

VIRTUAL PHYSIOLOGICAL ANTHROPODYNAMICS

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1. Introduction

A new biomechanical three-dimensional (3D) model for the human body based on computer-generated virtual model is proposed. Using maps obtained from the special kinds of photos of the body of a real subject, it is possible to attribute personality to the virtual character, while computer animation offers dynamic of movements and characteristics within the confines of space and time of the virtual world. Computer animation of virtual 3D character can be performed in two ways – conventionall, animated key frames, or by using motion capture systems. A new approach to computer-generated animation of virtual 3D characters called «VatoSABA» (1. version) using in one software package minimal costs and ease of operation, characteristic for key frame animation, as well as accuracy and speed, that is characteristic for motion capture systems.

As an example is presented simple 3D model of the human jaw. In the model all forces are resolved into components according to a selected coordinate system. The muscular forces act on the jaw, along with the necessary force level for chewing as some kind of mandible balance, preventing dislocation and loading of nonarticular tissues.

Here, we will start with the discussion about the application of the mechanics to the living systems or materials. Such an approach to mechanical analysis of living systems is different to that one used in engineering because of its functional complexity of the living systems. Living systems are the constructin of many organic systems, that we should study them and also their interactions. Partially is important interaction of the human with its environment. The relationship between man and environment has ever been a subject of investigation. Scientific studies on five senses have been carried out since the time of Aristotle.

Man communicates in two different ways. One is effected in contact with the outside world and another with its own body. The first way of communication is through five senses known as hearing, sight, smell, taste and touch; the second way through the proprioceptive system. Fischer and Braun (1889). They involved an approximative method which is known as "coefficient's method". They supposed the existance of fixed relations between length of body segment and its mass. From this relations they were able to determine center of gravity, radius of inertia and, of course moment of inertia. Accuracy of this method was doubtful because those coefficients were determined only on three male cadavers. Much more accurate results in stipulating of the human body mass distribution and respective segmental centres of gravity were determined by Dempster (1961). Division of the body segments is shown in the figure. Also is shown the way of the use of the specially constructed tub; by mean of plunging of body segments into the tubs water that was squeezed out was the measure of the segment volume. This has determined a kind of an auxiliary skeleton presented in Fig. 1.

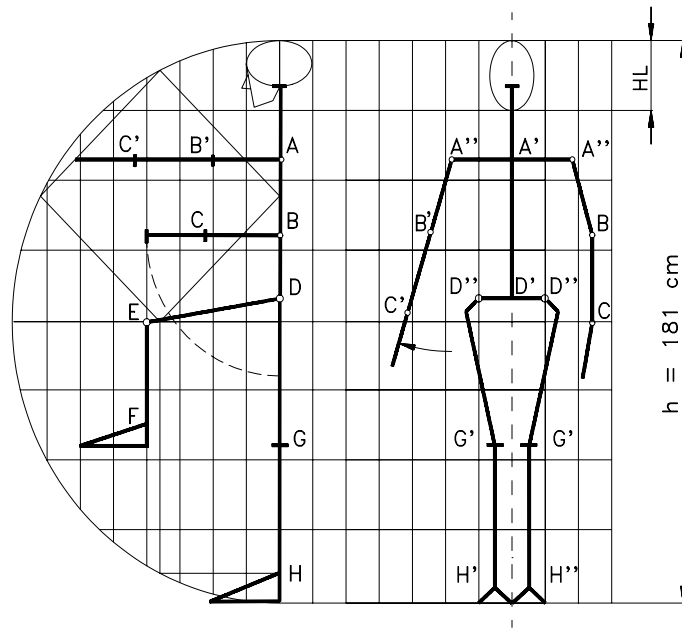


Figure 1. The planar skeleton model is done by definitions of the characteristic points A,B, ..., H. All defined lengths between the points represent characteristic linear anthropomeasures.

Upon the determined "skeleton", as the next step, one can draw-in the countour of the subject, but usually it is not necessary. However, the following should be kept in mind:

- all characteristically joints, as e.g. hips and shoulders should be in positions to make possible movement of the extremities;
- sizes of muscular structures and fat as well as the skin should fit the auxiliary skeleton so that the legs can be put together and the arms lowered along the body. The reliability of the above method of the human contour was checked as follows:

For a selected height and mass of the tested persons which corresponds to the highest value of the height of 181 cm and mass of 86 kg, the measuring of the characteristic lengths was performed (e.g. of the upper leg, foot etc.). The obtained values of anthropomeasures, can easily be compared with measured Kroemer's subject of mean values of 172 cm height were the corresponding variations range of the male and female anthropomeasures.

2. Measuring and modeling methods

In the procedure of the measuring technique, where from it is obvious that the measures we are able to measure, are different to those we need in motion description, where the centres of joints are of great importance. There is also another reason, that was some kind of impetus for us when we tried to develop a new method. Namely, by means of, let us to say, classical method that took too much time in its procedure, at which the end we have only so-called "static anthropomeasures" we are not satisfied because it is not enough for biomechanical analysis. Mentioned reasons were impetus for us to develop an automatized method for anthropomeasuring. Due to this method, besides static anthropomeasures are dynamic anthropomeasures, i.e. central dynamics moments of inertia of the body segments as well the general dynamic moments of the inertia of the whole body. The method was established for measuring of males and females. The difference between the parts of the method for males and for females was in the segmental models, as we shall see later. In both cases the model of the body has been modelled using 16 geometric solids. The measuring procedure comprises recording of the marked subject by means of the measuring system ELITE. Three dimensional coordinates of the marked points, that were calibrated with a special procedure, are the input data for calculating static and dynamic anthropomeasures using the special program written in MATLAB. Measuring has been performed on 120 male and 120 female of Croatian population, that was earlier proved to be very close to the Central Europe population.

2.1 Virtual 3D model in a computer environments

Computer 3D animations of a virtual model and computer-generated environment is defined by the sequences of surfaces, bordered with 3D cloud coordinate points, obtained by means of 3D scanners. This results in a characteristically equal model of the subject, corresponding to a particular dotted cloud, and describing the segmental measures of the real model in question.

The whole of the virtual model of the human segment, in our case the human head, is made on the basis of the knowledge of body volume and cross section, as well as approximate mechanical behavior of the body in movement. To animate virtual 3D characters it is necessary to:

- design and develop animated skeleton model of the head, with adequate data basis for movements;
- design and model 3D head of character model, to be animated by skeletal movements;
- perform computer animation of the interaction between the virtual model and its near and far environment.

Conventional approach to the animation of 3D segment body models includes the animation of key frames. In this work is used S. Baksa new approach to computer-generated body segment model of virtual 3D characters called «*BodySABA*» using in one object package⁷. This approach offers, relatively modest costs and not much more time spent, for a quite good scanning results. A virtual model of a real body segment (in our case the bone of mandibla) can be developed employing hand modeling methods, using conventional anthropometric measuring procedures, or by import of contemporary 3D digitally scanned real models⁷. To design and model a virtual character using hand techniques and at adequately high level of quality, it is necessary to be familiar with anthropometric characteristics of the human body used as a starting point. Software package *ERSABA 4.2.*, developed by I. Baksa, was used to determine anthropometric values of the model. The software calculates, using some measured values, twenty-two characteristic anthropometric values, necessary for conventional CG modeling of digital virtual characters, Fig. 2⁷.

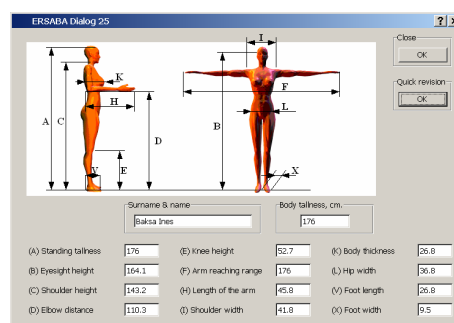


Figure 2. On-screen presentation of characteristic antropometric value of a real model, 176 cm tall, in standing posture

Based on photographs of a real SFG model, and using conventional CG techniques, digital virtual character model is designed and constructed. Fig. 3 shows the phases of constructing the segment of the head of the virtual model.

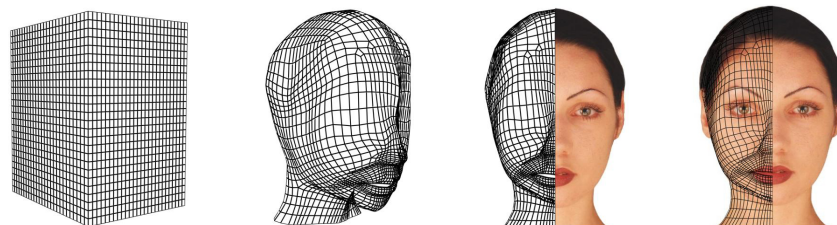


Figure 3. Phases in hand modeling of a virtual 3D character's head⁷

A contactless coordinate-measuring device, so called digital 3D scanner, can be used instead of conventional tape measure and the equipment for defining human body dimensions and volumes. The

result of stereoscopic measurements of the body is a 3D cloud of coordinate points, which represent the body measured. These measurements enable easy construction of a digital virtual model. The measuring system employed enhances accuracy and efficiency, compared to conventional methods. The results obtained are not just the object measurements, but also its forms and volumes.

Digital 3D scanners consist of one or more (most modern up to four) digital high-resolution measuring modules, translator units for moving the device, and quite often software solutions for determining 3D characteristics of the objects to be measured. As far as construction and size are concerned, there are small desktop models, ideal for digitizing smaller objects for CAD/CAM industries, development of prototypes, research, animations, special effects, medicine and reverse engineering⁵. Mini models are used to digitize medium size objects, where measuring accuracy and preciseness are important factors. This type of scanners offers best results in medical research, anthropometry, esthetic surgery and artistic manufacturing of portrait sculptures. Body models obtained using a 3D scanner are ideal for 3D computer animators, ergonomists, anthropologists, physicians, designers, and other professionals who require a precise and reliable 3D model of the body in question. The equipment described can, in some 15 seconds, scan an average adult human body in three dimensions, and record more than 200.000 measuring points defined by coordinates, as seen in Fig. 4. As real actors are an agglomeration of highly diverse variants of shapes and body sizes, the above density of measuring points is adequate to calculate and present on-screen a reliable virtual model. The set of points scanned corresponds with the 3D model body and ideally presents the subject in unit time⁷.



Figure 4. 3D cloud of coordinate points of a virtual model of the subject scanned

Attributing parameters to unorganized individual coordinate points of a 3D measuring cloud. The results obtained through computerized investigations make possible to construct a surface model out of a dotted 3D cloud, or constructing a characteristic arc, based on spatially coordinate defined points⁶. To construct a digital model based on 3D coordinate measuring cloud, it is necessary to define the characteristics used in a mathematical triangular interpolation⁷. Either surface definition or volume definition can be used as methods in defining these characteristics.

Most researchers, in designing a geometrical model employing reverse engineering, focus upon the procedure of taking a series of surfaces defined by coordinate points of a 3D measuring cloud. This results in a characteristically equal model of the actor, corresponding to a particular dotted cloud, and describing the bodily measures of the character in question. The whole of the virtual model of human body is made on the basis of the knowledge of body volume and cross section, as well as mechanical behavior of the body in dynamic movements.

3. Results

Because of the preliminary character of the present biomechanical analysis aimed only at finding out just a possibilities of such an analysis, we analysed only one macerated mandibla. The adequate presentation is given in Fig. 5.

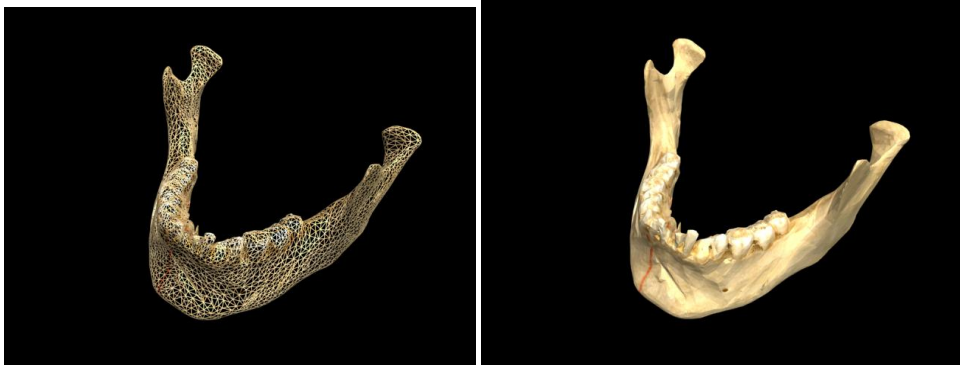


Figure 5. Presentation of the analysed mandibla with mesh configuration and later as smooth and highlights presented 3D model

Later we adopted such a mandibla to the head skelton, to show a possible movemet of the jaw, as it is presented in Fig. 6.

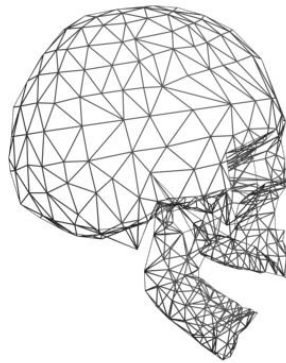


Figure 6. Adapted mandibla to the head skelton showing a possibility of jaw rotation

4. Conclusions

Using conventional, hand, or more modern (but more expensive), digitally scanned 3D anthropometric human body characteristics, it is possible to construct a digital 3D biomechanical model, with adequate kinematic-dynamic rules of internal skeleton construction movement.

Computer animations of characters and virtual environments are broadly used in entertainment, for practical and educational purposes. Some of the most outstanding areas include advertising, archeology, fine arts, bioengineering, entertainment, movies, forensics, medicine, multimedia, simulation, scientific simulations and visualizations, space exploration, sports, TV, etc.

Computer animators should possess extensive knowledge of anthropological and biomechanical characteristics of human body, should be experts in design and construction of virtual 3D characters, but should also a feeling for time, mechanical behavior and movements of both living and non-living systems. They should be able to recognize, define and produce the feeling of liveliness and neutrality, so as to be able to give virtual life to their cyber subjects. Future developments of the software application *BodySABA* will result in improved automatic defining of anthropometric and ergonomic characteristics of biomechanical models and digital subjects, as well as in better matching of anatomic and psycho-physiological investigations of human body, based on 3D virtual simulations and analysis of virtual characters. The purpose of future versions of software accessory *CLOSABA 0.4*. is to

develop more advanced computer-based simulation for biomechanical use in a different bioengineering problems.

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