Simulation in Computer Graphics

Introduction

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- http://cg.informatik.uni-freiburg.de/ -> teaching
Course Information

- key course
  - pattern recognition and computer graphics (rasterization-based rendering)

- specialization courses
  - advanced computer graphics (ray tracing)
  - simulation in computer graphics (e.g., fluids)

- master project, lab course, Master thesis
  - two tracks: simulation, rendering
## Seminars / Projects / Theses in Graphics

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<th>Rendering Track</th>
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Outline

- motivation
- topics overview
- organization
Course Goals

- physically-based animation of the dynamics of
  - rigid bodies
  - deformable objects
  - fluids

rigid bodies
fluids

deformable objects – 1D, 2D, 3D
Course Goals

- interplay of simulation components
  - model generation
  - collision detection, contact handling, constraints
  - effects

mesh generation  contact handling  constraints

phase transition
Applications

- computational medicine

- pre-operative planning in cranio-maxillofacial surgery

- interactive hysteroscopy simulation for educational purposes

- intra-operative support in orbital reconstruction
Applications

- robotics

- support of robot navigation in environments with deformable objects

- acceleration of robot navigation with simulation environments
Applications

- entertainment technologies
  - ATI (Havok)
  - NVIDIA (PhysX)
  - Crytek (CryEngine)
  - Pixar
  - Ubisoft
Applications

- entertainment technologies
- interactive dynamic animations
  - physically-plausible
  - robust
  - versatile
- focus on the interplay of different animation aspects
  - model generation
  - dynamics
  - collision handling
  - constraints

interacting deformable objects
Applications

- animation (with Pixar)
Applications

- automotive (with Fifty2)
Conventional and Physically-based Animation

- conventional animation
  - keyframes, interpolation
  - fully controllable
  - predefined, non-interactive

- physically-based animation
  - driven by physical laws
  - computed in real time
  - interactive
Scientific Computations and Physically-based Animation

- scientific computing / computational physics
  - reproduction of natural phenomena
  - substitute for real experiments

- physically-based animation
  - imitation of physical phenomena
  - plausible behavior
  - as much realism as possible within speed and stability constraints
  - focus on data structures and algorithms
Outline

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Topics

- particle systems
- mass-point systems
- fluids
- rigid bodies
- collision detection
Particle Systems

- collection of many small simple particles with mass m, position x, velocity v
- particle motion influenced by force F
- dynamics governed by F=ma
- time integration to compute position and velocity over time
Particle Systems

snow, dust, sand

fire

smoke
Mass-Point Models

- discretization of an object into *mass points*
- representation of forces between mass points with *springs*
- force-deformation relation, topology, constraints, damping
Generalized Spring Forces

- deformation based on constraints
  - distance preservation
  - area preservation, surface tension
  - volume preservation

- wide range of material stiffness

- melting fluid-like behavior
Geometric Constraints

- restrict the motion of mass points
  - keep a mass point at a position
  - force a point onto a curve or surface

Local Constraint Methods for Deformable Objects
**Fluids**

- **Lagrangian approach**
  - Velocities computed on moving particles
  - Information advected with particles

- **Eulerian approach**
  - Velocities computed on a fixed grid
  - Grid cells represent information
Fluids – Lagrangian Approach

www.youtube.com – 3 Ships – Fluid simulation with 20 million particles
Fluids – Lagrangian Approach
Fluids – Lagrangian Approach

www.youtube.com – 3 Ships – Fluid simulation with 20 million particles
Rigid Bodies

- mass points connected by springs with infinite stiffness
- entire body described by position and orientation
- forces at mass points cause translation and rotation of entire body
Topics

- particle systems
- mass-point systems
- fluids
- rigid bodies
- collision detection
Collision Detection

- detecting interferences of objects
- rigid objects represented as triangulated surfaces
- avoiding time-consuming triangle-triangle intersection tests using pre-computed data structures
  - bounding volumes, space subdivision, distance fields
Collision Handling for Deformable Objects

Volumetric contact handling

Dynamic contact

Resting contacts

Spillmann, Freiburg
Tentative Course Syllabus

- particles
  - ordinary differential equations
- mass-point systems
  - deformable objects
  - stability
  - constraints
- fluids
  - mostly Lagrangian
- rigid bodies
- collision detection
  - spatial data structures
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Exercises / Exam

- exercises
  - by appointment
  - first exercise on Oct 20
  - smaller exercises in the first part
  - larger project towards the end

- exam
  - oral exam based on slide sets
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