Modeling and Simulation of Sharp Creases

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1. Introduction

A sharp crease is a unique behavior of a pressed cloth that reveals a fabric specific combination of elasticity and plasticity. It creates a stiff column like ridge along the crease direction, revealing straight lines and breaks. Previous work addressed the wrinkles and creases by manipulating the bending resistance [1,3]. This paper presents a new technique for the realistic animation of sharp creases using a set of hard angle constraints and the implicit constraint scheme for stable and effective constraint enforcement over a large time step.

2. Method and Implementation

Modeling the sharp creases by exploiting only the bending or flexural resistance could be insufficient since it shows complex combination of stiff and soft behavior when it makes an angled ridge or crumples to form breaks. Our model utilizes bending resistances combined with implicit hard constraints activated as necessary to correctly simulate the intricate behavior. To model the resistance to the flapping direction (red), a flapping angle constraint is applied only when the angle goes beyond a threshold. Initially soft bending springs are used in the flapping direction until it reaches a pre-determined critical point where it is replaced with a hard constraint to simulate the preserved apex acute angle.

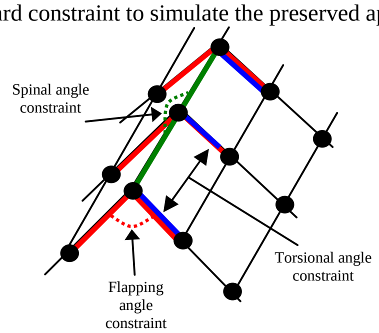

Figure 1: Three constraints for a sharp crease

A spinal angular constraint is applied along the ridge direction (green). The spinal angular constraint involves three nodes and it is set at the beginning to simulate the column like stiff behavior along the ridge. Finally, to simulate the torsional rigidity that prevents twisting between rows of flapping angular constraints, additional torsional angular constraints are used (blue). The neighboring flat area is modeled with relatively strong bending springs. This is to simulate the paper-like flat behavior that tries to maintain the planar configuration while guaranteeing the effortless flapping. The above three angular constraints have their own limit in terms of the amount of constraint forces that they can withstand. If the constraint force grows beyond a pre-defined threshold, the constraints are released to simulate the effect of breaking ridges and buckling. Deactivation of constraints is equally important as timely activation since it may introduce unnecessary stiff behavior. For a flapping angular constraint, we use relative velocities and constraint force directions to determine the condition of the constraint release. The constraint is released immediately when the node is moving toward the folding direction and activated when the angle becomes close to flat.

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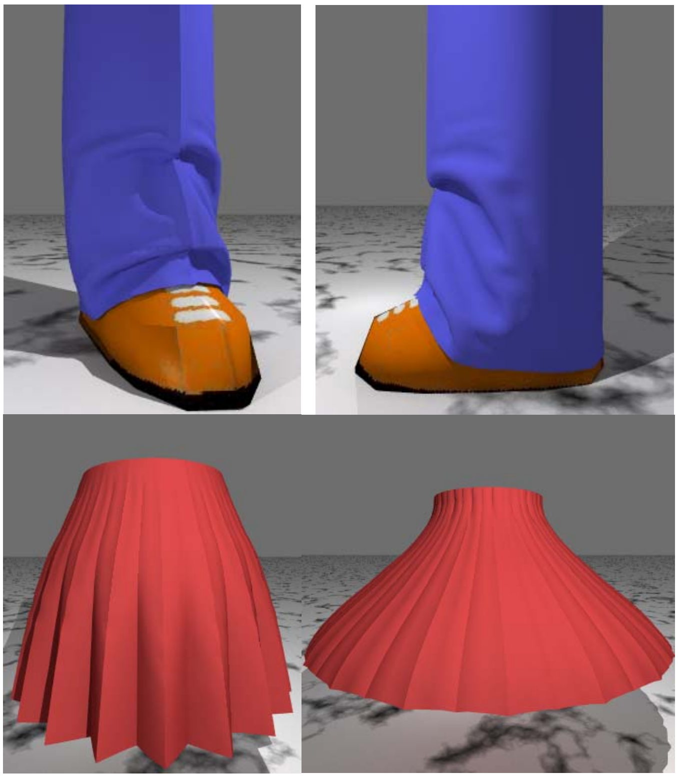

Figure 2: Simulated sharp creases in pants and a skirt

The spinal and torsional constraints are released when the amount of constraint forces are increased to their predefined threshold. Unlike the flapping angular constraint, these two constraints remain unconstrained after the break. The formulation of angular constraint is straightforward. The two unit vectors $\boldsymbol{v_1}$ $\boldsymbol{v_2}$ from two edges form an angle $\boldsymbol{\theta}$ and the constraint is represented as $\boldsymbol{\Phi = v_1 \cdot v_2 - \cos\theta = 0}$.

Constraint forces are computed within the Lagrange multipliers framework. Lagrange multipliers, used in conjunction with the ODE system, often don't converge to the solution instantly and quite often demonstrate overshoot or oscillations. Baumgarte addressed the problem by employing a second order stabilization. We used implicit constraint enforcement [2] that converges quickly, and doesn't require additional computational load. The pants simulation involves 6,400 nodes and 12,640 triangles with approximately 652 constraints (time varying) and the frame rate on a 2GHz PC was about 0.2 sec per frame.

References

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