

Rigid Body Dynamics, Fracture, & Deformation

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Last Time?

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Today

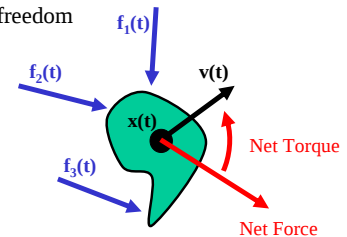
- **Rigid Body Dynamics**
- Finite Element Method
- Deformation
- Fracture

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Rigid Body Dynamics

- Could use particles for all points on the object
 - But rigid body does not deform
 - Few degrees of freedom

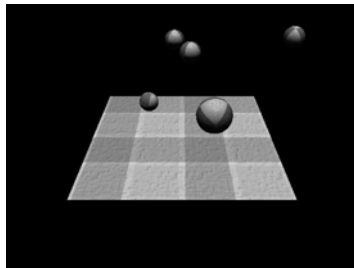
- Use only one particle at the center of mass
- Compute Net Force & Net Torque



Nice Reference Material: <http://www.pixar.com/companyinfo/research/pbm2001/>

Rigid Body Dynamics

- Physics
 - Velocity
 - Acceleration
 - Angular Momentum
- Collisions
- Friction



from: Darren Lewis

<http://www-cs-students.stanford.edu/~dalewis/cs448a/rigidbody.html>

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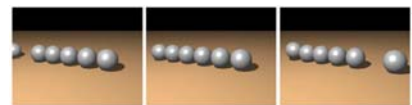
Collisions

Victor J. Milenkovic & Harald Schmidl
Optimization-Based Animation
SIGGRAPH 2001

- We know how to simulate bouncing really well
- But resting collisions are hard to manage



Guendelman, Bridson & Fedkiw
Nonconvex Rigid Bodies with Stacking
SIGGRAPH 2003



Questions?

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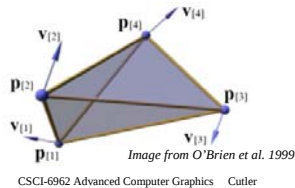
Today

- Rigid Body Dynamics
- **Finite Element Method**
- **Deformation**
- Fracture

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Simulation of Non-Rigid Objects

- We modeled string & cloth using mass-spring systems. Can we do the same?
- Yes...
- But a more physically accurate model uses *volumetric elements*:



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Finite Element Method

- To solve the continuous problem (deformation of all points of the object)
 - Discretize the problem
 - Express the interrelationship
 - Solve a big linear system
- More principled than Mass-Spring

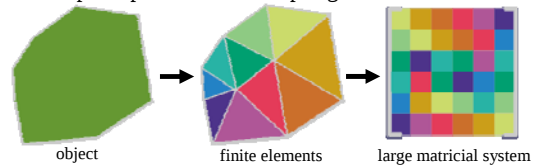
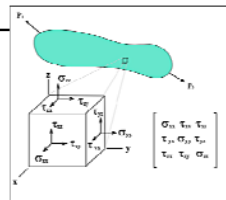


Diagram from Debunne et al. 2001

Strain & Stress

- **Stress**
 - the internal distribution of forces within a body that balance and react to the loads applied to it
 - *normal stress & shear stress*
- **Strain**
 - material deformation caused by stress.
 - measured by the change in length of a line or by the change in angle between two lines

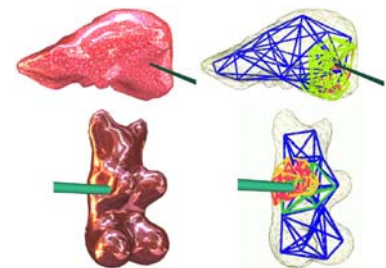


http://en.wikipedia.org/wiki/Image:Stress_tensor.png

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Level of Detail

- Interactive shape deformation
- Use high-resolution model only in areas of extreme deformation

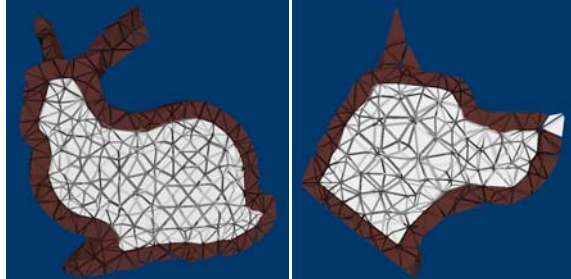


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Gilles Debunne, Mathieu Desbrun, Marie-Paule Cani, & Alan H. Barr
Dynamic Real-Time Deformations using Space & Time Adaptive Sampling
 SIGGRAPH 2001

Multiple Materials

Mueller, Dorsey, McMillan,
Jagnow, & Cutler
Stable Real-Time Deformations
Symposium on Computer
Animation 2002



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Tree Stump



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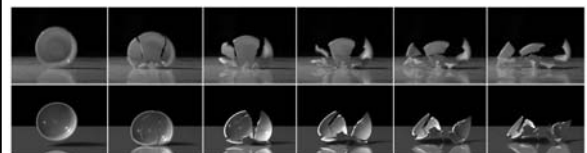
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- **Fracture**

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Fracture

James O'Brien & Jessica Hodgins
*Graphical Modeling and
Animation of Brittle Fracture*
SIGGRAPH 1999

- Fracture threshold
 - Remeshing
 - Material properties
 - Parameter tuning
- need connectivity info!



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Fracture Opening Modes

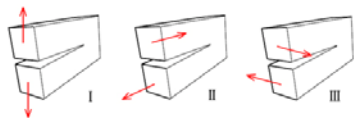


Figure 6: Three loading modes that can be experienced by a crack. Mode I: Opening, Mode II: In-Plane Shear, and Mode III: Out-of-Plane Shear. Adapted from Anderson [1].

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Fracture Propagation

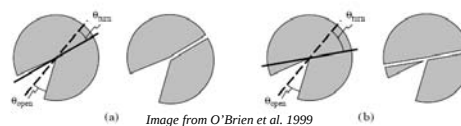
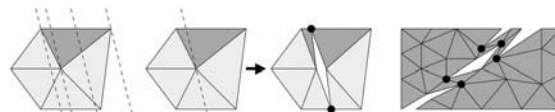
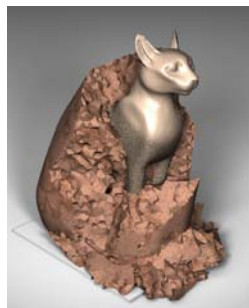
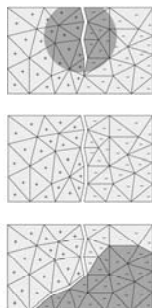


Image from O'Brien et al. 1999



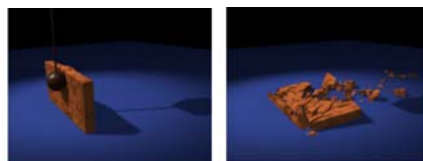
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Fracture Propagation

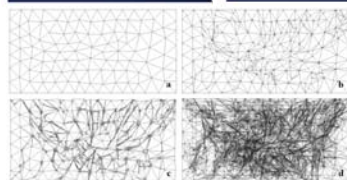


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Local Mesh Refinement

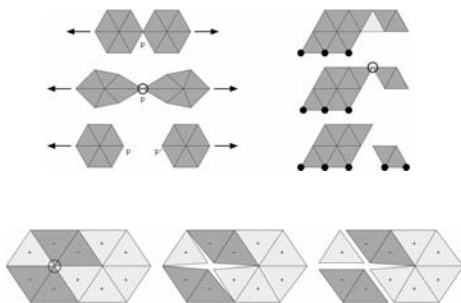


Images from O'Brien et al. 1999



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Managing Fracture Adjacency



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