RETARGETING MOTION OF CLOTHING TO NEW CHARACTERS

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Abstract: We show how to transfer the motion of cloth from a source to a target body. The obvious method is to add the displacements of the source cloth, calculated from their position in the initial frame, to the target cloth; but this can result in penetration of the target body, because the shape of the target body. To overcome this problem, we compute an approximate source cloth motion, which maintains the initial spatial relationship between the cloth and the source body; then we obtain a detailed set of correction vectors for each frame, which relate the exact cloth to this approximation. We then compute the approximate target cloth motion in the same way as the source cloth motion; and finally we apply the detail vectors that we generated for the source cloth to the approximate target cloth, thus avoiding penetration of the target body. We demonstrate the retargeting of cloth using figures engaged in dance movements.

1 INTRODUCTION

Clothing simulation is an area in which physically based techniques pay off, and quite a lot of work along these lines has been reported (Terzopoulos and Fleicher, 1988, Breen et al, 1994, Carignan et al, 1992, Vollino and Thalmann, 1995, Baraff and Witkin, 1998 , Zhang and Yuen, 2000). Tools derived from physically based techniques are available in commercial modeling animation packages, such as Maya and Syflex. These tools are a great help to animators, but physically realistic cloth simualtion remains difficult and time consuming, even using commercial packages. So, it would be useful to be able to capture cloth motion in the same way as we capture human body motion (Pritchard and Heidrich, 2003, White et al, 2007). At the moment, there are a few systems for capturing cloth motion, but there will appear some in the future.

Assuming that capturing cloth motion is feasible in the near future, we want to devise a method of reusing, or more precisely retargeting, a cloth motion from one body to another.

Although a cloth motion obtained this way will be less physically realistic than the original, in most cases all that is required is plausible cloth behavior, not strict physical accuracy.

Motion retargeting techniques have been developed for the body (Gleicher, 1998, Lee and Shin, 1999, Choi and Ko, 2000) and the face (Noh and Neumann, 2001, Pyun and Shin, 2003, Na and Jung, 2004), but there is no published work on retargeting cloth motions to new characters.

The basic method of retargeting the motion of one character to another is to transform the source motion so that the resulting motion satisfies constraints imposed by the new character, while preserving the characteristics of the source motion as far as possible. To retarget a cloth motion we need to consider the source body motion, the source cloth motion, the target body motion, and the target cloth configuration at the initial frame, as shown in Figure 1. This is a more constrained problem than that of retargeting facial motions, where only the source facial motion and the configuration of the target face at the initial frame are used in a typical implementation.

The simplest way to obtain a target cloth motion is to compute the displacement of the source cloth at each frame from the initial frame, and add that displacement to the position of the target cloth at the initial frame. But when we see the resulting target cloth motion together with the target body motion, we find that the cloth penetrate the body. That is

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because the target cloth motion was created without considering the target body motion at all.

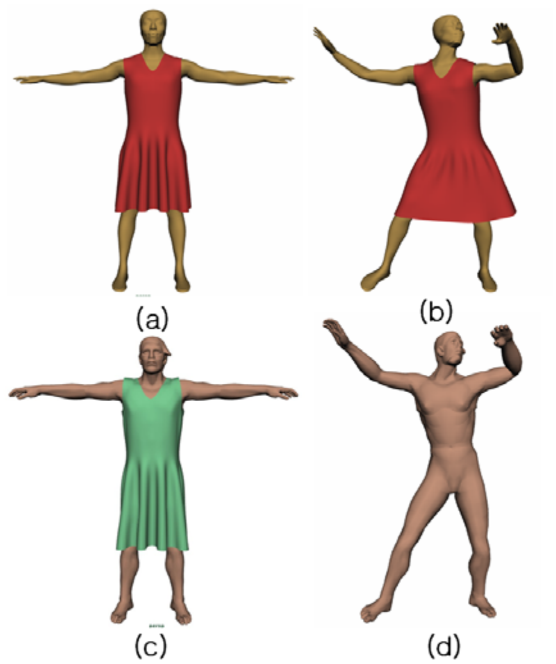

Figure 1: The input to and output of cloth motion retargeting: (a) the source cloth at the initial frame; (b) the source cloth at the k-th frame; (c) the target cloth at the initial frame; (d) the target body at the k-th frame for which the cloth have to be computed. The initial configurations (a) and (c) are supposed to correspond to each other.

To overcome this problem, we retarget the source cloth motion to the target body in two phases. First, we extract an approximate source cloth motion from the original motion, so as to capture the overall behavior of the source cloth without colliding with the source body. Then we compute the detailed motion of the source cloth by subtracting the approximate source motion from the original source cloth motion. In the same way, we find an approximate target motion that captures the overall behavior of the cloth while avoiding collision with the target body. Adding the detailed motion to the approximate target cloth motion produces the target cloth motion. The new cloth may still penetrate the target body slightly, so collisions should be detected and resolved. We only need to deal with the collision in a single frame; Collisions do not propagate as they would in a true simulation as described by Baraff et al, 1998.

In our experiments, the motion of the target body is obtained from the motion of the source body using the commercial Maya software. This could be done using any method of body motion retargeting (Gleicher, 1998, Lee and Shin, 1999, Choi and Ko, 2000). The cloth motion is obtained by using Syflex, a plug-in in Maya. We assume that the source and target cloth meshes have the same number of vertices and the same connectivity.

2 THE PROPOSED METHOD

2.1 Body-oriented Cloth

To compute the approximate motion of cloth, we adopt the surface-oriented deformation technique (Singh et al, 2000), in which an object is deformed so that it follows the motion of a deformer object. The motion of the deformable object is computed in such a way that (the surface of) the deformable object maintains its initial spatial relationship with (the surface of) the deformer object as that object moves. The deformer and deformable meshes do not need to have the same connectivity. Although the deformer object should be a single contiguous mesh, the deformable object may consist of several patches. When the technique is applied to movement of cloth, the body is the deformer, and the cloth is the deformable object. In this paper, we will use terms "body-oriented cloth" and "deformed cloth" interchangeably.

The surface-oriented deformation involves two steps: registration and deformation. During the registration step, the extent to which each "control element" (triangular face) k of the deformer object influences each vertex P of the deformable object, is computed. The weight in which control element k influences vertex P, w_k^P , is inversely proportional to the distance from P to the plane of the face k. The influence weight w_k^P , k = 1; n, where n is the number of control elements in the deformer object, are normalized. In practice, w_k^P , k = 1; n are set to zero except for a few control elements which are selected by the user.

At the registration step, the local coordinates, P_k^O , of each vertex P of the deformable object are also computed, with respect to the reference system defined on each control element k of the deformer object. These local coordinates P_k^O represent the initial spatial relationship between the deformer and deformable objects.

As the deformer object moves, the deformation step computes the world space coordinates, P_k^{def} , of each vertex P of the deformable object with respect to control element k of the deformer object, so that P_k^{def} has the same local coordinates as P_k^O in the coordinate system of control element k of the changed deformer object. Now, the new position P^{def} of vertex P is computed by averaging over all control elements, as follows:

$$P^{def} = \sum_{k=1}^{n} w_k^P P_k^{def} \quad (1)$$

Note again that w_k^P , $k = 1; n$, are zero except for a few control elements. Although simple in principle, this surface-oriented deformation algorithm produces good results in many situations. The algorithm is also implemented in Maya and called the “wrap deformer”.

2.2 The Retargeting Procedure

Using the surface-oriented deformation, cloth motion retargeting can now be achieved by the following procedure:

1. Set up the initial configurations of the source cloth and the target cloth so that they correspond to each other. The initial configurations should not contain deep wrinkles, because they are supposed to be representative configurations of the approximate motions of the source and target cloth.
2. Perform an appropriate registration with respect to the source body (the deformer object) and the source cloth (the deformable object), using their initial configurations.
3. Determine the body-oriented source cloth at each frame, as shown in Figure 2, by performing surface-oriented deformation. At the initial frame, the deformed cloth has the same configuration as the original cloth.
4. Find the body-oriented target cloth at each frame, by using the same registration technique as Step 3 (See Figure 3). This causes the body-oriented target cloth to have the same relationship with the target body as the body-oriented source cloth have with the source body. It means that the body-oriented target and source cloth are making the same approximate motion. But the approximate target motion does not collide with the target body because the rough source motion does not collide with the source body.
5. Compute the detail vectors that position the source cloth relative to the body-oriented source cloth, by subtracting the body-oriented cloth (as shown in Figure 2) from the original source cloth at each frame. This process is illustrated in Figure 4. We assume that the original cloth mesh and the body-oriented cloth mesh have the same connectivity, and so the detail vectors are simply the differences between the corresponding vertices on both meshes.
6. Add the detail vectors of the source cloth to the body-oriented target cloth, to produce the target cloth at each frame. This process is illustrated in Figure 6.

Figure 2: The body-oriented source cloth.

Figure 3: The body-oriented target cloth.

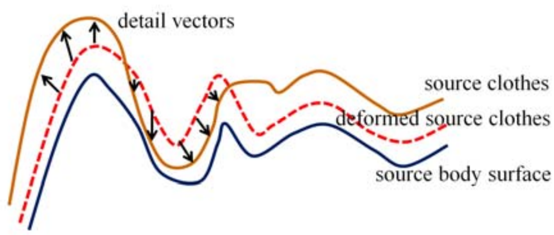

Figure 4: The detail vectors of the source cloth relative to the body-oriented (deformed) source cloth.

3 RESOLVING COLLISIONS

The body-oriented target cloth does not penetrate themselves or the target body, because of the way they are generated. But when we add the detail vectors of the source cloth to the body-oriented target cloth, the resulting target cloth may penetrate themselves or the target body, as shown in Figures 5 and 6.

The problem of collision detection and avoidance in cloth simulation has been a hot issue (Baraff et al, 2003). But we are able to address the problem using a relatively simple technique. We justify it by observing that errors affect just one frame, and do not propagate forward as they would in a simulation.

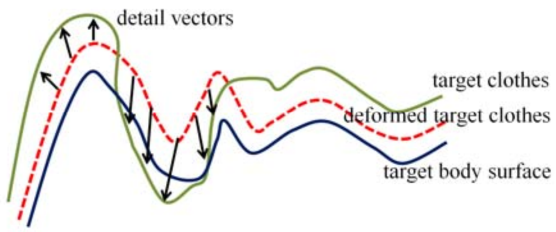

Figure 5: Adding the detail vectors of the source cloth to the body-oriented target cloth(deformed target cloth), to produce the target cloth motion. The target cloth may penetrate the target body.

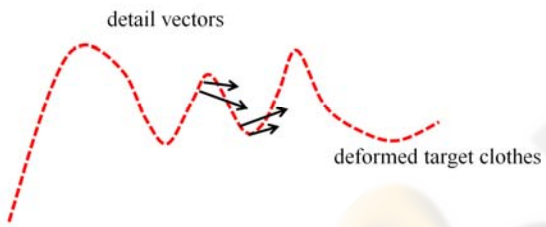

Figure 6: Some detail vectors intersect some part of the deformed target cloth. Adding the detail vectors to the deformed target cloth would cause the resulting target cloth to intersect themselves unless the affected part would not move away by its own detail vectors.

3.1 Self-collision

Self-intersection of the target cloth may be caused when the detail vectors penetrate the approximate target cloth, as shown in Figure 5. We have observed no self-collision, and we assume that they are unlikely, provided that the initial configuration of the target cloth does not have deep wrinkles, a property which is inherited by the deformed cloth, because they have the same spatial relationship with the body. Although we set up the initial configurations of the source and target cloth so as not to have deep wrinkles, we do not know what depth of wrinkles would cause self-collision in the resulting target cloth. When situations as Figure 5 occur, we avoid them by reducing the lengths of the detail vectors. Self-penetrations are unavoidable at the bend of a knee or an elbow. But any self-penetration would tend to be invisible in such areas.

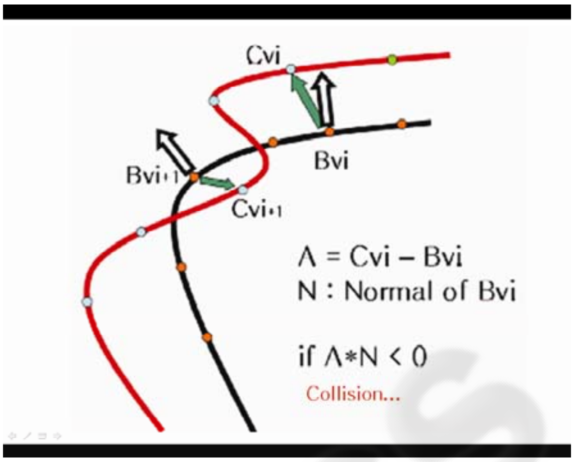

Figure 7: Collision detection and its resolution. The black line represents the body and the red line the target cloth. The green arrow, which connects a cloth vertex to the nearest body vertex, represents a penetration vector. The white arrow represents a vector normal to the cloth surface. If the dot product of normal vector and the penetration vector is negative, collision has occurred.

3.2 Cloth-to-body Collision

Figure 7 shows a situation where the target cloth penetrates the target body. This situation can be reversed by moving the penetrating cloth vertices in the direction of the normal vectors at these vertices by the extent of the penetrations (See Figure 7). Even if collisions are avoided for each cloth vertex, it does not resolve all collisions. The supplementary video shows that there is residual penetration. We are implementing collision avoidance techniques proposed by Zhang et al(2000) and Volino et al(2000) to see if they help remove residual penetration.

4 RESULT

The results of our experiments on retargeting cloth are shown in Figures 8, 9, and 10. The accompanying video demonstrates that these results are visually satisfactory. Though the retargeted motion will be less natural than the original motion, this disadvantage will often be outweighed by an ability to create cloth motion cheaply for characters in crowd scenes, avatars on the internet, and game characters.

Figure 8: A cha-cha: (left) the source motion(a woman) and (right) the target motion(a baby).

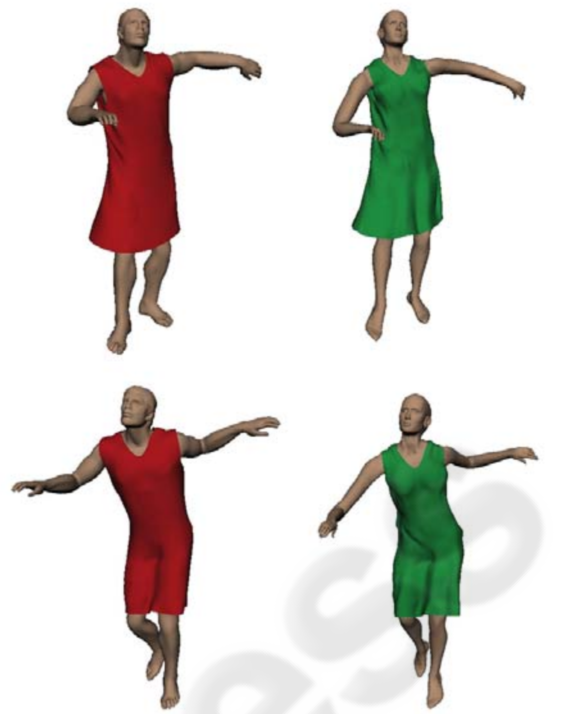

Figure 9: A jive (faster even than the cha-cha): (left) the source motion (a man) and (right) the target motion (a woman). Though this dance is so fast, the wrinkles of the source cloth transfer well to the target cloth.

5 CONCLUSIONS

We have presented a simple but effective method of retargeting cloth motion from one character to another that meets two objectives: the resulting cloth motion does not penetrate the target body but follows the movement of the target body smoothly; the details of the source cloth motion is reflected in the target cloth motion. The first objective has been achieved by creating “body-oriented” source cloth which moves over the source body, and “body-oriented” target cloth which move in the same way. The body-oriented cloth motion is approximate, and the details of the source cloth motion can be captured by subtracting the body-oriented motion from the original source cloth motion. The target cloth motion is then obtained by adding these details to the body-oriented target cloth motion. Potential collisions between the computed target cloth motion and the target body are resolved by simple and cheap methods.

Cloth motion retargeting problem is similar to facial motion retargeting, in that both cloth and faces are represented by meshes. But there is a crucial difference. Facial motion retargeting involves only a single surface, i.e. the skin of the face. But cloth motion retargeting involves two surfaces, the surface of the cloth and the surface of the underlying body. Our contribution is to handle both surfaces satisfactorily.

Our method relies on the assumption that the body-oriented deformation of the initial configuration of the cloth produces a good approximate motion of the cloth, relative to which the details of the cloth motion can be measured. This assumption is reasonable and our experimental results confirm it, but there will probably be better ways to compute the approximate version of a given cloth motion without collision. Finding those better ways is interesting future work.

Cloth-body collision detection and avoidance in the target cloth motion have not been fully dealt with. We need to devise better ways to relocate the cloth that have penetrated the body, so that the resulting configuration is sufficiently smooth as well as collision-free. Another goal is to retarget cloth motion when the source cloth and the target cloth do not have the same connectivity. We can still represent the body-oriented source and target cloth by creating a new mesh for each, with the same connectivity; but then representation of the detail vectors from the body-oriented surface to the original surface is still a problem.

Figure 10: A very fast house dance: (left) the source motion and (right) the target motion. The results are as good as those of Figure 9.

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