A Physical Model for Cloth Movement Animation

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Abstract

Natural cloth movement is one of more challenging problems in computer animation. Since it is based on free object movement physics, there are no exact solutions or formulae for exactly representing cloth movement. The two most common approaches are the differential approach and the physical method. This poster presents cloth movement simulation using the physical method.

1 Problem and Motivation

The main problem in describing free object movement in real time is that object changes shape and position due to the internal forces that are acting within the object and external forces that are caused by interaction with the object's environment. It is very time consuming to update a large number of points that represent the object in a simulated environment. It is almost impossible to exactly describe or even take into account every point that would enable us to faithfully describe the movement, even on very powerful computer systems.

Speed and accuracy are the two main factors in choosing models. The differential approach uses cloth trajectory and its derivatives (velocity and acceleration) to calculate positions of points on the surface and the position of cloth is obtained by interpolation. The physical method uses forces that act on cloth from outside and forces that are acting within the cloth itself in order to calculate position and shape. It is less computation intensive and produces more accurate results. The main goal of this project is to find a satisfying method of cloth movement that will closely represent "real-world" movement.

2 Related Work

Different approaches have been explored regarding this problem. Ling, Damodaran and Gay [1] use the panel method for cloth surface approximation in a differential model. The model is constructed from trapezoidal surfaces and is based on aerodynamic theory and quasi-steady force models. Aerodynamic theory is used to calculate force distribution of the air flow on a cloth surface and quasi-steady model deals with stream velocity of the relative air flow and unsteady air flows. Provot [2] uses the mass-spring model to describe rigid cloth behavior. This model is derived from elastically deformable models and is improved to take into account non-elastic properties of woven fabrics. The model is approximated by a network of masses and springs, and the movement is evaluated using the numerical integration of fundamental law of dynamics. Mechanical method and triangular approximation of cloth as a deformable object is used by Vollino, Courchense, Thalmann [3]. This model uses irregular triangular meshes and Newton's motion equation to determine the object's position in small time steps along with a general collision detection algorithm.

3 Approach and Uniqueness

System implemented in this project is intended to simulate cloth movement in steady airflow. The main idea is to implement basic motion equations on the set of points in such manner that the distances between points are preserved. In this way, we can select points that are sufficiently close to one another so that even bending of cloth can not change the distance unless they are physically touching. This enables us to use a simple collision detection algorithm, in which cloth orientation is not the main concern. By using simple physics, the computational intensity is significantly reduced, resulting in fast physical model for simulating cloth movement.

Points on the cloth surface are connected to form a mesh that represents the surface. The forces acting on the surface are evaluated at each point and the mesh is then deformed to represent a new state of the surface. In order to achieve greater reality, new positions are evaluated in small time intervals to produce smoother surface deformations. The acting forces are divided into two groups: (1) *internal forces* - the ones that are occurring in the cloth due to dragging and stretching of cloth (elasticity), and (2) *external forces* such as air resistance, gravity and wind. The resulting force vectors from these two groups are then combined and applied to a point for evaluating its position in the next time interval. The elasticity of cloth is represented as tolerance within which the distance between neighboring points can vary.

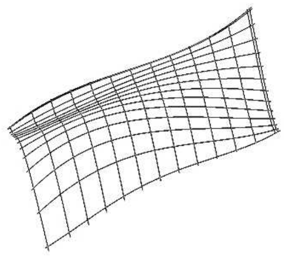
The internal force vector is calculated at the current point, positions of its neighbors, and their distances from the current point. This vector specifies in which direction and how far the current point will move in next time interval with respect to cloth constraints. The major factor in calculating an internal force vector is that points are initially selected such that distances between neighboring points can not change due to bending of cloth and distance changes only when points are overlapping each other in which case the distance is zero. The distances between unaffected points remain the same. This constraint on distance between points greatly simplifies calculations and surface presentation.

External forces consist of constant factors such as gravity and air resistance that affect the free falling object by upward airflow. In this project, wind is assumed to be uniform. More precisely, wind comes from one direction and the airflow is consistent and equal at all points in space. The resulting external vector is used to determine the new position of the point and does not take into account the constraints imposed by internal forces. The final position of the current point is derived from both internal and external vectors.

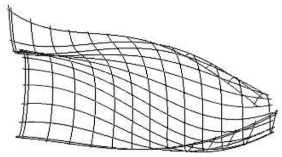
For each time interval, these calculations are repeated for each point in the surface representation. New positions of points are calculated in a spiral fashion going from points on the edges of the surface toward the center. Since points on the edge of the surface are less influenced by the neighboring points, and are influenced heavily by the external forces, this spiral order of calculation ensures more realistic results. This process continues until the object lands on a given surface.

As an example, Figure 1 shows the falling of a handkerchief without wind influence. Figure 1(a) is the position at time = 1 (one second of falling), while Figure 1(b) is an instance of time = 5.

The approach used in this project is unique, because it uses a simple representation in which all points are assumed to be independent of each other until the final calculations are made. In this way, the calculations are simplified and the speed of execution is increased.



(a) An instance of $time = 1$



(b) An instance of $time = 5$

Figure 1: Free fall of a Handkerchief

4 Results and Contributions

This approach to cloth movement presents a computationally inexpensive and effective simulation model. The resulting simulation approximates to great extent realistic "real-world" movement and can be used in variety of systems that are concerned about air flow and free fall influences on soft objects.

References

[1] Li Ling, M. Damodaran, and Robert K. L. Gay, Aerodynamic Force Models for Animating Cloth Motion in Air Flow, *The Visual Computer*, Vol. 12 (1996), pp. 84–104.

[2] Xavier Provot, Deformation Constraints in a Mass-spring Model to Describe Rigid Cloth Behavior, *Proc. Graphics Interface '95*, 1995, pp. 147–154.

[3] Pascal Vollino, Martin Courchense, and Nadia Magnenat Thalmann, Versatile and Efficient Techniques for Simulating Cloth and Other Deformable Objects, *SIGGRAPH '95*, 1995, pp. 137–144.