Introduction to Computer Graphics

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04/02 Introduction & projective rendering

11/02 Prodedural modeling, Interactive modeling with parametric surfaces

25/02 Introduction to OpenGL + lab: first steps & modeling

04/03 Implicit surfaces 1 + lecture/lab: transformations & hierarchies

11/03 Implicit surfaces 2 + Lights & materials in OpenGL

18/03 Textures, aliasing + Lab: Lights & materials in OpenGL

25/03 Textures in OpenGL: lecture + lab

01/04 Procedural & kinematic animation + lab: procedural anim

08/04 Physically-based animation: particle systems + lab: physics 1

22/04 **Physically-based animation: collisions, control** + lab: physics 2

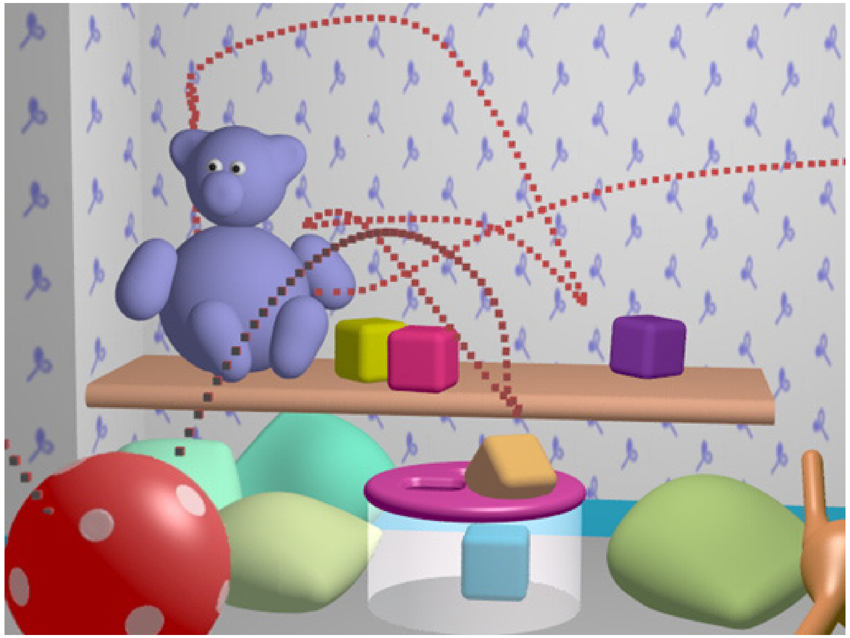
29/04 Animating complex objects + Realistic rendering

06/05 Talks: results of cases studies

Interactions (collisions) between objects

Processing them: an advantage of physically-based models!

- Continuous solutions
  - Intersections of trajectories
  - Back to the contact time!
- Discrete time solutions
  1. Detect penetrations
  2. Model contact
  3. Respond to collisions

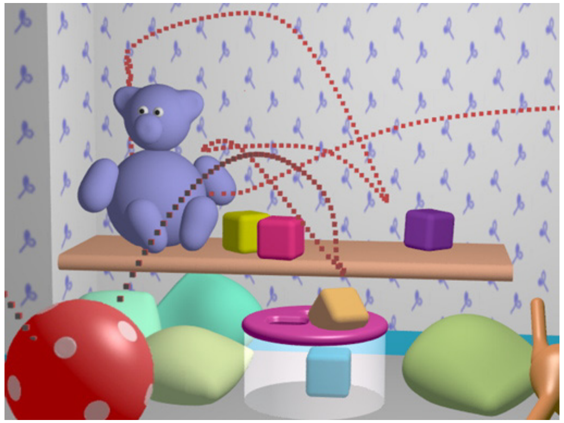


Physically-based models
Interactions between objects

1. Detect interpenetrations

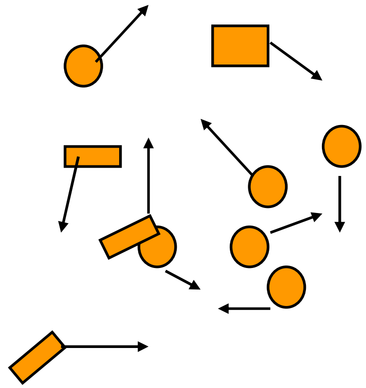
- Broad phase
  - Event-based processing
  - Use a space grid
  - Use bounding volumes

- Narrow phase
  - Intersection of geometry

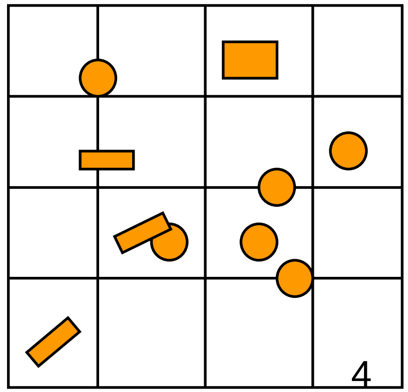


Interactions between objects

1. Detection: broad phase



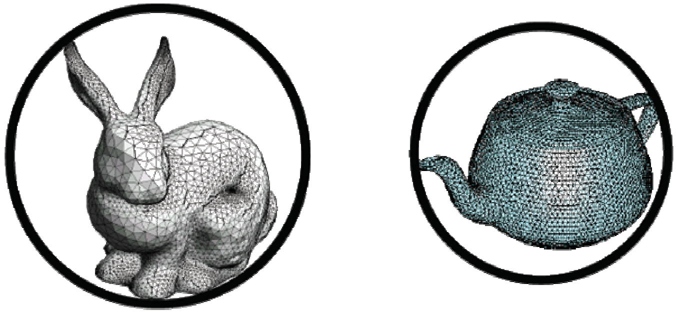
- Event-based detection
  - For rigid solids with bounded acceleration
    Guarantee that a pair cannot collide before …
  - Use a temporal queue to store the next tests



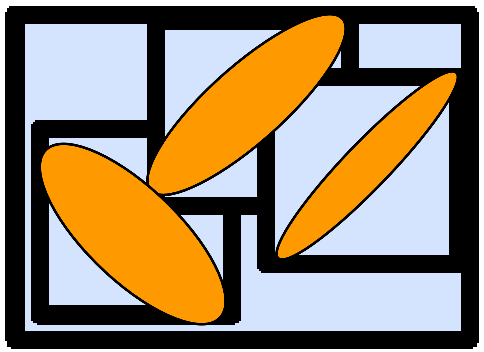
- Space grid
  - Each cell: list of objects intersecting it
  - Tests: pairs of object in the same cell

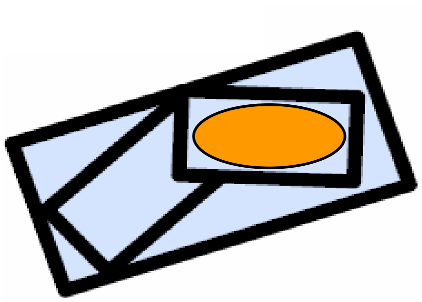
Interactions between objects

1. Detection: broad phase



- Use bounding volumes
  - Spheres
    distance > R1 + R2 ?
  - Axes parallel bounding boxes (ABB)
    X1-max > X2-min ?
  - Oriented bounding boxes (OBB)

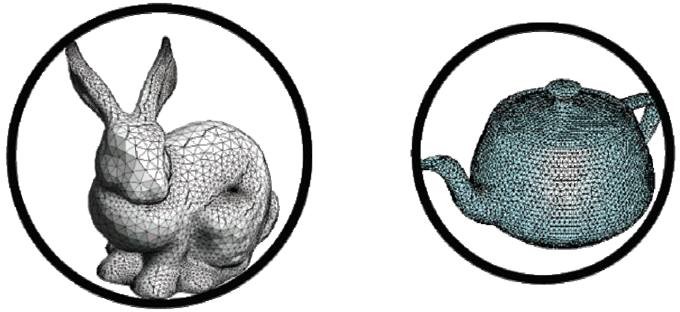




Physically-based models

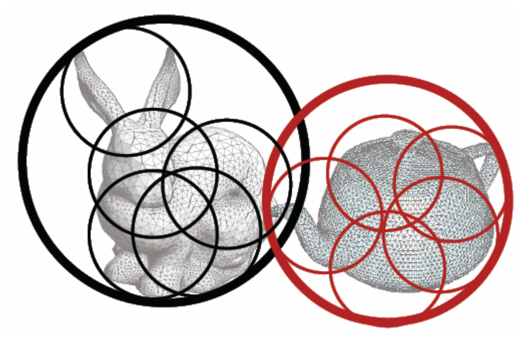
Interactions between objects

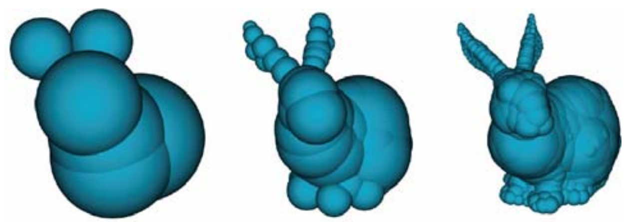
1. Detection: broad phase



- Hierarchies of bounding volumes
  - Divide & conquer approach

    refine if the parents intersect
  - Constant time, approximate detection
    Stop when needed





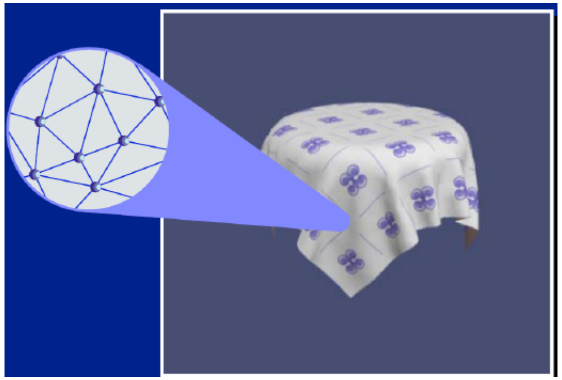
Interactions between objects

1. Detection: narrow phase

- For each pair of object

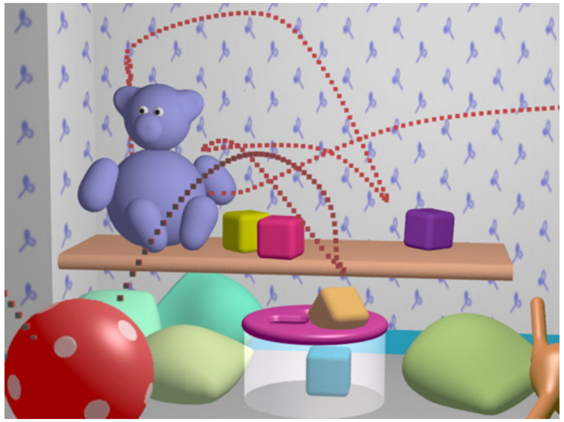
Use the geometric description

– Polygonal models: interection between pairs of faces (O(n^2))



– Tests point/field function if one of the objects is implicit (O(n))

(resrict to points of faces in bounding volume)



Physically-based models
Interactions between objects

1. Detection: narrow phase

- For each pair of object

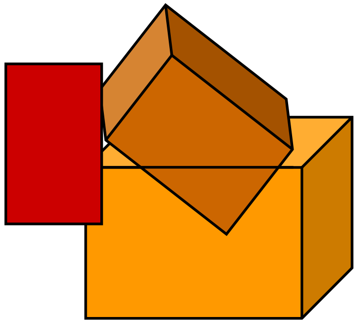
  Use the geometric description …

Notes

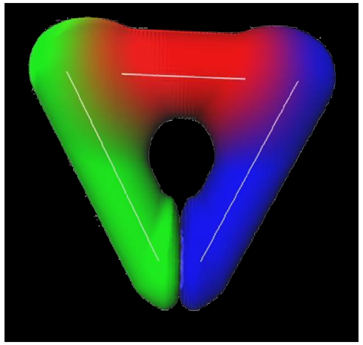
- Many recent methods are based on the graphics hardware (GPU)
- Difficult case: thin, deformable objects can cross between time steps

Interactions between objects

2. Contact modeling



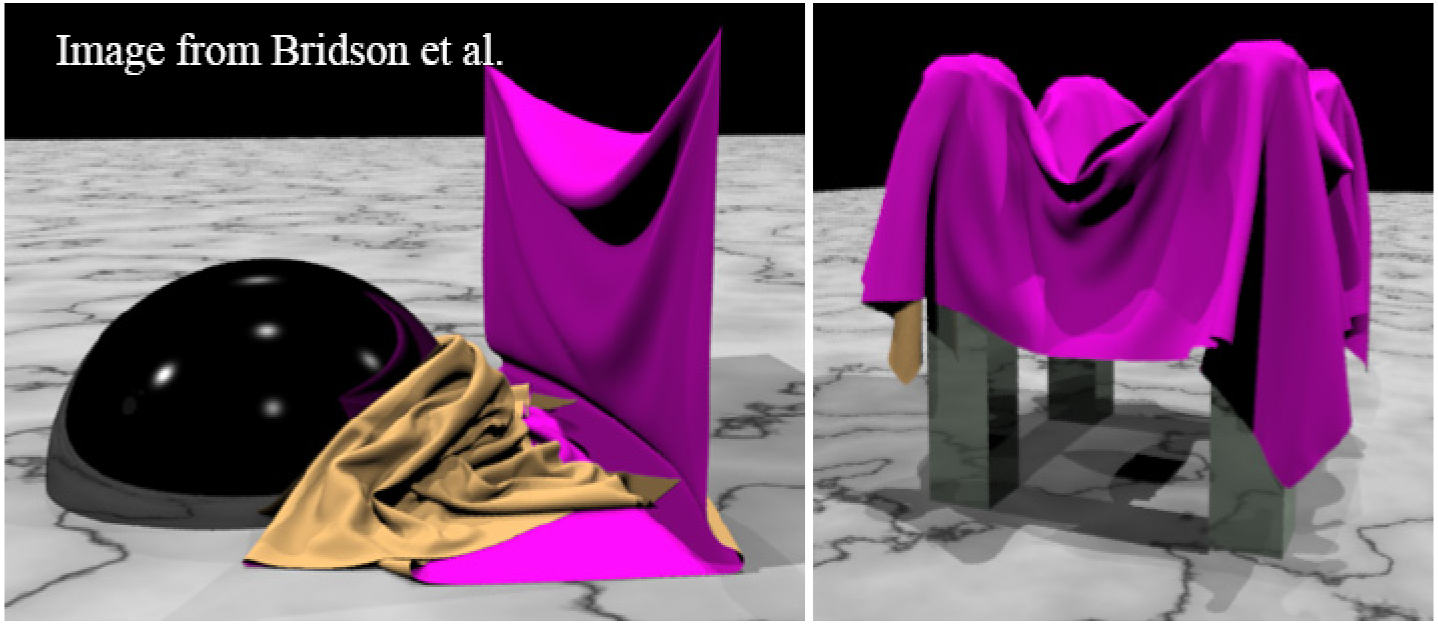
- Rigid objects
  - Back to a « valid configuration »?
    Inequalities expressing non-penetration
    Global system to be solved
  - Virtual reality: fast solution for a single collision
    Display non-penetrating copies



- Deformable models
  - Deform objects without moving them?

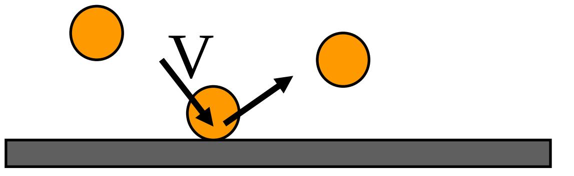
Interactions between objects

Problem for thin, deformable objects : Untangling cloth



Physically-based models
Interactions between objects

3. Response to collisions

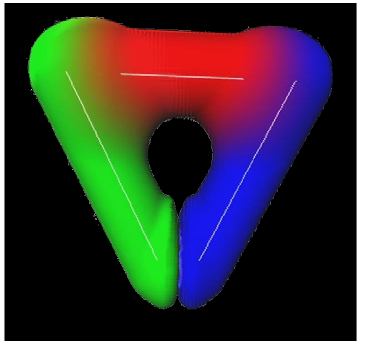


- Rigid bodies : 2 possible solutions
  - **Impulses**

    $V = V_t + V_n$

    Modified speed: $V := V_t - k\ V_n$

    (miror with energy decay in normal direction)
  - **Contact forces**

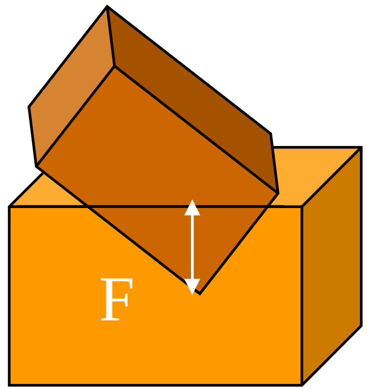


- Soft objects
  - **Contact forces**

Physically-based models
Interactions between objects

3. Response to collisions

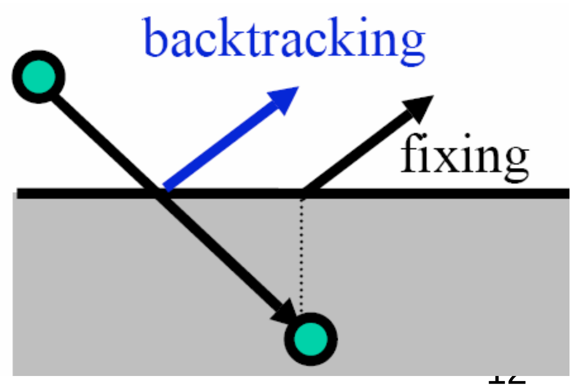
- "Penalty method" for response forces
  - Normal force fct of penetration
  - + Friction forces (viscous, dry…)



Virtual
spring
F = kl

Overshooting problem

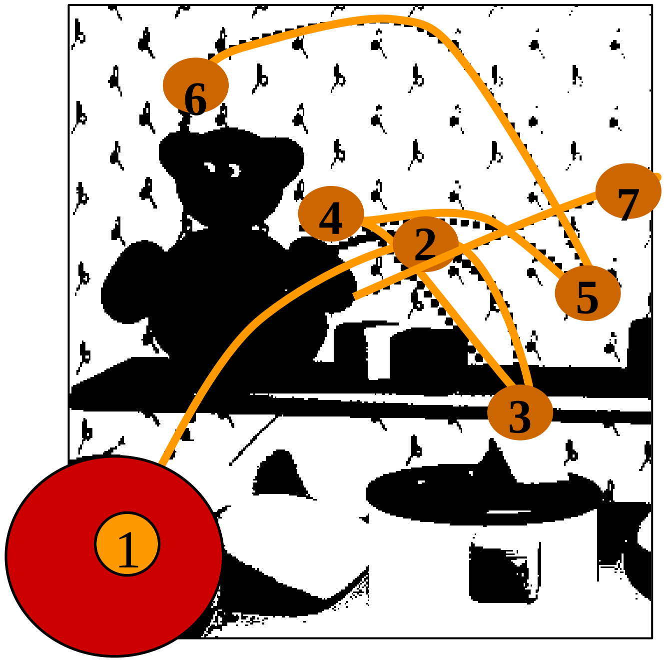
- Go back in time?
- Project the object to the closest point?
- Control energy after rebounce?
- Use adaptive time-steps?



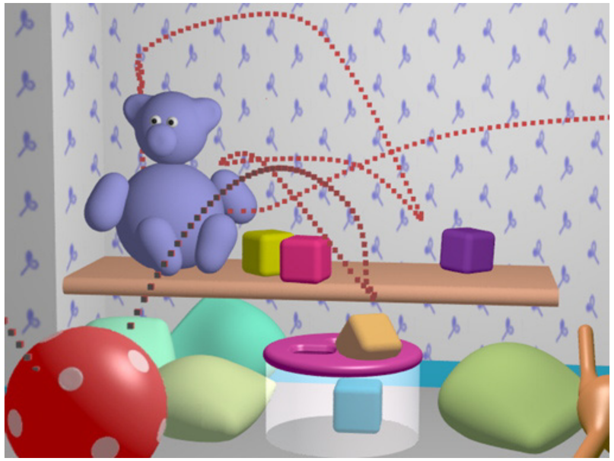
Motion Control
What the art direcor would like

« Help to realism »

- Master the scénario
  - Give approximate trajectories
  - Control some Dof, synchronize
- Use simulation
  - Realistic motion of floating parts
  - Collision detection and response
  - Improve realism of trajectories



Physically-based models
Motion control?



- Hard for inanimate objects
  - Unpredictable effect of collisions !
  - Instable
- Impossible for a character ?
  - Animation governed by muscle forces over time
  - Ex: a dinausaur descending stairs
    - More than 150° degrees of freedom to synchronize
    - Keep equilibrium!

Physically-based models
Motion control

Technics for combining realism and control ?

1. Imposing the motion of some Dof
2. Impoving a trajectory given by key-frames
3. Using/generating motion controlers

(and combinations of the above!)

Physically-based models
Motion control

1. Imposing the motion of some Dof

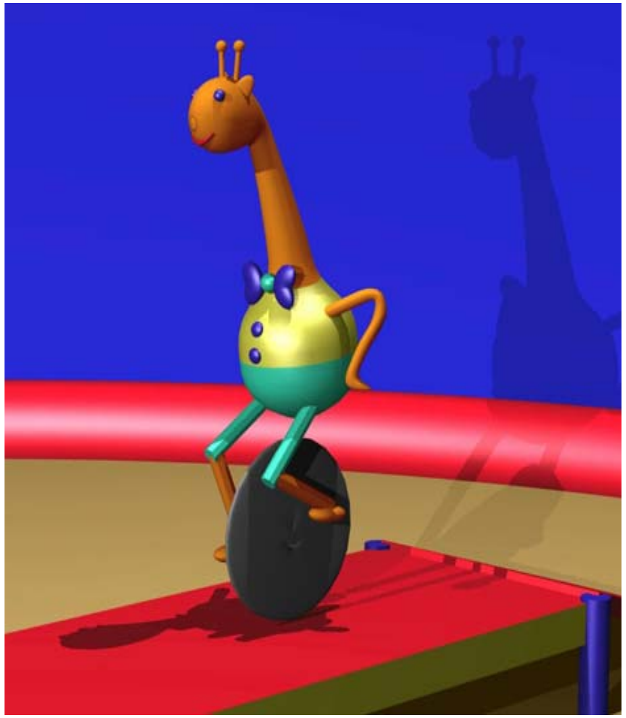
- *Goals*
  1. Imposed motion for some degrees of freedom
  2. The simulation computes the rest

- *Examples*
  - Swim : impose rotations of the arms
  - Swing : impose rotations of the legs

Physically-based models
Motion control

1. Imposing the motion of some Dof

- *Some resolution methods*
  - Inverse dynamics
  - Constraint forces (optimization)
  - Displacement constraints
    - Animate each part as independant
    - Iterate displacements until each constraint is reached



Motion control

1. Imposing the motion of some Dof

Results

Objects move as puppets (some parts pull the others)

For controlled DoF:

- No help to realism
- No deviation from ideal motion due to collision

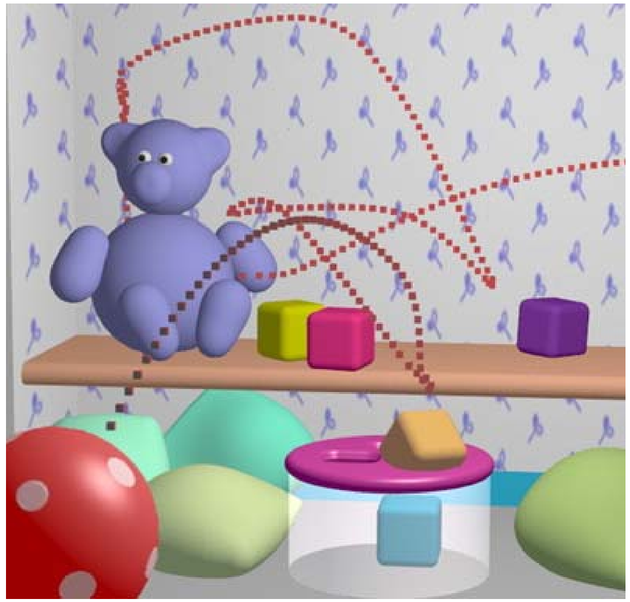
Physically-based models
Motion control

2. Improving trajectories given by key-frames

Simple method: Following a target

Physically-based model

- Attracted by a geometric target
- Computes speed, collisions…



- *Results*
  - Object are pulled as puppets
  - Fake realism !

Physically-based models
Motion control

2. Improving trajectories given by key-frames

Space-time constraints [Witkin, Kass 88]

1. The user specifies constraints (position/orientation at t_i)
2. The trajectory is improved through optimisation
   - Temporal discretization : unknowns X_i, F_i
   - Mecanics laws are used as constraints
   - A criteria is minimized (amount of internal energy used)

Physically-based models
Motion control

2. Improving trajectories given by key-frames

Space-time constraints *[Witkin, Kass 88]*

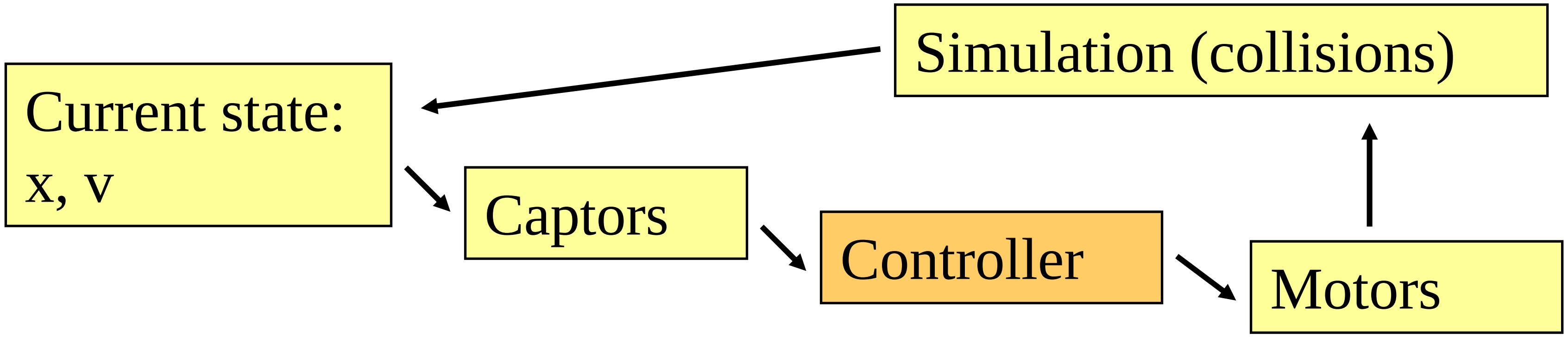
Results

- Attractive idea: “physically-based interpolation”
- Collisions cannot be handled automatically

Physically-based models
Motion control

3. Use/generate motion controllers

- *Method inspired from robotics*
  - Use a real simulation (ex walking: maintain equilibrium)
  - Muscular forces computed by a “controller”

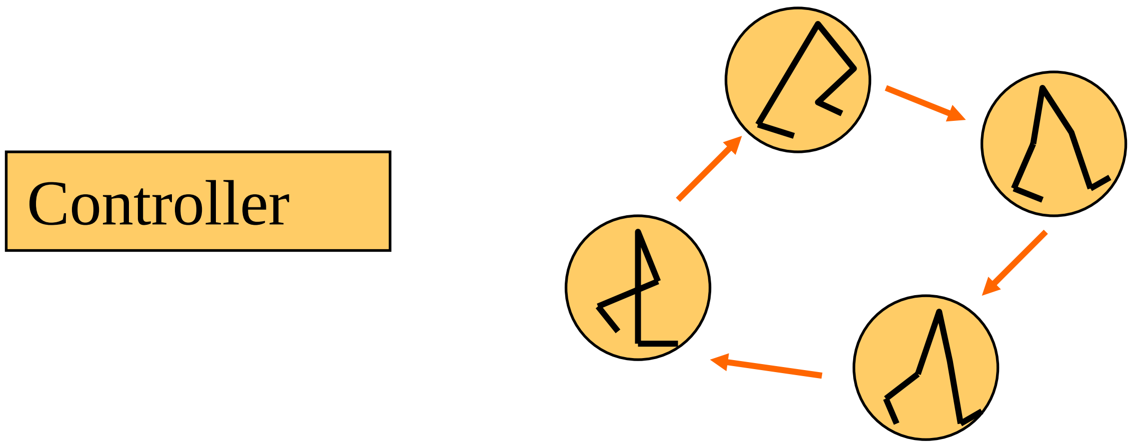


Physically-based models
Motion control

3. Use/generate motion controllers

– Controllers can act by pulling towards a succession of poses

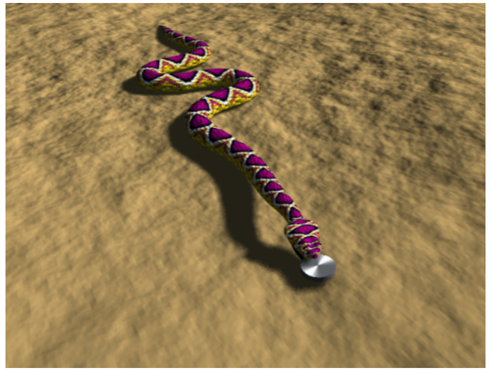
  - Blind control (mecanic toys)
  - Reactive control : take contacts into account (captors)



Physically-based models
Motion control

3. Use/generate motion controllers

Secret serpent



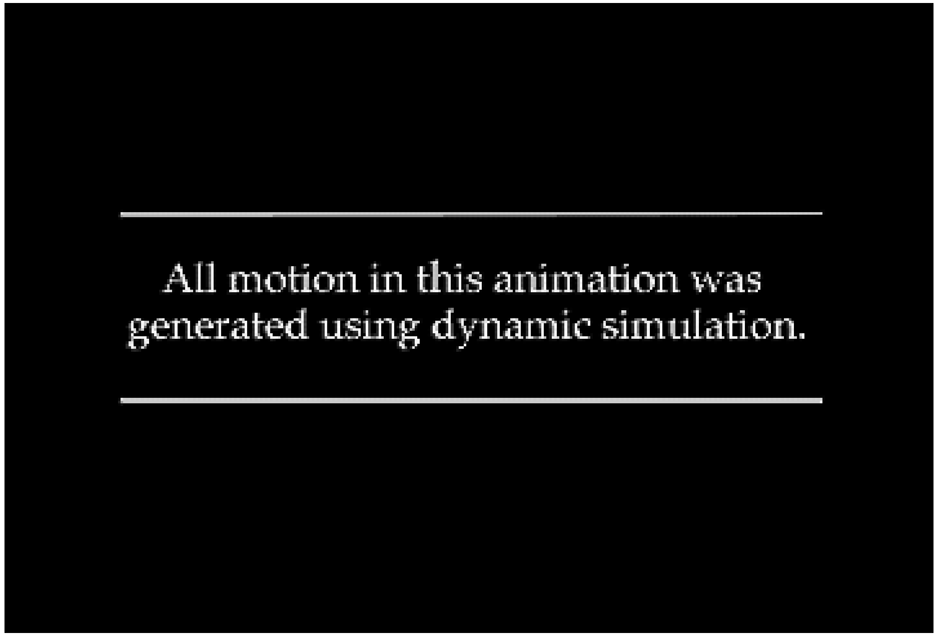
- Synthesis of controllers
  - Manual : example of athlitic motion *[Hod95]*
  - Optimisation : random search, selection, improvement *[VdP93-95]*
  - Genetic algorithms : population, crossings *[NM93]*

Find how a given creature can use its muscles!

Physically-based models
Motion control

3. Manual tuning of motion controllers

[Miller 89]

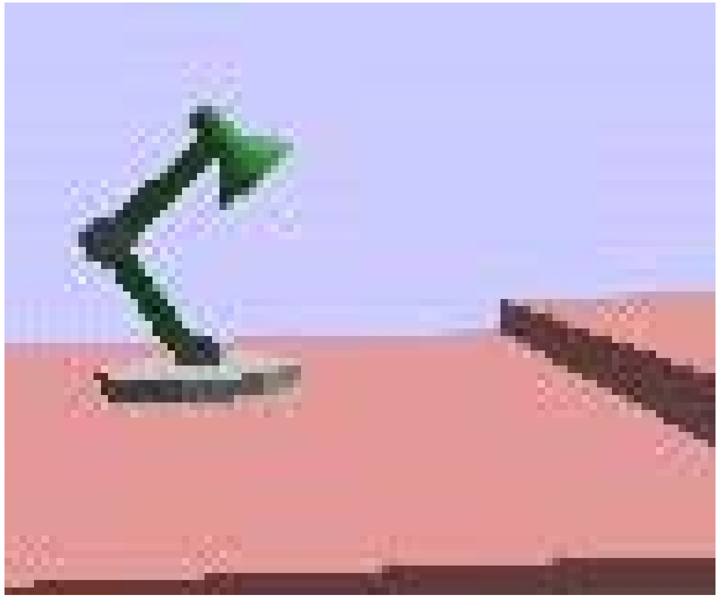


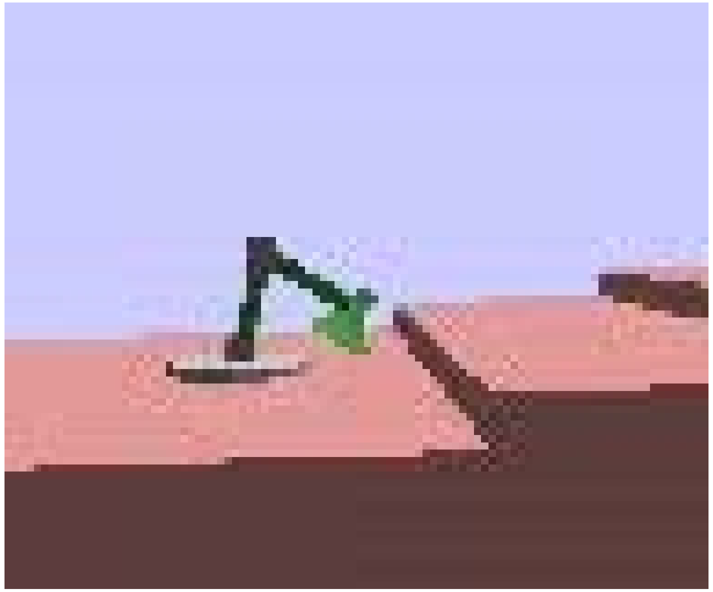
Athletics [Hodgins 95]

Physically-based models

Motion control

3. Automatic generation of motion controllers





[Van de Panne 93-2000]

Physically-based models
Motion control

3. Use/generate motion controllers

Complex motion

- Transition graphs between controllers

  Ex: walk + equilibrium, fall, get up

- Each controller is itself a graph of desired postures

The "captor" data play an essential part!