CS 6650
Computational Motion

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Description

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.*

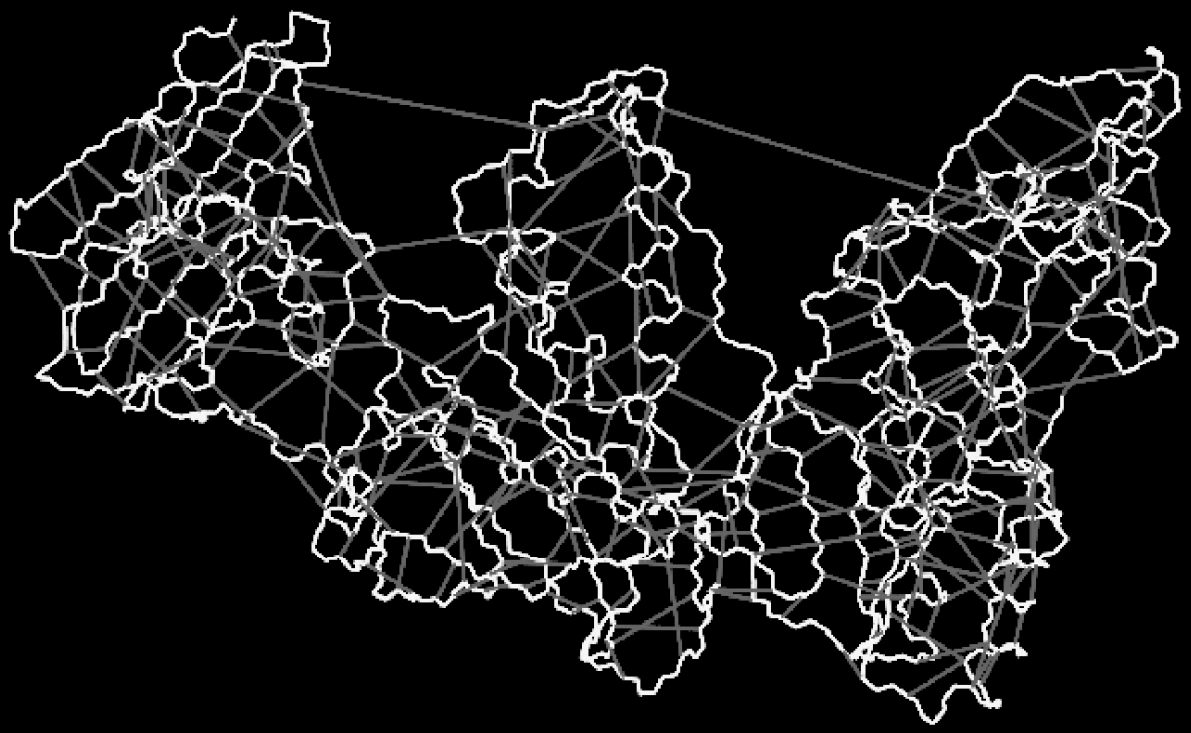
What will you do?

- 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



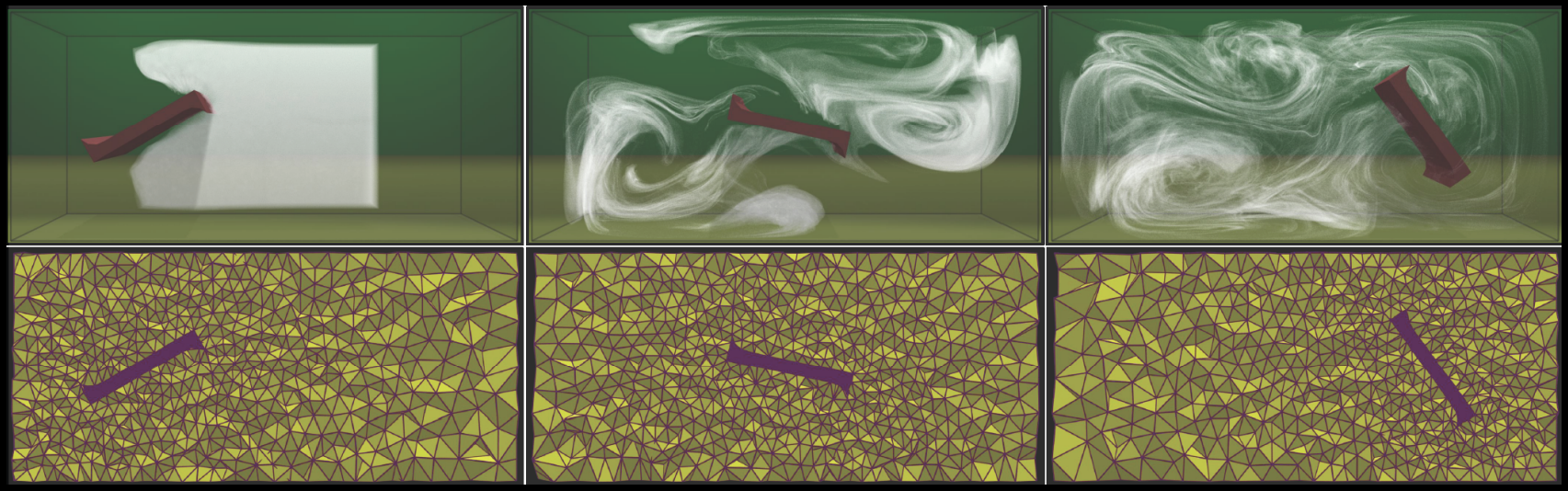
[Agarwal et al. 2004]

Kinetic Data Structures (KDS)

Complexity

What is Computational Motion?

Mesh Generation

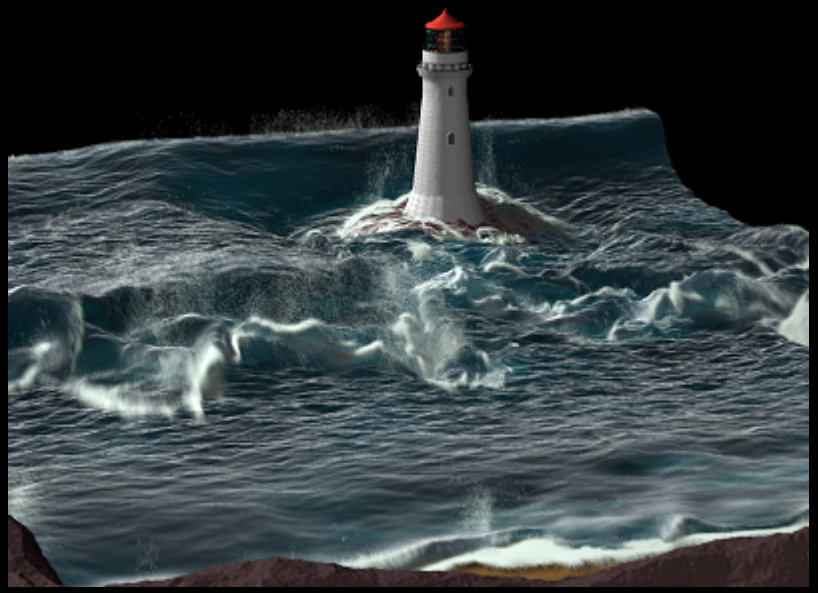


[Klinger et al. 2006]

- Dynamic meshes
- Meshing space-time domains

What is Computational Motion?

Physical Simulation

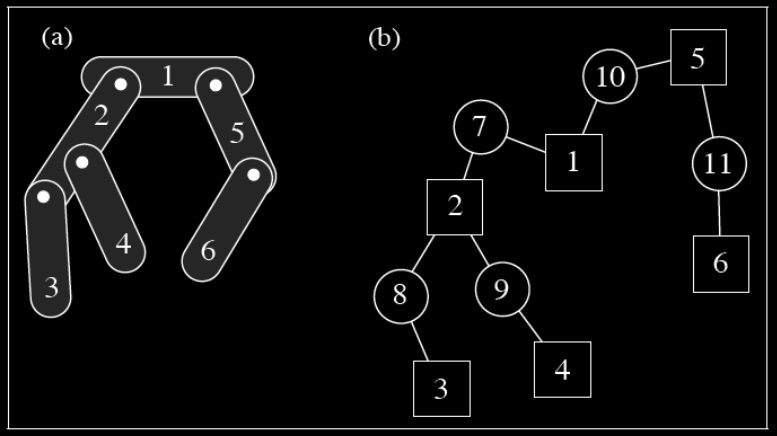


[Losasso et al. 2008]

[Selle et al. 2008]

What is Computational Motion?

Rigid Body Dynamics

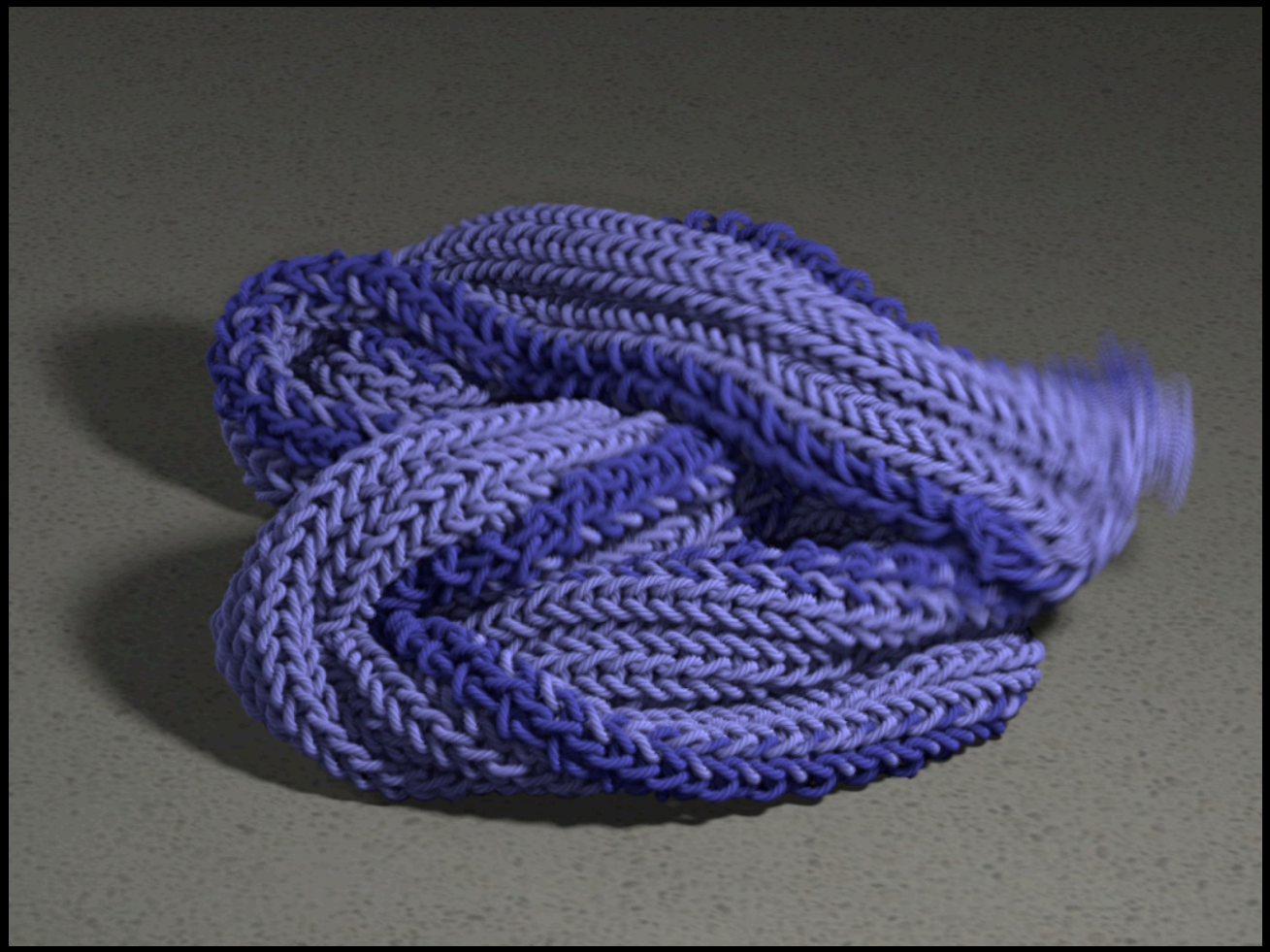


[Baraff 1996]

- Forward Kinematics
- Inverse Kinematics
- Dynamics
  - Featherstone
  - Linear-time methods

What is Computational Motion?

Deformable Objects

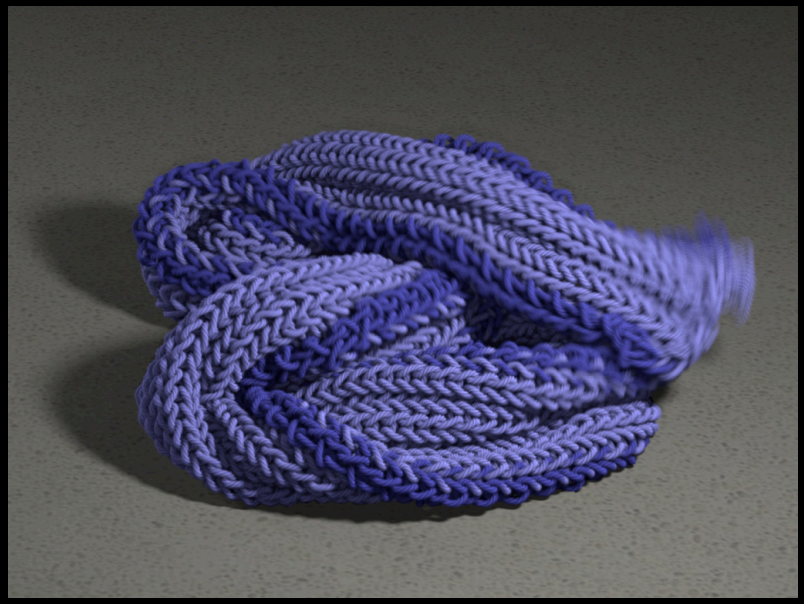


[Kaldor et al. 2008]

What is Computational Motion?

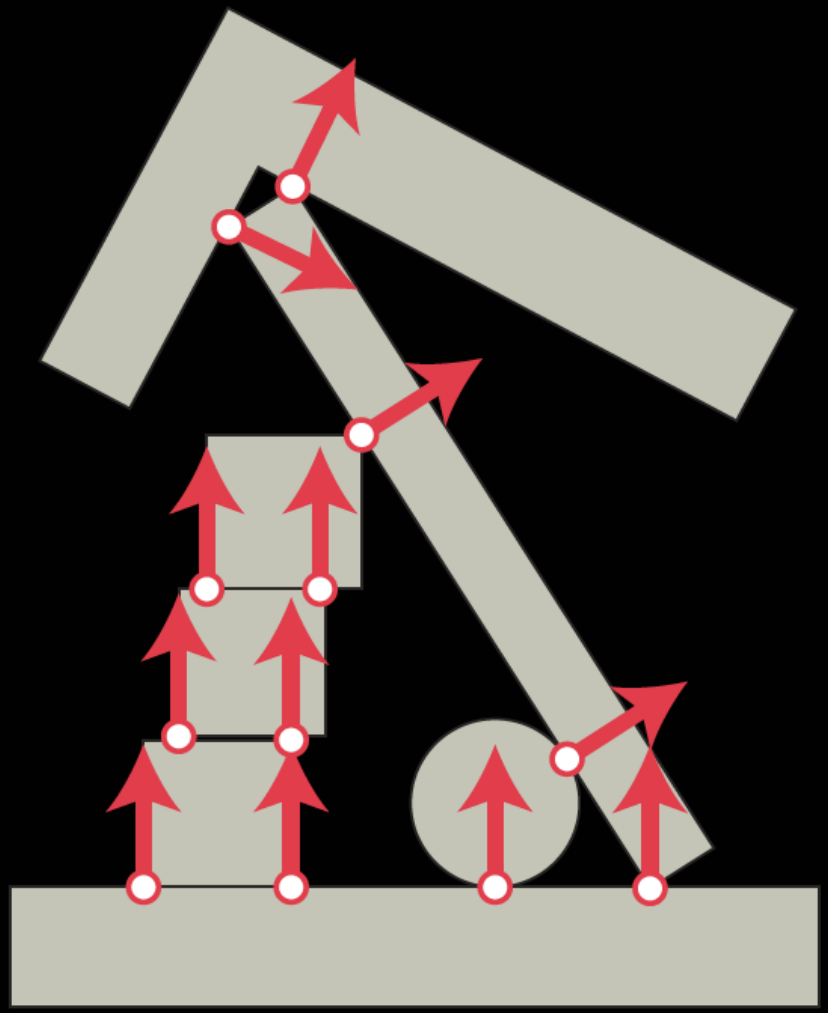
Constraints

- Differential Algebraic Equations (DAEs)
- Solvers



What is Computational Motion?

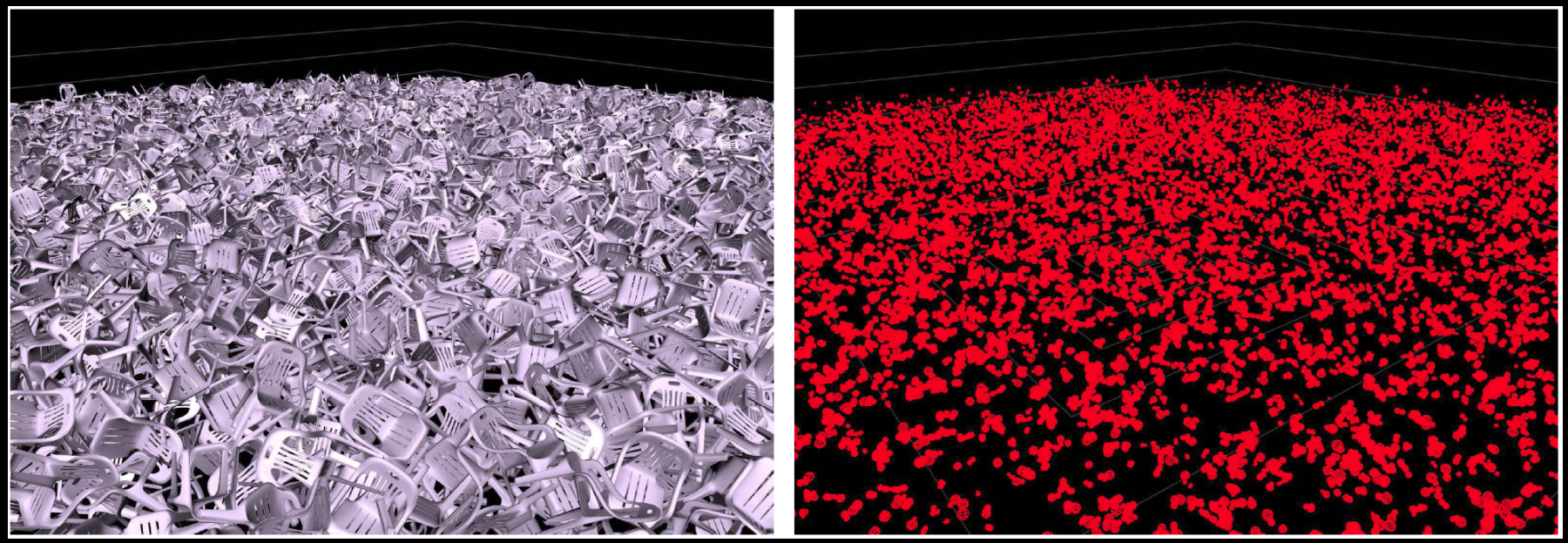
Contact



- Contact formulations
- Friction
- Constraint solvers

What is Computational Motion?

Collision Detection



[James and Pai 2004]

What is Computational Motion?

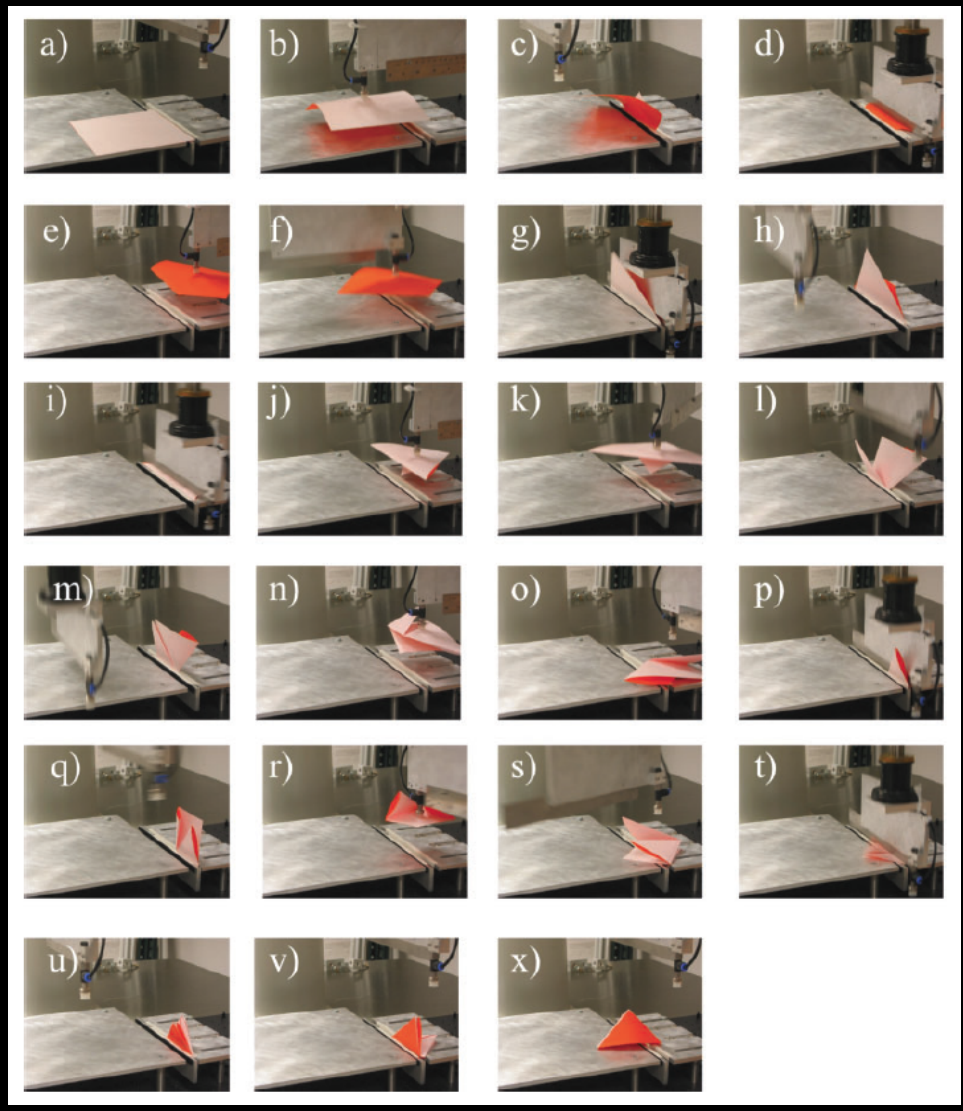
Modeling

- Robotics
- ```
  Pick up paper.
  Put paper in pocket.
  ```
  ```

What is Computational Motion?

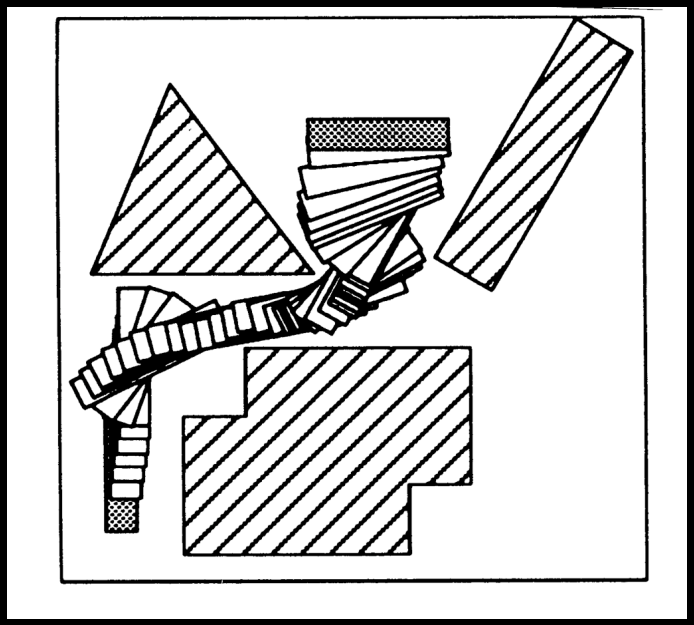
Robotic Manipulation

Robotic Origami Folding
[Balkcom and Mason 2008]



What is Computational Motion?

Motion Planning

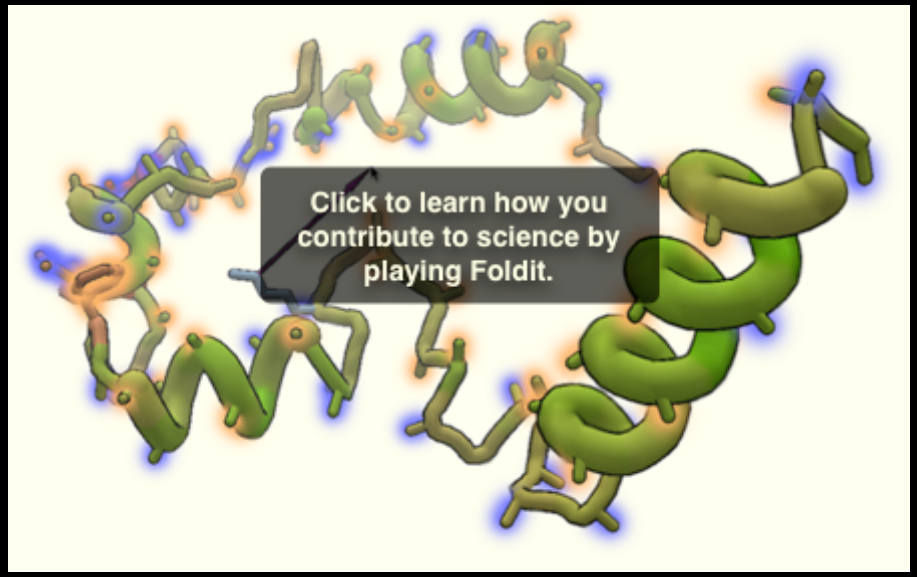


[Latombe]

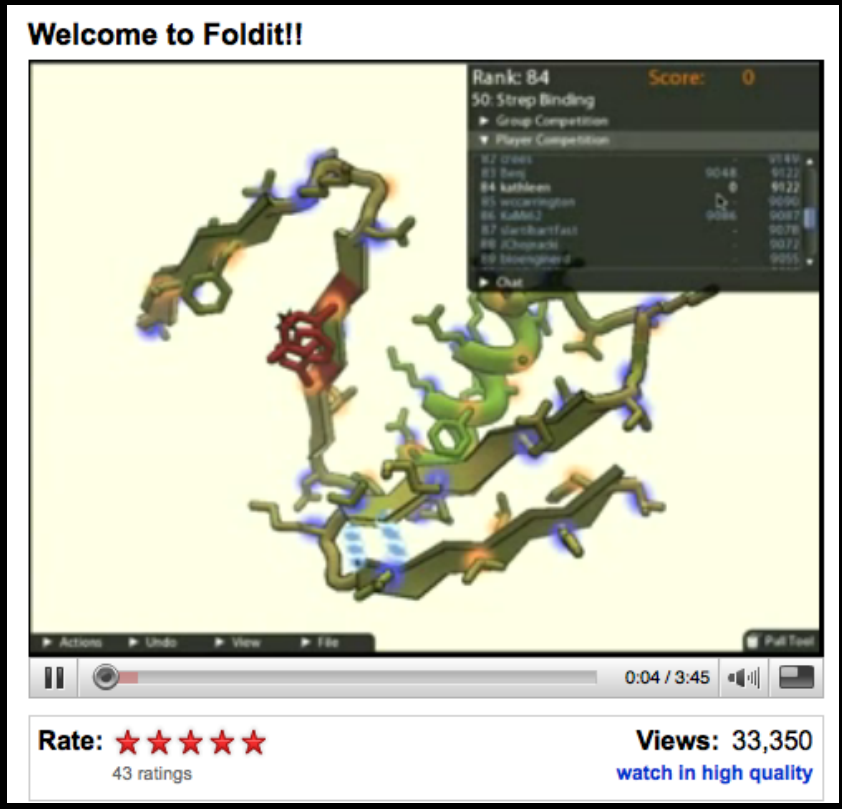
[Boeing VPS]

What is Computational Motion?

Serious Games (and not so serious ones)

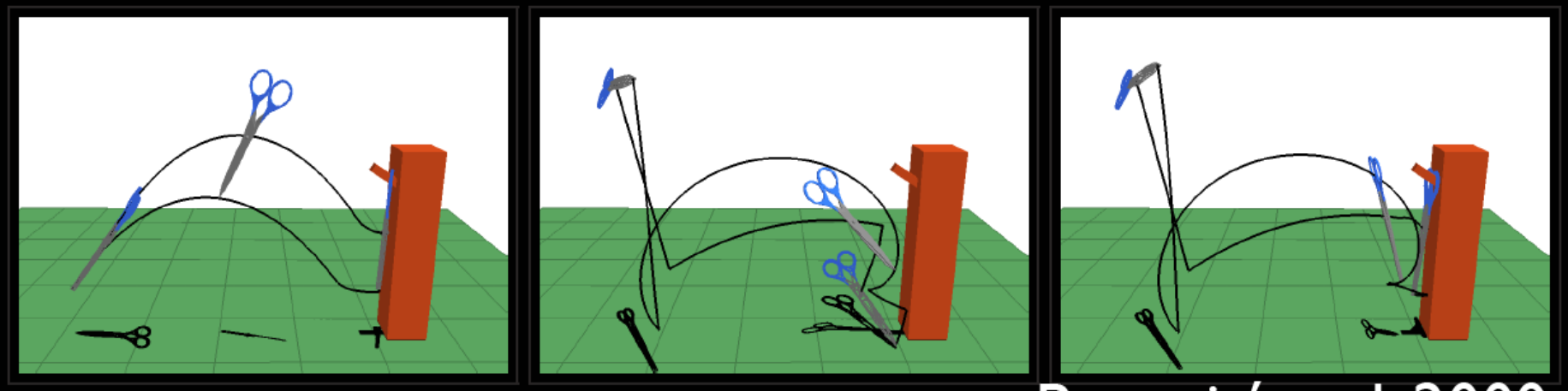


http://fold.it

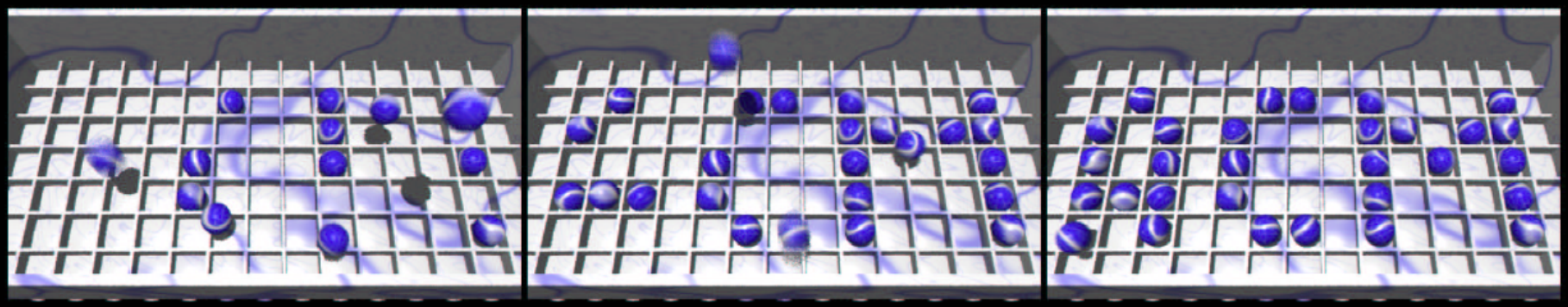


What is Computational Motion?

Control



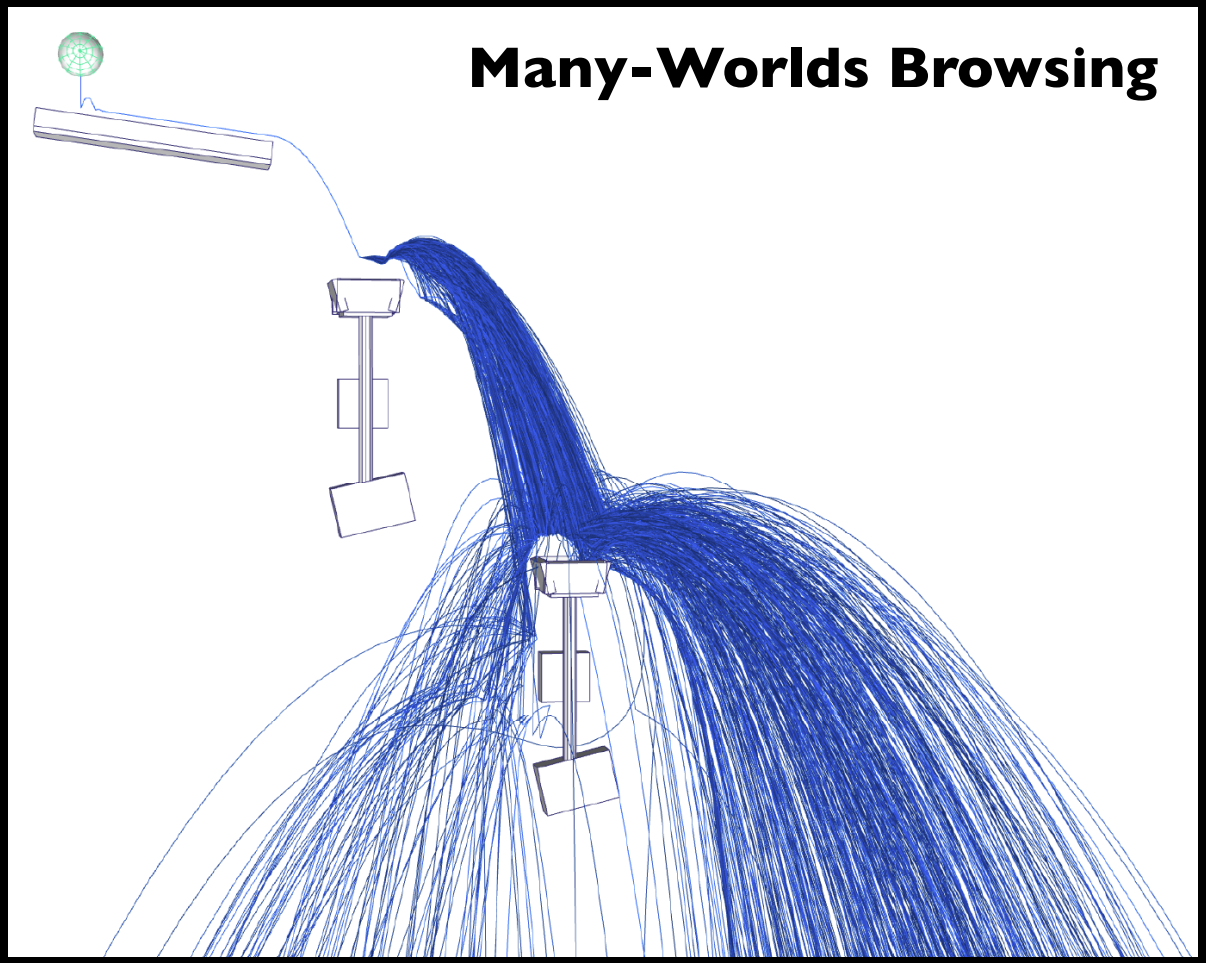
Popovic′ et al. 2000



Chenney and Forsyth 2000

What is Computational Motion?

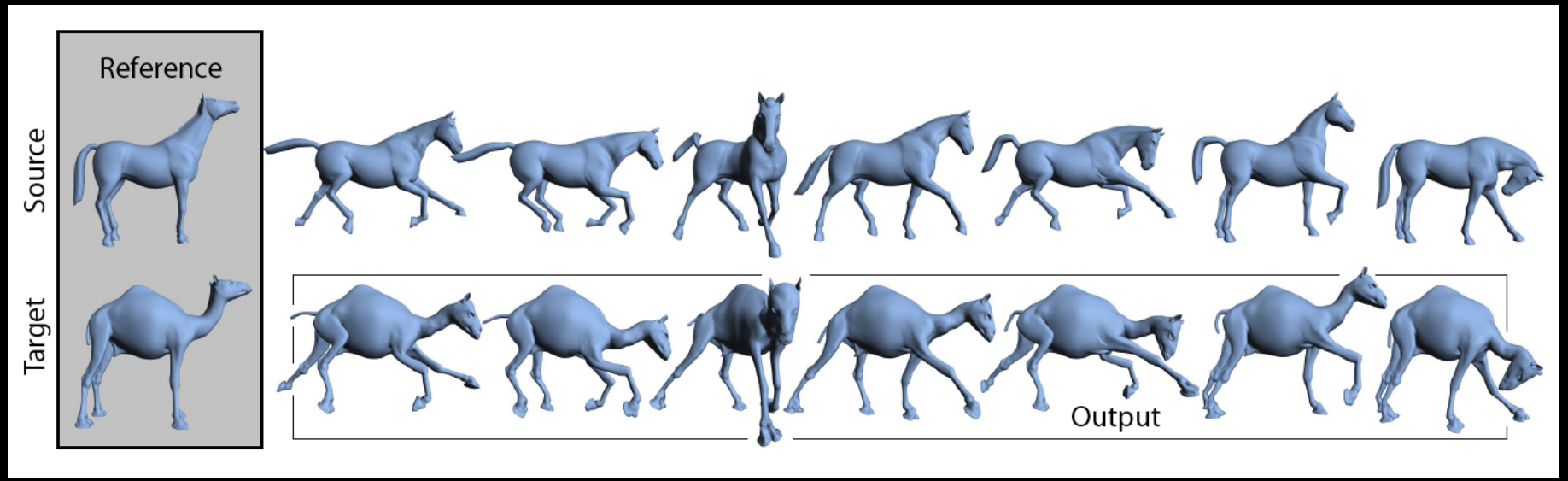
Data



[Twigg and James 2007]

What is Computational Motion?

Transfer and Editing

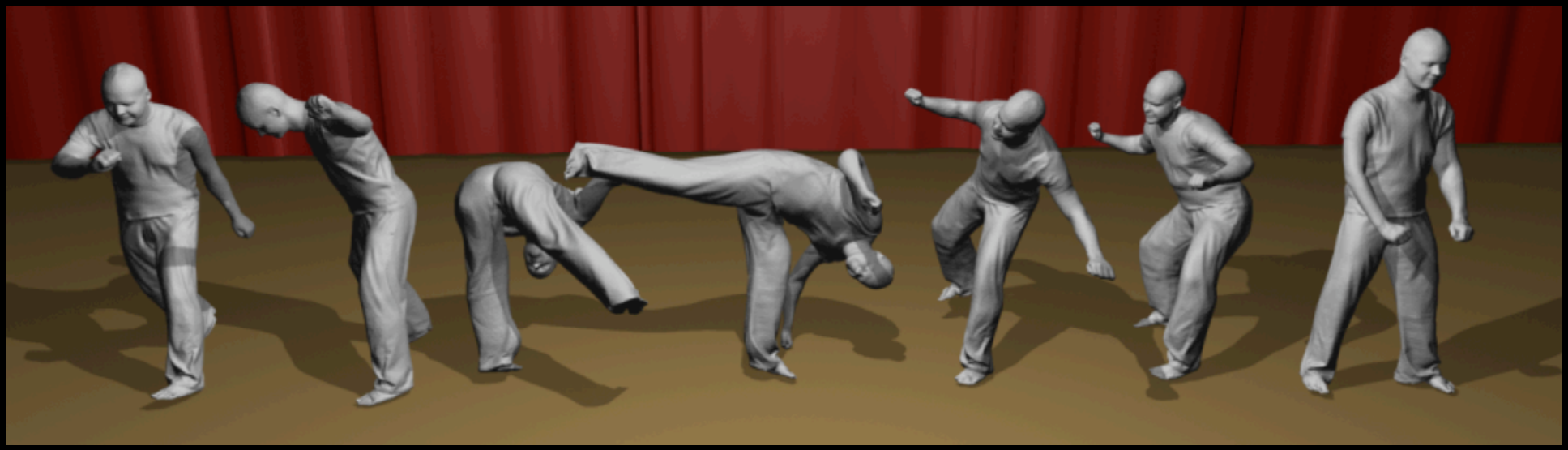


[Sumner and Popovic 2004]

- Gradient domain processing

What is Computational Motion?

Estimation

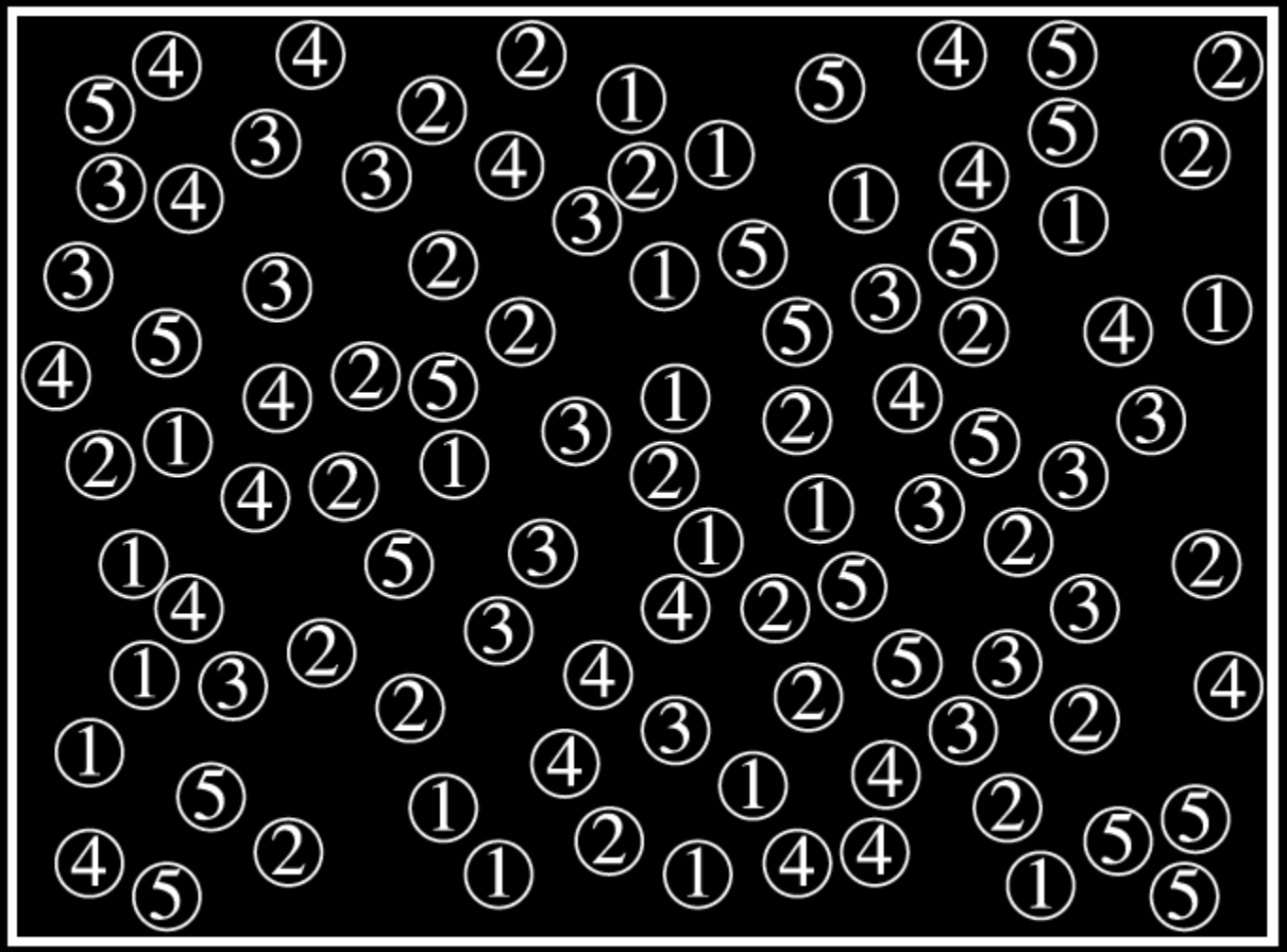


[de Aguiar et al. 2008]

- Scanning, sensing
- Inverse problems

What is Computational Motion?

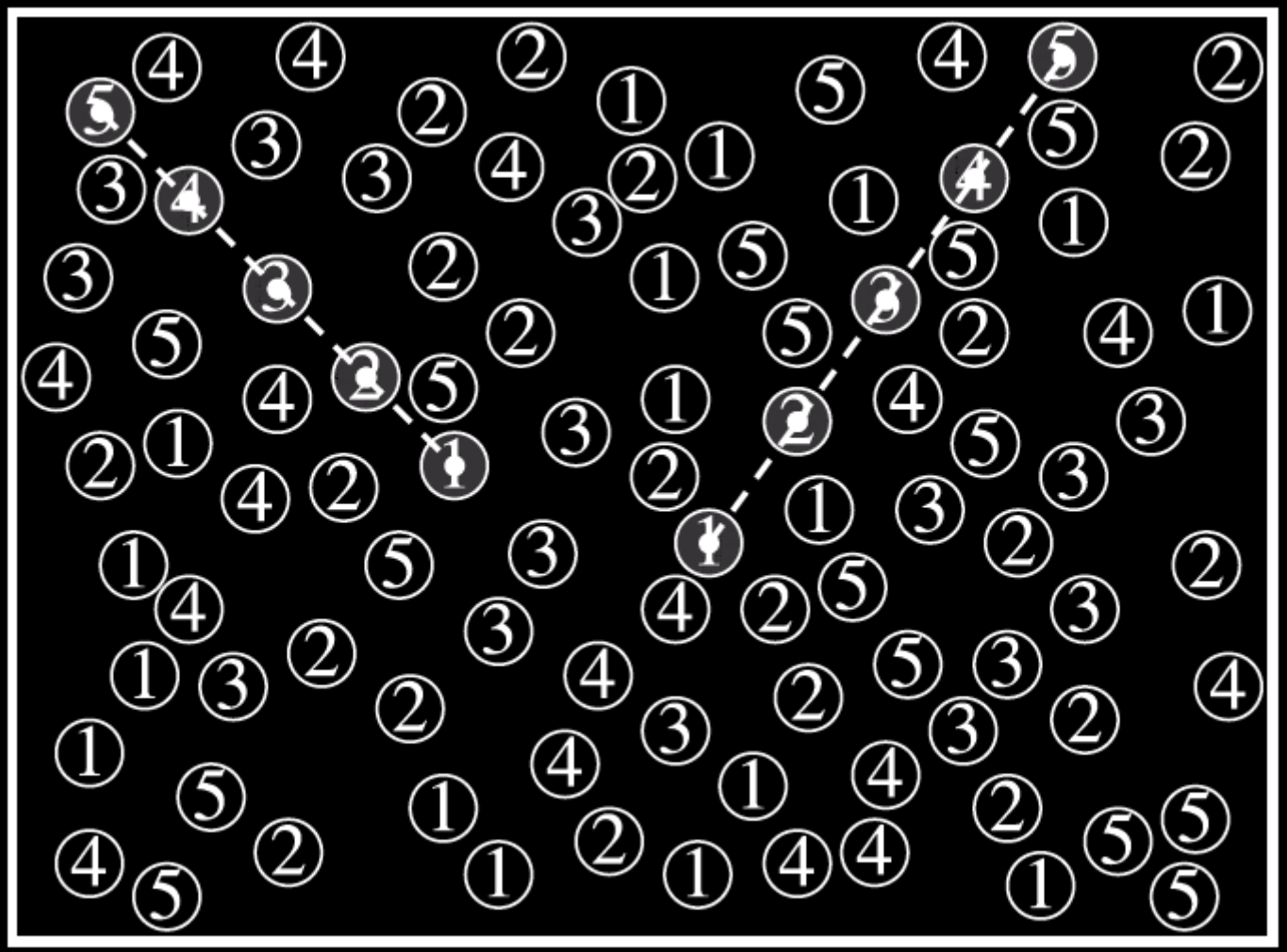
Spatio-Temporal Databases



[Jeremy Kubica]

What is Computational Motion?

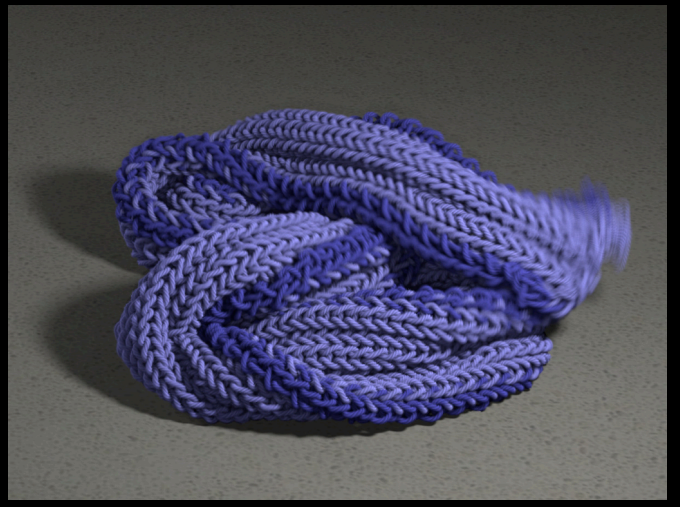
Spatio-Temporal Databases



[Jeremy Kubica]

What is Computational Motion?

Parallel Physics



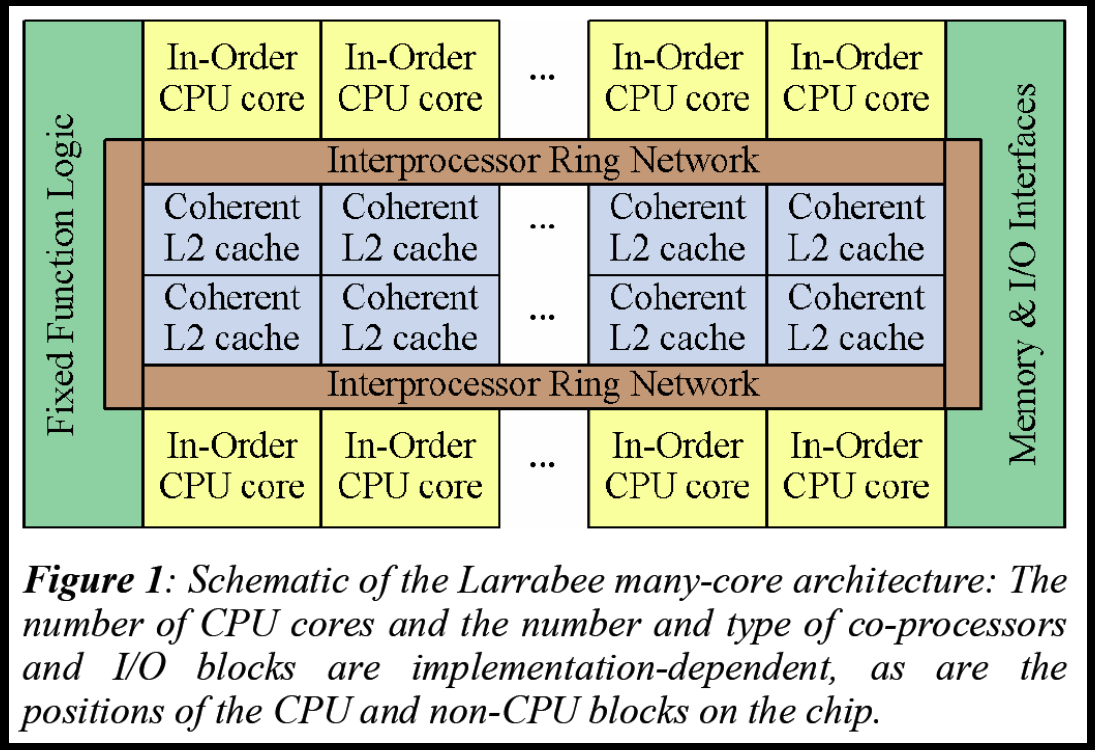
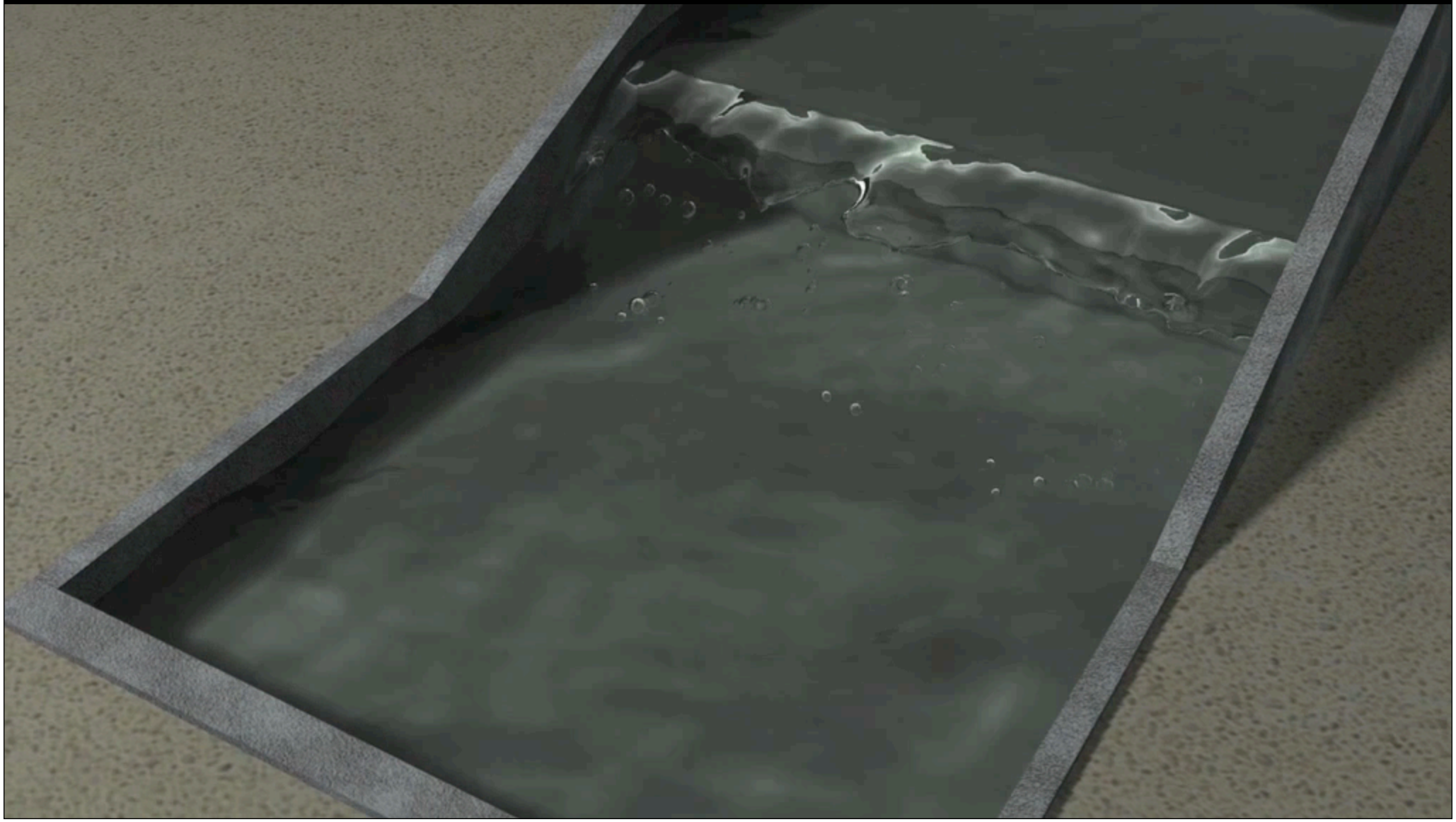


***Figure 1**: Schematic of the Larrabee many-core architecture: The number of CPU cores and the number and type of co-processors and I/O blocks are implementation-dependent, as are the positions of the CPU and non-CPU blocks on the chip.*

Intel's Larrabee [SIGGRAPH 2008]

What is Computational Motion?

Sound Rendering



What is Computational Motion?

Sound Rendering

It's a hot topic!

Outline

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, probabalistic 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

Etc...

 * 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

Agarwal et al., ACM Computing Surveys, 34, 4 (Dec. 2002), 550-572.