Critique for CS448B: Cloth Simulation

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1 Citation for Paper

`Large Steps in Cloth Simulation`, David Baraff and Andrew Witkin, Robotics Institute, Carnegie Mellon University, *SIGGRAPH 98*,pp 43-54.

2 Abstract

The bottle-neck in most cloth simulation system is that time steps be small to avoid numerical instability. This paper describes a cloth simulation system that can stably take large time steps.

3 Summary

Physically modelling cloth system and simulating it using these physically generated constraints has been of interest since quite long. Previous techniques physically modelling the cloth system had problem that the simulation needed to go through small time steps, to avoid numerical instability. In this paper, authors suggests, new way of modelling cloth physically, to overcome this particular problem, and thus making cloth simulation efficient.

In all physically based cloth simulation system, the main idea is to solve differential equation :

$$\frac{d^2x}{dt^2} = M^{-1}(\frac{\delta E}{\delta x} + F)$$

where, vector x represent the position of particle system, M is the diagonal mass distribution matrix, E-a scalar function of x-yields the cloth's internal energy, and F describes other forces on cloth. In this paper, author's model the cloth system differently. They model cloth as made of triangular meshes. The main idea, is to solve the system using *implicit* numerical intergration method rather than solving explicitly, like the ones used by previous approaches, eg. Euler's method, Runge-kutta method.

The cloth system model has different aspects. As noted before, authors model the cloth system as triangular mesh. The mass of a particle is determined by taking the 1/3 mass of the three triangles that contain it. Let n be number of particles in all, then the mass matrix M is the diagonal matrix $= D(m_1, m_1, m_1, m_2, \ldots, m_n, m_n, m_n)$. Internal forces that apply on these particles are of three types : stretch force - which is very strong since cloth does not tend to get expand/contract, shear force and bend force. The shear force is applied due to edge-edge collision and triangle-particle collision. Authors also model damping forces. There are 3 complementary damping forces to above 3 forces. So the particle system is said to evolve as equation :

$$\frac{d^2x}{dt^2} = M^{-1} f(x, \frac{dx}{dt})$$

Cloth particles have constraints too, for eg, cloth lying on a surface has constraint that particles have to lie on surface and move along the surface. They model constraints by reducing co-ordinates, basically, reducing degree of freedom of particles, so that they do not break the constrained movements.

As claimed by authors, by employing the implicit integration method for the solution of new time of particle position-velocity, the numberical instability is aparently not seen even for the large time steps and method is efficient. The main equation that need to be solved is :

$$\frac{d}{dt}\begin{pmatrix} x \\ v \end{pmatrix} = \begin{pmatrix} v \\ M^{-1} f(x, v) \end{pmatrix}$$

where $v = \frac{dx}{dt}$.

The aparent reason for the implicit method's stability is that, it depends on the both initial value and value for which computation is being done, irrespective to depending only on the initial value of the system.

With other details, the system they describe seem to work quite good for the cloth simulation.

4 Comment-Critique

The paper is quite well written. It describes most of the issues related to cloth simulation quite well. Physical cloth simulation is quite important due to its wide application. Moreover, physically modelled cloth simulation gives more realistic simulation.

Due to high computation cost attached with physically modelled cloth simulation system, it is always important to be able to compute large time steps in simualation, but due to incapability of previous systems, it was becoming numerically incapable - which was solved by authors by getting implicit integration method.

But as noted by authors, the system is not too stable, in the sense that, it is not guaranteed that for certain time step value, system will be stable. Hence, after computing new frame for some time step value it is important to check if it is not *instable* in the sense that it is *visually* good. Such time step method is called adaptive time step method. Authors suggest heuristic test to varify instability.

This is not completely satisfactory. It will be nice if one can ideally answer question like, with a given simulation method, the system will be stable below some timestep value. Another way to look at this issue is to be able to answer question whether given time step is there possibility of having instability.