Simulating Cloth

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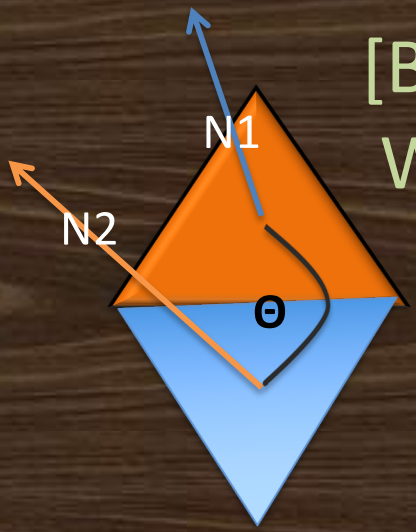
Cloth simulation overview

- 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]

$$\cos\theta = \mathbf{n}^A \cdot \mathbf{n}^B$$
$$\sin\theta = (\mathbf{n}^A \times \mathbf{n}^B) \cdot \mathbf{e}$$
$$C = \theta = \arctan\frac{\sin\theta}{\cos\theta}$$

Timestepping the forces

Explicit

$$\begin{pmatrix} \Delta\mathbf{x} \\ \Delta\mathbf{v} \end{pmatrix} = h \begin{pmatrix} \mathbf{v}_0 \\ \mathbf{M}^{-1}\mathbf{f}_0 \end{pmatrix}$$

- Fast
- Unstable with large timesteps

Implicit

$$\left(\mathbf{I} - h\mathbf{M}^{-1}\frac{\partial \mathbf{f}}{\partial \mathbf{v}} - h^2\mathbf{M}^{-1}\frac{\partial \mathbf{f}}{\partial \mathbf{x}}\right)\Delta\mathbf{v} = h\mathbf{M}^{-1}\left(\mathbf{f}_0 + h\frac{\partial \mathbf{f}}{\partial \mathbf{x}}\mathbf{v}_0\right)$$

- Must solve sparse linear system
- Can take large timesteps

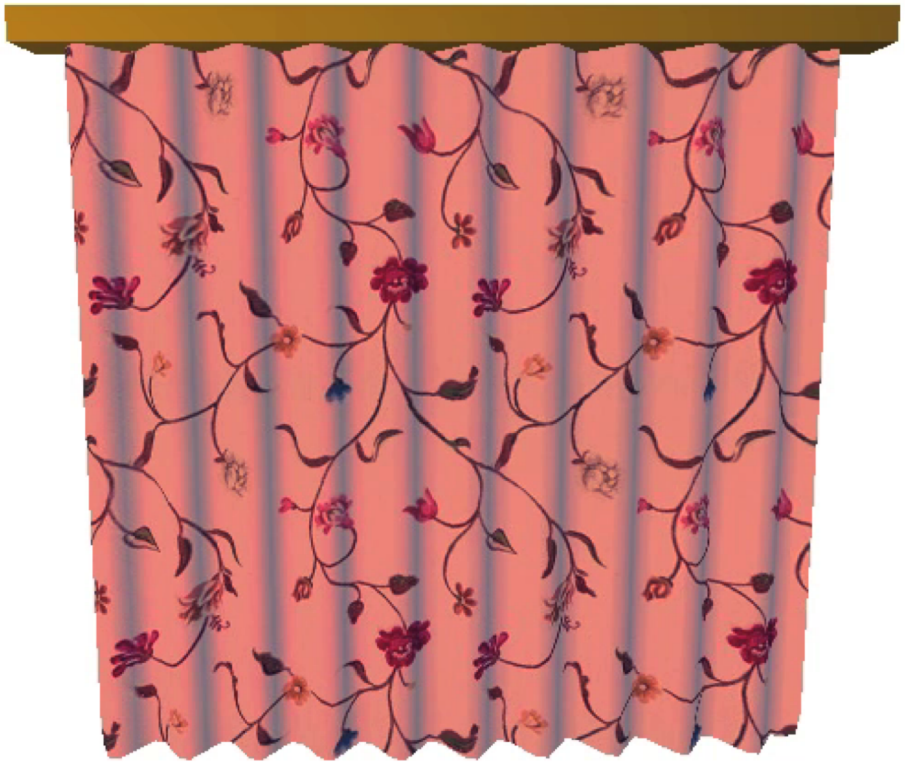
[Baraff and Witkin 1998]

Challenges

- Complexity of Formulas
  - 3rd order tensors
  - Large matrices
- Collapsing Triangles
  - Length of normal -> 0
  - Explosions

Results

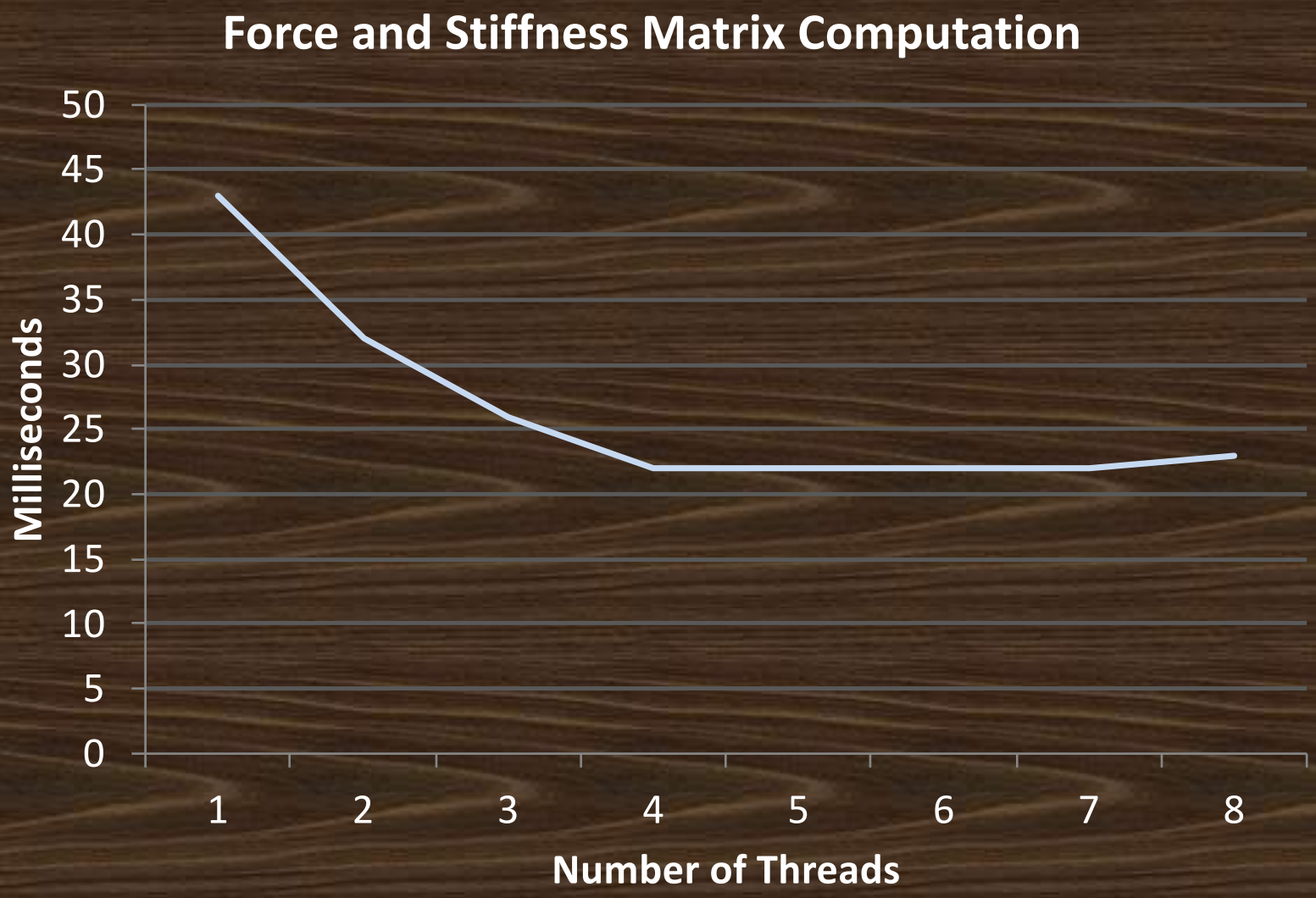
Model	Triangles	FPS	% Forces + Stiffness Matrix	% Solver
Curtain	2400	25	67	33



Model	Triangles	FPS	% Forces + Stiffness Matrix	% Solver
Curtain	2400	25	67	33

Model	Triangles	FPS	% Forces + Stiffness Matrix	% Solver
Skirt	4608	12	75	25

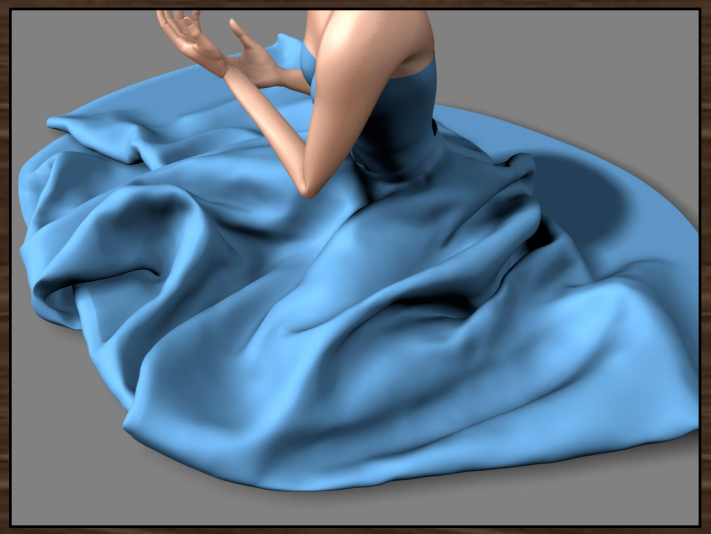
Multithreading



Other considerations

- Damping Forces
- Collision Detection

  [Bridson et al. 2002]
- Code Optimizations



[Govindaraju et al. 2005]