Real-time Cloth Simulation with Sparse Particles

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Physically-based dynamic simulation is a common technique for cloth animation. The clothes are modeled as a combination of mass-distributed particles and elastic forces that work between the particles. Typically between a few thousand and a hundred thousand particles are required to simulate cloth movement. Although many techniques have been developed for fast and robust simulation,[1] dynamic simulation requires too much computational time to animate clothes in real-time.

In this sketch, a novel technique for real-time cloth simulation is presented. The method combines dynamic simulation and geometric techniques. Only a small number of particles (a few hundred) are controlled using dynamic simulation to simulate global cloth behaviors such as waving and bending. The cloth surface is then smoothed based on elastic forces applied to each particle and the distance between each pair of adjacent particles. Using this geometric smoothing, local cloth behaviors such as twists and wrinkles are efficiently simulated (Figure 1).

Proposed Method

In the proposed method, PN triangles[2] is used to smooth a cloth mesh. This is a smoothing technique that substitutes a three-sided cubic Bézier patch for each triangular face of a mesh. It facilitates control of the smoothing mesh using the normal of the vertices, while other smoothing techniques such as subdivision (e.g. Catmull-Clark) and parametric (e.g. NURBS) surfaces generate a smoothed mesh from the vertices of a simple mesh. In addition, PN triangles ensures that the generated surface matches the original mesh on each vertex.

The cloth surface is smoothed by controlling particle normals and edge length using the PN triangles. Figure 2 illustrates the smoothing method. Figure 2 (a) is the original mesh and (b) is the smoothed surface using PN triangles without normal control. The normal of each particle is computed from the elastic forces that are applied to the particle from the adjacent faces. The elastic forces work so as to make the tangent of the cloth surface parallel with the elastic forces. Therefore we compute the normal direction by balancing the vectors that are orthogonal to the elastic forces – Figure 2 (c). In addition, when the length of an edge is shorter than its original length, the midpoint of the curve is moved so as to maintain the original edge length – Figure 2 (d). As a result, the smoothed surface reflects the elastic forces and maintains surface dimensions.

Implementation and Results

A particle-based dynamic simulation using the proposed method has been implemented. The proposed method is very simple and is easy to implement and integrate with an existing particle-based system. In terms of dynamic simulation, existing techniques[1] could be used. However, the proposed method efficiently smoothes the cloth surface in response to the distance between adjacent particles by setting low stiffness of the cloth, while standard systems maintain the shape of the cloth by setting high stiffness.

Figure 3 shows a snapshot of the resulting animation. Forty particles of the skirt were controlled using dynamic simulation – Figure 3 (a), and 4,096 triangles used for the smoothed surface – Figure 3 (b). The computational time was approximately 30 milliseconds for each frame of the 30 Hz simulation. As a result, the skirt was animated in real-time. The proposed method has potential for use in computer games, virtual studios, and virtual fashion shows.

References
1. Baraff, D. & Witkin, A. (1998). Large steps in cloth simulation. *In Proceedings of SIGGRAPH 98*, 43-54.
2. Vlachos, A., Peters, J., Boyd, C., & Mitchell, J. (2001). Curved PN triangles. *Proceedings of the 2001 ACM Symposium on Interactive 3D Graphics*.

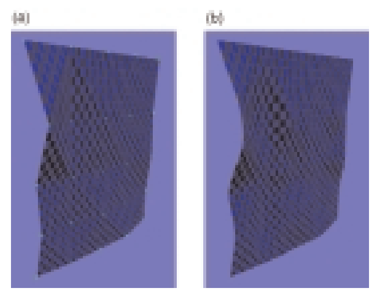

Figure 1. An example of the proposed approach: (a) a small number of particles (25 particles in this case) are controlled using dynamic simulation; (b) the cloth surface is then smoothed using geometrical techniques (2,048 triangles were rendered).

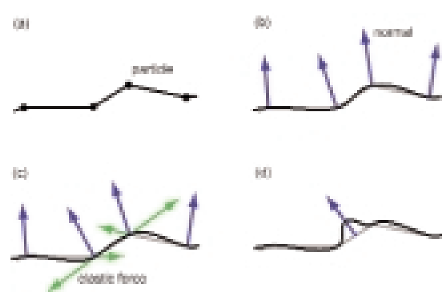

Figure 2. Smoothing method: (a) a section of an original mesh -- the middle edge is shortened and the elastic forces are working so as to part the two vertices; (b) the smoothed surface by PN triangles; (c) with normal control; and (d) edge length control.

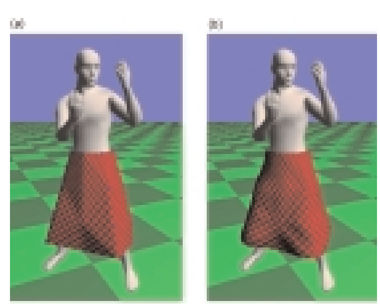

Figure 3. A snapshot from an animation of a skirt: (a) the controlled mesh (40 particles); and (b) the smoothed surface (4,096 triangles).