CS 277 - Experimental Haptics
Lecture 9

Deformable Models (I)

Outline

- Introduction
- Spring Models
- Computing Dynamics in the Haptics Loop
- Filling Sphere Approach for Elastic Models
- Computing Collision Detection in Real Time
- Demonstrations

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overview

simulators

running offline

- CAD design tools
- movie rendering
- building a look-up-table
- games
- model tuning and calibration

running real-time

- interactive games
- flight simulator
- haptic simulator
- real robot controller
- weather forecast

- haptics
- robot control

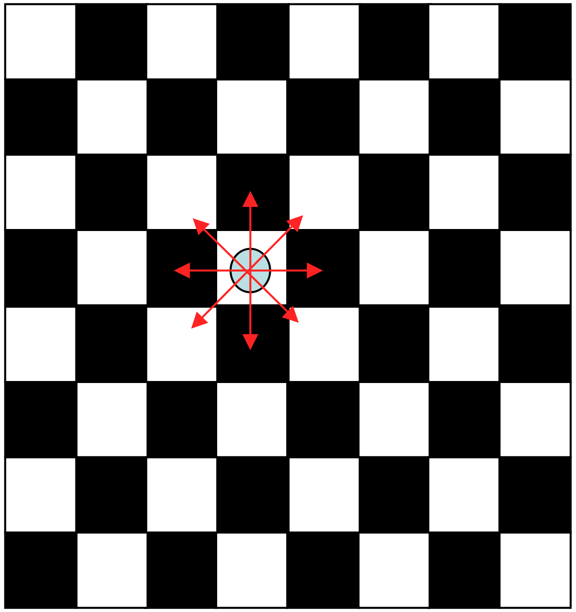
- graphic animation
- games

- CAD tools
- apps

- industrial simulations
- movie renderings

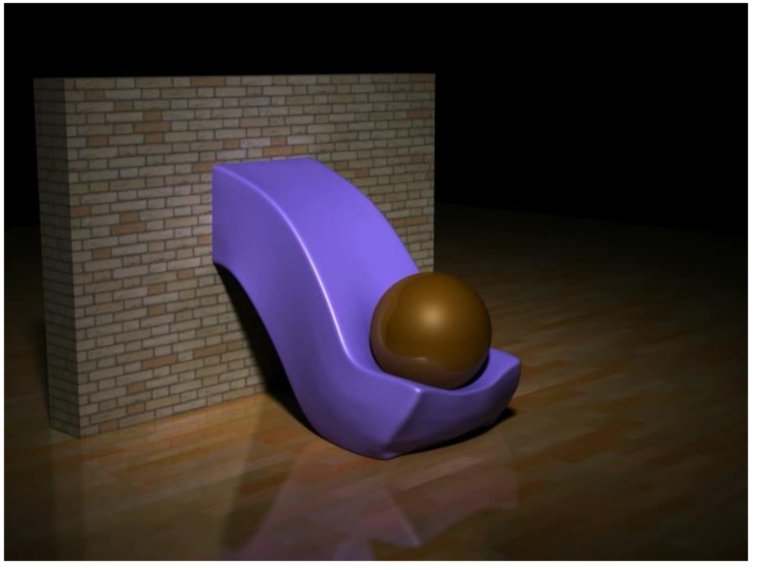
1ms 0.1s 1s 10s 1m 1h 1day

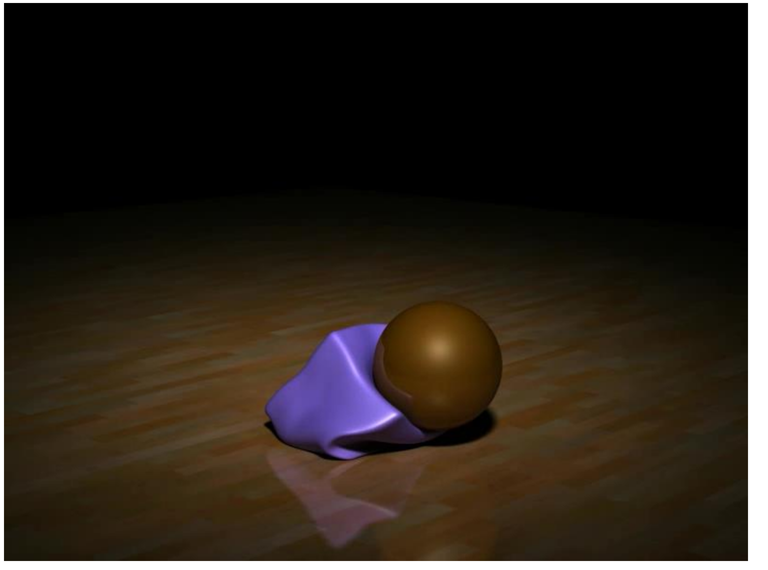
Discrete Events



In discrete-event simulation, the operation of a system is represented as a chronological sequence of events. Each event occurs at an instant in time and marks a change of state in the system.

Haptic Simulation





- To make objects look, behave and feel realistic when forces are applied.
- To provide visual and force feedback to the user in real time.

Haptic Simulation

- Input
  - Object model (non-deformed geometry)
  - Forces
    - Over whole volume (e.g., gravity)
    - Over the surface (e.g., pressure, drag)
    - Concentrated loads (e.g., poking with haptic device)

- Output:
  - New, deformed geometry
    - Static equilibrium
    - At each time step (dynamic)
  - If using meshes, just need node displacements
  - Usually assumes invariant topology (e.g., no cutting)

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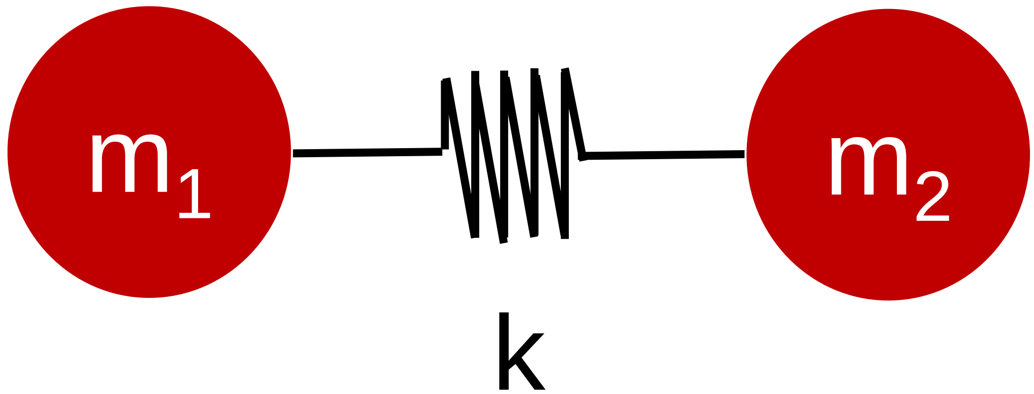
Spring Models



- Discretize the object into a collection of N nodes interconnected with springs
- For each node i, just using Newton's F=ma law, with some velocity-dependent damping,

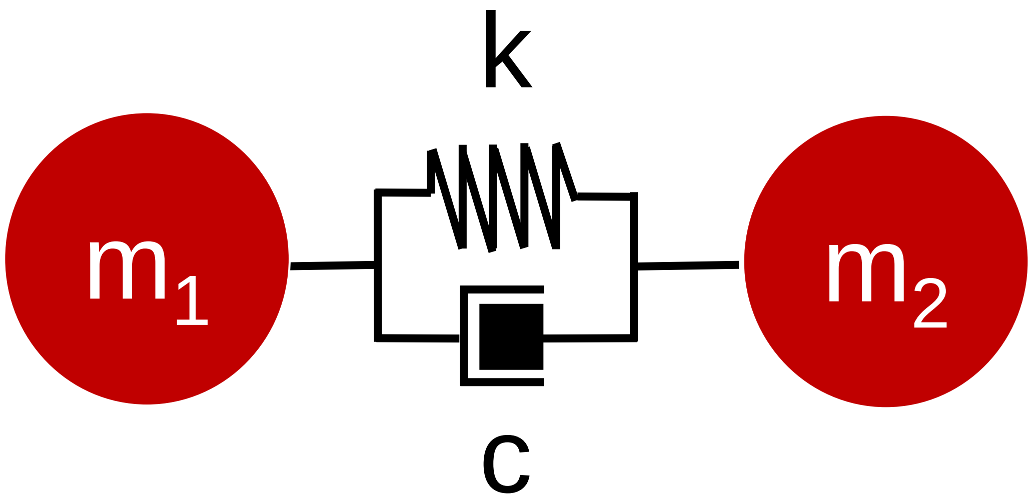
gravity

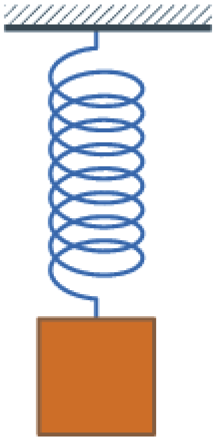
$$m_i \ddot{\mathbf{x}}_i = -\gamma_i \dot{\mathbf{x}}_i + \sum_j \mathbf{g}_{ij} + \mathbf{f}_i$$

damping

external forces
(i.e. springs)

Spring Models





$$F_{\mathrm{d}} = -cv = -c\dot{x} = -c\frac{dx}{dt}$$

$$Fs = -k\,x$$

Implementation

(1) For each mass node, compute all external forces

- springs interconnecting mass nodes
- reaction forces between colliding mass nodes
- gravitational forces

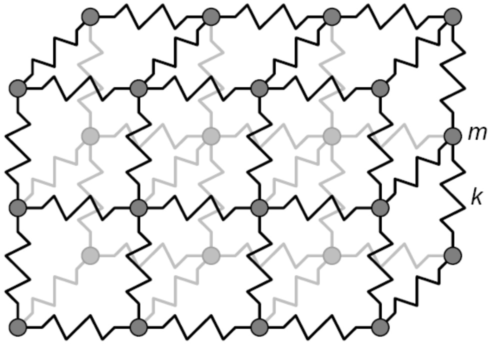
(2) Compute Acceleration

$a = F / m$

(3) Update Velocity and Position through integration over time dt

$v = v_{prev} + a\,dt$

$x = x_{prev} + v\,dt + ½\,a\,dt^2$



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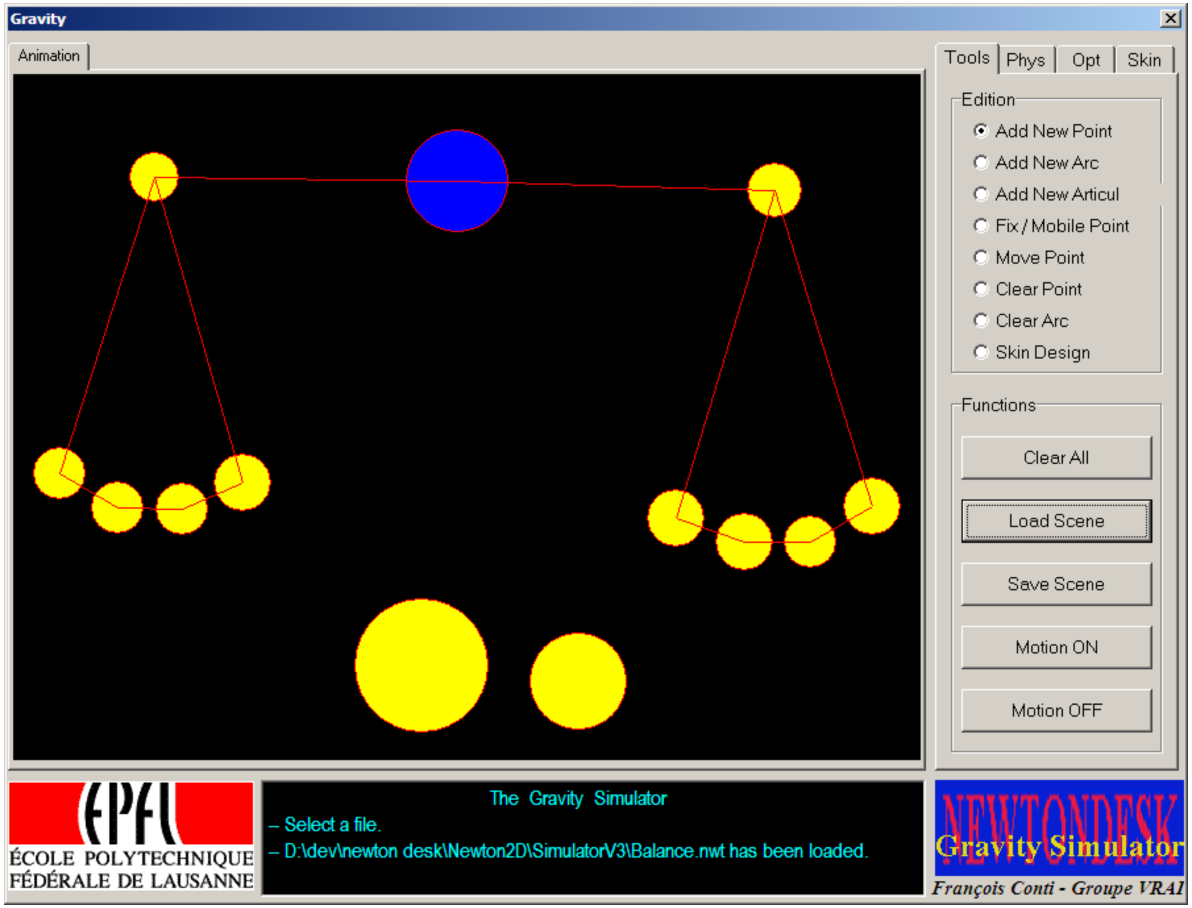
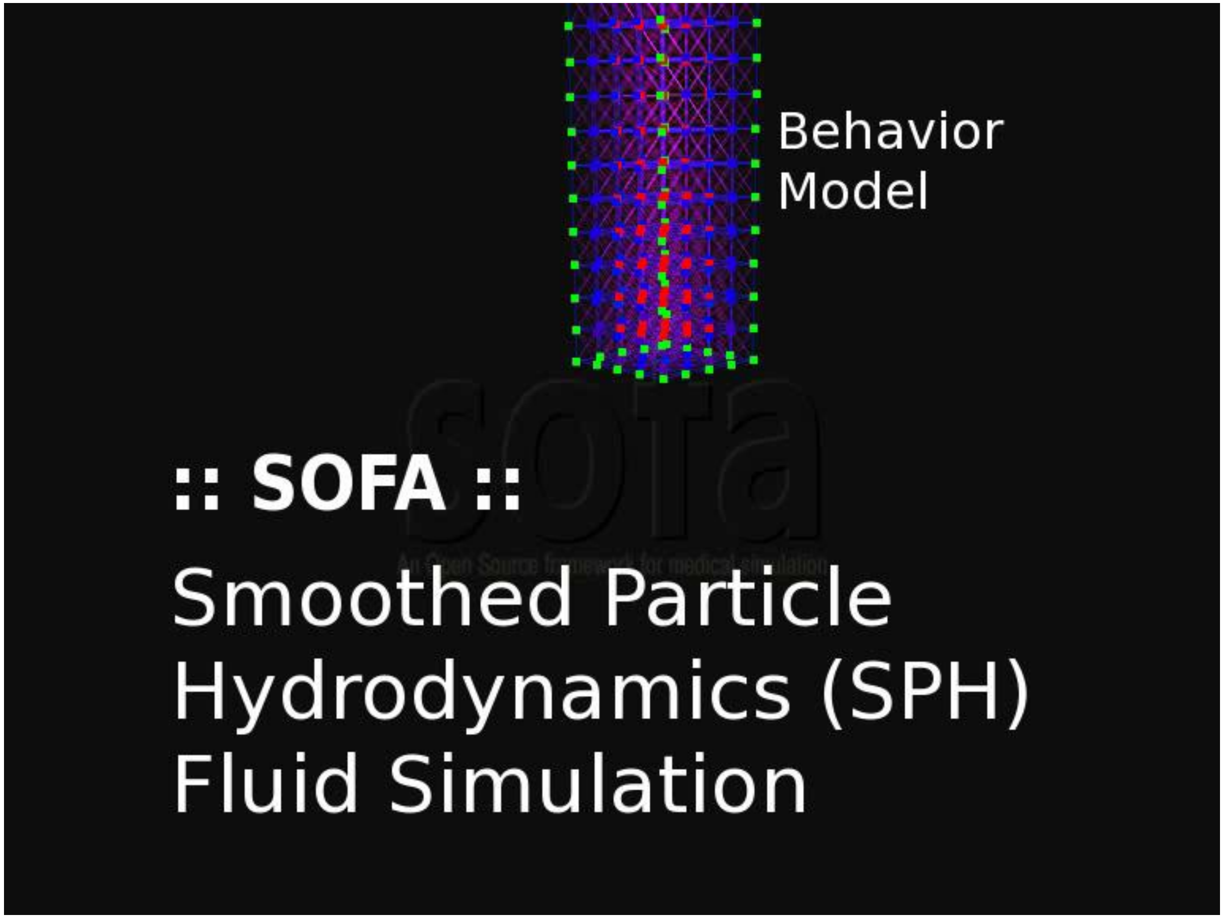
Demonstration



Haptic Simulation



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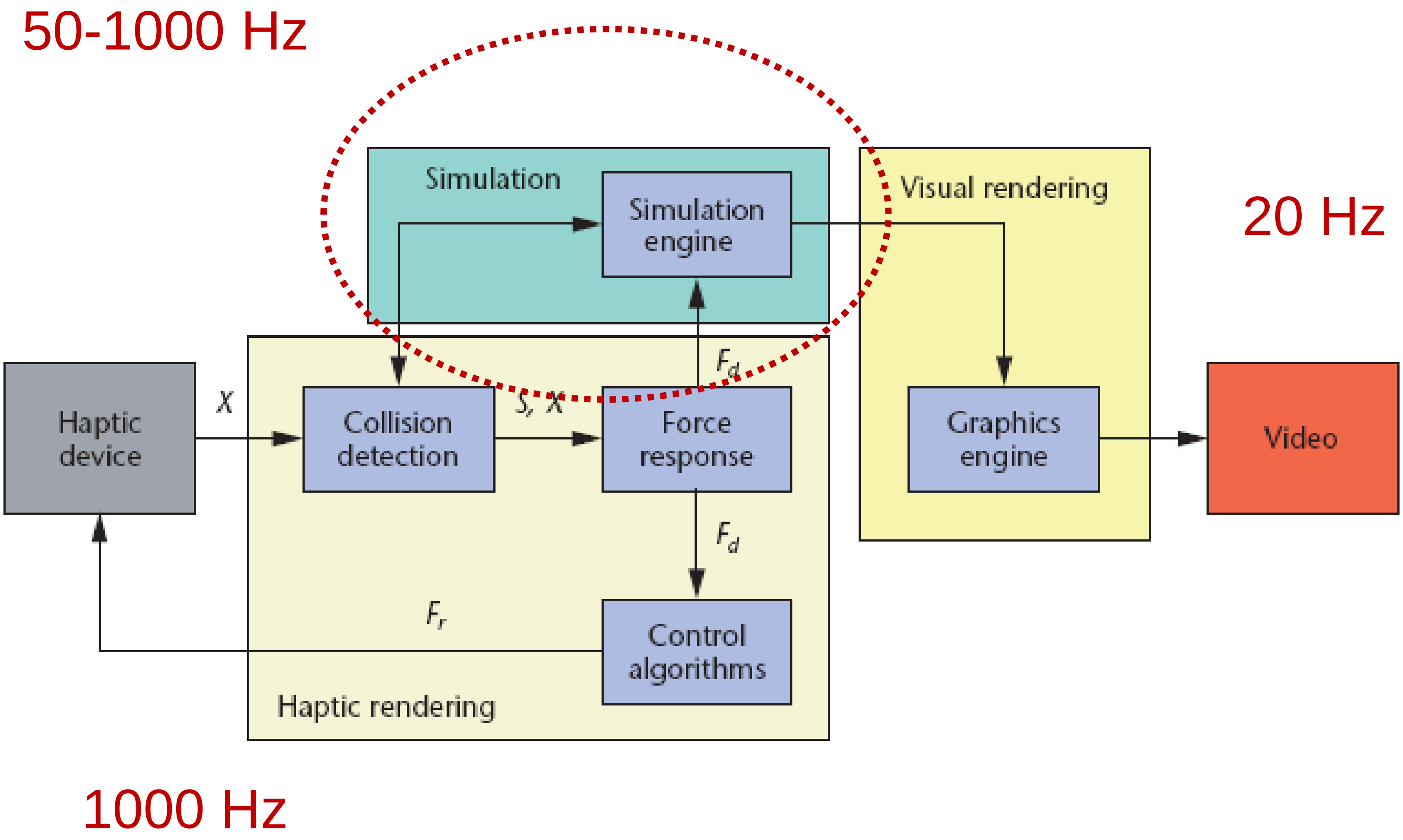
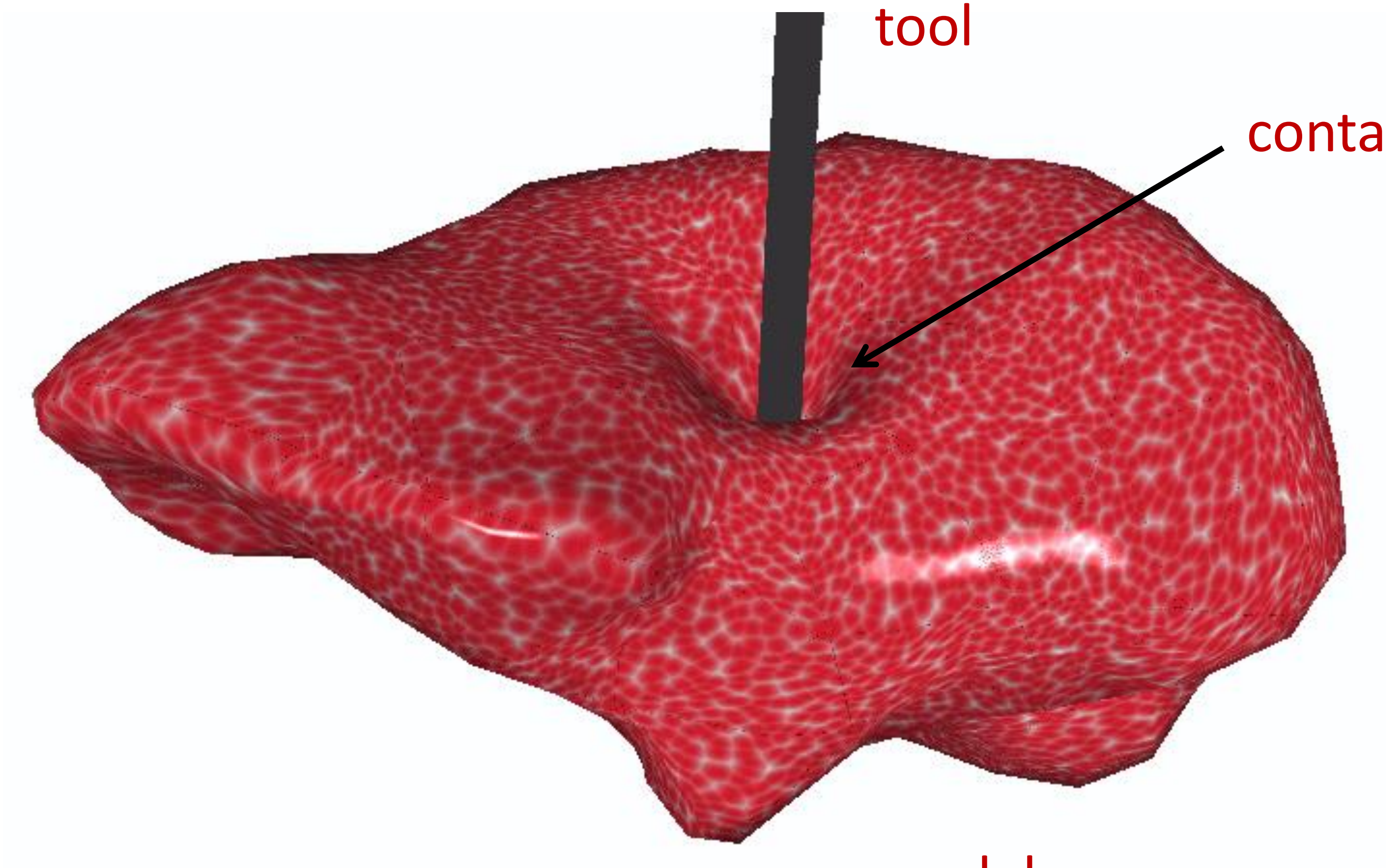
Computing Dynamics



Deformable Mesh



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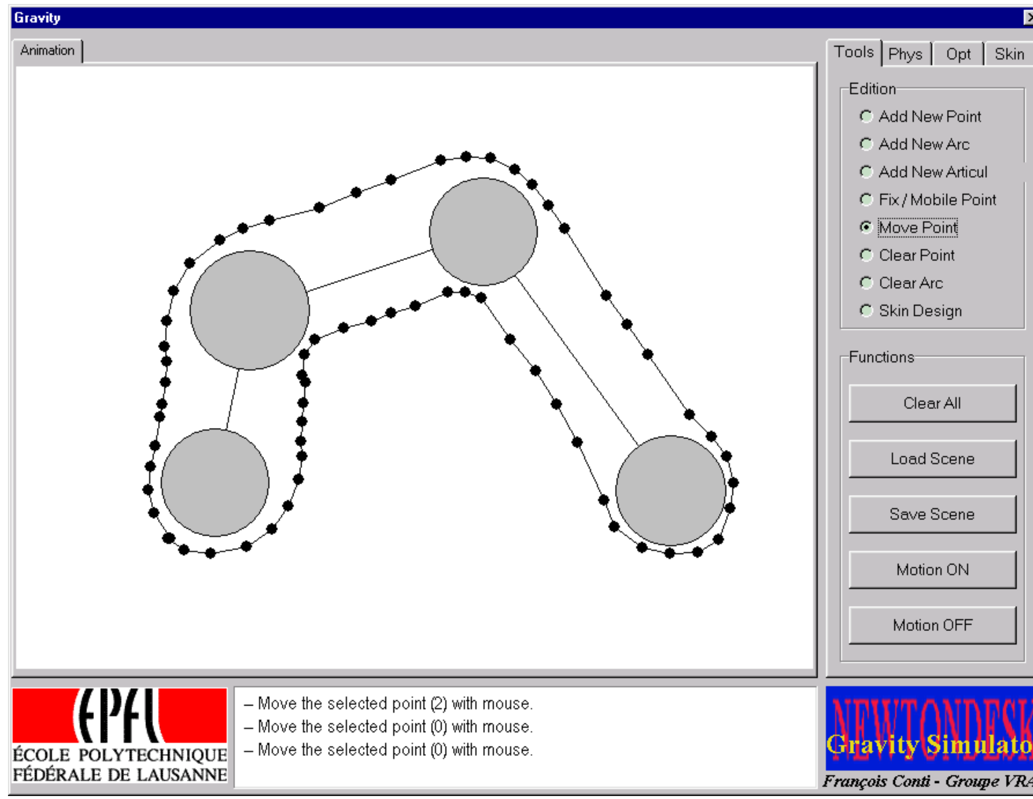
Filling Sphere Approach (2D)



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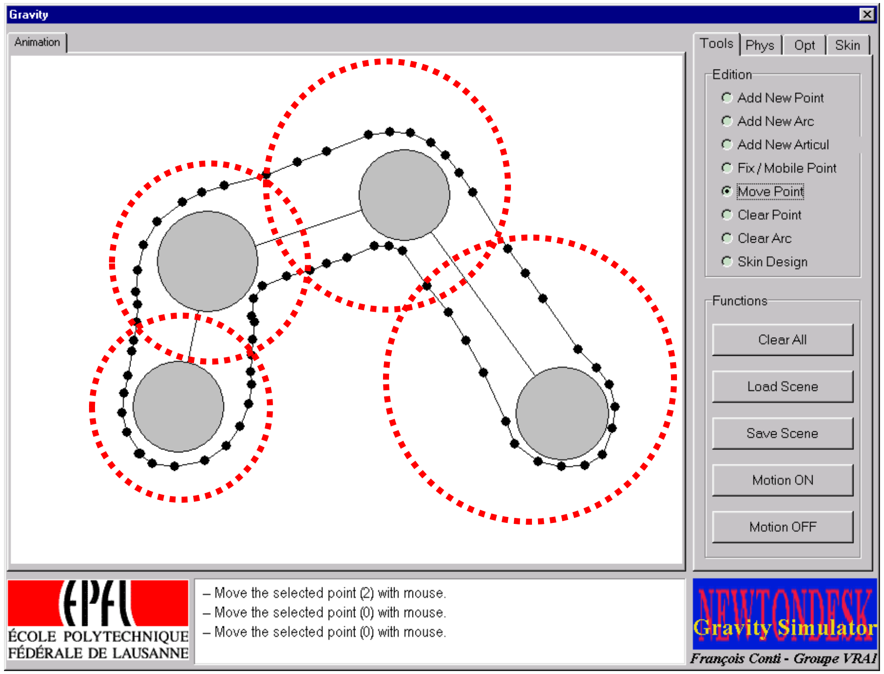
Collision Detection

Collision detection with deformable meshes are difficult to achieve in real time due to the constant change of their geometry (constant update of the collision detection model)

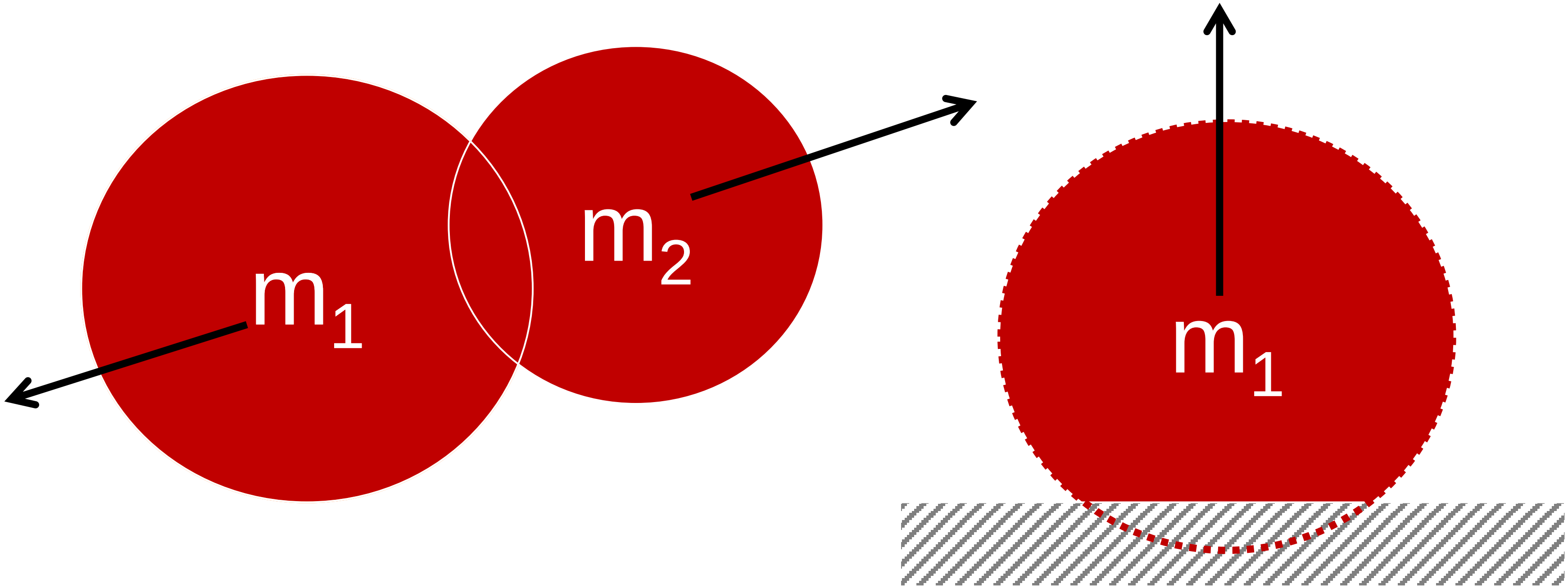
- How can we compute a collision between a segment and deformable mesh?
- How can we compute collisions between deformable meshes?

Collision Segment-Mesh

1. Collision detection is first performed between the input segment and the collision spheres composing the skeleton of the model.
2. Collision between the segment and the triangles are then searched locally



Collision Mesh-Mesh



Reaction forces are computed between mass nodes

$F_r = -k\,x$

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