A Parametric Human Body Modeling Tool

Başar Uğur

Computer Engineering
Boğaziçi University
Email: basar.ugur@boun.edu.tr

Ali Vahit Şahiner

Computer Engineering
Boğaziçi University
Email: alivahit.sahiner@boun.edu.tr

Abstract—**This paper presents a locally controlled, easy to use, morph-based body modeling tool for virtual applications. Morphing is a shape interpolation technique widely used for 3D modeling. It is simple and stable. For local control we have carried out an anthropometric segmentation of the body. Smooth continuity at the boundaries of individual segments is achieved by weighted interpolation. The paper also presents a virtual dressing application where the modeler is employed.**

I. Introduction

3D human body models are used in a wide spectrum of applications that require images of human replicas. Their use in film and entertainment industry and on internet is very common. Now that the support for 3D graphics technology in wireless applications is getting very strong, human replicas will start to play an important role in this field as well.

Parametric modeling of human body provides an in-built economy to the replica creation and therefore should be considered in wireless applications where communication bandwidth is a critical issue. It is possible to enable the creation of a replica at a remote site that keeps a default geometric description just by sending a few parameters. These parameters are then used to customize (personalize) the default geometry. In this sense parametric modeling is a data compression tool.

This paper presents a parametric human body modeler based on shape interpolation. The paper is organized as follows. A taxonomy for existing body modeling methods are given in the next section. Shape interpolation is described in section III. Body modeler and anthropometric body segmentation is explained in section IV. Following section briefly presents the virtual dressing room application. Conclusions follow this.

II. Related Work

The block diagram given in Fig. shows a categorization for existing techniques in human body modeling.
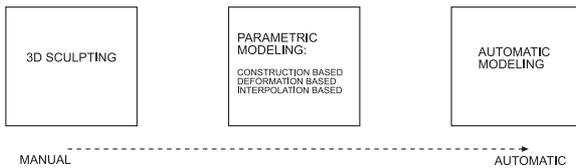

Fig. 1: Techniques in human body modeling

Human body modeling by 3D sculpting is an approach frequently used by artist-modelers where a spherical or a rectangular mesh is converted into body parts by modifying them with the tools of a general purpose modeling tool. Commercially available 3D software such as Maya, 3Dmax, Softimage are some examples. This approach, although effective, is very time consuming and requires expertise of the software package used. It is widely employed for 3D animation and special effects work in the film industry, where the body models for specific characters are developed once and used in the entire film. Using this technique in human body personalization for general use is too costly. Below Figure 2 illustrates how a human hand is modeled by a combination of geometric transformations.
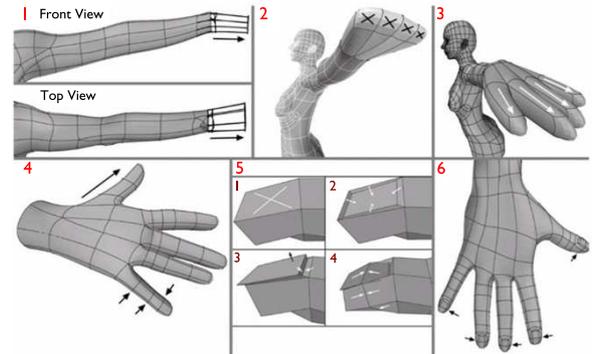

Fig. 2: An example of 3D sculpting: Modeling the hand

Automatic modeling approaches, on the other hand, usually exploit sophisticated hardware or software to capture data from the bodies of real humans. 3D laser scanning [1][2], shape from structured light, shape from silhouettes, shape by analysis of images[3][4] and image sequences[5][6] are among the techniques employed. This approach is usually the only alternative if a high level of detail modeling of a person is required. One example is the Civilian American and European Surface Anthropometry Resource Project (namely CAESAR) data set [7]. This data set contains the most extensive sampling of laser scanned human body measurements. Although very efficient and effective the required hardware is usually expensive and requires the person whose body will be modeled to be available at the site where the data acquisition system resides.

Parametric approaches start with a pre-modeled human body set and create new body models from these by parametrically modifying them[2][8]. Pre-modeling is usually achieved by employing a 3D sculpting and/or an automatic technique. In constructive methods one can parametrically control how the body model will be built using building blocks, in deformation based methods one can control how the existing model will be deformed to make it look like the intended one[9], and in interpolative methods one can control the blending among existing models for creating the new one.

III. SHAPE INTERPOLATION

Shape interpolation is based on the idea of creating new shapes by blending existing shapes. The term 3D morphing is widely used for the specific case where two pre-constructed and properly aligned polygonal meshes (a *morph-source* and a *morph-target*) are used to create in-between shapes. In-between shapes are created by parametrically combining matching primitive pairs on the source and target shapes (Fig. 3).
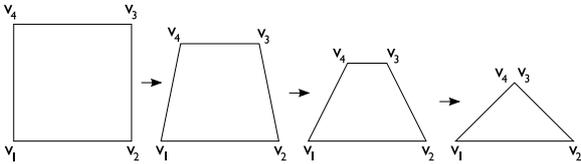
Fig. 3: A shape interpolation example in 2D, where a square is morphed into a triangle.

Given two sets of vectors S and T where each vector keeps the 3d coordinates of a mesh vertex, an in-between shape $B(u)$ can be parametrically defined as a linear combination as follows:

$$
\begin{aligned}
S &= \{s_i \mid i = 1 \ldots n\} \\
T &= \{t_j \mid j = 1 \ldots m\} \quad m \geq n & (1) \\
\mu &= \{(k, l) \mid s_k \in S, t_l \in T\} & (2) \\
B(u) &= \{s_k + u \cdot (t_l - s_k) \mid \\
& \quad s_k \in S, t_l \in T, (k, l) \in \mu\} & (3)
\end{aligned}
$$

Here the set μ is the mapping. Establishing μ requires finding the matching pairs of vertices between the source and target meshes. This can be done manually or automatically with the aid of a software tool.

Morphing causes the source shape to be transformed globally as a whole. Segmentation of both the source and the target shapes are required if local control is desired. Then the transition can take place locally from one source segment to the matching target segment. This process however can lead to unwanted artifacts as shown in Figure 4.

In our modeler to maintain smoothness at the boundaries of segments a weighted interpolation is used. An in-between shape is defined as:
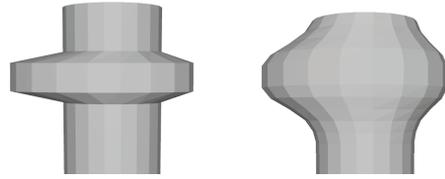
$$
B(u) = s_k + u \cdot w_k \cdot (t_l - s_k) \tag{4}
$$

Fig. 4: Discrete (left) and smooth (right) interpolation

|	Body Measurement	Definition
1	Stature	Vertical distance between the top of the head and the bottom of the heel bone.
2	Leg Length	Vertical distance between the crotch level and the bottom of the heel bone
3	Arm Length	Distance from the armscye shoulder line intersection over the elbow to the far end of the wrist bone.
4	Neck Girth	Girth of the neck base
5	Chest / Bust Girth	Convex hull circumference at chest / bust height
6	Under-bust Girth	Horizontal girth at the height just below the breasts
7	Waist Girth	Horizontal girth at waist height.
8	Hip Girth	Horizontal girth at largest convex hull at hip area.
9	Upper Leg / Thigh Girth	Horizontal girth at the largest convex hull at the upper leg.
10	Lower Leg / Lower Limb Girth	Horizontal girth at the largest convex hull at the lower leg.
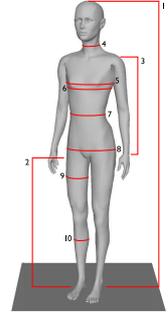
TABLE I: Anthropometric measurements of the human body

IV. BODY MODELER

We have developed a locally controlled, easy to use, morph-based body modeling tool for virtual applications. Initially a number of morph targets (both for women and men) are sculpted using commercially available software (Fig. 5). Morph targets are segmented anthropometrically and cali-
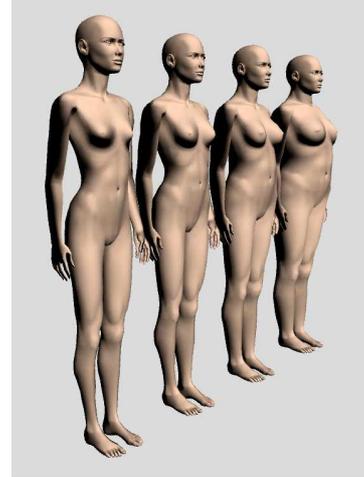
Fig. 5: Female target models having dress sizes 34, 40, 46 and 52

brated using industry standard body measurements from garment industry. Table I shows the anthropometric parameters used in segmentation of the human body.

We have used three skeletal length parameters for defining the body. These are body height, leg length and arm length. Modifying a length parameter can be achieved by a vertical scaling. However, scaling displaces the vertices and and causes

a problem on segment boundaries. Our modeler copes with this problem by re-translating the displaced vertices when required.

All the remaining parameters are body girth measurements. Body calibration is achieved by finding the convex hull [10] for the body at the predefined girth positions, calculating the actual girths of the 3D model at these positions and comparing these to the standard measurements. If required the model is modified by scaling horizontally at these positions. (Fig. 6)
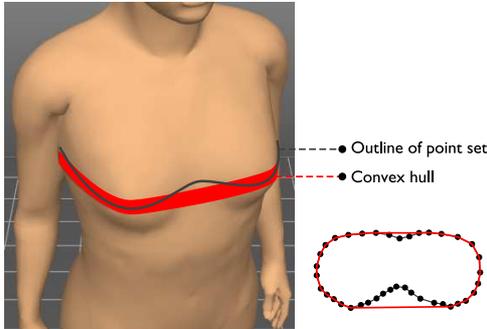

Fig. 6: Visible girths in the 3D environment

A. Segmentation

For segmentation and mapping we have used the tool that we have developed for editing polygonal meshes. This tool employs a winged edge table data structure [11]. Table II shows the set of *data table*s kept for this data structure.

Edge	Vertices		Faces		Left Traverse		Right Traverse	
	Start	End	Left	Right	Pred	Succ	Pred	Succ
E_a	$\mathbf{v}_x$	$\mathbf{v}_y$	F_1	F_2	E_b	E_d	E_e	E_c

Vertex	Incident Edge
$\mathbf{v}_x$	a
$\mathbf{v}_y$	c

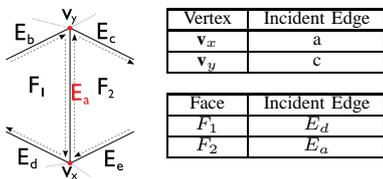| Face	Incident Edge
F_1	E_d
F_2	E_a

TABLE II: Edge, Vertex and Face-related data stored in winged edge structure.

The data structure is constructed using the edges in a polygonal mesh. Each edge is defined by its start and end vertices. The two faces shared by an edge are called the wings of the edge and they are stored in the data structure as well. Edges of each wing are also stored in a clockwise order. Left and right wing's edges are stored as the *predecessor* and *successor* respectively. We also keep two more tables for vertices and faces. The vertex table has one entry for each vertex which contains an edge that is incident to this vertex. The face table has one entry for each face which contains an edge that is one of this face's boundary edges.

Winged edge data structure provides a direct access to the neighbors of an individual vertex. Thus it is straightforward to find all the closest neighbors of a set of vertices. This has allowed us to grow, and to assign weight coefficients to each

segment region in a step by step fashion. Figure 7 shows the segmentation for the waist area. The vertex set in each segment once labeled can be saved and loaded as a VRML file.
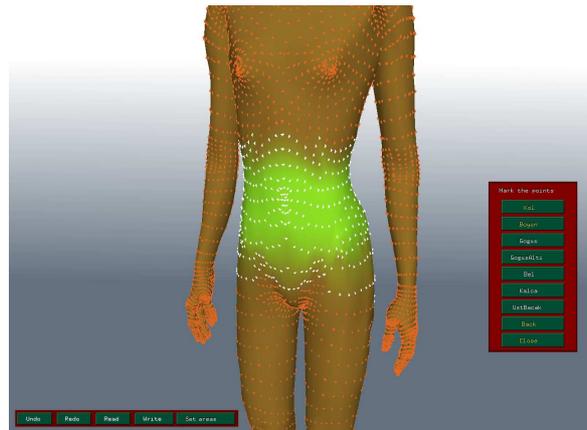

Fig. 7: The Segmentation Tool

V. VIRTUAL DRESSING ROOM

We have incorporated the body modeler into a Virtual Dressing Room application where the users create their virtual replicas and dress them using photographic images of real garments. This is achieved with the aid of a compositing subsystem which creates dressed images of virtual replicas by manipulating layers of photographic images of garments and layers of images of the modeled body (see Figure 8).

Fig. 8: The multilayer compositing

Body images are synthesized by the Ray Tracing renderer that we have developed. We have accelerated the ray tracing process by utilizing a bounding box decomposition technique where a hierarchical octree is fitted to the modeled body [12].

Octrees are constructed by recursively subdividing rectangular volumes into eight subordinate octants until the resulting leaf volumes, or voxels, meet some criterion for simplicity. The leaves of the octree which intersect with the shooting ray are pushed onto a testing stack. Then all the leaves in that stack are searched for the closest intersecting polygon. As seen in Figure 10, all the tested leaves are candidates for containing the actual intersection. The acceleration works by finding the
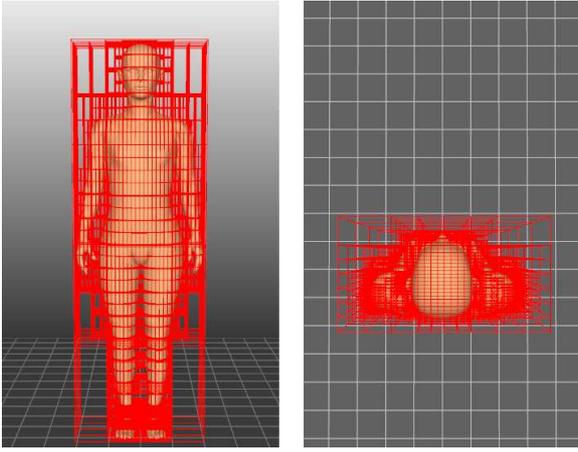
Fig. 9: Octree fitted to modeled body

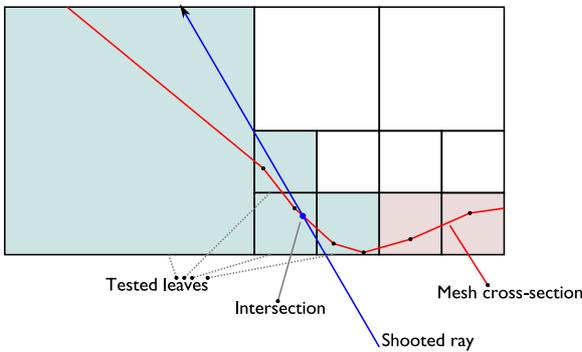candidate leaves in O($log\ n$) time instead of traversing the whole structure in O(n).

Fig. 10: 2D representation of a ray shooting iteration using octrees

After obtaining the point of intersection, we calculate the illumination at that point (to be used as the pixel color). Surface illumination calculation is done by using local diffuse illumination where the surface normal, position of the light source and the camera coordinates are taken into account. An ambient term is also added to simulate global diffuse illumination. Since specularity of the body skin is ignorable specular reflection is discarded. For anti-aliasing, we have implemented super-sampling using a stratified jittered pattern.

A. User Interface

The user interface for the modeler (Fig. 11) has been implemented using OpenGL and contains common GUI elements such as sliders and textboxes. It enables the users to select an overall body size, to enter their skeletal and girth body measurements, and adjust the body model using sliders.

Once the body is modeled, the user can personalize the face of the model. For this purpose firstly a face photograph (JPEG or BMP format) file is loaded. With the help of the face editor, the parts of the image containing the dress and the background is removed (Fig. 12) leaving the face and the hair extracted.
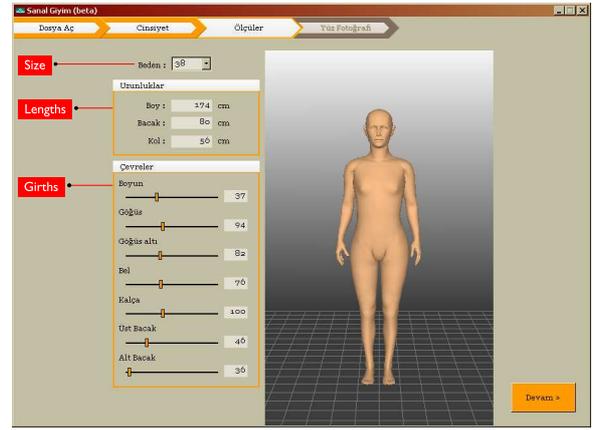

Fig. 11: Virtual Dressing Room - Body Personalization
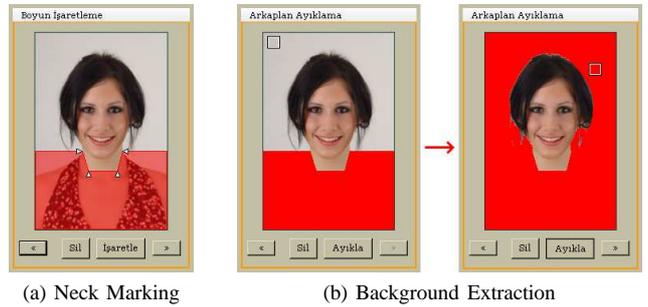

(a) Neck Marking   (b) Background Extraction

Fig. 12: Face Personalization Wizard

Garment specific information (length, bust size, hip size and other such parameters) to be used in the garment fitting process are entered to the system via an easy to use software module developed for this purpose. Garments are also metrically marked to guide the fitting process.

Figure 13 shows the Virtual Dressing Room application final render window with the associated web site window. Multiple views allow the user to have a better idea of the garment fit.

Fig. 13: The Dressing Room

VI. Conclusion

We have presented an easy to use and intuitive 3D modeling tool for personalization. Tool is based on parameterized shape interpolation. To enable local control, we have used anthropometric segmentation of the body. Smooth geometric continuity between the body segments is achieved via weighted interpolation. Early experiments have proved that a wide spectrum of human bodies can be successfully modeled. The tool is incorporated into a web-based virtual dressing application where users create their virtual replicas on their local machines and dress them by downloading garments from the web server. Trials has shown that the application provides meaningful feedback in terms of dress fitting.

References

[1] B. Allen, B. Curless, and Z. Popović, "The space of human body shapes: reconstruction and parameterization from range scans," in *SIGGRAPH '03: ACM SIGGRAPH 2003 Papers*. New York, NY, USA: ACM, 2003, pp. 587–594.

[2] H. Seo and N. Magnenat-Thalmann, "An automatic modeling of human bodies from sizing parameters," in *I3D '03: Proceedings of the 2003 symposium on Interactive 3D graphics*. New York, NY, USA: ACM, 2003, pp. 19–26.

[3] W.-S. Lee, J. Gu, and N. Magnenat-Thalmann, "Generating animatable 3D virtual humans from photographs," in *Computer Graphics Forum (Eurographics 2000)*, M. Gross and F. R. A. Hopgood, Eds., vol. 19(3), 2000.

[4] A. Hilton, D. Beresford, T. Gentils, R. Smith, and W. Sun, "Virtual people: Capturing human models to populate virtual worlds," in *CA '99: Proceedings of the Computer Animation*. Washington, DC, USA: IEEE Computer Society, 1999, p. 174.

[5] H.-D. Yang and S.-W. Lee, "Reconstructing 3d human body pose from stereo image sequences using hierarchical human body model learning," in *ICPR '06: Proceedings of the 18th International Conference on Pattern Recognition*. Washington, DC, USA: IEEE Computer Society, 2006, pp. 1004–1007.

[6] B. Rosenhahn and R. Klette, "Geometric algebra for pose estimation and surface morphing in human motion estimation," 2004, pp. 583–596.

[7] http://store.sae.org/caesar/.

[8] Z. B. Azouz, M. Rioux, C. Shu, and R. Lepage, "Characterizing human shape variation using 3d anthropometric data," *Vis. Comput.*, vol. 22, no. 5, pp. 302–314, 2006.

[9] M. Kasap and N. Magnenat-Thalmann, "Parameterized human body model for real-time applications," in *CW '07: Proceedings of the 2007 International Conference on Cyberworlds*. Washington, DC, USA: IEEE Computer Society, 2007, pp. 160–167.

[10] R. Graham, "An efficient algorithm for determining the convex hull of a finite planar set," vol. 1, pp. 132–133, 1972.

[11] B. G. Baumgart, "Winged edge polyhedron representation." Stanford, CA, USA, Tech. Rep., 1972.

[12] G. A.S., "Space subdivision for fast ray tracing," *Computer Graphics and Applications, IEEE*, vol. 4, no. 10, pp. 15–22, Oct. 1984.