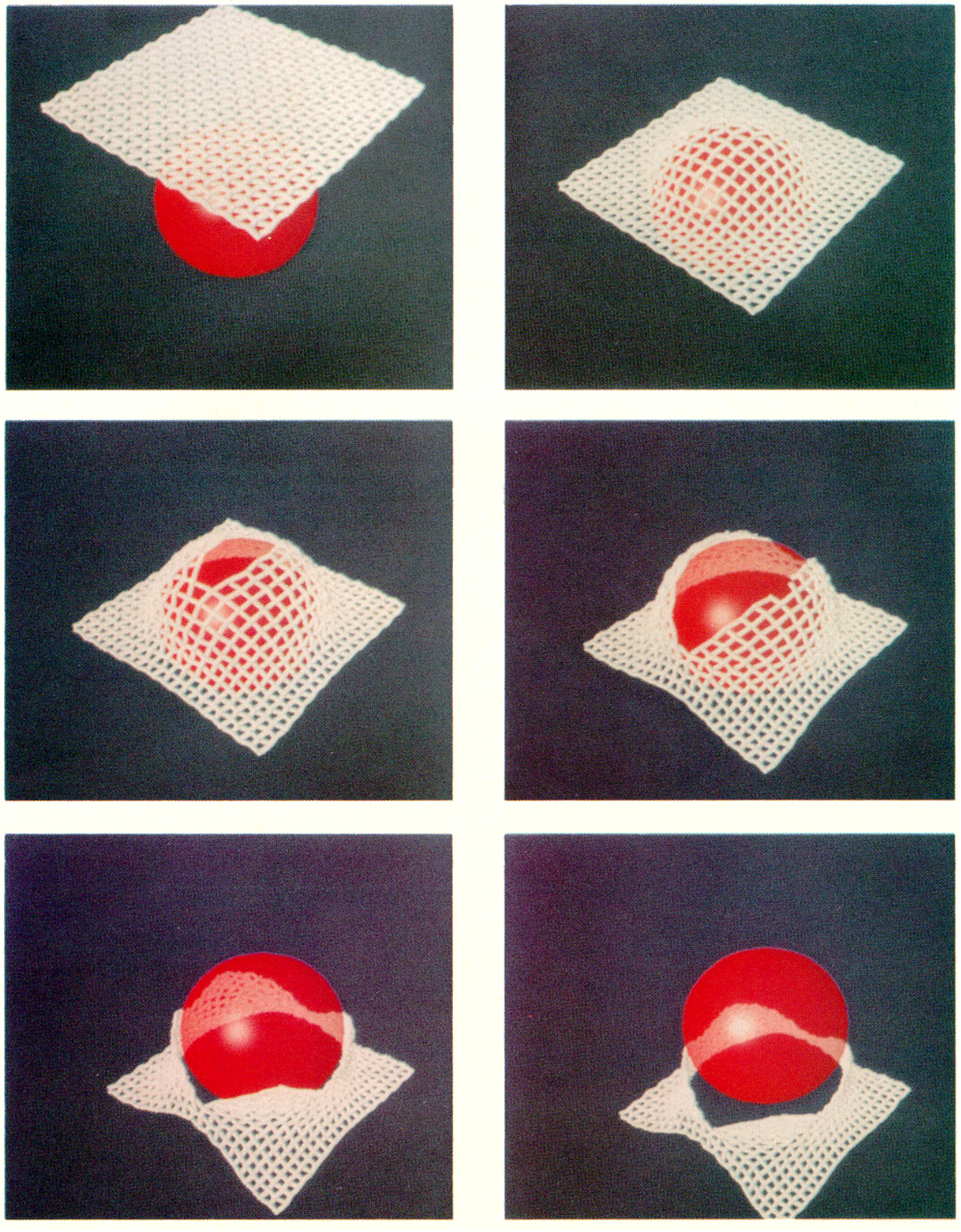
Further topics in modeling dynamics of solids

- Topics for presentation - you may choose any of the papers cited, to present next week!
  - Email the instructor directly (or post your preference on Piazza) to claim a slot, Monday (Nov 4), Wednesday (Nov 6) or Friday (Nov 8).
- Aim for a 20-min presentation (15 min on slides/ video, plus 5 min for questions)
- PowerPoint or Keynote (plan on having slides ready 24hrs prior to presentation)
- The instructor will pad the schedule with topics not presented by students

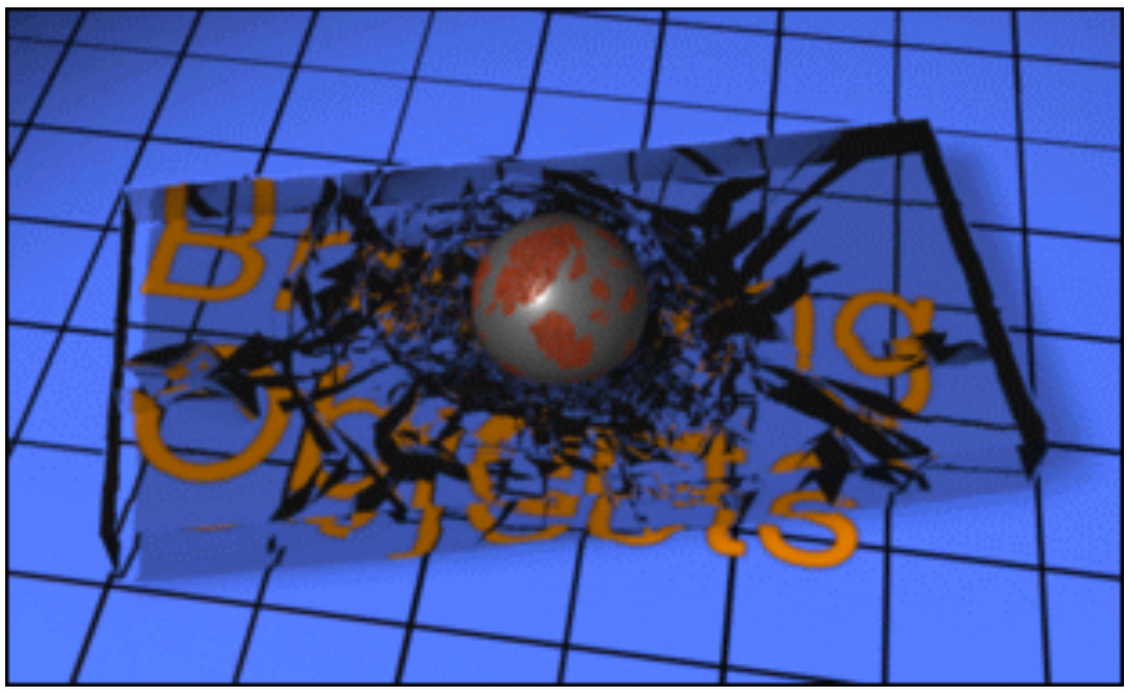
Fracture

- Terzopoulos & Fleischer, "Modeling Inelastic Deformation, Viscoelasticity, Plasticity, Fracture", SIGGRAPH 1988
- Part of pioneering early papers introducing deformable objects in computer graphics
- Modeled cloth elasticity using finite differences
- Fracture performed by breaking mesh edges when they would exceed a stretch threshold



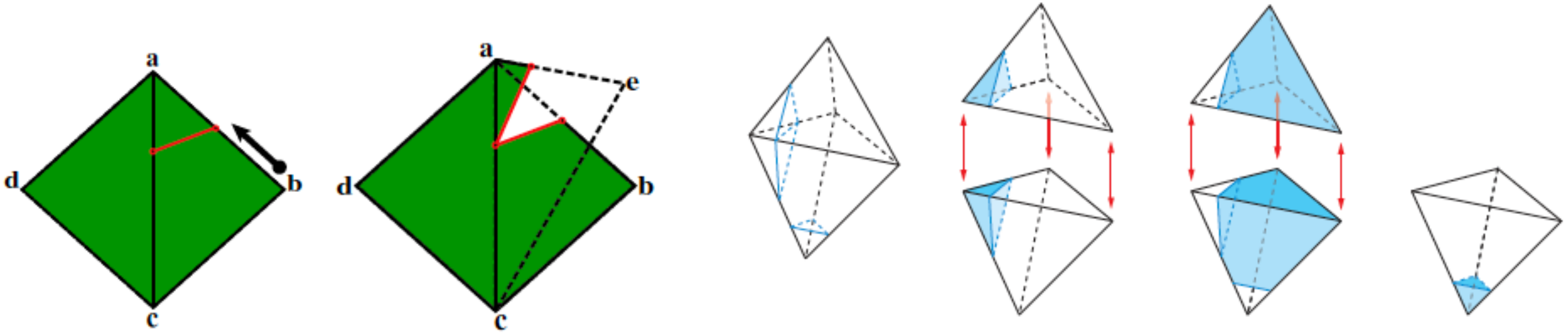
Fracture

- O'Brien & Hodgins. "Graphical Modeling and Animation of Brittle Fracture". SIGGRAPH 1999.
- One of the first uses of Finite Element Discretization for Computer Graphics Applications
- Modeled "rigid" fracture, in the sense that fragments were not allowed to sustain large deformation while cracks formed and propagated.
- Geometry subject to continuous local remeshing as cracks evolved.



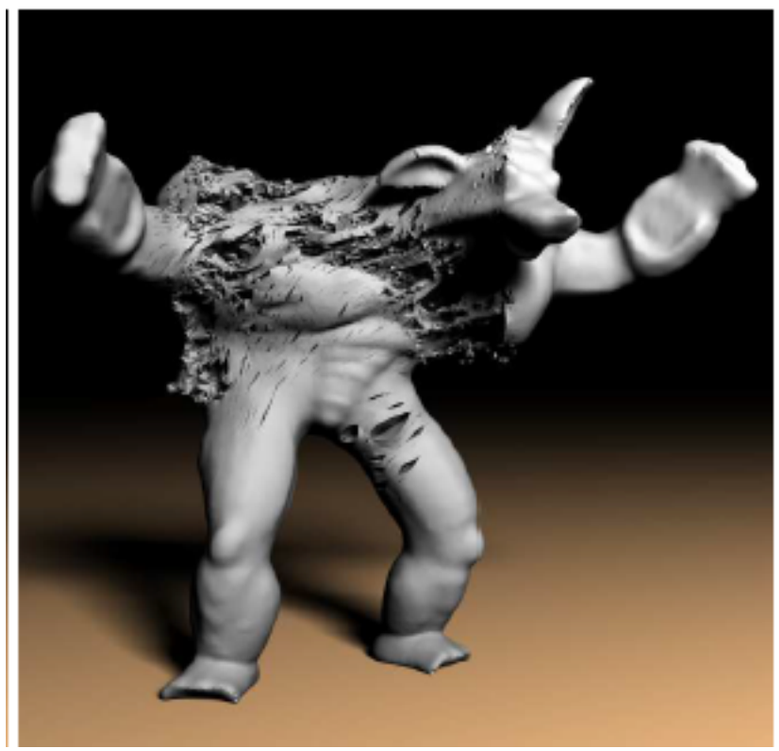
Fracture

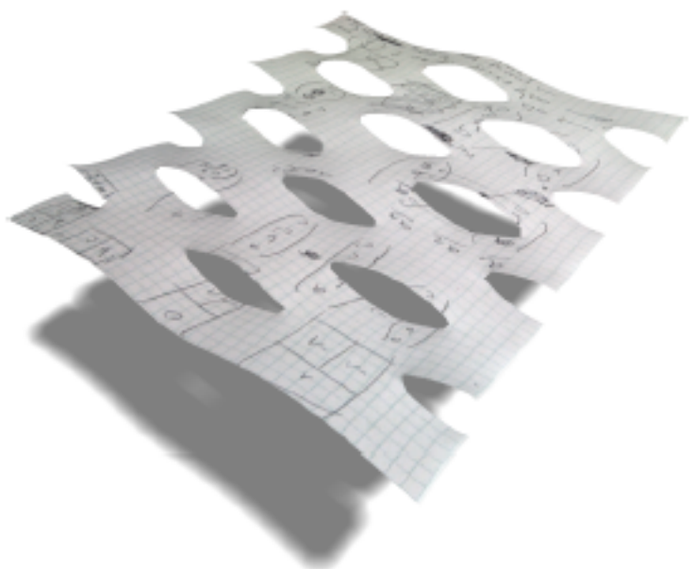
- "Virtual-Node Methods"
  - Avoid remeshing by simulating elements as half-full (or half-empty) and embedding cracks into duplicates of original mesh

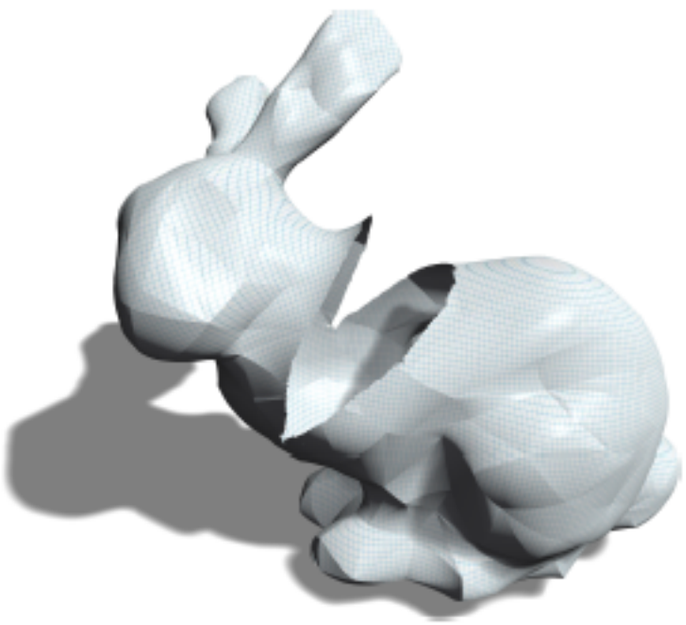


Fracture

- "Virtual-Node Methods"
  - Molino et al, "A Virtual Node Algorithm for Changing Mesh Topology During Simulation", SIGGRAPH 2004
  - Sifakis et al, "Arbitrary Cutting of Deformable Tetrahedralized Objects", SCA 2007
  - Kaufmann et al, "Enrichment Textures for Detailed Cutting of Shells", SIGGRAPH 2009 [YouTube]





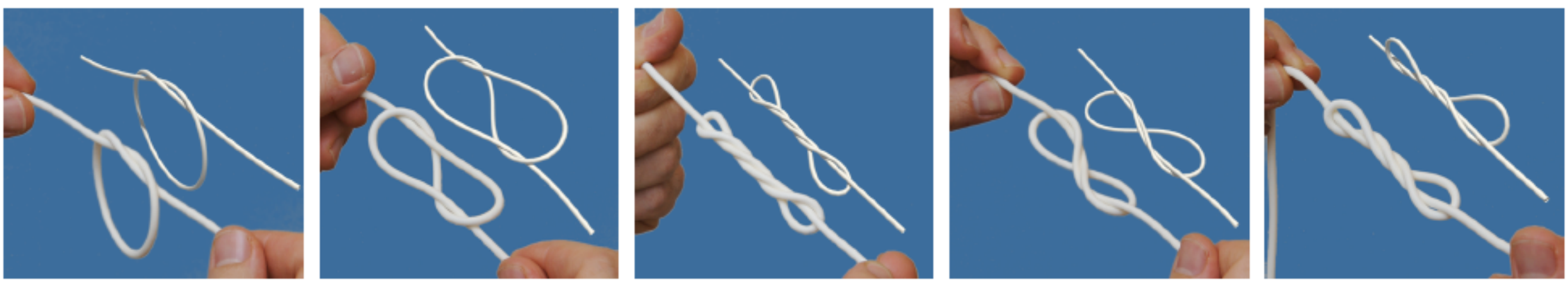


Fracture

- Real-time fracture
  - Parker & O'Brien, "Real-time deformation and fracture in a game environment", SCA 2009 [YouTube]
  - Mueller et al, "Real time dynamic fracture with volumetric approximate convex decompositions", SIGGRAPH 2013 [YouTube]
- Boundary element & boundary integral methods
  - Zhu et al, "Simulating Rigid Body Fracture with Surface Meshes", SIGGRAPH 2015 [Vimeo]
  - Hahn & Wojtan, "High-resolution brittle fracture with boundary elements", SIGGRAPH 2015 [YouTube]

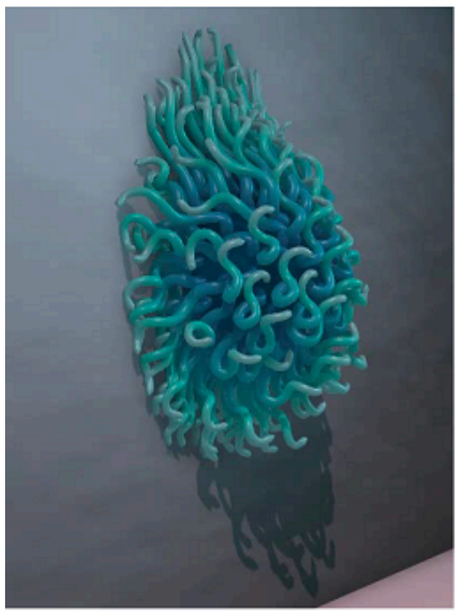
Strands, elastic rods, and hair

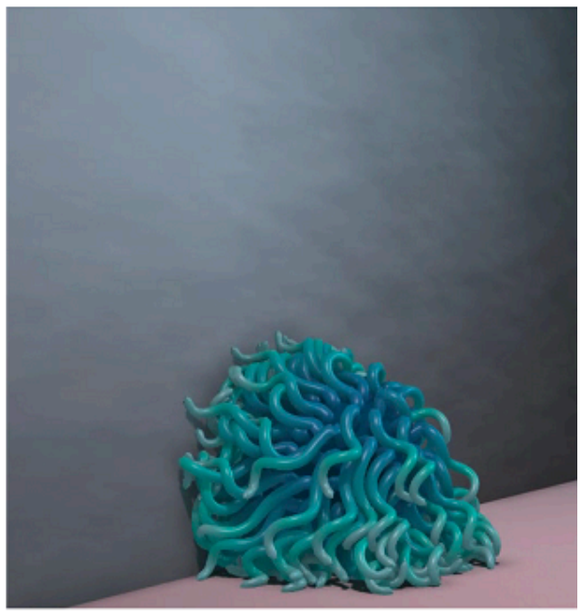
- Discretization of twist/torsion response
  - Pai, "STRANDS: Interactive Simulation of Thin Solids using Cosserat Models", Eurographics 2002
  - Bergou et al, "Discrete Elastic Rods", SIGGRAPH 2008
- Discretization of wire positions supplemented with a representation of a *coordinate system*, which is allowed to twist/rotate by different amounts throughout the length of the wire, to capture torsion



Strands, elastic rods, and hair

- Position-based formulations (for interactive applications)
  - Umetani et al, "Position Based Elastic Rods", SCA 2014 [YouTube]
- Extensions to strands of viscous fluids
  - Bergou et al, "Discrete Viscous Threads", SIGGRAPH 2010



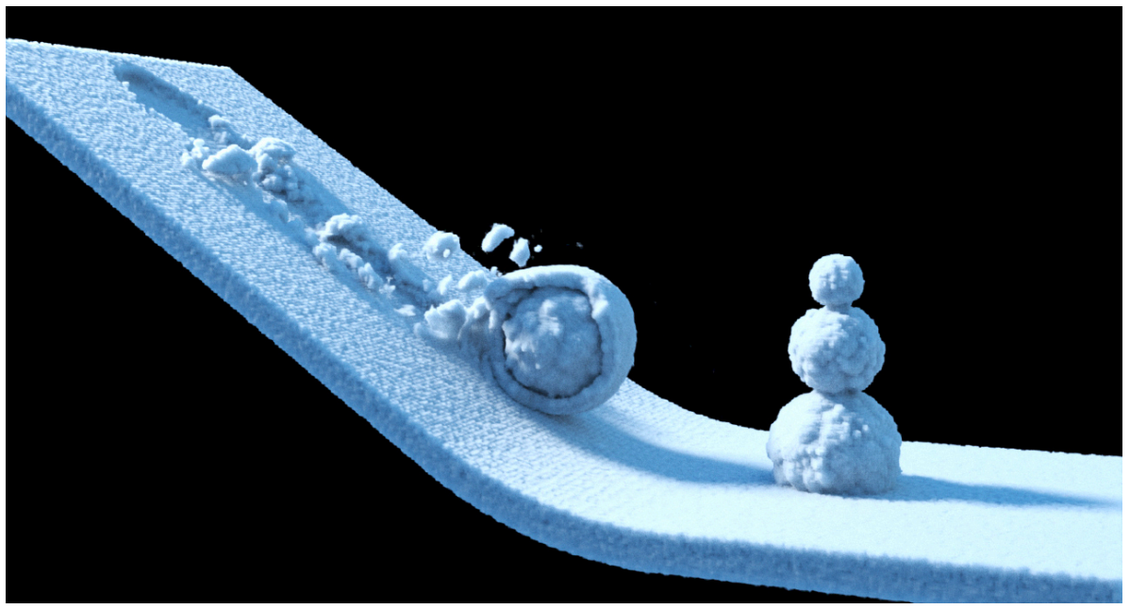


Strands, elastic rods, and hair

- Extensions to hair (esp. curly hair)
  - Bertails et al, "Super-Helices for Predicting the Dynamics of Natural Hair", SIGGRAPH 2006
  - Selle et al, "A Mass-Spring model for Hair Simulation", SIGGRAPH'08
- Hair Collisions
  - McAdams et al, "Detail Preserving Continuum Simulation of Straight Hair", SIGGRAPH'09 [Vimeo]
- Daviet et al, "A hybrid iterative solver for robustly capturing Coulomb Friction in hair dynamics", SIGGRAPH Asia'11

Material Point Method

- Hybrid method, using particles as primary representations of physical properties, and a background grid as a "scratchpad" for computing elastic/plastic forces.
- Easily accommodates topological changes in the simulation
- Introduced for Snow simulation in "Frozen"
- Extended to many phenomena, including melting, cloth, sand, foam, etc.



Material Point Method

- *Snow:* Stomakhin et al, "A Material Point Method for Snow Simulation", SIGGRAPH 2013
- *Melting:* Stomakhin et al, "Augmented MPM for phase-change and varied materials", SIGGRAPH 2014
- *Sand:* Klar et al, "Drucker-Prager Elastoplasticity for Sand Animation", SIGGRAPH 2016
- *Cloth/Hair:* Jiang et al, "Anisotropic Elastoplasticity for Cloth, Knit and Hair Frictional Contact", SIGGRAPH 2017
- *Mixtures:* Pradhana et al, "Multi-species Simulation of Porous Sand and Water Mixtures", SIGGRAPH 2017