WRINKLE EFFECT IN CLOTH SIMULATION USING FLUIDITY CONTROL

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ABSTRACT

In complex environment, the wrinkle effect is essential in cloth simulation for realism in animated soft objects. Animating wrinkle effect requires more computation which leads the unacceptably slow simulation. In this paper, we use fluidity control in general soft body with variation of parameter values to present the wrinkle effect in cloth simulation. The fluidity control in our simulation is fast since only nearby surface points are used in this computation. For the general soft body model in this paper, the structure of the model is provided the structure control while the surface deformation is presented by the fluidity control. For the realism of the model, the gravitational control is exerted for free fall motion of the model. The result presented in the paper shows that the various parameter values in the control can generate wrinkle effects in the cloth simulation.

1. INTRODUCTION

Nowadays, the computer simulations has become more realistic. The techniques for soft body are becoming increasingly general. The general soft body model enables simulation of a variety of soft body materials by adjusting the parameter values for specific soft body behaviors. This research focuses on how to apply general method of soft body model into specific property of the material such as cloth. The property can be specified by the parameters of body control, surface deformation, volume control, and gravitation. To control these parameters we use body mesh structure to maintain configuration among surface points, fluid modeling to deform the details of the surface, internal pressure to approximated the simulated molecules within the soft body. Finally, free fall motion of soft body is generated by gravitational field.

Remainder of this paper is structured as follows. Section 2 describes previous works. Section 3 discusses a general soft body model. Sections 4 presents wrinkle effect using fluidity control. Section 5 demonstrates the results of fluidity control in cloth simulation. Section 6 concludes our work.

2. PREVIOUS WORKS

In cloth simulation, several techniques have been proposed by many researchers to present the cloth behaviors of drapes, folds, and wrinkles, for different properties of textiles. In some cloth-specific properties, the cloth behaviors deals with large deformations for cloth in high flexibility. In recent work, underwater cloth simulation has been described in the term of internal and external dynamics of cloth underwater.

In complex environments, such as air, water, or oil, Eberhardt *et al.* describe the fast, flexible, particle-based model to animate the drapes of different types of cloth, which require the calculation of exact trajectories of moving particles (Eberhardt, Weber, & Strasser, 1996). They have investigated a suitable description of internal forces for each particle in the form of force plots of tension, shearing, and bending. These later are used to calculate trajectory of a particle via an integration of the Lagrange differential equation. the particle locations, inside or at the border of cloth provide different levels of air resistance to particular particles. The visual results of different textures present draping and vibrating effects in their simulations.

Bhat *et al.* investigate cloth simulation from video data of real fabrics in (Breen et al., 2003). An algorithm to estimate the parameters of cloth simulation from video data of real fabric is proposed in this paper for the needs of parameter adjustment to achieve the appearance of a particular fabric. Two consecutive video frames are used to provide the cloth parameters from the folds of fabrics. The dynamic and static tests on small fabric swatches give appropriate simulation parameters which are later used to simulate the fabrics that are worn by a human actor. Four different types of fabrics (linen, fleece, satin, and knit) are simulated to demonstrate the performance of this approach.

Bridson *et al.* present the simulation of clothing with folds and wrinkles in (R Bridson, Marino, & Fedkiw, 2003). A mixed explicit/implicit time integration in numerical analysis is used for the cloth appearance. A detail in contact regions of the cloth is achieved by a physically correct bending model combining with an interface forecasting technique. In this proposed method, a post-processing method preserves folds and wrinkles on cloth-character collision. Additionally, a dynamic constraint mechanism supports the control in large scale folding. Later, the simulation realism is achieved by using these techniques to control folds and wrinkles on cloth simulation.

Bridson *et al.* propose the technique for robust treatment of collision, contact and friction for cloth animation for actual modeling of cloth thickness in (Robert Bridson, Fedkiw, & Anderson, 2005). For the smooth and interference free data in sharp folds and wrinkles in a cloth mesh, the post-processed scheme with subdivisions has been used in this paper. Since the sharp folds can generate the intersections between elements of subdivisions, the repulsion and collision impulses are used to adjust the cloth positions with no intersection at the end of adjustment. In addition, the static friction model provides the stable folds and wrinkles as shown in the simulation of a curtain that is draped over a ball.

Decaudin *et al.* present the folds generated by the collision with the virtual mannequin (Decaudin et al., 2006). The different buckling patterns for a cylinder of fabric describes the patterns of diamond buckling, twist buckling, and axis aligned folds. Diamond buckling is presented by the compression of a cylinder of cloth maintaining a zero Gaussian curvature which has a diamond shape that appears when an elbow or a knee of a character is bent or the sleeves of a sweater are pulled up. The parallel folds are generated when the body twists and when a loose skirt hangs under gravity. The proposed method to produce these folds works on an fabric cylinder. The visual result of this simulation shows the realistic 3D mannequin dressed in the designed garment.

Müller *et al.* introduce a method to avoid the velocity layer required to provide the new position of the model (Müller, Heidelberger, Hennix, & Ratcliff, 2007). Since there is instability problem in the explicit Euler method, point based dynamics provide the new position immediately after the model constraints, including constraints of collision. The new locations of points are calculated by the solver approach that tries to satisfy all constraints of the model. Using this method, all points in the models can be generated immediately during the simulation. To show the effectiveness of the method, cloth simulation with animated game characters is presented in the paper.

Ozgen *et al.* simulate underwater cloth with fractional derivatives in (Ozgen, Kallmann, Ramirez, & Coimbra, 2010) by using a particle-based cloth model that includes half-derivative viscoelastic elements to describe the internal and external dynamics of the cloth. The cloth responds to fluid stresses and the behavior of particles in a viscous fluid by this method. The fluid viscosity component in fractional cloth model produces bump propagations on the surface of the model. The equation of motion in this paper is Fractional Differential Equation (FDE) to where both explicit and implicit numerical solution techniques can be extended. To present the realism of the simulation, the underwater cloth deformation has been demonstrated and compared with real clothes.

3. A GENERAL FORMAL MODEL OF SOFT BODIES IN MOTION

This section, the general formal model of soft body model can be described as a structure of the model that is composed of a list of surface points, a list of edges connecting between the points, and a list of triangles connecting between the edges of the model. The structure of the model is defined as

$\boldsymbol{p}_i$ is the list of the surface points.

F_i is a set of forces for each surface point of the soft body ,

v_i is a set of velocities for each surface point of the soft body,

Each force at point i is defined as $F_i = \left\langle F_{bi}, F_{ai}, F_{vi}, F_{gi} \right\rangle$, where $\boldsymbol{F}_{bi}^t$ is the force of the body structure control, F_{ai}^t is the force of the fluidity control, $\boldsymbol{F}_{vi}^t$ is the force of the volume control, and $\boldsymbol{F}_{gi}^t$ is the force of gravity. All of these controls are presented at point i.

To satisfy a level of softness of the model, we present a parametric model of different control. As indicated previously, the composite force, $\boldsymbol{F}_i^t$, of the surface point i at time t is based on the controls of components. With this assumption, $\boldsymbol{F}_i^t$ is defined as:

$$\boldsymbol{F}_i^t = \alpha \boldsymbol{F}_{bi}^t + \beta \boldsymbol{F}_{fi}^t + \gamma \boldsymbol{F}_{vi}^t + \delta \boldsymbol{F}_{gi}^t, \qquad (1)$$

where parameters, $\alpha, \beta, \gamma,$ and δ are parameters of body structure control, fluidity control, volume control, and gravitational field, respectively, where $\alpha > 0$ and $\beta, \gamma, \delta \geq 0$. Constraints may exist for relations among these components.

In this manner, the various force parameters exerted on each soft body surface point can be adjusted to obtain specific types of soft body behaviors.

4. WRINKLE EFFECT USING FLUIDITY CONTROL

Fluidity is the study how the fluid flows and sometimes is known as hydrodynamics. The properties of the fluid are normally described in the terms of density(ρ) , pressure ($\boldsymbol{F}^{\boldsymbol{t}}_{\boldsymbol{fpi}}$), and viscosity ($\boldsymbol{F}^{\boldsymbol{t}}_{\boldsymbol{fvi}}$).

In this paper, we present the wrinkle effect using fluidity control in the general soft body model. For the behavior of fluidity control, the free moving particles, which are the surface points in our model, interact with nearby surface points within a radius. We use the model technique called the smoothed particle hydrodynamics (SPH) developed originally for astrophysics problems and later used in interactive applications of particles based on fluid simulation (Müller, Charypar, and Gross 2003; Müller et al. 2005). For the implementation of the model, SPH is simpler than other fluid modeling such as FEM or FVM. An interpolation method is used in SPH to distribute quantities in a local neighborhood of each particle using radial symmetrical smoothing kernels. Poly6, spiky, and viscosity smoothing kernels in Müller, Charypar, and Gross (2003) and Müller et al. (2005) describe fluid density, fluid pressure, and viscosity forces in our model. Thus, during fluid force calculation, fluid density and fluid pressure are computed to generate fluid pressure force and fluid viscosity force as presented as follows.

Related to the model developed in Müller, Charypar, and Gross (2003) and Müller et al. (2005), fluid density is given by:

$$\rho_i^t = \sum_j m_j W_{poly6}(l_{ij}^t, h_w), \ \forall j \text{ such that } l_{ij}^t \le h_w \quad , \tag{2}$$

where ρ_i^t is the density at surface point i at time t, m_j is the mass at surface point j , and h_w is the core radius of SPH.

Next, fluid pressure is generated from fluid density as:

$$L_{\boldsymbol{i}}^t = k(\rho_{\boldsymbol{i}}^t - \rho^0), \tag{3}$$

where L_i^t is the fluid or liquid pressure at surface point i at time t , k is the gas constant, $\rho_{\boldsymbol{i}}^{\boldsymbol{t}}$ is the density at surface point i at time t , and ρ^0 is the initial density.

Fluid pressure force at the soft body surface point i , $\boldsymbol{F}^t_{fpi}$, is computed as:

$$\boldsymbol{F}^t_{fpi} = -\sum_j m_j \frac{L_i^t - L_j^t}{2\rho_j^t} \nabla W_{spiky}(l_{ij}^t, h_w), \quad \forall j \text{ such that } l_{ij}^t \le h_w, \tag{4}$$

where m_j is the mass at surface point j , L_i^t and L_j^t are fluid or liquid pressure values at surface points i and j respectively at time t , ρ_j^t is the density at surface point j at time t , and h_w is the core radius of SPH.

Finally the fluid viscosity force at the soft body surface point i , $\boldsymbol{F}^t_{fvi}$, is generated by:

$$\boldsymbol{F}^t_{fvi} = \mu \sum_j m_j \frac{\boldsymbol{v}_j^t - \boldsymbol{v}_i^t}{\rho_j^t} \nabla^2 W_{viscosity}(l_{ij}^t, h_w), \quad \forall j \text{ such that } l_{ij}^t \le h_w, \tag{5}$$

where μ is the viscosity of fluid, m_j is the mass at surface point j , $\boldsymbol{v}_i^t$ and $\boldsymbol{v}_j^t$ are the velocities at surface points i and j respectively at time t , ρ_j^t is the density at surface point j at time t , and h_w is the core radius of SPH.

The fluidity control generated by fluid force, $\boldsymbol{F}^{\boldsymbol{t}}_{\boldsymbol{ai}}$, is the combination of two different forces: (1) fluid pressure force, $\boldsymbol{F}^t_{fpi}$, and (2) fluid viscosity force, $\boldsymbol{F}^t_{fvi}$. Hence, we define the fluid force as follows:

$$\boldsymbol{F}^{\boldsymbol{t}}_{\boldsymbol{ai}} = \boldsymbol{F}^{\boldsymbol{t}}_{\boldsymbol{fpi}} + \boldsymbol{F}^{\boldsymbol{t}}_{\boldsymbol{fvi}} \quad , \tag{6}$$

where $\boldsymbol{F}^t_{fpi}$ is fluid pressure force at surface point i and $\boldsymbol{F}^t_{fvi}$ is fluid viscosity force at surface point i .

In order to model volume of the soft body an internal pressure force must push the surface points outward. This volume is created by pressure force generated by the molecules within the soft body. Without volume, the soft body may become flat, much like fabric or cloth after colliding with the environment.

5. RESULTS

Three demonstrations with different parameter values of fluidity control have been presented in this section. The environment of the scene composes of a hanger with 2,151 vertices and a cloth with 12,290 vertices hanging on the hanger where the collision detection occurs between the hanger and the cloth to hold the cloth. The simulation has three different sets of parameters $\alpha, \beta, \gamma,$ and δ which are body structure control, fluidity control, volume control, and gravitational field, respectively, where $\alpha > 0$, and $\beta, \gamma, \delta \geq 0$.

The animated cloth illustrates the main effects of fluidity control from fluid parameter to implement the winkle effect of the cloth. The parameter sets are presented in table 1 and results of parameter set A, B, and C are demonstrated in figures 1 - 3, figures 4 - 6, and figures 7 - 9, respectively.

Table 1: Experiment parameters for winkle effect in cloth simulation

Parameter sets	α	β	γ	δ
A	1	0	1	1
B	1	1	1	1
C	1	2	1	1

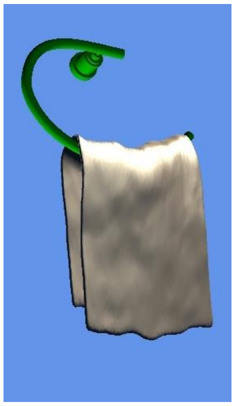

Figure 1. The screenshot is captured at 1st frame of the simulation for experiment set A.

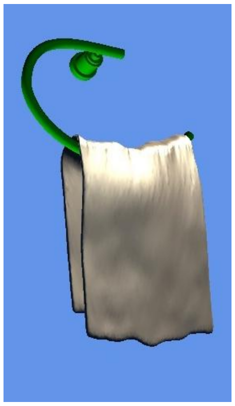

Figure 2. The screenshot is captured at 200th frame of the simulation for experiment set A.

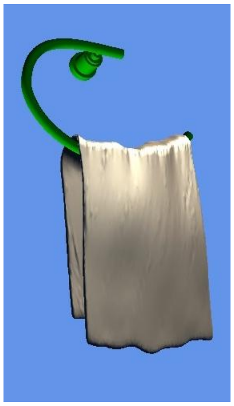

Figure 3. The screenshot is captured at 400th frame of the simulation for experiment set A.

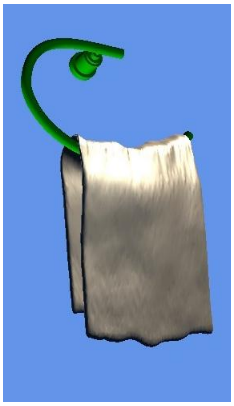

Figure 4. The screenshot is captured at 1st frame of the simulation for experiment set B.

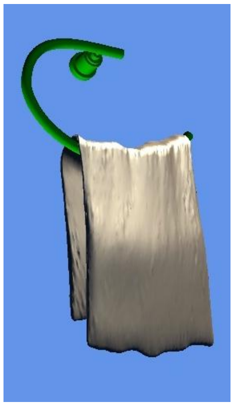

Figure 5. The screenshot is captured at 200th frame of the simulation for experiment set B.

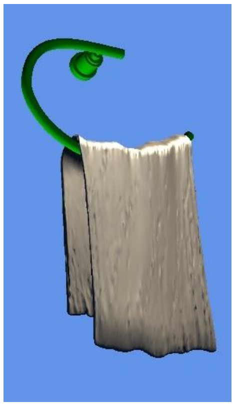

Figure 6. The screenshot is captured at 400th frame of the simulation for experiment set B.

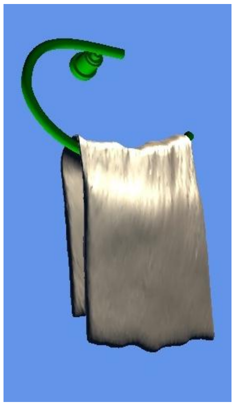

Figure 7. The screenshot is captured at 1st frame of the simulation for experiment set C.

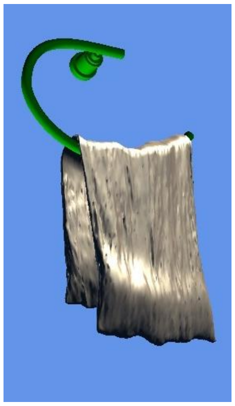

Figure 8. The screenshot is captured at 200th frame of the simulation for experiment set C.

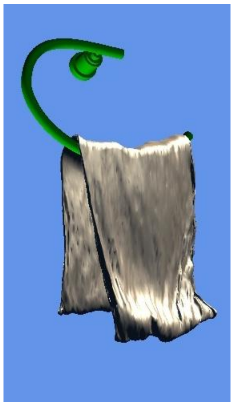

Figure 9. The screenshot is captured at 400th frame of the simulation for experiment set C.

The result of the parameter set A which is presented in figures 1 to 3 shows that the simulation of cloth becomes smooth when the fluidity control is set to 0. When the parameter value of fluidity is increased to 1 as set in parameter set B, the result of the cloth presets more wrinkle on the surface as demonstrated in figures 4 - 6. When the parameter value of fluidity is increased to 2 as set in parameter set C, the result of the cloth presets even more wrinkle on the surface as demonstrated in figures 7 - 9. The results of these parameter sets shows that the fluidity control can create the wrinkle effect on the cloth simulation.

6. CONCLUSION

As we have presented in the simulation set, the our general soft body control that composes of body control, surface deformation, and gravitation, can be adjusted to simulate different types of soft bodies. Focusing of the fluidity control the winkle effect that can be used in cloth simulation in different levels. If the cloth needs more wrinkle effect, then it can be achieved by increasing the fluidity parameter value. In the future work, the wrinkle effect can be applied in the cloth on animated characters.

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