Adding Physics to Animated Characters with Oriented Particles

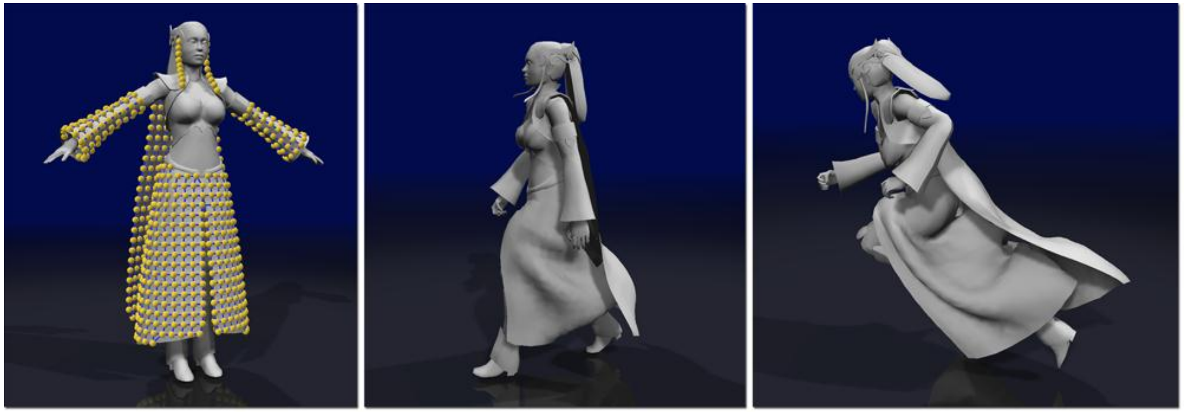
Matthias Müller   Nuttapong Chentanez

NVIDIA

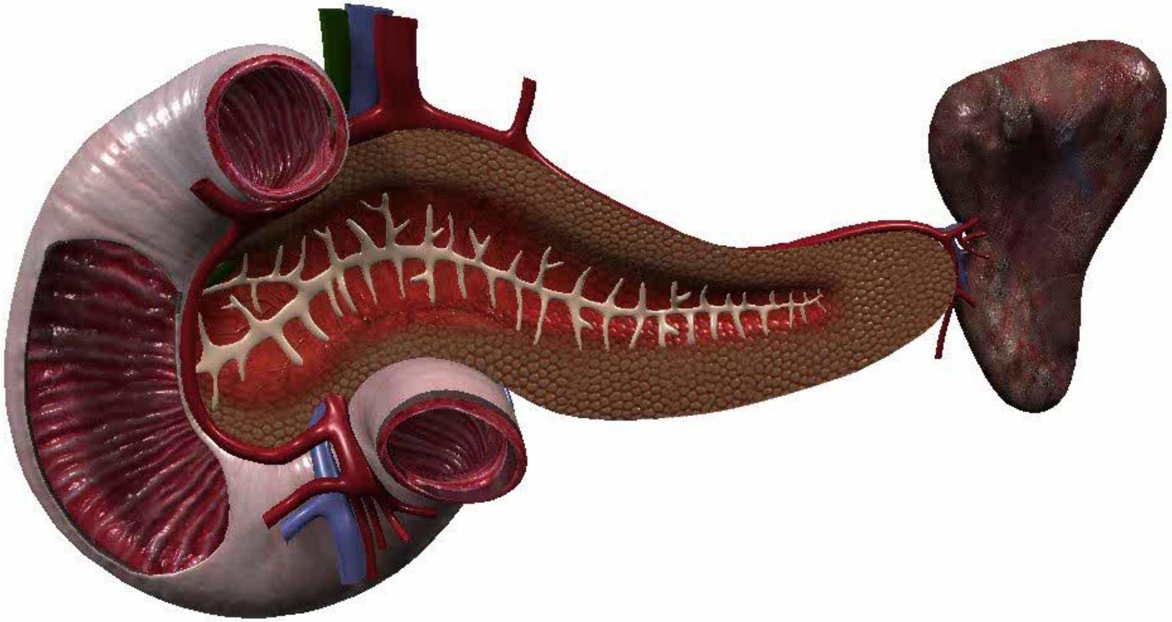
Motivation

- Solid Simulation with Oriented Particles
- Handles passive material

- How to combine it with animated characters?



Passive Simulation

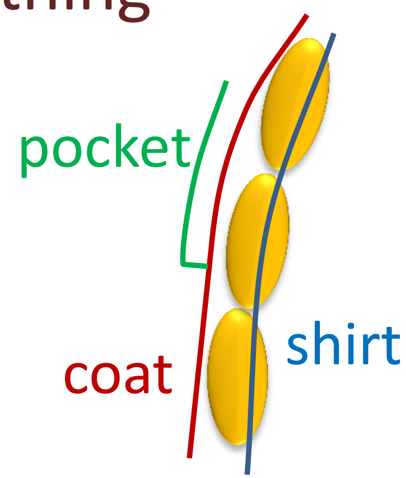


Animation Driven Simulation

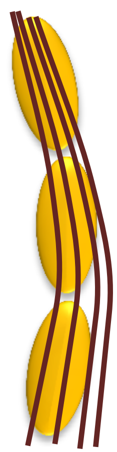
Key Features

- Oriented Particles allow robust skinning of complex geometry to physical representation.
- This allows the simulation of:

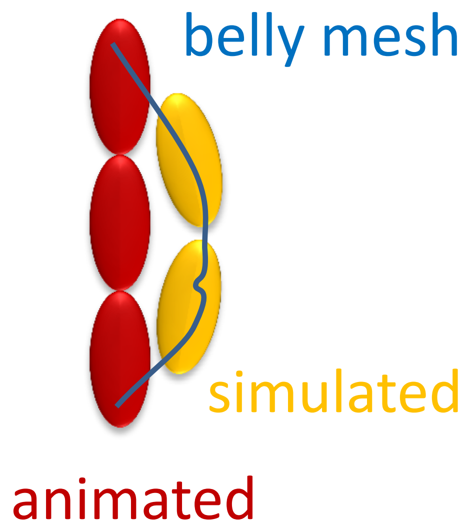
Multi-layered clothing



Hair



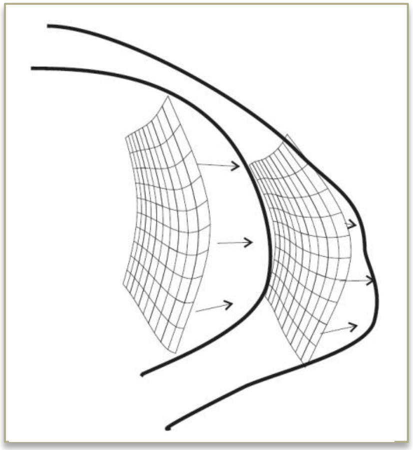
Deformable skin



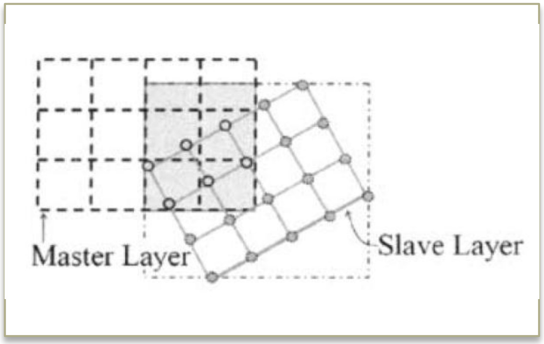
Related Work

Multi-Layered Clothing

- Visual mesh = simulation mesh
- Pull meshes towards iso-surfaces around bones [Pérez et al. 1999]

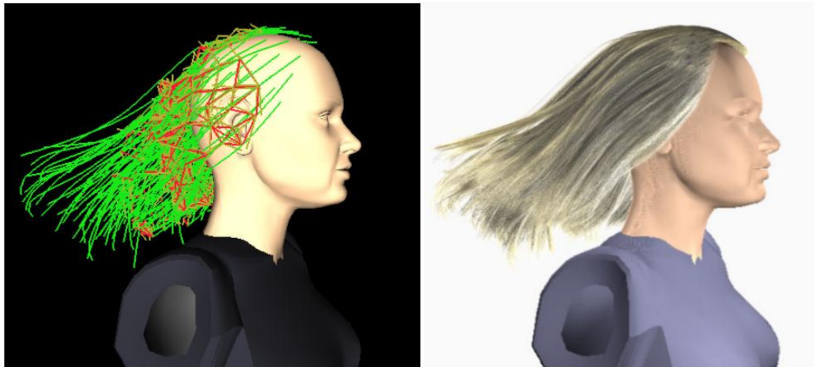


- Couple layers via barycentric interpolation [Wong et al. 2004]

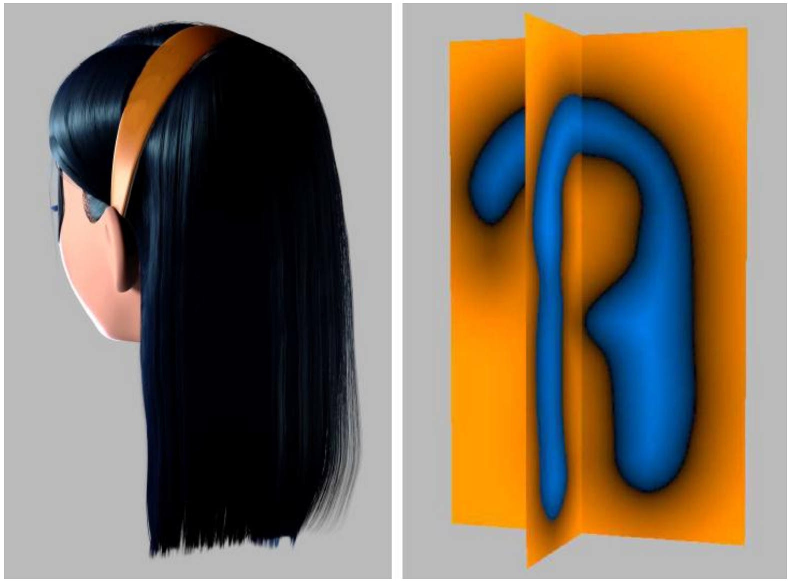


Hair

- Use key hairs, Interpolate other hairs [Chang et al. 2002]

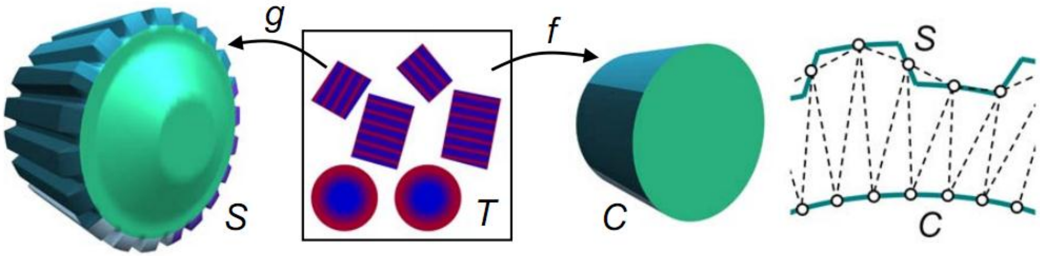


- Use regular background grid for hair interactions [Petrovic et al. 2005]

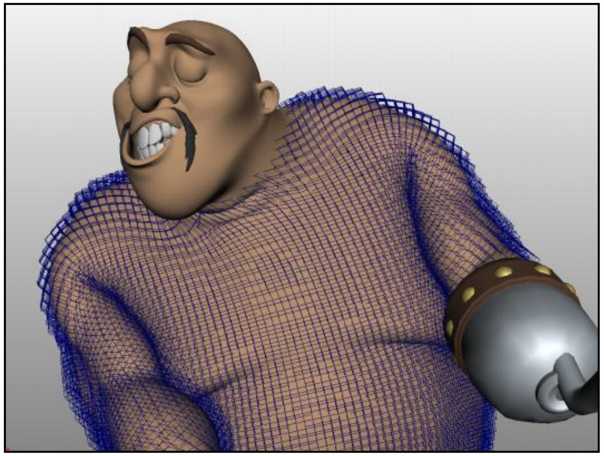


Deformable Skin

- Dynamic deformation texture [Galoppo 2008]

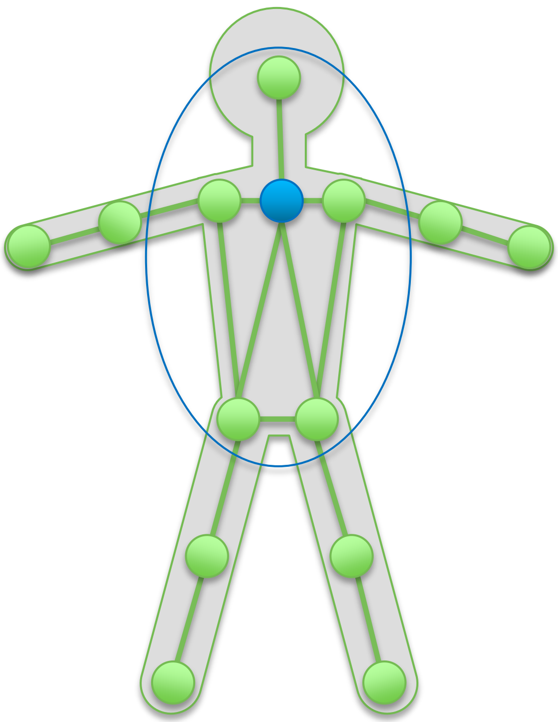


- Hexahedral simulation mesh. Interpolation of visual mesh [McAdams 2011]

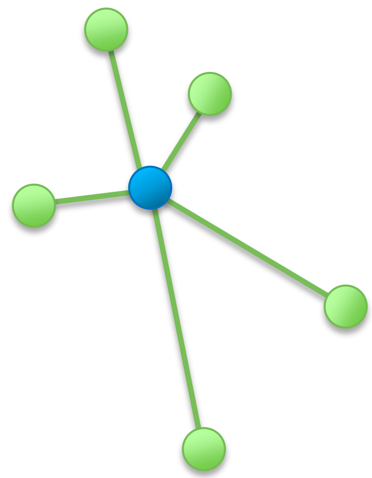


Oriented Particles Recap

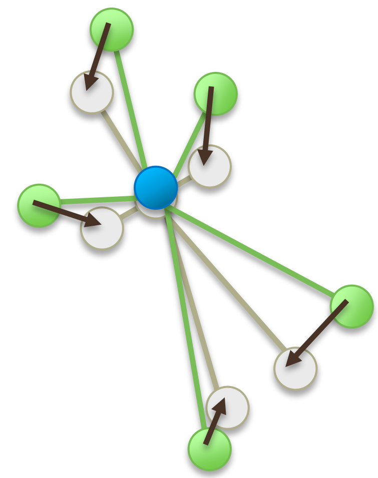
Simulation



One shape match constraint per particle



Deformed state



Move towards matched rest configuration

Orientation for Stabilization

- Orientation information stabilizes shape matching
- Rotation via polar decomposition of

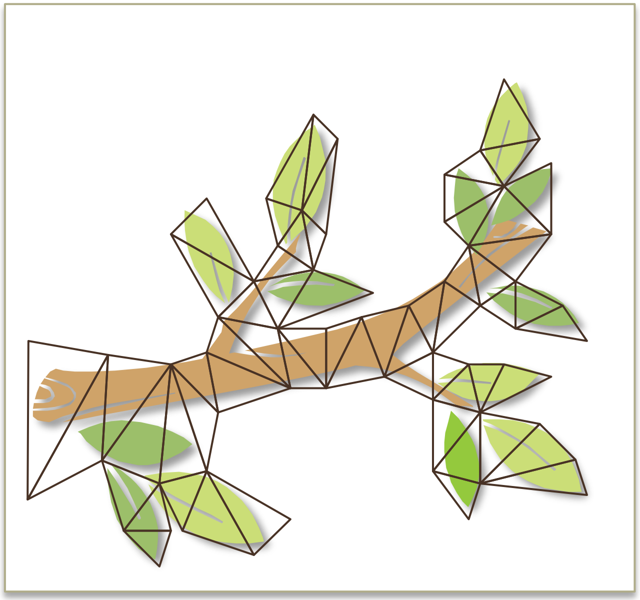
$$\mathbf{A} = \sum_i \left(m_i(\mathbf{x}_i - c)(\bar{\boldsymbol{x}}_i - \bar{\boldsymbol{c}})^T\right)$$

- Singular in sparse regions

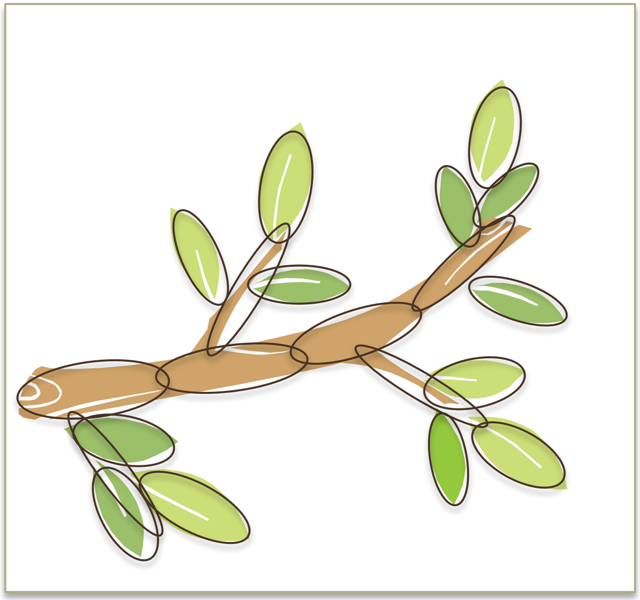
$$\mathbf{A} = \sum_i \left(\mathbf{A}_i + m_i(\mathbf{x}_i - c)(\bar{\boldsymbol{x}}_i - \bar{\boldsymbol{c}})^T\right)$$

- $\mathbf{A}_i$ derived from particle's orientation
- Non singular even for single particle

Orientation for Collision Volumes

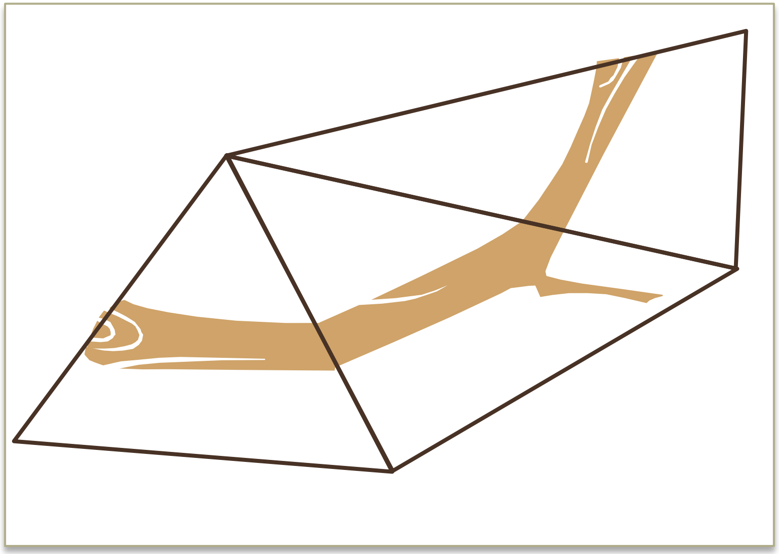


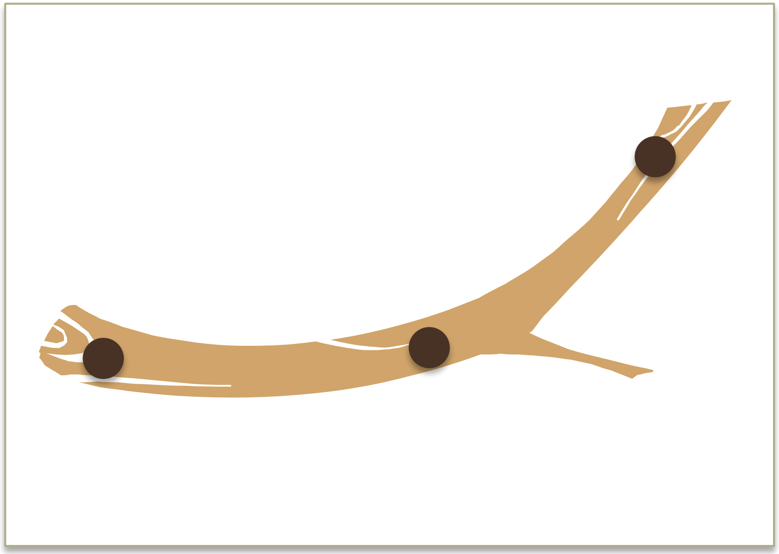
Traditional:
Volumetric mesh



Ellipsoids

Orientations for Skinning



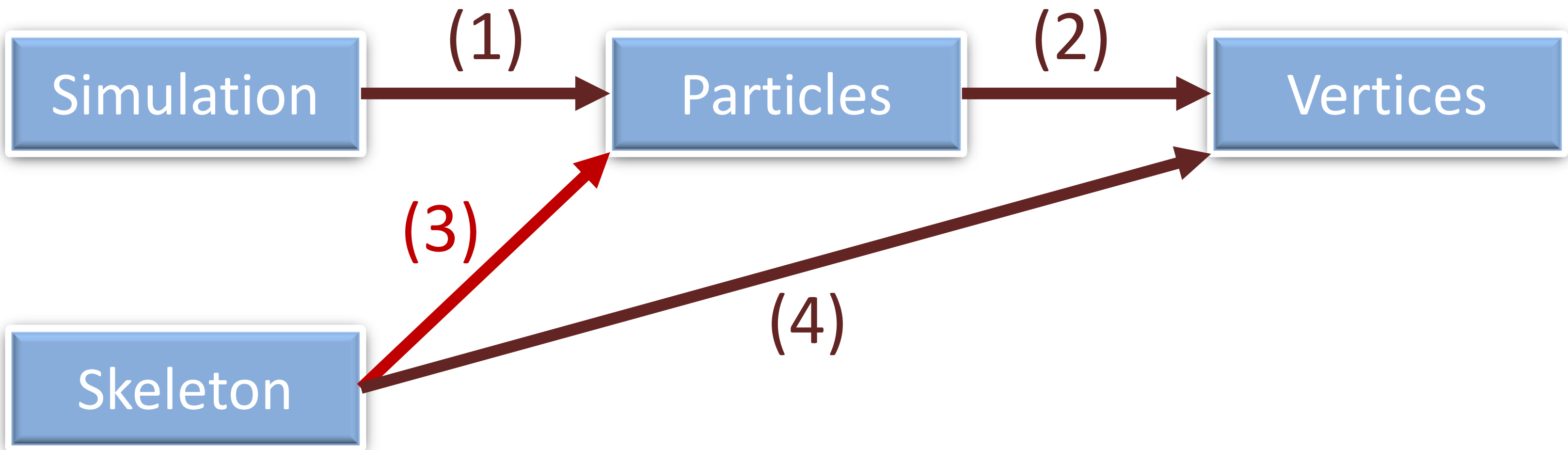


- Barycentric interpolation w.r.t. surrounding tetrahedron
- Piecewise linear

- Linear blend skinning w.r.t. k closest oriented particles
- Curved

Method

Two-Way Skinning



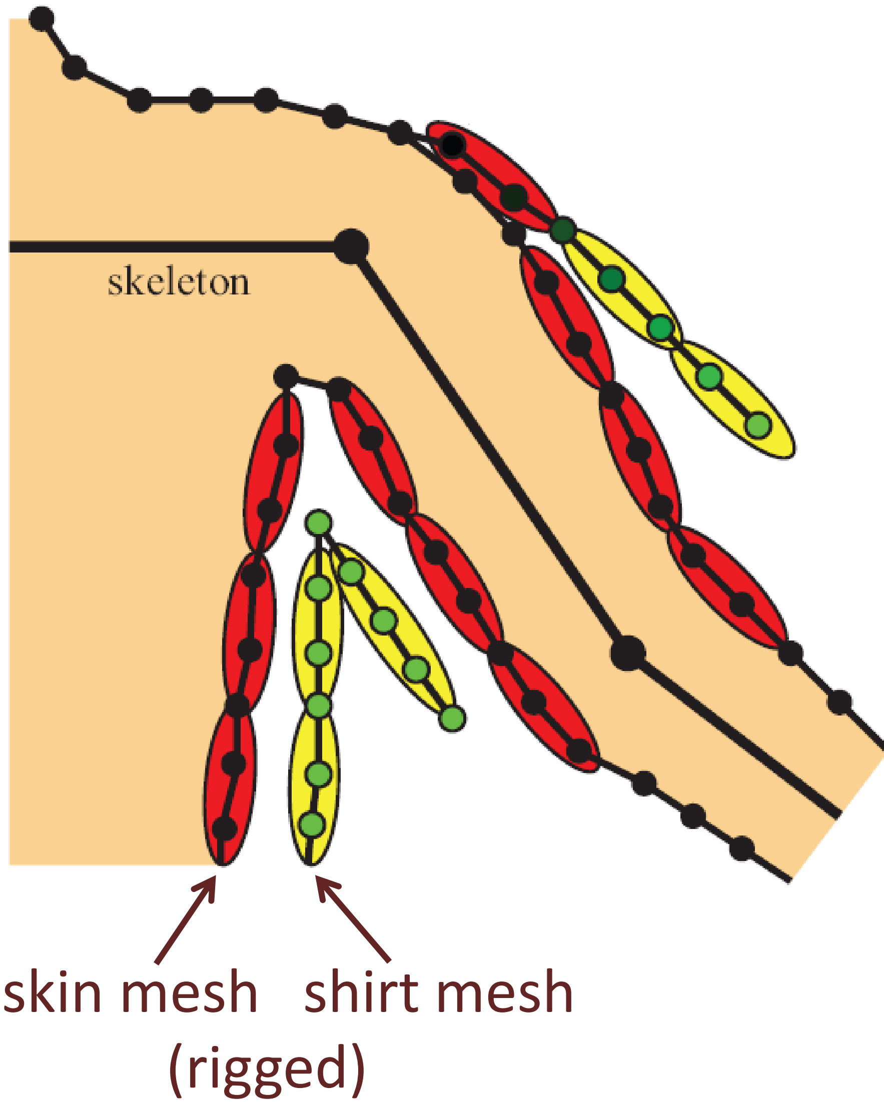
Particles driven by simulation

Vertex – particle skinning

Skeleton animates particles (new)

Skeleton animates vertices (rigged mesh)

Example



Simulated particle

Animated particle

Vertex skinned to skeleton

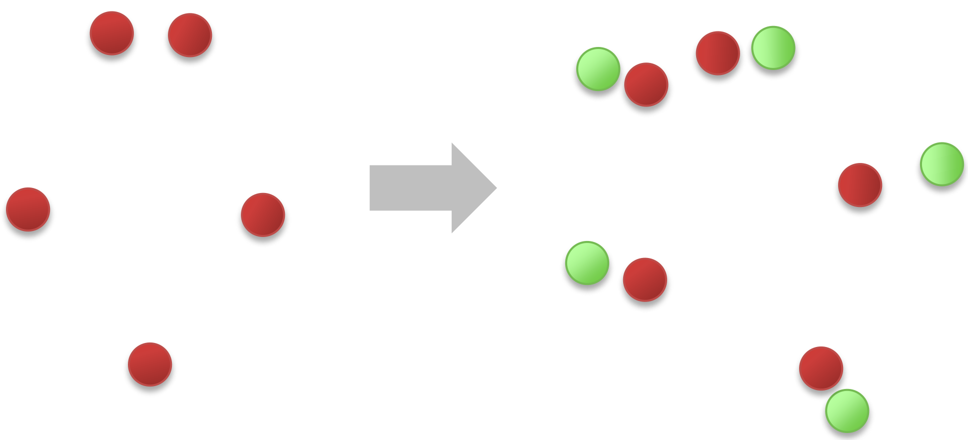
Vertex mixed skinning

Vertex skinned to particles

Momentum Conserving Skinning

- A creature cannot change its center of mass
  (or the center of mass of itself and the object it interacts with)

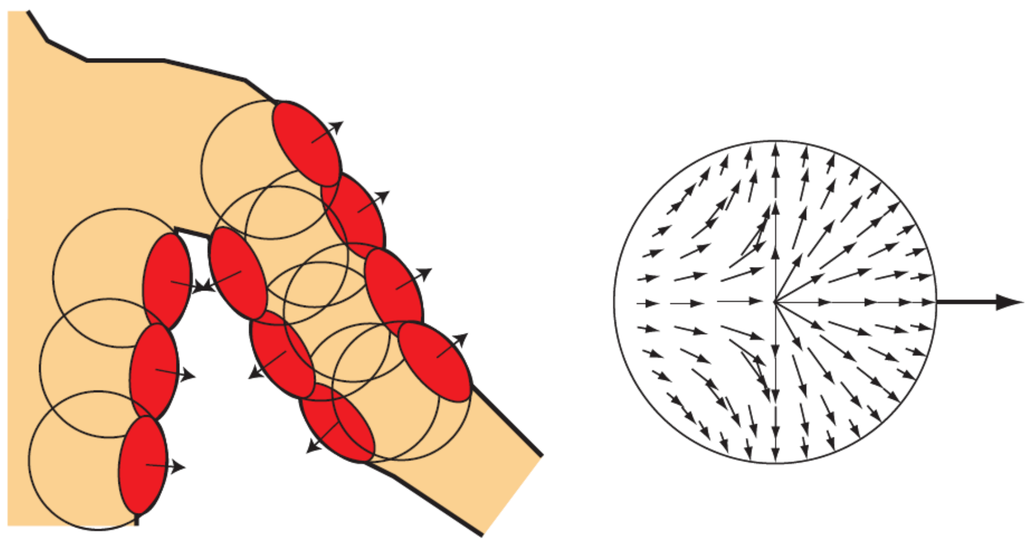
- Fit animated with current particle positions (shape matching)



Baron Münchhausen

Stabilization of Collision Handling

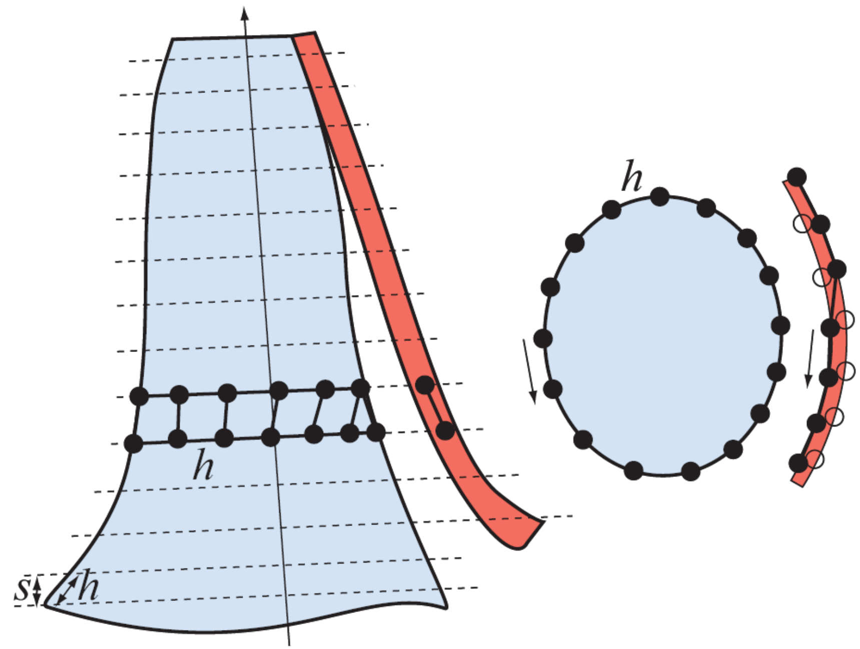
- High ellipsoid aspect ration → flat surface
- But thin collision layer!



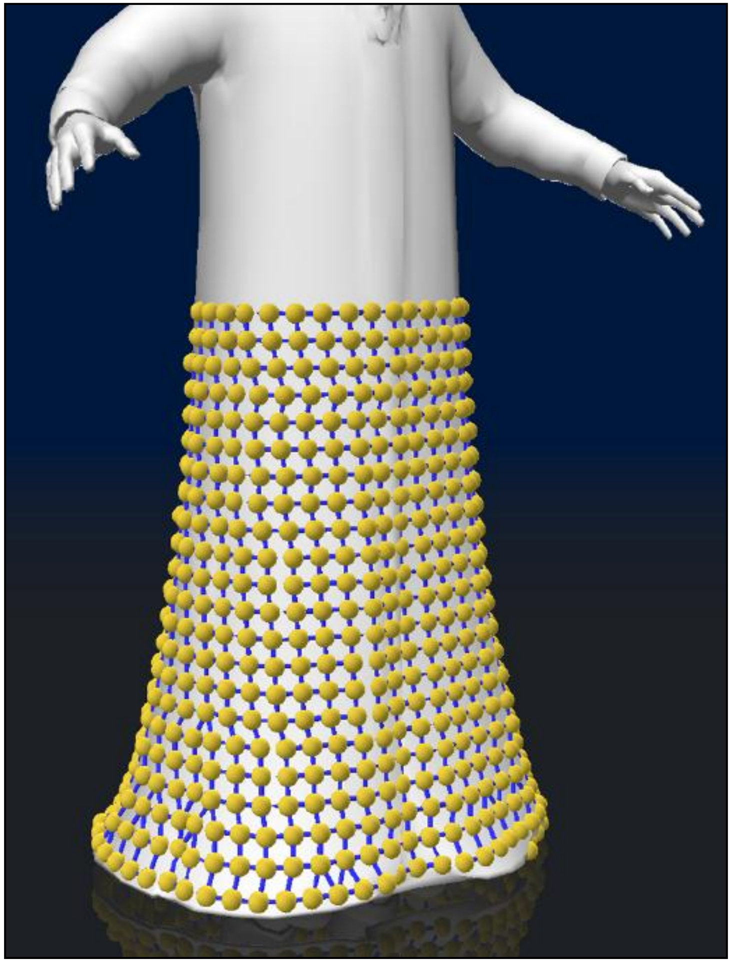
- Surface particles
  - use enveloping spheres for collision detection
  - project in the direction of outward normal

Mesh Generation

- Optimal for clothing:
  – regular quad mesh
- Auto creation for arbitrary geometry:
  – Determine main axis
  – Series of cut planes perpendicular to axis
  – Place vertices evenly along cut lines
  – Only if no close vertices already exist



Mesh Examples



Results

Fast Motion

700 particles, 7k triangles, 90 fps

Girl With Cape

1400 particles, 12k triangles, 40 fps

Momentum Conserving Monster

130 particles, 40k triangles, 240 fps

Thick Cloth

780 particles, 7k triangles, 60 fps

Hair

220 particles, 17k triangles, 300 fps

Thank you for your attention!