View-dependent deformation for virtual human modeling from silhouettes

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ABSTRACT

The primary objective of this research work is to develop an efficient and intuitive deformation technique for virtual human modeling by silhouettes input. With our method, the reference silhouettes (the front-view and right-view silhouettes of the synthetic human model) and the target silhouettes (the front-view and right-view silhouettes of the human from the photographs) are used to modify the synthetic human model, which is represented by a polygonal mesh. The system moves the vertices of the polygonal model so that the spatial relation between the original positions and the reference silhouettes is identical to the relation between the resulting positions and the target silhouettes. Our method is related to the axial deformation. The self-intersection problem is solved.

KEY WORDS: Deformation, View-dependent, Virtual human, 3-D object extraction.

1. INTRODUCTION

New techniques in Information Technology are now changing our daily life. There is increasing demand for a virtual fitting room through Internet in fashion industry. During the development of the virtual fitting room, a low-cost human shape capture system is required to be built. This paper presents an efficient and intuitive deformation technique for virtual human modeling by silhouette input. The whole procedure of virtual human modeling is shown in Fig. 6, where Fig. 6a and 6b are the photographs of the front view and the right view of the first author of this paper, Fig. 6c and 6d are the contour extraction results (by the approach of Wang et al., 2001) [1], Fig. 6e is the synthetic model, Fig. 6f and 6g are the contour extraction results of the synthetic model (by the same approach), Fig. 6h, 6i and 6j show the deformation result by our technique, and Fig. 1 is the appearance of the human model in the virtual fitting room.

With our method, the reference silhouettes (the front-view and right-view silhouettes of the synthetic human model) and the target silhouettes (the front-view and right-view silhouettes of the human from the photographs) are used to modify the synthetic human model, which is represented by a polygonal mesh. The system moves the vertices of the polygonal model so that the spatial relation between the original positions and the reference silhouettes is identical to the relation between the resulting positions and the target silhouettes. The movement is perpendicular to the view direction, and vertices do not move in the view direction. Thus, it is called view-dependent deformation. Our method is related to the axial deformation. The self-intersection problem is solved.

Fig. 1. Virtual fitting room

2. PREVIOUS WORK

The modeling and animation of deformable objects have been an active area of research for a long time. Free-form deformations (FFDs) [2] and their variants [3,4,5,6] are popular and provide a high level of geometric control over the deformation. FFDs are useful for coarse-scale deformations but not finer-scale deformations, even if a very dense lattice or customized lattice shape is defined. Axial deformation [7] provides a more compact representation in which a line segment or a curve is used to define an implicit global deformation. Wire deformation [8] is related to axial deformation, although it has a different motivation and formulation. It improves the axis-based deformation considerably by adding more
control parameters. Our deformation approach is also related to axial deformation, and is view-dependent.

Correa et al. (1998) [9] presented a depth-preserving warp method. The warp distorts the model in only two dimensions to match the artwork from a given camera perspective, yet preserves 3D effects such as self-occlusion and foreshortening. In their approach, no self-intersection happens. We solve the self-intersection problem in our model with reference to their model.

3. DEFORMATION

Our method is related to axial deformation described by Lazarus et al. (1994) [7]. But different from axial deformation, the inputs to our deformation method are the model, camera parameters, and pairs of reference and target curves. Our deformation maps a point in the view-dependent coordinate space to a different point in the same space. Thus, the first step of our algorithm is to transfer the coordinates of all the vertices of object $\Phi$ to the view-dependent coordinate space; the view-dependent coordinate space here has depth coordinate. The following deformation is operated in the view-dependent space without changing the depth coordinate, and after deformation, the coordinate of each vertex is transferred back into the model space.

For a given point $p$ in the view-dependent space of the object $\Phi$, we want to find the corresponding point $q$. Two coordinate systems: one on the reference curve and the other on the target curve are defined with a particular value of $u$ (Fig. 2). The reference curve coordinate system has its origin at $R(u)$, and $\hat{x}_r(u)$ is given by the tangent of $R$ at $u$. Likewise, the target curve coordinate system has its origin at $T(u)$, and $\hat{x}_t(u)$ is given by the tangent of $T$ at $u$. $\hat{y}_r(u)$ and $\hat{y}_t(u)$ can be determined by rotating $\hat{x}_r(u)$ and $\hat{x}_t(u)$ 90 degree in anti-clockwise direction.

After defining the coordinate system, we can find $x$ and $y$ coordinate of $p$ in the reference curve coordinate system:

$$x(u) = (p - R(u)) \cdot \hat{x}_r(u)$$

$$y(u) = (p - R(u)) \cdot \hat{y}_r(u).$$

Next, we determine the point $q(u)$ corresponding to $p(u)$ by

$$q(u) = T(u) + x(u)\hat{x}_t(u) + y(u)\hat{y}_t(u)$$

This is the location where we deform $p(u)$. The only left problem is how to determine the parameter $u$. Lazarus et al. [7] found closed point $R(u_p)$ of $p$ on $R(u)$, use $u_p$ as the parameter to compute the deformation. If there is more than one point with a minimum distance, they define $u_p$ to be the parameter with the smallest value.

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distance $d(u)$ between the projected points of $p(u)$ and $R(u)$ on the view direction. Thus, we choose the contribution to be
\[ c(u) = \frac{1}{\varepsilon + d(u)^f} \]  
(3)

where $\varepsilon$ is a small constant to avoid singularities when the distance is very close to zero, and $f$ is a constant that controls how fast the contribution falls off with distance. In Fig. 3c, we use $\varepsilon = 10^{-6}$ and $f = 3$. The self-intersection problem is solved.

\[ q^* = \frac{1}{n} \sum_{i=0}^{n-1} \hat{q}_i \]  
(4)

where $n$ is the number of the views. It is very straightforward.

6. INFLUENCE AREA

After using equation (2) to calculate the deformed position of $q(u)$, obviously, the positions of all points on the original object $\Phi$ are changed (we call it global deformation). Such deformation sometimes does not follow users’ expectation, i.e., when deform the synthetic human model in Fig. 4b to the silhouette in Fig. 4a, the deformation method of equation (2) leads to the torsion of the arms (Fig. 4c, inside the circle) for it is too close to the silhouette. This does not follow the intention of the users. Here, we introduce a parameter $r$, which can be used to define the influence area of the deformation to avoid this problem; the parameter $r$ controls the deformation area though influencing the function $c(u)$.

The new function $c(u)$ should satisfy the following three constraints:

**Constraint 1** If $d(u) > r$, the function should be zero;

**Constraint 2** The function should fall off with the growth of the distance function $d(u)$ when $d(u) \leq r$, and it should be a single value function;

**Constraint 3** The function should have a maximum value of 1 when $d(u) = 0$, and have a minimum value of 0 when $d(u) = r$ ($C^0$ continuity).
It is not hard to find that the following function satisfies the above constraints.

\[
c(u) = \begin{cases} 
1 - \frac{d(u)}{r}, & d(u) \leq r \\
0, & d(u) > r 
\end{cases} \quad (4)
\]

The curve of the contribution function \( c(u) \) in equation (4) is shown in Fig. 5 (curve A). To change the continuity at \( d(u) = 0 \) from \( C^0 \) to \( C^1 \), the contribution function is changed to

\[
c(u) = \begin{cases} 
1 - \left(\frac{d(u)}{r}\right)^2, & d(u) \leq r \\
0, & d(u) > r 
\end{cases} \quad (5)
\]

The curve of the contribution function \( c(u) \) in equation (5) is shown in Fig. 5 (curve B). To change the continuity at \( d(u) = r \) from \( C^0 \) to \( C^1 \), the contribution function is changed into

\[
c(u) = \begin{cases} 
\left(\frac{d(u)}{r}\right)^2 - 1, & d(u) \leq r \\
0, & d(u) > r 
\end{cases} \quad (6)
\]

The curve of the contribution function \( c(u) \) in equation (6) is shown in Fig. 5 (curve C).

After applying the new representation of \( c(u) \) above into equation (2), we can obtain a local deformation result (Fig. 4d). Fig. 6. shows the result of a male virtual human modeling from silhouettes; after the modeling, the human model can be used in the virtual fitting room to fit the 3D garments on Internet.

7. CONCLUSION AND DISCUSSION

In this paper, we develop an efficient and intuitive deformation technique for virtual human modeling by silhouettes input. With our method, the reference silhouettes (the front-view and right-view silhouettes of the synthetic human model) and the target silhouettes (the front-view and right-view silhouettes of the human from the photographs) are used to modify the synthetic human model, which is represented by a polygonal mesh. The system moves the vertices of the polygonal model so that the spatial relation between the original positions and the reference silhouette is identical to the relation between the resulting positions and the target silhouette. The movement is perpendicular to the view direction, and vertices do not move in the view direction. Thus, it is called view-dependent deformation.

Our deformation method is related to the axial deformation. The self-intersection problem is solved. A special processing method is presented for deforming the arms from the right view. The region definition here is simple – only a distance constant is given. Further work can be done to let users define influence region with curved boundaries as shown by the approach of Singh and Fiume [8].

8. ACKNOWLEDGEMENT

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REFERENCES


Fig. 6. Virtual human modeling