

A Particle Model based on Measured Mechanical Properties of Woven Cloth

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1. Introduction

Even though a particle model based on the mechanical properties of woven cloth has been proposed by Breen *et al*[1], there are problems to describe cloth behavior precisely and reflect cloth dynamics. In this paper, we describe a precise relationship between measured mechanical properties of cloth and the particle model. Moreover, a collision model describing the rotation as well as move of particles resulting from impulse is integrated to the particle model. Some experiments involving two cloth materials are performed to validate the proposed cloth model.

2. Modified particle model for cloth simulation

2.1. Forces and torques acting on particles

Breen *et al* represented woven cloth by a particle system where each intersection corresponds to a particle, and cloth springs were imagined acting on the yarn segments between crossing-point particles(see fig.1). Here, each particle denotes a cloth segment of $\sigma \times \sigma$ area. Then the measurement data of fabrics, produced by the Kawabata Evaluation System(KES) for woven fabrics which is a standard set of fabric testers[2], are used for the mechanical property calculation.

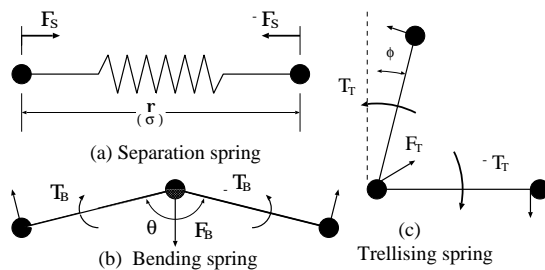


Figure 1. Cloth springs in particle system

Even though cloth mechanical properties have been included in the particle model, the accuracy of cloth simulation is insufficient. Here, based on the KES measurement principle, we modify the magnitudes calculation of the force and torques in fig.1 to the equations shown in eqs.(1). Here, $F_s(\varepsilon)$, $T_B(\theta)$ and $T_T(\phi)$ denote the functions approximating KES stretch, bend and shear plots respectively. Fig.2 is a KES bend plot of thin wool material which shows the non-linear relationship of the bend moment M versus the bend curvature K .

$$\begin{cases} F_s(\varepsilon) = F(\varepsilon) \cdot \sigma \cdot 978.80. \\ F_c(-\varepsilon) = F_s(\varepsilon) \cdot \alpha \quad (0 \leq \alpha \leq 1) \\ T_B(\theta) = M(K) \cdot \sigma \cdot 978.80 \\ T_T(\phi) = F(\phi) \cdot \cos \phi \cdot \sigma^2 \cdot 195.76 \end{cases} \quad (1)$$

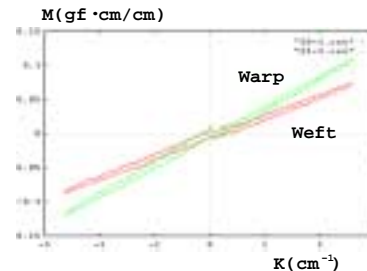


Figure 2. KES bend plot

2.2. Collision and repulsion

To simplify the matter, we deal with both cloth-cloth and cloth-body collisions as vertex-face contact. Whether a vertex(A) will intersect a triangular face(B) or not is judged by using an Euclid 4×4 determinant. Once a collision is detected, the impulse is obtained by using eqs.(2).

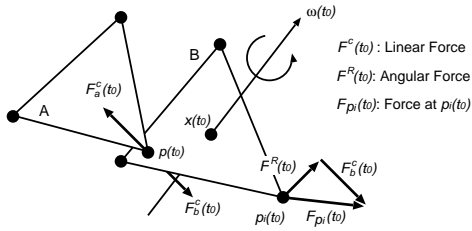


Figure 3. Repulsion between A and B

Here, $F_a^C(t_0)$ denotes the impulsive force acting A, v_{rel}^- denotes the initial relative velocity of A and B in the normal direction ($\hat{n}(t_0)$), M_a and M_b represent the masses of A and B. At the colliding moment (t_0), the face can be regarded as a rigid body, such that, the impulsive force acting on B, which is equal to the reverse of $F_a^C(t_0)$, will rotate B as well as move it (shown in fig.3). The impulsive force acting on each particle of B ($F_{p_i}^C(t_0)$) can be calculated further.

$$\begin{cases} J = F_a^C(t_0)\Delta t = j\hat{n}(t_0) \\ j = \frac{-(1+\epsilon)v_{rel}^-}{1/M_a + 1/M_b} \end{cases} \quad 0 \leq \epsilon \leq 1 \quad (2)$$

3. Experimental results and discussion

Using the particle model that integrates collision, we carry out experiments on two types of cloth materials: thick cotton and thin wool. Both cloth self-collision and the collision between cloth and its supports are involved.

Fig.4 shows the simulation of tablecloths (40[cm] × 40[cm]) put on a table (20[cm] × 20[cm]). Here, the upper figures are taken photographs of real samples made of thick cotton and thin wool; the middle figures are generated by Breen's particle model, the obvious cloth over-stretching is a problem though the effect of materials has been shown; the bottom figures which visualize the real tablecloths more precisely are produced by our modified particle model.

To reflect cloth dynamics, the free falling of a thick cotton ribbon of size 1.5[cm] × 60[cm] is simulated as shown in fig.5. The ribbon rotates as well as moves when it collides with an object, it shows natural cloth behavior. The last figure in fig.5 shows the photograph of a real fallen down ribbon, it is close to the convergent state of the simulation.

4. Conclusion

A modified particle model integrating collision is described in this paper. The experiments have demonstrated that the proposed model can not only simulate cloth drape accurately, but also visualize cloth dynamics depending on

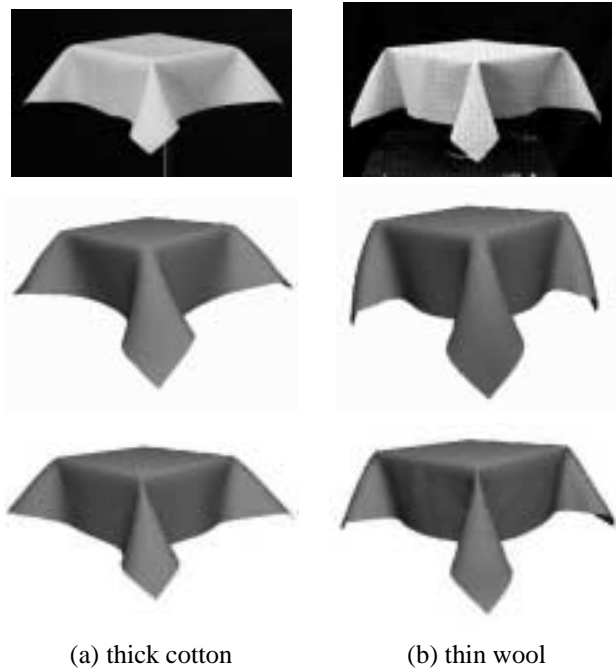


Figure 4. Tablecloths

cloth mechanical properties. The model is expected to be used in clothing modeling for apparel CAD and other related areas.

References

- [1] Breen, D. E., House, D. H., and Wozny, M. J., "Predicting the Drape of Woven Cloth Using Interacting Particles," *Proc. SIGGRAPH '94*, 1994, July, pp. 365-372.
- [2] Kawabata S., *The Standardization and Analysis of Hand Evaluation*, The Textile Machinery Society of Japan, 1980.



Figure 5. A falling down cloth ribbon