CS 6650
Computational Motion

Professor:       Doug James
Office Hours:  When you can find me in my office
Phone:            607-255-9215
Email:             Best way to reach me
Covers computational aspects of motion, broadly construed. Topics include the computer representation, modeling, analysis, and simulation of motion, and its relationship to various areas, including computational geometry, mesh generation, physical simulation, computer animation, robotics, biology, computer vision, acoustics, and spatio-temporal databases. Students implement several of the algorithms covered in the course and complete a final project. This Spring 2011 offering will also explore the special role of motion processing in physically based sound rendering.
What will you do?

- Attend lectures
- Do a few assignments
- No exams
- Give short paper presentations
  - Everyone reads paper
  - Discuss paper in class
  - Submit questions before class
- Propose and implement a major project
What is Computational Motion?
What is Computational Motion?

Computational Geometry

Kinetic Data Structures (KDS)

Complexity

[Agarwal et al. 2004]
What is Computational Motion?

Mesh Generation

- Dynamic meshes
- Meshing space-time domains

[Klinger et al. 2006]
What is Computational Motion?

Physical Simulation

[Losasso et al. 2008]

[Selle et al. 2008]
What is Computational Motion?

Rigid Body Dynamics

- Forward Kinematics
- Inverse Kinematics
- Dynamics
- Featherstone
- Linear-time methods
What is Computational Motion?

Deformable Objects

[Kaldor et al. 2008]
What is Computational Motion?

Constraints

- Differential Algebraic Equations (DAEs)
- Solvers
What is Computational Motion?

Contact

- Contact formulations
- Friction
- Constraint solvers
What is Computational Motion?

Collision Detection

[James and Pai 2004]
What is Computational Motion?

Modeling

- Robotics
  - Pick up paper.
  - Put paper in pocket.
What is Computational Motion?

Robotic Manipulation

Robotic Origami Folding
[Balkcom and Mason 2008]
What is Computational Motion?

Motion Planning

[Boeing VPS]

[Latombe]
What is Computational Motion?

Serious Games (and not so serious ones)

http://fold.it
What is Computational Motion?

Control

Popovic’ et al. 2000

Chenney and Forsyth 2000
What is Computational Motion?

Data

Many-Worlds Browsing

[Twigg and James 2007]
What is Computational Motion?

Transfer and Editing

- Gradient domain processing

[Sumner and Popovic 2004]
What is Computational Motion?

Estimation

- Scanning, sensing
- Inverse problems

[de Aguiar et al. 2008]
What is Computational Motion?

Spatio-Temporal Databases

[Jeremy Kubica]
What is Computational Motion?

Spatio-Temporal Databases

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What is Computational Motion?

Parallel Physics

**Figure 1**: Schematic of the Larrabee many-core architecture: The number of CPU cores and the number and type of co-processors and I/O blocks are implementation-dependent, as are the positions of the CPU and non-CPU blocks on the chip.

Intel’s Larrabee [SIGGRAPH 2008]
What is Computational Motion?

Sound Rendering
What is Computational Motion?

Sound Rendering

It’s a hot topic!
Euler-Lagrange equations of motion, and computational complexity
Elastic models, e.g., cloth
Integration methods; quasistatics
Subspace integration methods

Sound rendering (modal sound, transfer, fluids, fracture, …)

Constrained dynamics and DAEs
Integrating constrained dynamics

Rotational & rigid-body motion
Robot dynamics algorithms
Frictional contact
Collision detection and deformation bounds
Elastic rods, e.g., yarn-level cloth

Incompressible flow
Fluid-solid coupling
Bubbly flows

Gradient-domain shape and motion modeling
Adaptive & asynchronous integration (TimeWarp, Spatial, Temporal)
Data-driven methods; precomputation-based methods
Character animation; biped control; controllers
Motion planning; control, manipulation, uncertainty, e.g., pushing
GPU physics
Tree-codes for N-body problems
Haptic rendering; multi-rate simulation
Describing motion
* parameterization
* kinematics

Dynamics and integration

Constraints
* type, e.g., holonomic
* unilateral contact and friction

Rigid bodies
* Kinematics
* dynamics
* contact

Constraint solvers
* DAE integrators
* LCP

Deformable bodies
* survey
* invertible elements

Gradient-domain processing
* deformation gradient
* Eg: deformation transfer

Articulated systems
* forward and inverse kinematics; style
* dynamics
* Featherstone's algorithm
* rigid vs deformable

Reduced-order dynamics
* dimensional model reduction
* reduced deformable models
* multi-res approximation, e.g., CHARMS

Collision processing
* discrete vs continuous
* space-time bounds
* data structures (KDS, BVH, ...)
* reduced-order collision processing
* Bounded deformation trees
* real-time algorithms (Hubbard, Barbic, ...)

Friction
* friction models
* principle of maximal dissipation
* solvers, e.g., LCP

* iterative schemes

N-body fast-summation schemes
* Barnes-Hut; fast multipole method (FMM)

Shape-matching dynamics
* matching algorithms (basic, lattices, trees)
* fast summation; dynamic programming
* damping

Motion planning
* Planning schemes, e.g., potential fields, probabilistic roadmaps, RRT, etc.
* robotic manipulation, e.g., pushing, grasping

Motion design in computer animation
* Popovic
* Many-Worlds Browsing
* Reverse-time schemes

Motion as noise
* Noise models
* Eg: characters, fluids, contact

Motion compression
* complexity (running the numbers, information)
* approximation schemes

Motion estimation
* sensing
* state estimation (Kalman filtering)
* distributed parameter estimation (imaging, tracking, ...)

Data-driven motion

Motion capture; motion graphs

Issues from computational geometry
* dynamic mesh generation

Spatio-temporal databases and queries
* Eg: sensor networks
* Eg: asteroid problem

Fluids
* Eulerian vs Lagrangian views
* Level sets
* Fast-marching algorithm
* Advection schemes

* Fast solvers
* Multi-physics simulations

HAPTICS: Haptic rendering
* point contact; "god object"
* passivity
* approaches for distributed contact
* friction

SOUND: Vibration and sound radiation modeling
* wave equation; Helmholtz eqn
* radiation and scattering
* fundamental solutions
* solvers (general, source simulation, etc.)
* multiple time-scale approximations

PERCEPTION AND PSYCHOPHYSICS
* multi-sensory; JND
* collisions and contact
* crowds
* computational issues
Papers for discussions and projects

• Start thinking now

• Look at previous webpage, and SIGGRAPH/etc papers online
Read for next Monday

Algorithmic issues in modeling motion