Crowd Cloth Simulation

Abstract

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Keywords: Cloth simulation, Adaptive Meshing

1 Related Work

In this section we give a brief overview of related work on cloth simulation, especially adaptive cloth simulation.

1.1 Mesh Simplification

Mesh Simplification methods compute a reduced-polygon count approximation of a model, while attempting to preserve its shape. Most of the existing work in mesh simplification has been targeted towards rendering acceleration [Luebke et al. 2002]. At a broad level, the simplification algorithms can be classified into static simplification algorithms or dynamic simplification algorithms.

The static approaches pre-compute a discrete series of levels-of-detail (LODs) in a view independent manner [Cohen et al. 1996; Garland and Heckbert 1997; Erikson et al. 2001]. At run time, the rendering application selects one of the static LODs based on the error threshold. As a result, the run-time overhead is relatively small. However, switching between different static LODs can result in "popping" artifacts or discontinuities in the simulation.

The view-dependent or dynamic algorithms pre-compute a hierarchical data structure that encodes a continuous range of detail. View-dependent simplification originated as an extension of the progressive mesh (PM) [Hoppe 1996]. A PM is a linear sequence of increasingly coarse meshes built from an input mesh by repeatedly applying edge collapse operations. Also, dynamic simplification has been applied to the problem of collision detection [Yoon et al. 2004].

Subidivision meshes: Subdivision meshes are a way to describe a surface using a polygonal model. Unlike normal polygonal model, the surface of subdivision meshes is perfectly smooth. Subdivision mesh schemes take the original polygonal model and produce an approximation of the surface by adding vertices and subdividing existing polygons.

Currently, there are three commonly used subdivision schemes[Catmull and Clark 1978; Doo and Sabin 1978; Loop 1978]. The Catmull-Clark and Doo-Sabin schemes are based on quadrilateral tessellations, while the Loop scheme is based on triangular tessellations.

This classical subdivision scheme is based on uniform meshes. So, it is impossible to adjust this scheme into adapted multiresolution tessellations. To remove this problem of adaptivity, 4-8 mesh [Velho and Gomes 2000] is used togather with Catmull-Clark and Doo-Sabin subdivision scheme[Velho n. d.]. This 4-8 subdivision method incorporates the power of 4-8 meshes into the classical subdivision surfaces.

1.2 Cloth Model

Terzopoulos et al. [D. Terzopoulos and Fleischer 1987] is the first to model deformable object using physics. They use the theory of elasticity to simulate and animate their deformable model. Each object has a potential energy of deformation, and they integrate motion equation to find deformation of object. Breen et al. [D. E. Breen and Wozny 1994] propose a woven cloth draping technique. They focus on the characteristic drape of particular fabrics so that they can simulate different kinds of fabrics, such as cotton, wool, etc. Choi et al.[Choi and Seidel 2002] adjust buckling effect to cloth simulation. They notice that cloth models suffer from a post-buckling instability that may cause some problems when wrinkles are formed. Simulation which adjusts immediate buckling assumption results very realistic wrinkles without post-buckling instability. These works shows relatively good quality. But due to complexity of energy function, these take so much time to simulate cloth in real-time.

Provot [Provot 1995] uses a cloth model which is modeled with a mass and massless springs. The internal force is the sum of the tensions of all springs which linked a mass to its neighbors. Summing this internal forces and external forces, we can predict the next position of mass. This idea is simple but very efficient both implementation and simulation, and the result is good-looking. For these results, many researches are based on this model [R. Bridson and Anderson 2002; **?**; Zhang and Yuen 2001; Villard 2002].

Numerical Solver Baraff et al. [Baraff and Witkin 1998] use an Euler implicit integration method to solve the formula of the internal energy of cloth. This integration method generates a sparse matrix at each time step, and they solve this matrix using conjugate gradient method. Furthermore, the authers develop a technique that can be used on adaptive time step. The computation time of this simulation is faster than Euler explicit method.

1.3 Adaptive Cloth Simulation

Hutchinson et al. [D. Hutchinson and Hewitt 1996] are the first to put a multi-grid method and cloth simulation together. They use Provot's mass-spring model[Provot 1995]. At the beginning of simulation, coarse mesh is generated and simulated. Mesh is refined when angle between two adjacent edges exceeds a given threshold. When refine occurs, two squares that share these edges are subdivided into 16 sub-squares. This is a good idea, but Provot's mass-spring system is not well-adopted to adaptive mesh. So results are very satisfactory, and more, computational time is very slow.

Zhang et al.[Zhang and Yuen 2001] present a method using multi-level meshes. Their mechanical model is Provot's system. Surface is discretized into uniform triangular mesh. They simulate fabric draping with a coarse mesh. If the mesh is nearly at equilibrium, they refine the mesh. In this refinement step, each triangle is subdivided into four smaller triangles. Using this process, they obtain a fine uniform mesh. This idea can only be used for "static" draping.

Villard et al. [Villard 2002] suggest adaptive meshing for efficient cloth simulation. They use modified Provot's system, which generate almost same results even if mesh resolution is different. They assume cloth as uniform quadrangular mesh. At the first of simulation, coarse mesh is simulated. At simulation step, if the angle between the normal of one particle and the normal of adjacent surface exceeds some threshold value then they refine this particle: all 4 neighbor squares are subdivided into 4 smaller squares. Result is very realistic and computation time is quite fast.

In summary, there are some researches about adaptive cloth simulation, but most of them adjust this idea very briefly. They only use this idea to refine mesh with very simple cloth object, for example, a handkerchief with uniform quadrangular grid. We want to show a complete framework for adaptive cloth simulation, and use this idea to simulate crowd people with cloth.

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