Augmented Reality for 3D Avatar using Laser Scanned Body Data

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Abstract

An implementation of a motion editor using laser-scanned 3D body data and the animated result in augmented reality are reported in this paper. Joint points of the skeleton in the body were picked up as pivot points for 3D rotation. The body data were framed to skeleton model and organized as hierarchical structure. In order to implement the 3D animation of the laser scanned body data, the vertexes of the objects were connected as skeleton structure and animated to follow dynamic patterns inputted by user. The proposed method can provide *various 3D motion of the body in augmented reality.*

Keywords: *3D animation, laser scanned body data, skeleton, augmented reality*

1. Introduction

In TV, Movie and Game market, production of 3D contents using virtual character is gradually increasing. Also 3D body animation contents are rapidly propagated with the development of realistic motion description technique. In augmented reality as a part of the 3D contents, the actual and virtual images become unified by mixing and blending the both, so that sometimes the real and virtual images can't be distinguished.

As researches for implementing 3D character animation, non-hierarchical modeling, hierarchical modeling and skeletal modeling are widely used for 3D character animation. In non-hierarchical model 3D animation can be carried out to handle each parts of the body respectively fitting to the desired motion. In the anatomy based hierarchical model, hierarchical structure among the parts of body is constructed as its anatomical relationship. The hierarchical structure of the body is very useful to restrict the moving pattern on animation. In skeletal model, the body object is formulated as the skeleton based structure. In the skeletal model, the skeleton means only an abstract system of parameters but from this concept animation works can be achieved more easily. In recent researches, skeletal and hierarchical model are used as mixed. Ip, Chan and Lam [1] suggested anatomy based hierarchical model in which the structure of bone and muscle were defined and hand gestures were codified in terms of muscle action. The BVH hierarchical model was introduced by Ortiz, Oyarzun, Aizpurua and Posada [2], in which inverse kinematics was used for description of motion. . Kim, Jang and Bien [3] reported a gesture recognition system in which gesture animation were implemented by rotation and translation matrix operation applying separately to the rigid and the non-rigid parts of the body. As for effective rotation Hermit curve for effective rotation in arbitrary direction were proposed, where the motion generated became smooth and natural without quirks [4]. An effective animation technique using skinning was reported in [5]. For the 3D body animation, however, most of the 3D modeling works depend on manual works using graphic package tool such as MAYA or 3D MAX. In such modeling works, avatar model is used having less reality than the body data.

We introduce a motion editor for 3D body animation using laser scanned body data and report the result of the 3D body animation represented in augmented reality. The scanned body data set used in this research consists of only 3D position vectors of vertex and texture information. Using the editor, the body data which were scanned in static posture can be operated so as to show successive dynamic pose according to the predetermined gestures. The body data were framed to skeleton model and organized as hierarchical structure in order to edit the 3D body object. Hence skeleton was formulated into the body object and the object tissues which covered the skeleton were transformed in order to fit to the determined pose by means of moving the vertexes of polygon on the tissue. Transformation extent of the tissue affected by skeleton's moving was defined here in order that computing process for the movement of the vertexes on tissue was carried out in real time. The proposed method can represent various 3D motion of the body in augmented reality.

2. 3D Animation Using the Body Data

2.1. Laser Scanned Body Data

The body data were obtained using a laser scanner (Cyberware whole body scanner WB4). This body dataset is composed of about 120,000 points and the 260,000 polygons. We transformed the body data to ASE (ASCII Standard Export) file format, which consists of the 3D coordinate position vectors, the connection information among vectors, and the texture information. The ASE dataset is about 48 MB per person and its resolution is approximately within 1 mm in both the horizontal and vertical axes. Figure 1 shows the body data projected from 4 directions. To minimize the occluded area the body was scanned in the posture broadening both legs about 30cm and spreading arms to 30 degree angle between the body and the arm.

Figure 1. The Body Data were obtained using a Laser Scanner

2.2. Modeling of The 3D Body Object for Animation

The body object should be framed to skeleton model with hierarchical structure in order to implement 3D body animation. The laser-scanned body data have no information for skeleton frame and hierarchical structure. Hence the joint points were defined by picking in order to frame skeleton model. The hierarchical structure can be formed also with the joints.

We defined the joint points of the body object to determine the cross point between a line from the point picked by mouse and a polygon on the joint of body. If a line started from mouse pointer along viewing line crosses through a polygon on the joint which is designated manually, then the position of the crossed polygon is determined as the picked point. As the joint points picked by mouse 14 points are selected. The 3D body object is framed as skeleton model using the 14 points. The skeleton model and the joint points are illustrated in Figure 2.

The selected points for skeleton model include symmetric pairs such as the top and bottom of the backbone, left and right points of the pelvis, shoulder, elbow, fingertip, knee and tiptop as shown in Figure 2.

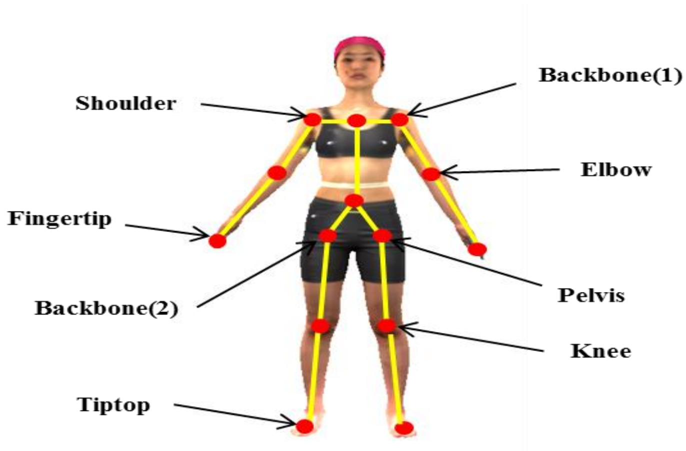


Figure 2. The Skeleton Model of the Body and the Joint Points

The skeleton defined between the joint points means only an abstract system of parameters. Therefore skeleton model can be framed as such that all polygons on the body object should be connected to each skeleton which belongs to it. To connect it, the body object should be partitioned into several objects. The object of the body can be partitioned on the basis of each joint point within determined ranges and all the points in the each partitioned area are combined and aligned to its new objects. In our research the body object was partitioned into 10 objects as shown in Figure 3.

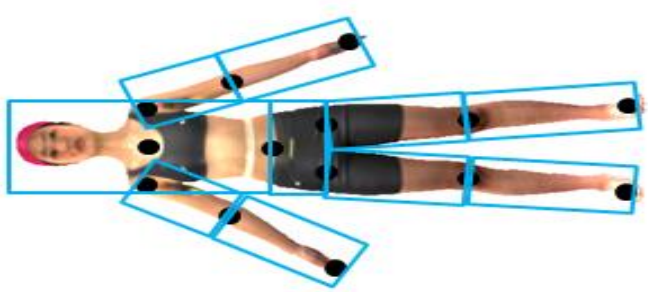


Figure 3. Partitioned Body and its Area

The partitioned object should be connected skeleton and built to hierarchical structure related as parent and child. If a parent object moves or rotate, then child object of it should be controlled to move along the parent object. In this research pelvis object is positioned as top level. Figure 4 shows the hierarchical structure among objects.

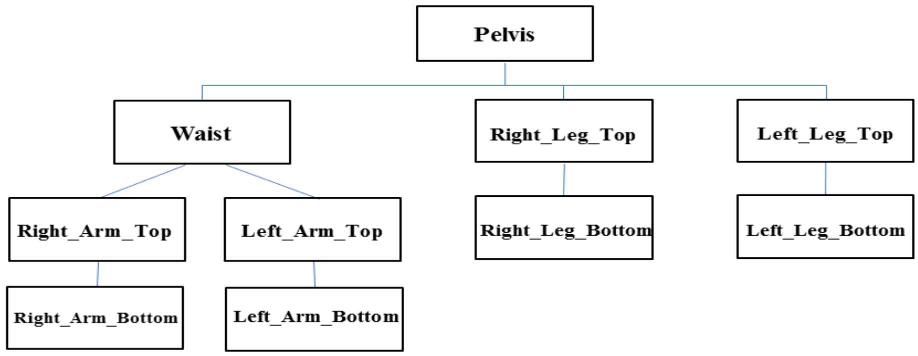


Figure 4. Hierarchical Structure among Objects

2.3. Controlling 3D Animation of the Body

In order to implement 3D animation of the body, the skeleton connected with hierarchical structure is rotated. When the skeleton is rotated, the vertexes of polygon connected with the skeleton also should be rotated to relative extent as rotation of the skeleton. Furthermore the rotation of skeleton should be controlled according to hierarchical structure. Movement of child skeleton, that is, should be controlled so as to follow the movement of parent skeleton. Equation 1 means the control for animation in hierarchical structure.

$$P_{end} = M_{child} M_{parent(n)} M_{parent(n-1)} \cdots M_{parent(1)} P \qquad (1)$$

In equation 1, $P = (x, y, z, 1)^T$ and $P_{end} = (x', y', z', 1)^T$ mean the 3D position vector of vertex (x, y, z) before and after moving. The upper character ^{T} represents transpose of a matrix. The transform matrix M can be interpreted into the following equation 2.

$$P_{end} = T^{-1} R(\theta_0) T P \qquad (2)$$

In equation 2 T means translation matrix, R means rotation matrix.

The transform equation 2 is very useful to represent bending motion in elbow, knee, pelvis, but is difficult to represent torsion of arm, leg and body in the equation. The torsion can be represented using equation 3 which provides the rotation for vector axis. [6]

$$P_{end} = T^{-1} R_x(\alpha)^{-1} R_y(\beta)^{-1} R_z(\theta) R_y(\beta) R_x(\alpha) T P \qquad (3)$$

In equation 3, α, β mean the angles between the pivot axis for rotation and the x-axis, the y-axis respectively. R_x and R_y mean rotation matrices for x-axis and for y-axis rotation respectively. The torsion can be represented using equation 3 but the equation has problems in performance time and output quality. Many operations among matrices are needed as 7 times in equation 3. As another problem gimbal lock is occurred. Gimbal lock is the loss of one degree of freedom in a three-dimensional space that occurs when the axes of two of the three gimbals are driven into a parallel configuration, "locking" the system into rotation in a degenerate two-dimensional space [7]. In order to avoid gimbal lock quaternion is used [6]. Equation 4 shows quaternion equation. In equation 4, u_x, u_y, u_z are directional vector of unit vector u.

$$P_{end} = T^{-1}M_R(\theta)TP \tag{4}$$

$$M_R(\theta) = \begin{pmatrix} u_x^2(1-\cos\theta)+\cos\theta & u_xu_y(1-\cos\theta)-u_z\sin\theta & u_xu_z(1-\cos\theta)+u_y\sin\theta & 0 \\ u_yu_x(1-\cos\theta)+u_z\sin\theta & u_y^2(1-\cos\theta)+\cos\theta & u_yu_z(1-\cos\theta)-u_x\sin\theta & 0 \\ u_zu_x(1-\cos\theta)-u_y\sin\theta & u_zu_y(1-\cos\theta)+u_x\sin\theta & u_z^2(1-\cos\theta)+\cos\theta & 0 \\ 0 & 0 & 0 & 1 \end{pmatrix}$$

2.4. Interpolation on the Joint

Result after transformation around the joint shows unnatural interval or holes among vertexes. In order to interpolate these faults, an interpolation based on rotation angle is proposed in this research. In this interpolation the rotation angle given to the model are applied propositionally to the position of the vertex. The transformation in skin will be different to the position, so that interpolation areas on each joint are defined as illustrated in Figure 5.

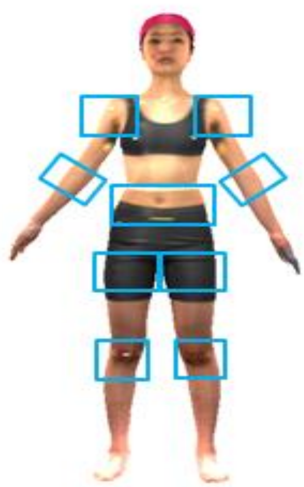


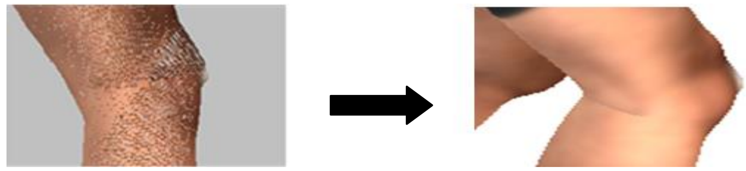
Figure 5. The Interpolation Areas defined on the Joints

The vertexes in the interpolated areas have a weight to rotation angle from 0.0 to 1.0. This weight can be defined to what extent of ratio that the rotation angle of the frame will be applied to the rotation angle of vertex. However the weight has a fixed difference in ratio, the result of the interpolation shows unnatural output. To avoid the problem we defined the ratio of weight as Hermit curve interpolation. Equation 5 shows Hermit curve interpolation.

$$\omega = -2S_v^3 + 3S_v^2 \ \left(S_v = \frac{|l_v|}{|L_v|}\right) \tag{5}$$

In equation 5, l_v means the distance between the basis of the frame and the vertex which needs weight. L_v is the distance between the top and the bottom in the interpolation area.

Figure 6 shows the border on knee joint between the pelvis and the leg. From (A) of the figure many cracks can be observed due to 3D rotation. (B) of the figure is the output applied to our proposed interpolation method. From the figure (B) we can't observe such cracks shown in (A).



(A) (B)

Figure 6. The Interpolation areas defined on the Joints

Figure 7 represent the result of walking movement operated in our proposed system. From the results we can observe the body walks as similar as active walking.

Figure 7. Walking Animation Applied to our Proposed Algorithm

Figure 8 shows the result of the torsion animation. We can confirm our weighted interpolation method can show good results.

Figure 8. Interpolated Results for Torsion by the proposed Algorithm

3. Implementation of 3D Animation on Augmented Reality

Our goal in this section is to show the 3D body animation mixing with active moving image under Android mobile OS. A marker, which is an image, works to show the animation graphics to monitor instead of itself if it is recognized by a camera. Figure 9 shows a marker to be recognized. This marker was made in monochrome image.

Figure 9. A Marker to be Recognize

We used some tools to implement animation in augmented reality. Table 1 lists the tools used in this paper for augmented reality.

Table 1. Tool List was used for Implementing Augmented Reality in this Research

Tool	Tool content
JDK	Java Development Kit
Eclipse IDE	Java IDE
Android SDK	Android Development Library
Android ADT	Android Development Tool
Unity 3D	3D Game Development engine
QCAR SDK	Augmented reality SDK

QCAR [8] in Table 1 is used to recognize the marker. The recognition using QCAR is very successful, so that it shows over 99% success rate in recognition. Recognition module of marker made in QCAR should be imported in UNITY [9] which unifies recognition module of QCAR and graphic animation module. Figure 10 shows the combined result of the marker and the 3D body object in augmented reality. We implemented the body animation in augmented reality under Android OS. QCAR and UNITY support Android OS.

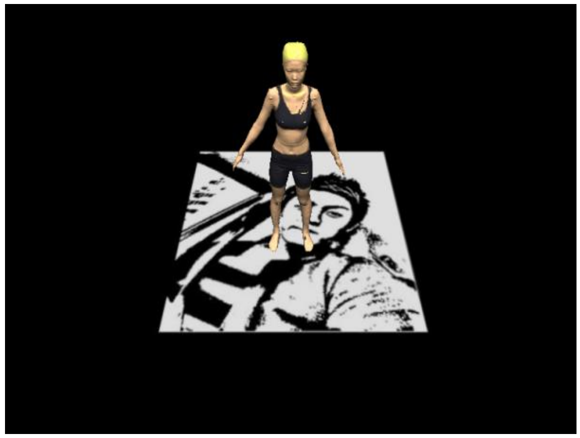


Figure 10. Marker and the 3D Body Object

Figure 11 shows the marker, the scene moving android phone to the marker and the result in augmented reality. We have a plan to recognize real facial images [10, 11] as marker to find its avatar, so that the marker of the recognized facial image can find and connect with its avatar in further study.

(A) (B) (C)

Figure 11. Marker and the 3D Body Object in Augmented Reality

4. Conclusions

We introduced the editing system for 3D body data animation and also showed the implemented result the 3D animation in augmented reality. The motion editor for 3D body animation shows good results and proved our proposed algorithm's effectiveness. Our research has a merit in using the laser-scanned body data instead of a graphic avatar since it can be used for the service which should use only real body data. Especially, using this system digital actor can serve instead of stunt actor in dangerous action. Also the result presented in augmented reality can be used in fairy tale since child can have interest to see self-animation in fairytale.

Acknowledgements

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