects in 30 poses, is created with a common template using a texture-based registration technique [9]. An example can be seen in Figure 3 c).

• Dyna - Using over 40,000 scans of ten subjects, a dynamic body shape dataset is created by Pons-Moll et al. [10]. The dataset is a physics simulation of soft tissue motions in dynamic mesh sequences. A frame of a female subject is illustrated in Figure 3 d).

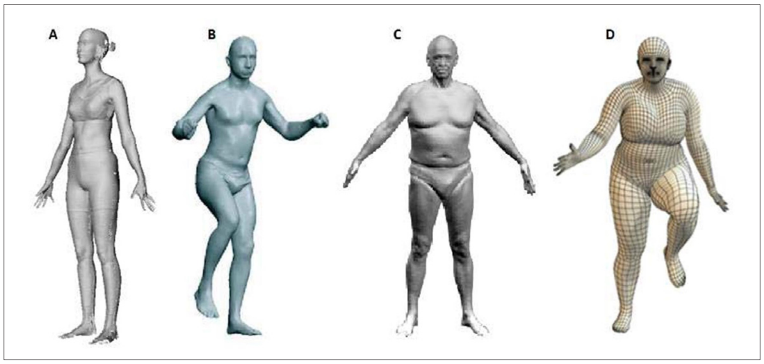

Figure 4. Examples, from left to right, from CAESAR database [6], SCAPE database [8], FAUST [9] and Dyna database [10]

4. Human Body Shape Modeling

The methods for the human body shape modeling can be categorized into four categories: direct model acquisition, image based reconstruction, template model-based scaling and statistics-based model synthesis [11].

4.1 Direct Model Creation

This method represents a construction of a human form and anatomical models via 3D scanning. 3D scanners or RGB R scanners with Kinect are used for the object/human model acquisition. The huge problem with this method is the holes and gaps in the scanned data, due to the self-contact (for example the armpits). This causes the topological structure of the scanned model. In the case of phase changes, the human will obtain unrealistic shape. Apart from the acquisition error of the capturing device (e.g. holes and noise in a scan), the clothes are additional difficulties for the body representation.

A good practice is meshing hands, feet and head separately of the body [4]. They contain more details, like the hair on the head.

Figure 5. Example of scan of a human torso, clothed with a t shirt

For example, in Fig. 5 a 3D scan of human (male) torso, clotted with a T shirt is presented. Referring the measurement landmarks (see Fig. 1), there are 11 landmarks which we want to obtain, but the information is missing (due to the T shirt, which gives wrong information about the real sizes): 2 - upper arm length, 4 - length of scye, 5 - back length, 13 - waist girth, 17 - abdomen girth, 18 - height hip girth, 19 - underbust girth, 20 - chest bust length, 21 - back width, 22 - chest bust width, 24 - shoulder length.

4.2 Image-based Reconstruction

The image-based reconstruction, or photogrammetry is a process for recovering the exact positions of object's surface points applying measurements made in multiple separated 2D images from a set of angles. The creation of a digital human model consists of the following steps: 3D point cloud generation; structuring and modelling (segmentation the relevant anthropometric information and mesh generation); texturing and visualization [12]. The produced model often still contains gaps (the noise and depending on the background of the subject), but is cheap and accessible (requires a set of 2D images).

To create a 3D representation of a human figure, Ramakrishna et al. used 2D coordinates of anthropometric landmarks in a 2D image. The method can work with a simple body poses and estimates the camera using a matching algorithm, working on the image projections. Ramakrishna et al. propose a condition for the sum of squared limb-lengths, computed in closed form, necessary for the creation of realistic 3D human configurations. The method is robust to missing data [13].

4.3 Template model-based Scaling

The template model-based scaling method is a process of deformation of a single template human body model to obtain an additional model. From this template model, its landmarks (limbs) and proportions are scaled and adjusted to create new body shapes. The first step of the template model is marking the specific regions and identifying them with unique numbers. After that, a correspondence of specific regions of the main body mesh (set of vertices) is done. This process is based on the measurement landmarks extracted from ISO-7250 and ISO- 8559 standards, illustrated in Figure 1 [2]. It is a simple method, which generate new datasets with small resources (only one body scan).

Donlic et al. [14] propose anthropometry-based approach can successfully segment various body-types. They utilize a generated 3D body model to segment six specific body parts of the human: head, torso, left and right arm, and left and right leg. Their approach is sensitive to outliers and the quality of the 3D reconstruction, due to the low-cost scanner that they had used.

4.4 Statistics-based Model Synthesis

A statistical shape model can be built using a set of examples of a shape. For the training set, each shape is represented by a set of n labelled landmark points. They are consistent from one shape to the next one. Given a set of such labelled training examples, they need to be aligned into a common coordinate frame. The idea is to minimize the sum of squared distances to the mean of the set. Then, each shape can be represented by a 2n element vector. The aligned training set forms a cloud in the 2n dimensional space. It can be considered as a sample from a probability density function, the cloud is approximated with a gaussian. The Principle Component Analysis (PCA) is used to pick out the main axes of the cloud. It models only the first few, which accounts for the majority of the variation.

First parametric modeling method of 3D body shape is that of Anguelov et al. [8], introducing the fundamental Shape Completion and Animation for PEople (SCAPE) method. SCAPE is a statistical model that captures variation in both individuals' shape and pose. The method is based on a decomposition of the body shape into both articulated and nonrigid deformations. The method is presented in Figure 6. The 3D body shape is represented as a triangular mesh. For a triangle face fk, pose deformation Q_k and body identity-dependent shape deformations S_k, with identity-dependent shape parameters β, are applied. The deformation Q_k is predicted from the nearest body part joint angles α. To take into account all changes between different humans, the deformation matrix S_k, calculated from the parameters β in the PCA subspace, is computed. After that, each body part (a single bone) to which the triangle f_k is assigned, is rotated by an articulated rigid rotation R_k [15].

Many follow works are based on this method. For example, a variant of a SCAPE model is Loper et al. [16] and Pishchulin et al. [7].

Loper et al. [16] propose a realistic learned linear model of human body shape and pose, using PCA. The resulting principal components become body shape blend shapes. As a preprocessing step, authors register a template mesh for each scan and pose normalize the data. Loper et al. trained and tested the algorithm with the CAESAR dataset. On the trained meshes, they fit the algorithm and then compare the vertex errors. The similarity with SCAPE is that the Loper's model decomposes the body shape on the same way. The difference is that Loper's model is based on a vertex approach and corrective blend shapes are used [16].

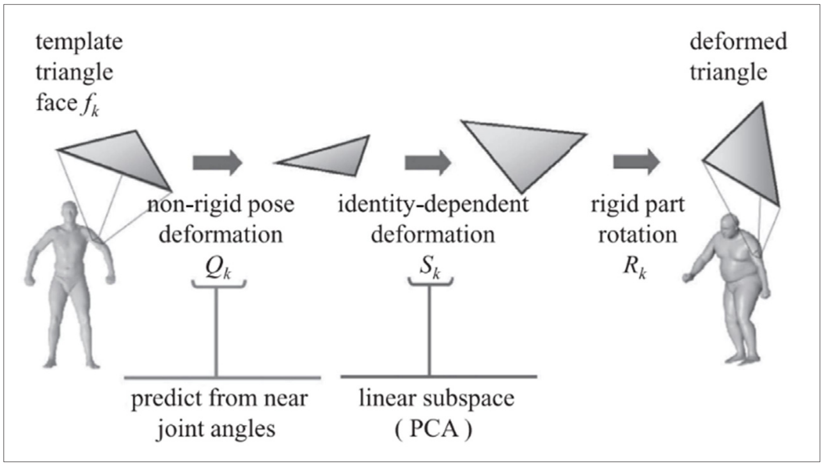

Figure 6. Working mechanism of SCAPE (issue from [15])

Pishchulin et al. [7] uses a statistical model of 3D human shape and pose to rebuild the statistical body representation and learned from a database, based on CAESAR dataset [6]. For the human body reconstruction, they use sparse input data. They propose a method for scan alignment that quantitatively lead to the best learned models.

5. Conclusion

Study of methods for generating human body models with different measurement ranges is one of the main problems of computer graphics. It comes from the complexity of the anthrop>logy itself. We have summarized the common technics used in such 3D human models, and mention some advantages and disadvantages. We have listed some of available 3D body datasets.

Acknowledgement

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