Simulating Cloth

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Cloth simulation overview

- Problem of interest
- Applications
- Challenges
  - Forces
  - Deformation
- “Large Steps in Cloth Simulation”

[Baraff and Witkin 1998]
Forces and stiffness matrices

- Cloth Forces
  - Stretch
  - Shear
  - Bend
- Bend Formula
- Force Derivatives

[Baraff and Witkin 1998]

\[
\begin{align*}
\cos \theta &= n^A \cdot n^B \\
\sin \theta &= (n^A \times n^B) \cdot e \\
C &= \theta = \arctan \frac{\sin \theta}{\cos \theta}
\end{align*}
\]
Timestepping the forces

Explicit

\[
\begin{pmatrix}
\Delta x \\
\Delta v
\end{pmatrix}
= h
\begin{pmatrix}
v_0 \\
M^{-1}f_0
\end{pmatrix}
\]

- Fast
- Unstable with large timesteps

Implicit

\[
\left( I - hM^{-1}\frac{\partial f}{\partial v} - h^2M^{-1}\frac{\partial f}{\partial x} \right) \Delta v = hM^{-1}\left( f_0 + h\frac{\partial f}{\partial x}v_0 \right)
\]

- Must solve sparse linear system
- Can take large timesteps

[Baraff and Witkin 1998]
Challenges

• Complexity of Formulas
  – $3^{rd}$ order tensors
  – Large matrices

• Collapsing Triangles
  – Length of normal -> 0
  – Explosions
Results
<table>
<thead>
<tr>
<th>Model</th>
<th>Triangles</th>
<th>FPS</th>
<th>% Forces + Stiffness Matrix</th>
<th>% Solver</th>
</tr>
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<tbody>
<tr>
<td>Curtain</td>
<td>2400</td>
<td>25</td>
<td>67</td>
<td>33</td>
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Multithreading

Force and Stiffness Matrix Computation

Milliseconds

Number of Threads
Other considerations

• Damping Forces

• Collision Detection
  [Bridson et al. 2002]

• Code Optimizations
  [Govindaraju et al. 2005]