AUTOMATIC SEGMENTATION OF 3D HUMAN BODY SCANS

XIANGYANG JU NAOUFEL WERGHI J. PAUL SIEBERT
3D MATIC Laboratory
Department of Computing Science
University of Glasgow, United Kingdom

ABSTRACT

Realistic human figure animation has to take account of the deformations of body, hands and face as well as the articulate motion. We proposed to make best utility of high quality 3D human body scans for human body animation by combining it with available human animation models, such that a specific person can be animated in the virtual world. The first phase of our work is to segment the scanned human body. In this paper we present a simple but effective geometric algorithm for automatic segmentation of 3D human body scans.

Keywords: segmentation, geometric algorithm, human animation, and 3D scans.

1. INTRODUCTION

There is an increasing demand for realistic human animation in numerous applications; for example, film post-production, interactive computer games, interactive education, simulation, medical training and surgery. So far it has been difficult, if not impossible, to produce highly realistic 3D human animations. Realism depends on believable appearance and realistic movements. The availability of 3D digitising technology means that real-life human bodies can be transferred into the virtual world[1]. Scanned data have accurate shapes associated with photographic textures. The scanner device can provide a surface of a polygonal mesh with hundred thousand of points but very little semantic information. On the other hand, human animation models provide useful tools to control articulated motions and body surface deformations according to body postures, but a large degree of skill and manual intervention is required to construct an automatically accurate animate model of a specific individual. Highly realistic human animation could be achieved by animating the scanned human body with realistic motions and surface deformations. However, there is a gap between the static scanned data and animation models. We aim to fill the gap by converting the scanned data into a form compatible with human animation models. What is required is a mean of conforming a generic human animation model to fit or "clone" the 3D geometry captured of a specific person. Hence, the conformation process yields a fully 3D animation human graphic character that has the appearance of the scanned individuals.

The first phase of our work is to segment the scanned human body surface. Segmentation is necessary to find the lump parts of the scanned human body corresponding to the generic model. Establishing correspondences is essential for the surface conformation. The segmentation method we developed here can be applied not only to human body animation, but also the fashion industry, biomedical sector and anthropometric surveys. The provisions of tools for automatic analysis of the 3D human body scan will be extremely beneficial for such kinds of application.

2. RELATED WORK

Realistic human figure animation requires the human models having accurate appearances and believable motions. Synthetic human body animation that provides excellent motion control mechanism has developed rapidly in recent years due to advanced computer technology. Various synthetic human body models are available to represent and deform the human body shape, which broadly divide into surface model, multi-layer model and anatomically based model[2]. Fua *et al.* (1998) and D'Apuzzo *et al.* (1999) fitted animation models to the surface data derived from multi-image video sequences in order to extract motion sequences for modelling[2,3]. Hilton and Gentils (1998) introduced a model-based approach for reconstruction from a set of low-cost colour images of a person taken from orthogonal views[4]. A generic 3D human model represented both the human shape and articulation structure. Mapping 2D-silhouette information from orthogonal view colour images onto generic 3D model captured the shape of a specific person. Colour texture mapping was achieved by projecting the set of images onto the deformed 3D model. None of these attempts have produced a highly realistic body shape for a specific individual.

On the other hand, 3D scanners can provide accurate geometry and photographic texture of a specific person. But the scanned data are lack of semantic information that are difficult to animate. We proposed to conform the animation model to the 3-D scanned human body data to realise the realistic human body animation. In the first phase of our work, we segmented the 3D human body scans automatically.

Although research on the human body segmentation dates back to several decades, it was not before the emergence of full human body scanners that research on real full human body shape began. The earlier work aimed at the extraction of body measurements needed for mass clothing production. Pargas *et al* (1997) developed a software package where sliced body scan data is edited and the body measurements are then extracted manually[6]. The attempts made to automate the measurement extraction were based on very approximately positioned body landmarks. Therefore the error margin of the measurements was significant. For the same application, Jones *et al.* (1995) focused on the torso part of the body[7]. They manually select a set of cross-sectional slices at the level of the key anatomical landmarks in the torso. These slices are fitted and then interpolated to generate a NURBS approximation. This technique ensures a good trade-off between compactness and surface detail representation. The approach remains particularly suited to clothing design, however, the process needs a lot of manual intervention although some attempts were made to automatically separate the torso and the upper part of the arms[8].

Nurre (1997) considered the automatic segmentation of the human body into its functional parts[9]. He approximated the body structure by a six-stick template representing the head, the two arms, the two legs and the torso. The goal was to segment the body into six segments corresponding to these parts. The approach combines global shape description, namely moment analysis and local criteria of proximity, which are derived from the pre-knowledge of the relative body parts positioned in a standard posture (standing body with arms held at the sides). The range data is organised into slices of data points. The horizontal slices are stacked vertically and the data points are assigned to the different body parts according to the slice's topology and its position in the body, e.g. a slice having two separated closed curves must represent points measured at the level of the legs. A slice consisting of three closed curves must belongs to the torso and arms area, a slice with two joined closed curves is assumed to correspond to the transition between the legs to the torso (at the level of the groin). Dekker *et al.*(1998) improved Nurre's work, with some efforts to enhance the localisation of the key landmarks of human body[10]. For instance they differentiated the slice circumferences in the torso area to locate the waist position. Additionally, in a recent work[11], they improved the model of the torso using a B-spline approximation. In this paper, we proposed a different method, which is simple and effective to segment the human body automatically.

3. 3-D BODY SCANNERS

3-D scanners may be divided roughly into active and passive categories. Passive scanners reconstruct the surface from stereo images or from a video recording of the object in relative motions. Active optical systems provide photorealistic representation of shapes and textures with reasonable speed.

3D-Matic has access to the C3D® photogrammetry system that can capture 3D models of people, animals and objects. The scanned surfaces are both metrically accurate and photo-realistic in appearance[12]. C3D® relies on camera-camera base line triangulation to perform depth sensing, highly accurate human form 3D data can now be collected in a matter of milliseconds (Figure 1). 3-D static whole body scanner based on the C3D® technology is now in construction.

Figure 1. A sample 3D model obtained by the C3D® photogrammetry system.

The most well-know optical triangulation 3D scanner is the one developed by Cyberware of Monterey, California, USA. Cyberware® products can capture photorealistic images of objects. The scanner's head contains a laser sheet generator, a system of mirrors, and black–white and colour video cameras. Scanning occurs by moving the object on a rotation and translation platform, or by moving the sensor around the object in a circular motion. One version, the whole body scanner Cyberware WB4, can digitise a complete human body as a combination of four scans in about 17 seconds. Each scan has 250×1000 points of resolution. The four scans can be glued together using commercial software packages. The final full body surface has a polygonal mesh with more than 42,000 triangles. Figure 2 shows a sample of whole body scanned data (Cyberware® data).

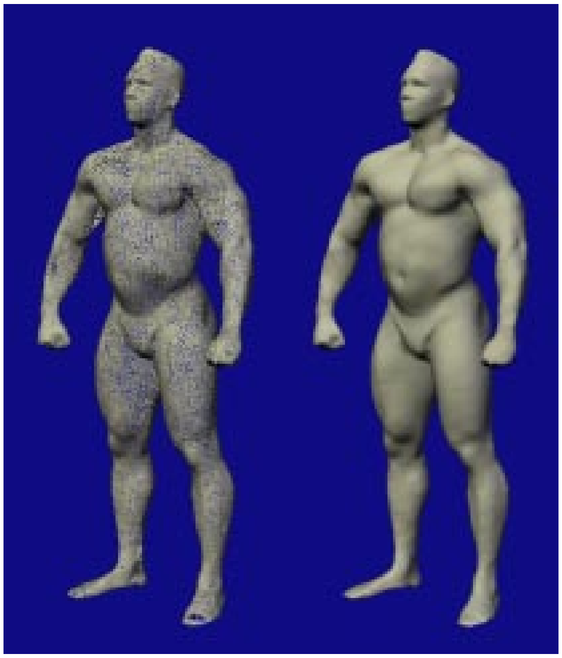


Figure 2. A Cyberware whole body model (Left – mesh, right – shaded surface)

4. AUTOMATIC SCANNED HUMAN BODY SEGMENTATION

Here, we introduce the procedure to segment the scanned human body surface of a standard posture (standing body with arms held at the sides, Figure 2).

4.1 3-D DATA TRANSFORMATION

The 3-D scanned surface is represented as a whole polygonal mesh. The vertices of the mesh usually are defined in an arbitrary Cartesian co-ordinate system. The vertices have to be transformed into their principal directions initially. Principal Component Analysis (PCA) is one of the methods that find variation modes and their weights from the original data[13]. It has been applied to find the directions in which a cloud of data points is stretched most. The co-ordinates of the vertices of the mesh can be transformed to their geometric centre and rotated into the principal directions. Here, we define the direction of the points stretched most as the X direction, and the direction of the points stretched least as the Z direction. That X Y Z axes are the direction of the height, width and thickness of the human body, respectively.

4.2 SLICING

After the surface data of the scanned human body are transferred into their principal co-ordinates, the human body surface is sliced horizontally (parallel to YZ plane). The contour at each slice can be used for further local landmark extraction.

First a plane is defined for the slicing. A point is selected as the centre of the slicing. Rays are fired from the defined centre into infinity within the defined plane in a star fashion (Figure 3). If there are intersections between the human body surface and the ray, the intersections are recorded for further analysis.

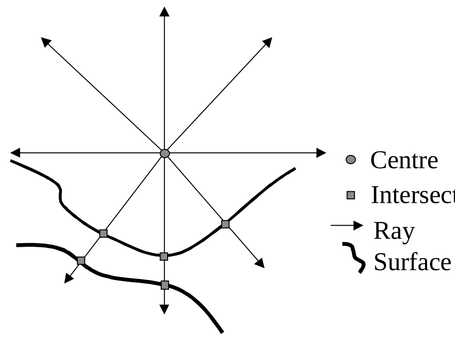
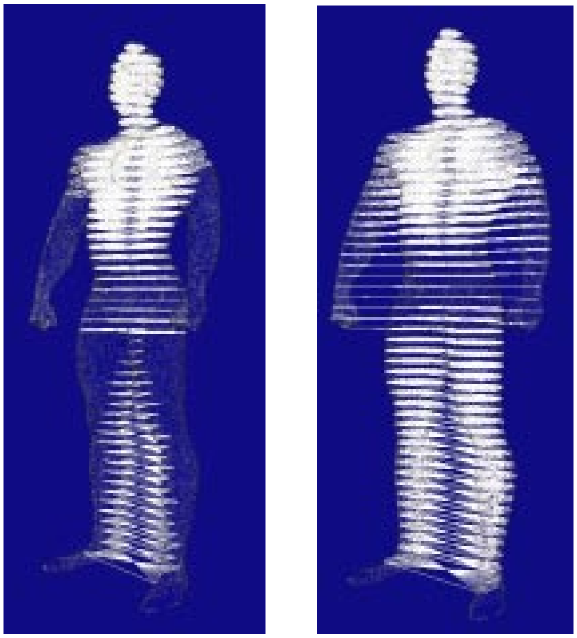


Figure 3. Illusion of the slicing setting

To extract the slices from the body surface, we define the centres of the slices along the principal axes X, Y and Z. The vertical slices parallel to XY and XZ planes have little use for body segmentation because of the uncertainty of the geometric centre and the principal directions. A slide misalignment of the geometric centre and the principal directions along the human body will give significantly different slices. The horizontal slices are elaborate. Slice centres are defined along the X-axis and uniformly distributed from the top of the head to the sole of the foot. At each slice rays are fired from their centre and the intersections between the rays and the surface are calculated.

Three options are available when we slice the scanned human body surface. We can collect the intersection closest to the centre of each ray only to form a collection of the closest intersections or we can collect every intersections of each ray to generate a collection of all intersections. The set of all intersections (Option 2) includes the closest intersections (Option 1) besides the intersections with the arms and far sides of the legs. Comparing the results of both options, we can segment the four limbs and torso (Figure 4).



(a) Option 1 (b) Option 2

Figure 4 Comparison of two options of intersection collection

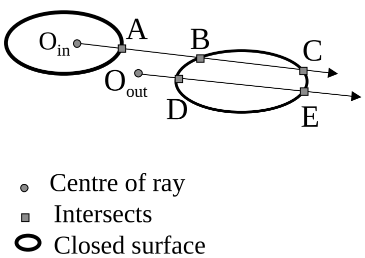


Figure 5. Illusion of the intersects of rays and closed surfaces

The third option of slicing is believed to be unique and that leads to effective segmentation. Observing the behaviour of the intersection between a ray and a closed mesh, we realise a property of the intersection (Figure 5). Because of the closure of the mesh, there are always an odd number of intersections (ABC in Figure 5) when the centre of the ray is inside the mesh; and there are always an even number of intersections (DE in Figure 5) when the centre of the ray is outside the mesh. After a ray is fired in a principal direction, the number of intersections is counted. When there are even numbered intersections, the centre of the slice sits outside of the body. That sequential pair of intersections, for example DE in Figure 5, can form new slice centres. New rays are fired from the new slices' centres and only the closest intersections to the new centres are collected. When there are odd numbered intersections, the intersection closest to the slice centre is discarded, for example A in Figure 5. The remaining sequential pair intersections (BC in Figure 5) can form new slices' centres and original slice centre (O_{in}) is included. Only the closest intersections to the new centres are collected. Figure 6 shows the results of the third slicing option. After the scanned human body is sliced horizontally, the contours of slices are used for segmentation.

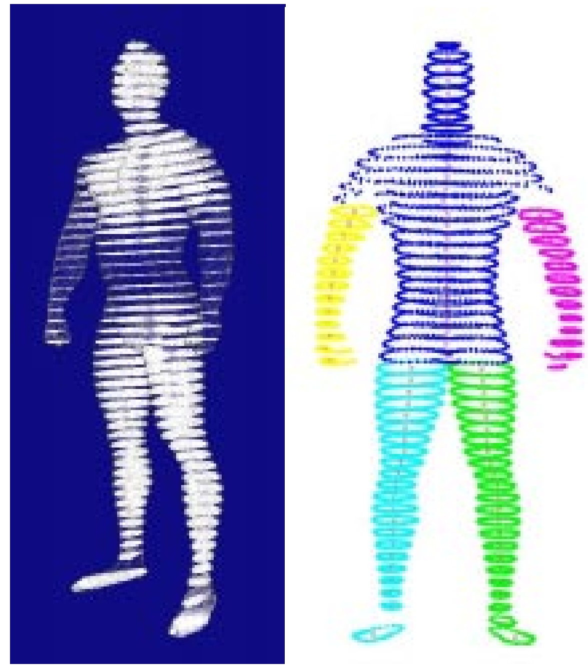


Figure 6. The results of the third slicing option

4.3 SEGMENTATION

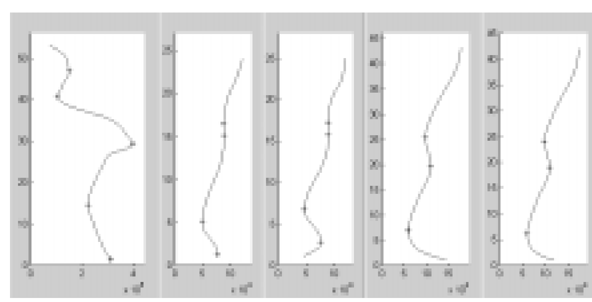


Figure 7. Girth distributions of head and torso, left arm, right arm, left leg and right leg from left to right of the graph

Based on the information of slices, the human body surface can be first segmented into five lump parts, head and torso, two arms and two legs (Figure 6). Then each part is further segmented based on curvatures of girth profiles of the individual parts. The zero-crossings of the profiles (dark dots in Figure 7) are used to determine the positions related to the neck, shoulder, waist, elbows, wrists, knees and ankles of the human body. The segmentation procedure has been tested on the scanned data and generic models. The results are repeatable and reliable (Figure 8). The programme was written in JAVA and ran on a PIII 600Hz PC, the procedure took less than ten minutes for segmentation of Cyberware® human body scanned data, although there was more room for optimisation.

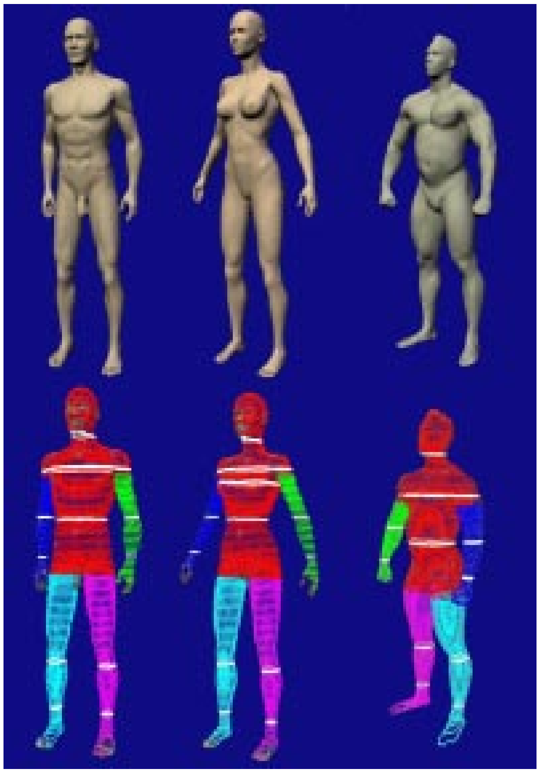


Figure 8. Human body models and their segmentations

5. HUMAN BODY ANIMATION

We used Poser4® to animate the whole body scanned data (Figure 2) to demonstrate the advantages of combining the scanned body data with a human animation model. Before the scanned human body can be animated in Poser4, it has to be articulated. The segments of the body were imported into Poser4. A hierarchical body structure was built up and the joints and joint parameters were edited, inverse kinematic chains of bodies were edited either. Figure 9 shows a few frames of the scanned body animation. A specific person can now be seen acting in the virtual world.

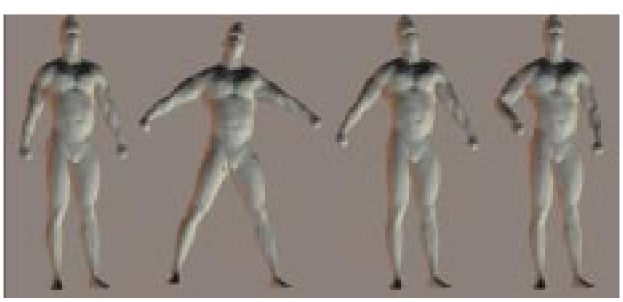


Figure 9 Human body animation

6. CONCLUSIONS

Here we presented an effective algorithm to segment the 3D human body scans, while the person stood in the standard posture. The procedure has been tested on male and female models and was proved to be repeatable. By combining the segmented 3D human body scans with the human animation model of Poser4®, we demonstrated the advantages of using the scanned body data for realistic human body animation.

7. FURTHER WORKS

The final goal of the project is to create a realistic human animation model that has accurate geometry appearance, realistic skin texture and believable motion and deformation controls. The segmentation procedure have to be further modified in order to extract the landmarks from the scanned data, that can be used to guide the conformation and further to control the motion and deformation. Local curvatures and local 3D surfaces of the human body will be investigated. The animation model will be conformed into the segmented scanned data to animate a specific person. The segmentation is developed on the scanned data of the standard posture. In order to cope with the scanned data at various postures, further development is required too. That involves research work on posture identification.

8. ACKNOWLEDGEMENT

Thanks are due to Cyberware® of Monterey, California, USA for their excellent 3D whole body scanned data and, Engineering and Physical Sciences Research Council for funding the project.

REFERENCES

[1] Petrov M, Talapov A, Robertson T, Lebedev A, Zhilyaev A and Polonskiy L 1998 Optical 3D Digitizers: Bring Life to the Virtual World. *IEEE Computer Graphics and Application*, May/June 28-37.

[2] Nedel L, Thalmann D 1998a Modelling and Deformation of Human Body using an Anatomy-Based Approach, *Proc. Computer Animation '98*, Philadelphia, IEEE Computer Society Press, 34-40.

[3] Fua P, Gruen A, Plänkers R, D'apuzzo N, Thalmann D 1998 Human Body Modelling and Motion Analysis From Video Sequences, *Proc. International Symposium on Real Time Imaging and Dynamic Analysis*, Hakodate, Japan, June.

[4] D'Apuzzo N, Plänkers R, Gruen A, Fua F and Thalmann D 1999 Modelling Human Bodies from Video Sequences, Proc. Electronic Imaging, San Jose, California, January.

[5] Hilton A and Gentils T 1998 Capturing human models to populate virtual worlds. *CVSSP Technical Report*, June.

[6] Pargas R P, Staples N J, Davis J S 1997 Automatic Measurement Extraction for Apparel from a Three-Dimensional Body Scan. *Optics and Lasers in Engineering*, 28(2), 157-172**.**

[7] Jones P R M, Li P, Brook-Wavell K, West G M 1995 Format of human body modelling from 3-D body scanning. *International Journal of Clothing Science*, **7**(1), 7-16.

[8] Li P, Jones P R M 1997 Automatic Editing and Curve-fitting of 3-D Surface Scan Data of the Human Body. *Proc. International Conference on Recent Advances in 3-D Digital Imaging and Modelling*, 296-301, Ottawa, Canada.

[9] Nurre J H 1997 Locating Landmarks on Human Body Scan Data. *International Conference of Recent Advances 3D Digital Imaging and Modeling*, 289-295, IEEE NJ USA.

[10] Dekker L, Khan S, West E, Buxton B, Treleaven P 1998 Models for Understanding the 3D Human Body Form. *Proc. IEEE Workshop on Model-Based 3D Image Analysis*, 65-74, Bombay, India, 1998.

[11] Douros I, Dekker L, Buxton B F 1999 Reconstruction of the surface of the human body from 3D scanner data using B-spline. *Proc. SPIE on Three-Dimensional Image Capture and Applications*, San Jose, California, January.

[12] Siebert J P and Marshall S J Human Body 3D Imaging by Speckle Texture Projection Photogrammetry. *Sensor Review*, 20 (3), 2000, 218-226.

[13] Jolliffe I T 1986 *Principal Component Analysis*. Springer Verlag, ISBN 0-387-96269-7.