• Related Graphics Research
  – dynamic simulations
  – optimizations & satisfying constraints
  – interactive vs. offline
  – high vs. low resolution models
  – procedural modeling
  – surface vs. volume representations
• Where does our problem fit?
  – Which aspects are most important?
  – Which things can be approximated or eliminated?

Warning…
• Lots of stuff
  – Took many people, many years to do
  – I won’t explain (don’t know) all the details
• Random sampling of SIGGRAPH
  – Not an exhaustive list
  – I may have missed some obviously more relevant citations… sorry!
• Interruptions encouraged!
  – Ask questions, make comments

Rigid Body Dynamics
• Physics
  – Velocity
  – Acceleration
  – Angular Momentum
• Collisions
• Friction

Particle Systems
Based on: Dorsey, Peterson & Hanrahan
Flow and Changes in Appearance
SIGGRAPH 1999
Images from:
Cutler, Dorsey, McMillan, Mueller & Jagnow
A Procedural Approach to Authoring Solid Models
SIGGRAPH 2002

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

• Fracture threshold
• Remeshing
• Material properties
• Parameter tuning
Collisions

- 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

Cloth

- Dynamic motion driven by animation

David Baraff & Andrew Witkin
Large Steps in Cloth Simulation
SIGGRAPH 1998

Collisions

Robert Bridson, Ronald Fedkiw & John Anderson
Robust Treatment of Collisions, Contact and Friction for Cloth Animation
SIGGRAPH 2002

• Approx 1 day to simulate (most time for collisions)

Simulations: Main Idea

- Engine: iterative solver
  - Euler, Runge-Kutta, implicit/explicit, ...
  - particle systems / finite element method
  - collision detection / response
  - fracture / deformation
- Input:
  - initial conditions
  - forces
- Output:
  - animation / dynamics, frame by frame positions
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Optimization

Bob Sumner & Jovan Popovic
Deformation Transfer for Triangle Meshes
SIGGRAPH 2004

Optimization

Bob Sumner & Jovan Popovic
Deformation Transfer for Triangle Meshes
SIGGRAPH 2004

Optimization

C. Karen Liu & Zoran Popovic
Synthesis of Complex Dynamic Character
Motion from Simple Animations
SIGGRAPH 2002

Optimization

Jeffrey Smith, Jessica Hodgins & Irving Oppenheim
Creating Models of Truss Structures with Optimization
SIGGRAPH 2002

apply local rotation & scale

apply global translation

adjust local deformation to maintain connectivity

• Minimal keyframes from user
• Common patterns of angular momentum (biomechanics data)
Optimization

- Constraints: loads, anchors, empty volumes
  - Intelligent placement of free joints can speed up convergence
- Object Function: minimize total mass

Optimization: Main Idea

- Engine: constraints solver
  - solving is easier if system is in a particular form (e.g., linear constraints)
- Specify constraints
  - floors should be horizontal, ...
- Minimize the objective/cost function
  - material, manufacturing, transportation, installation costs, ...

Related Graphics Research

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Simplification

Hughes Hoppe
Progressive Meshes
SIGGRAPH 1996

tetrahedral models:
Cutler, Dorsey & McMillan 2004

Level of Detail

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

Use high-resolution model only in areas of extreme deformation

Level of Detail

Eitan Grinspun, Petr Krysl, & Peter Schroder
CHARMS: A Simple Framework for Adaptive Simulation
SIGGRAPH 2002

Use high-resolution where needed to get sharp creases
Simplified Physics

Mueller, Dorsey, McMillan, Jagnow, & Cutler

Stable Real-Time Deformations Symposium on Computer Animation 2002

Reduced Deformation

Doug L. James & Dinesh K. Pai
BD-Tree: Output-Sensitive Collision Detection for Reduced Deformable Models

SIGGRAPH 2004

Level of Detail: Main Idea

• Target Application
  – model resolution
  – level of interaction / responsiveness

• Approximation in Representation / Solver
  – acceptable errors / inaccuracies?
  – prototyping / exploration / education vs. final construction documents

By Example

Funkhouser, Kazhdan, Shilane, Min, Kiefer, Tal, Rusinkiewicz & Dobkin

Modeling by Example

SIGGRAPH 2004

L-Systems

Prusinkiewicz & team at University of Calgary

Algorithmic Botany


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• Describe variations algorithmically
  – color
  – size
  – angle
  – density
  – shape
  – etc.
Procedural Modeling

- Describe variations algorithmically
  - street layout
  - density
  - height
  - texture

Modeling

- Automatically label corners, edges, & faces

Modeling

- Texture by orientation (vertical/horizontal/arch)
- Correctly wrap texture between features

Modeling: Main Idea

- User Interface
  - Modeling by example
- Procedural Modeling
  - Identify patterns / similarities
  - Develop a parameterized model

An aside: what’s “Generative”?

- Procedural Modeling: Capture pattern
  - simple description → lots of complexity
- Optimization: Goal Driven
  - reverse engineer to discover proper inputs
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Do We Need Dynamics?
- In many cases, we only want the static equilibrium, (which we can find more efficiently for larger models)

When might we want Dynamics?
- (Other than “because it’s fun”)
- Teaching tool: builds intuition about general physics/structural principles
- To understand a particular structure
- To understand our representation, assumptions & simulation (& figure out where it’s incorrect/incomplete)
- ?

Thoughts on a User Interface?
- Discuss SodaPlay?
- Where do the models come from?
  - Created with other applications?
  - How much editing do we want to support?
- What (expensive) tasks can we do offline?
- ?