A demonstration of cloth-simulation with position based dynamics

Nils Lenart

August 25, 2017

Abstract

This projects aim was to implement an alternative cloth model based on position constraints. Position based dynamics successfully displayed cloth like behavior and was able to do so in real-time.

1 Background

Cloth modeling is subject to long standing efforts in computer graphics. One popular way to model cloth is by treating the cloth as made up of discrete particles which are connected together by springs [..REF]. The systems is evolved with Newton's mechanics and the forces are computed by Hooke's formula. This is a natural way to solving the problem. Merely treating the cloth as based on springs often lead to unnatural behavior, such as high springiness and a rubbery impression. [Provot95] use constraints on the springs to prevent them from extending too much, which is a solution to this problem. The idea in this project is inspired by [Müller06], where the dynamics is entirely based on constraints. This gives a robust framework for modeling and good extensibility with constraints of interest.

2 The algorithm

The algorithm is a scaled down version of [Müller06]. The system is made up of a set of vertices, V, and a set of constraints, C. Each vertex $v \in V$ has a position x, a velocity v, a reciprocal mass $w = 1/m$. Each constraint has a type which is equality or inequality, and a constraint function which is a function of vertex positions. Equality type means that the constraint is satisfied when the function is zero, and inequality means that the constraint is satisfied when the function is positive.

The algorithms proceeds as follows: (1) apply external force (2) get potential positions (3) generate collision constraints (4) solve constraints (5) update positions and velocities (6) add friction.

2.1 The solver

In part (6) of the algorithm, the solver is responsible for changing the potential positions so that they satisfy the constraints. For every pair of distance constrained vertices their potential positions are updated by:

$$\Delta p_1 = -\frac{w_1}{w_1 + w_2}(|p_1 - p_2| - d)\frac{p_1 - p_2}{|p_1 - p_2|}$$

$$\Delta p_2 = +\frac{w_2}{w_1 + w_2}(|p_1 - p_2| - d)\frac{p_1 - p_2}{|p_1 - p_2|}$$

Where d is the distance of the constraint. This is then iterated n times for all constraints. This formula has the property that is will change the potential positions in the gradient of the constraint function while keeping the linear and angular momentum of the vertices conserved, which is according the the fundamental observations of physical nature [Müller06].

3 Implementation and results

This project will implement a demonstration program for interaction with a piece of cloth under position based dynamics. The program is implemented in processing. The program is simplified in comparison to the original paper by [Müller06]. All masses are set to 1 and only distance constraints are used.

3.1 The cloth

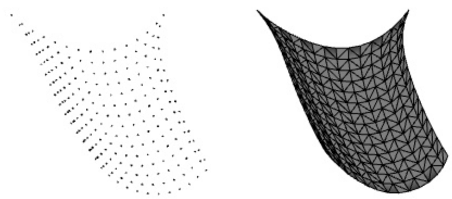

Figure 1 - To the left is a cloth showing the vertices, to the right a surface mesh interpolated onto the vertices.

The cloth is built out of vertices spaced out in a plane with a distance d between each adjacent vertex. Between adjacent vertices are a constraint of type equality that wants the distance to be d. This ensures a rigidness to the cloth so it doesn't stretch like rubber. At each timestep a set of potential positions p are generated from the current positions and velocities. The potential positions are updated to satisfy the constraints and the vertices are then moved to their correct positions.

3.2 Collision with sphere

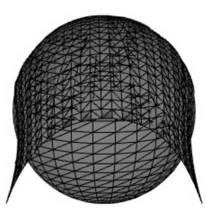

Figure 2 - The cloth colliding with a sphere.

At (3) in the algorithm, the potential positions are examined and any point closer to the sphere center than its radius will generate a collision constraint. The constraint is a distance constraint like the ones between the vertices but of time inequality, that is to say that the distance must be larger or equal to the radius r. The center of the sphere is treated as a vertex with reciprocal mass w set to 0. The interactive demo will feature a cloth that can be moved in two points by the mouse, and a sphere with which the cloth can collide.

3.3 Friction

After solving for one timestep, the velocities of the vertices that were part of a collision constraint are reduced by 10%. This makes the cloth stick to the surface of the sphere without sliding off too easily.

4 Further directions

The current implementation was successful in modeling a cloth-like object, and did so in real-time. Further additions are possible to make the cloth more life-like.

4.1 Self intersection

Self intersection constraints can be included to make the cloth not intersect itself.

4.2 Bending constraints

The current cloth behaves like silk, like a very thin material that has no resistance to bending. To model other materials, like thick canvas, bending constraints can be incorporated to model these.

4.3 Damping

Currently there is no damping in the implementation, which leads to a pendulum like behavior of the cloth under gravity. This can be solved by damping.

5 References

[Müller06] - MÜLLER M., HEIDELBERG B., HENNIX M., RATCLIFF J.: Position Based Dynamics. 3rd Workshop in Virtual Reality Interactions and Physical Simulation "VRIPHYS" (2006).

[Provot95] - PROVOT X.: Deformation Constraints in a Mass-Spring Model to Describe Rigid Cloth Behavior. Graphics Interface (1995).

[NMK+05] - NEALEN A., MÜLLER M., KEISER R., BOXERMAN E., CARLSON M.: Physically based deformable models in computer graphics. Eurographics 2005 state of the art report (2005).