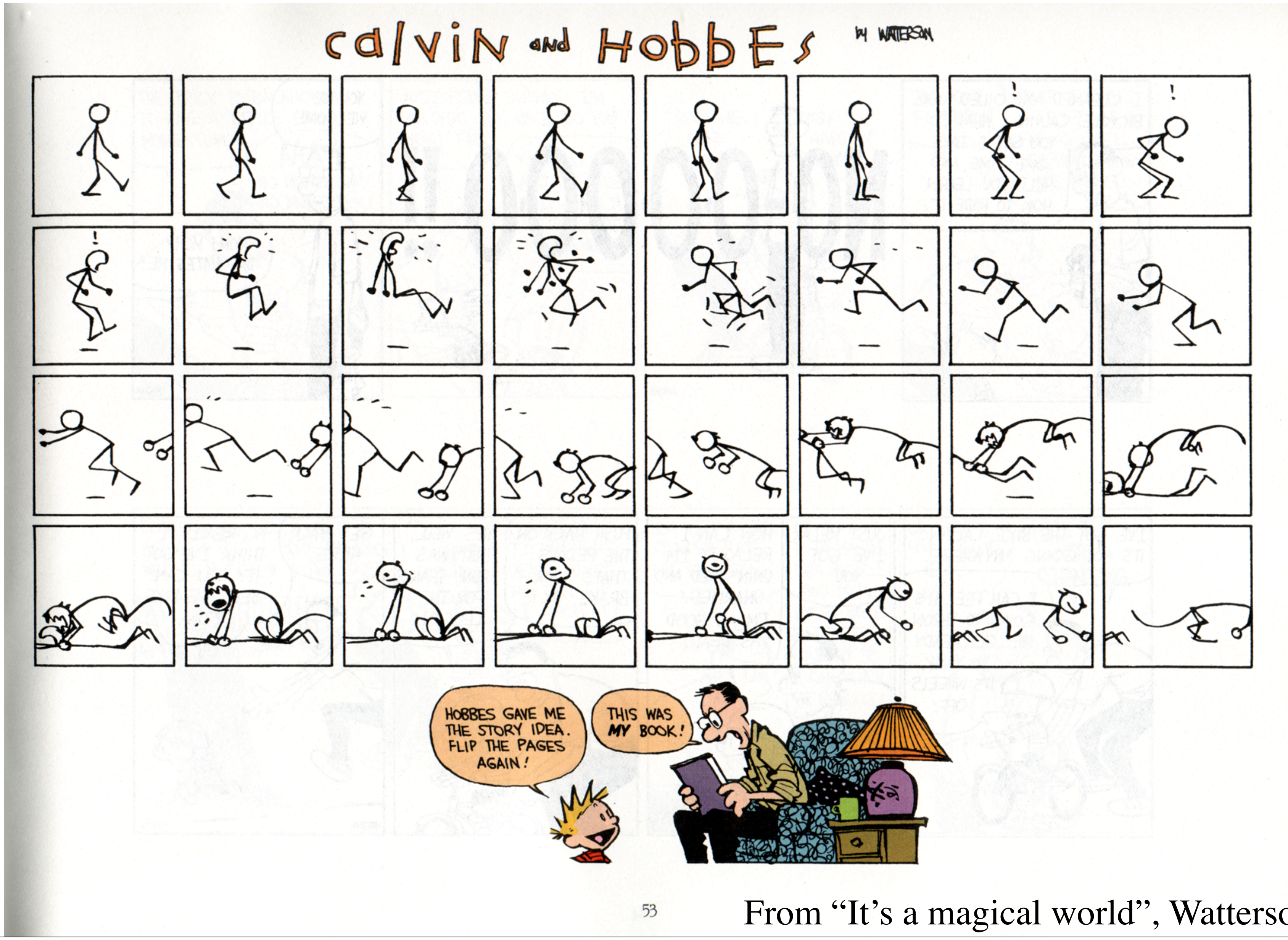
Animation

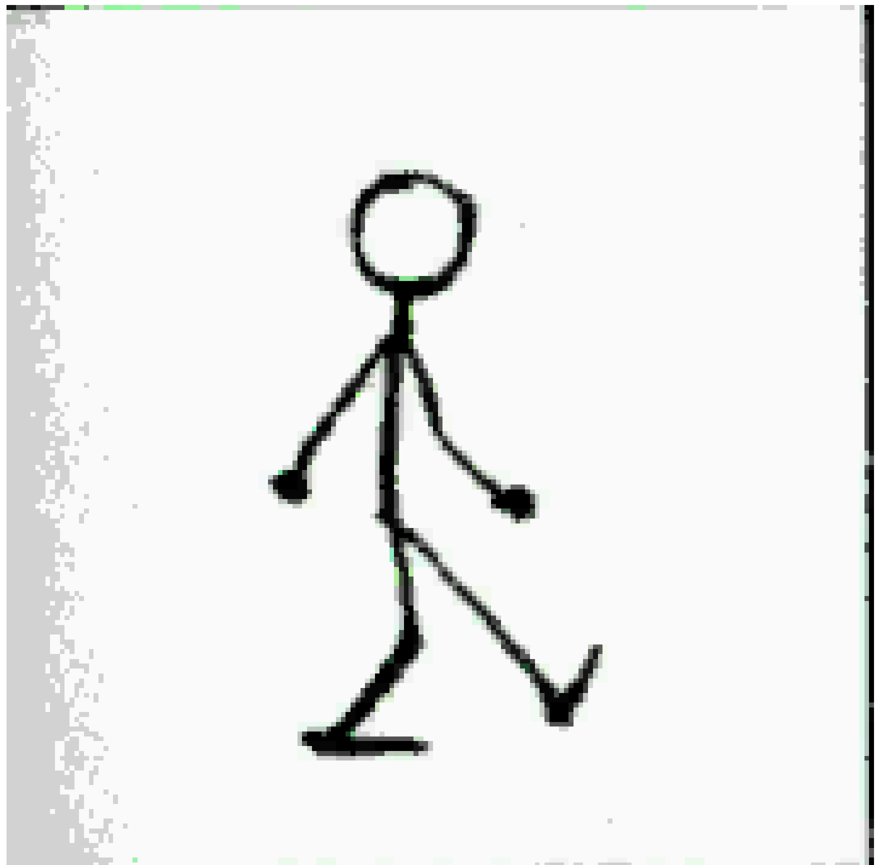
- Persistence of vision:
  - The visual system smoothes in time. This means that images presented to the eye are perceived by the visual system for a short time after they are presented. In turn, this means that if images are shown at the right rate (about 20-30 Hz will do it), the next image replaces the last one without any perceived blank space between them.
- Visual closure:
  - a sequence of still images is seen as a motion sequence if they are shown quickly enough - i.e. smooth motion between positions is inferred

Keyframing



From "It's a magical world", Watterson, 1996

Result



Basic techniques

- Keyframing:
  - generate frames by drawings, interpolate between drawings
- Stop motion:
  - put model in position, photograph, move, photograph, etc.
- Compositing:
  - generate frames as mixtures of video sequences
- Morphing:
  - mix video sequences while modifying shapes
- Procedural animation:
  - use some form of procedural description to move object

Keyframing - issues

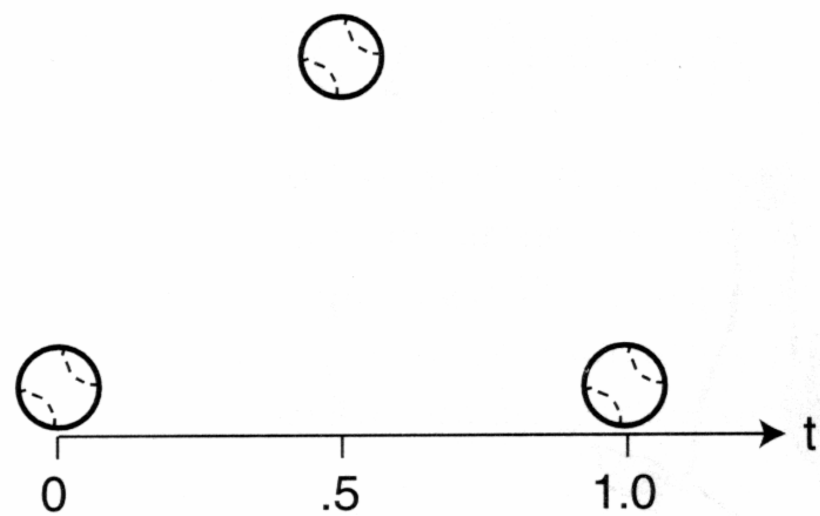


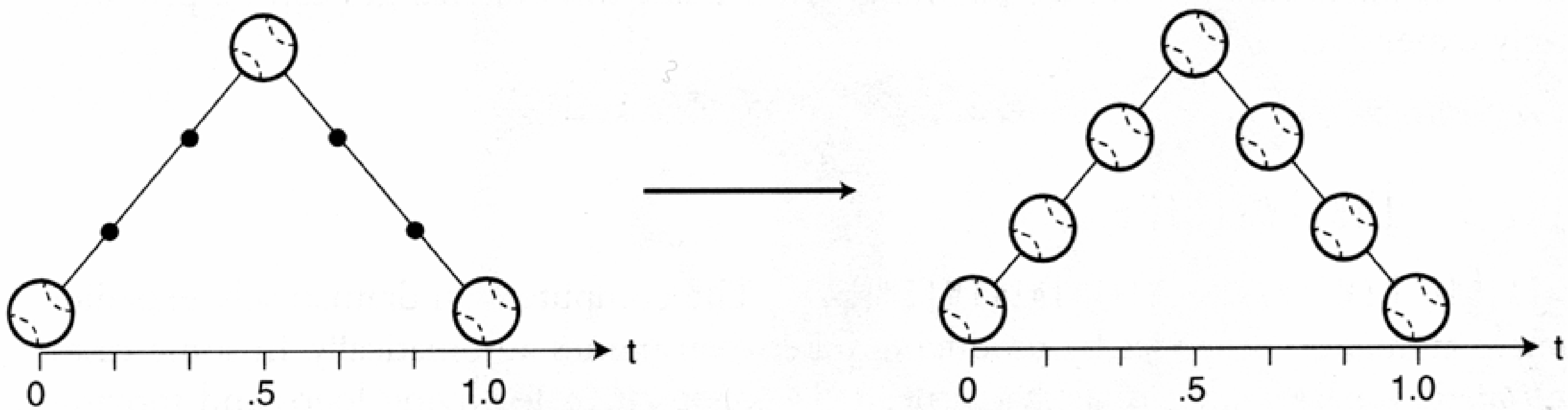
Figure 10.4 **Three keyframes.** Three keyframes representing a ball on the ground, at its highest point, and back on the ground.

- Generating frames by hand is a huge burden -- 1hr of film is 3600x24 frames
- Skilled artists generate key frames, inbetweeners generate inbetween frames
- Changes are hideously expensive
- Natural interpolation problem -- interpolate various variables describing position, orientation, configuration of objects

From "The computer in the visual arts", Spalter, 1999

Linear interpolation

Figure 10.5 **Inbetweening with linear interpolation.** Linear interpolation creates inbetween frames at equal intervals along straight lines. The ball moves at a constant speed. Ticks indicate the locations of inbetween frames at regular time intervals (determined by the number of frames per second chosen by the user).



From “The computer in the visual arts”, Spalter, 1999

More complex interpolation

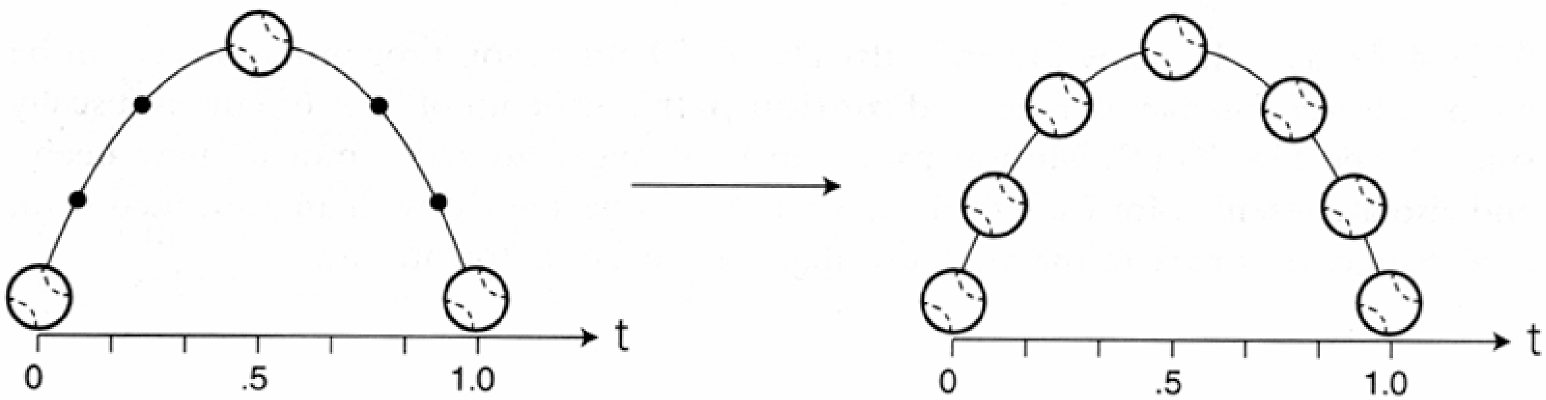


Figure 10.9 **Inbetweening with nonlinear interpolation.** Nonlinear interpolation can create equally spaced inbetween frames along curved paths. The ball still moves at a constant speed. (Note that the three keyframes used here and in Fig. 10.10 are the same as in Fig. 10.4.)

From "The computer in the visual arts", Spalter, 1999

Modify the parameter, too

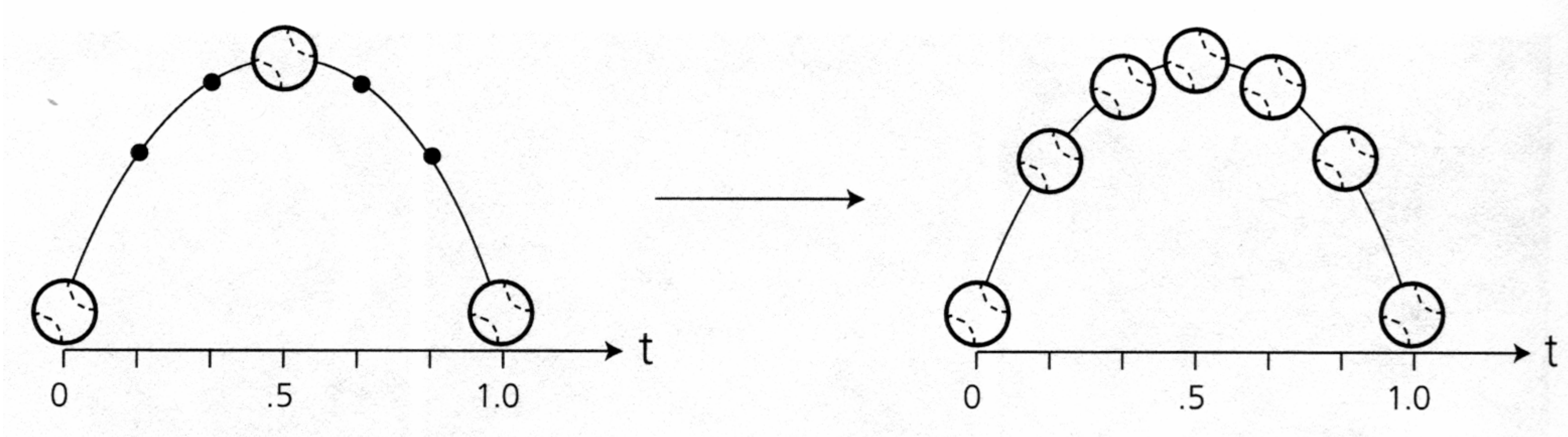
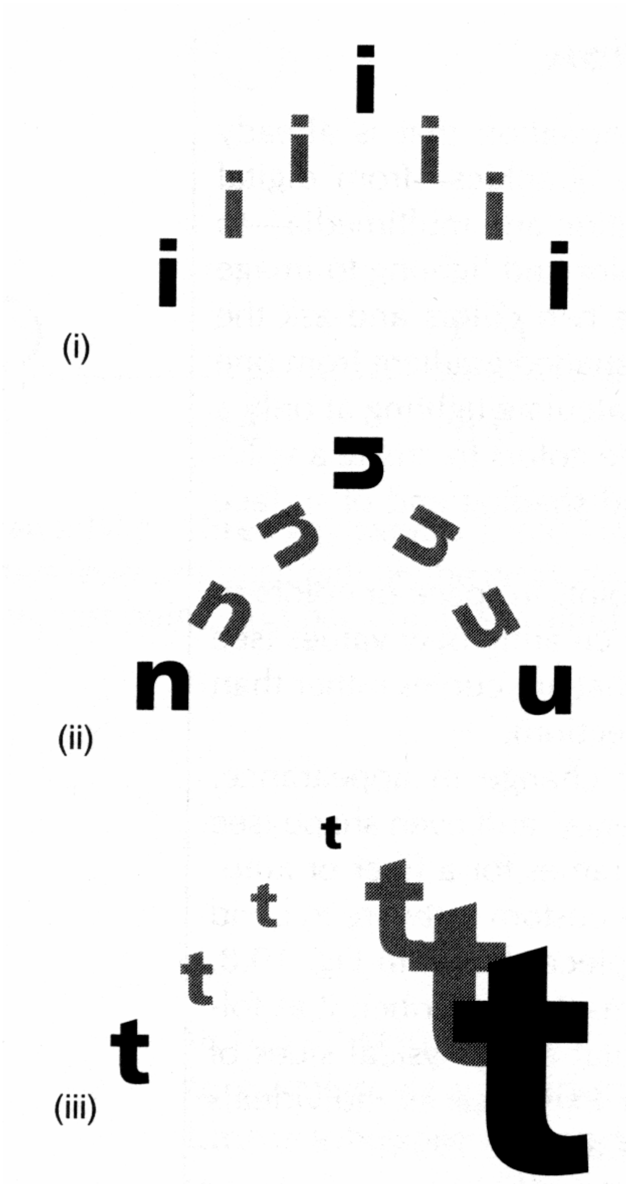


Figure 10.10 **Inbetweening with nonlinear interpolation and easing.** The ball changes speed as it approaches and leaves keyframes, so the dots indicating calculations made at equal time intervals are no longer equidistant along the path.

A use for parameter continuous interpolates here.
Notice that we don't necessarily need a physical ball.

From "The computer in the visual arts", Spalter, 1999

A variety of variables can be interpolated

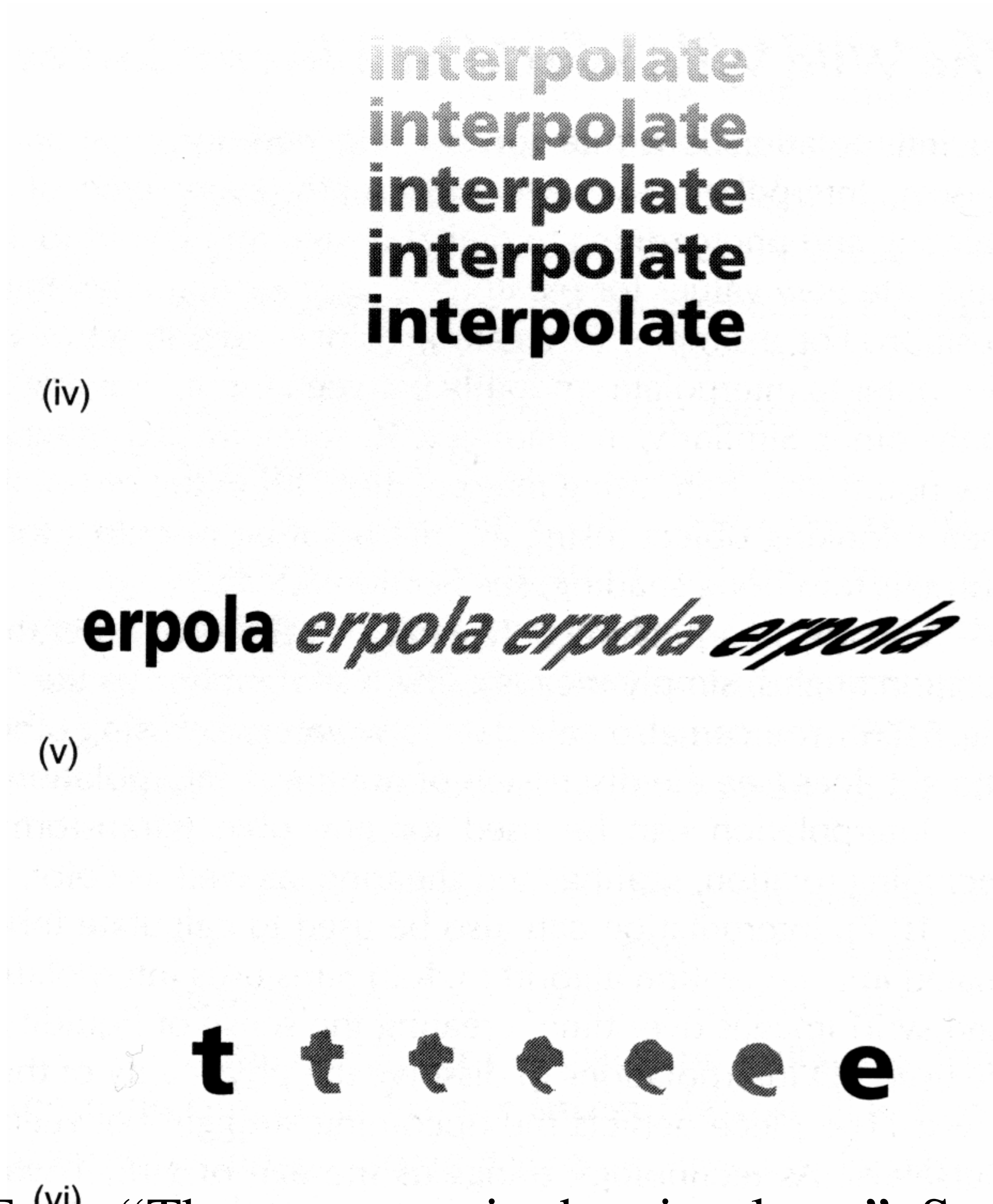


Position

Position and orientation

Position and scale

From “The computer in the visual arts”, Spalter, 1999

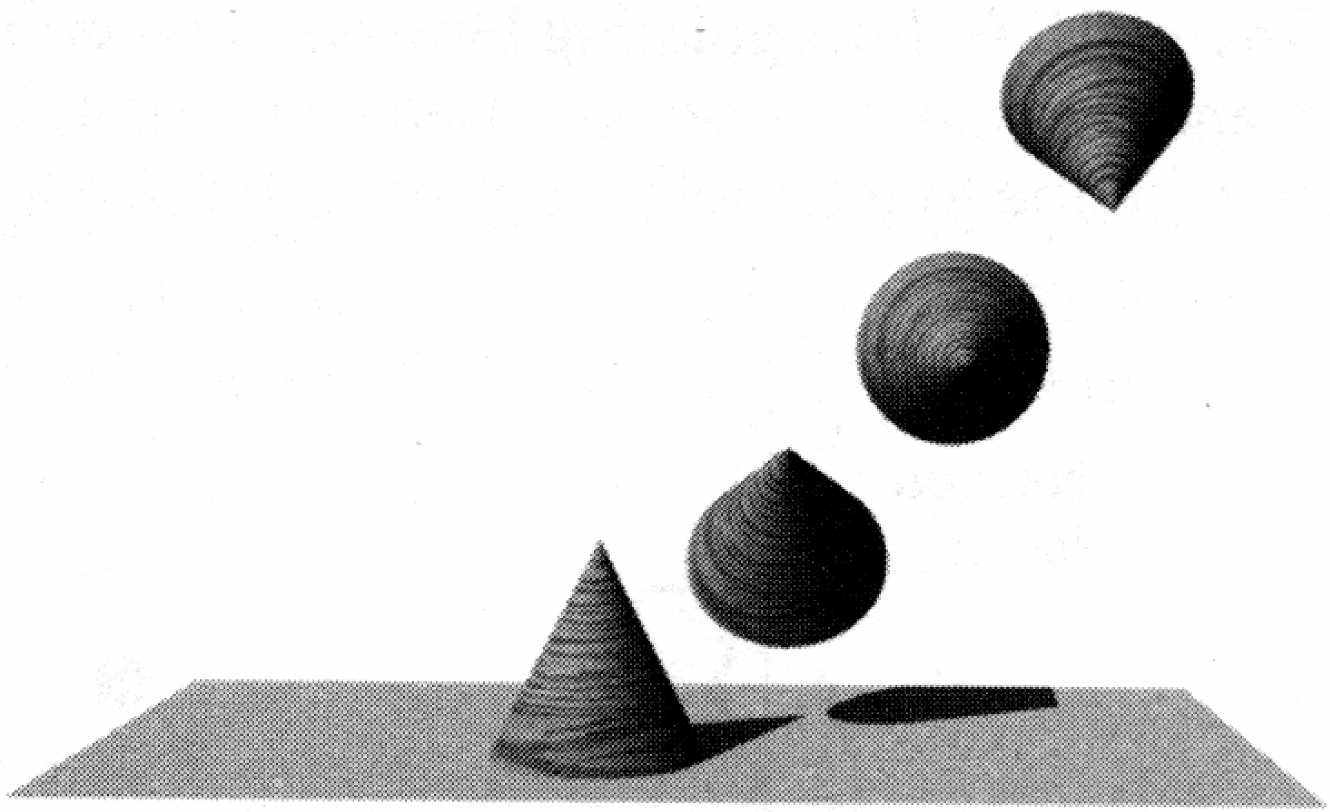


Grey-level

Shea
r

Shap
e

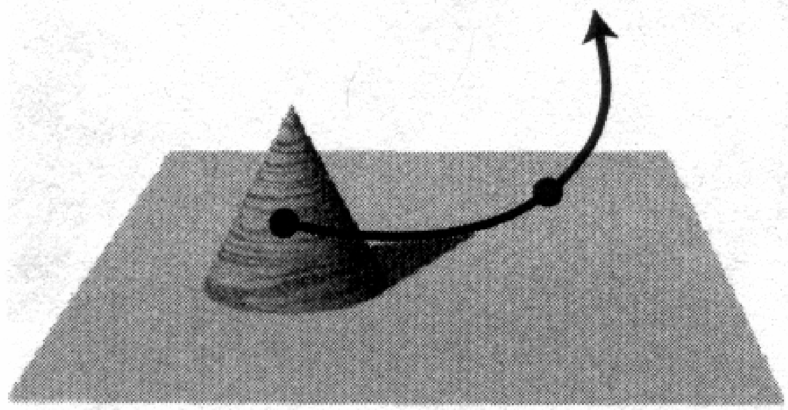
From “The computer in the visual arts”, Spalter, 1999

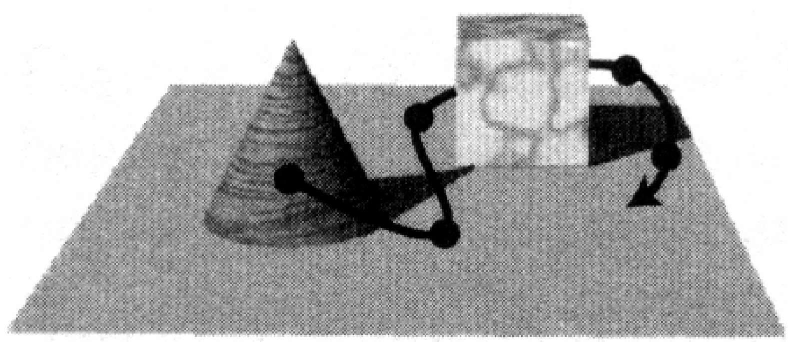


Position and orientation:

note that the position travels along a motion path

From “The computer in the visual arts”, Spalter, 1999

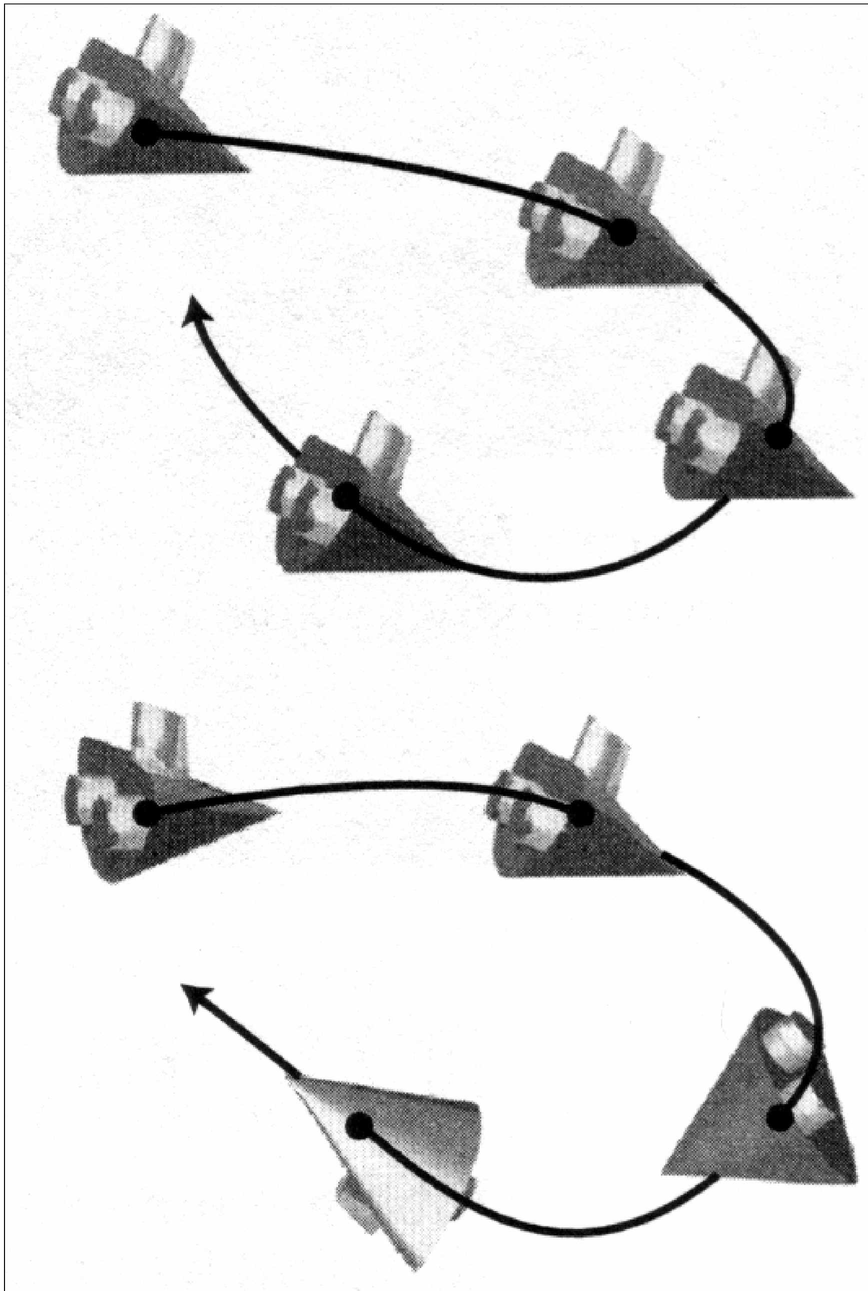




Various path specifications:

perhaps by interactive process;
two issues:
 building the path
 where are the keyframes?

From “The computer in the visual arts”, Spalter, 1999

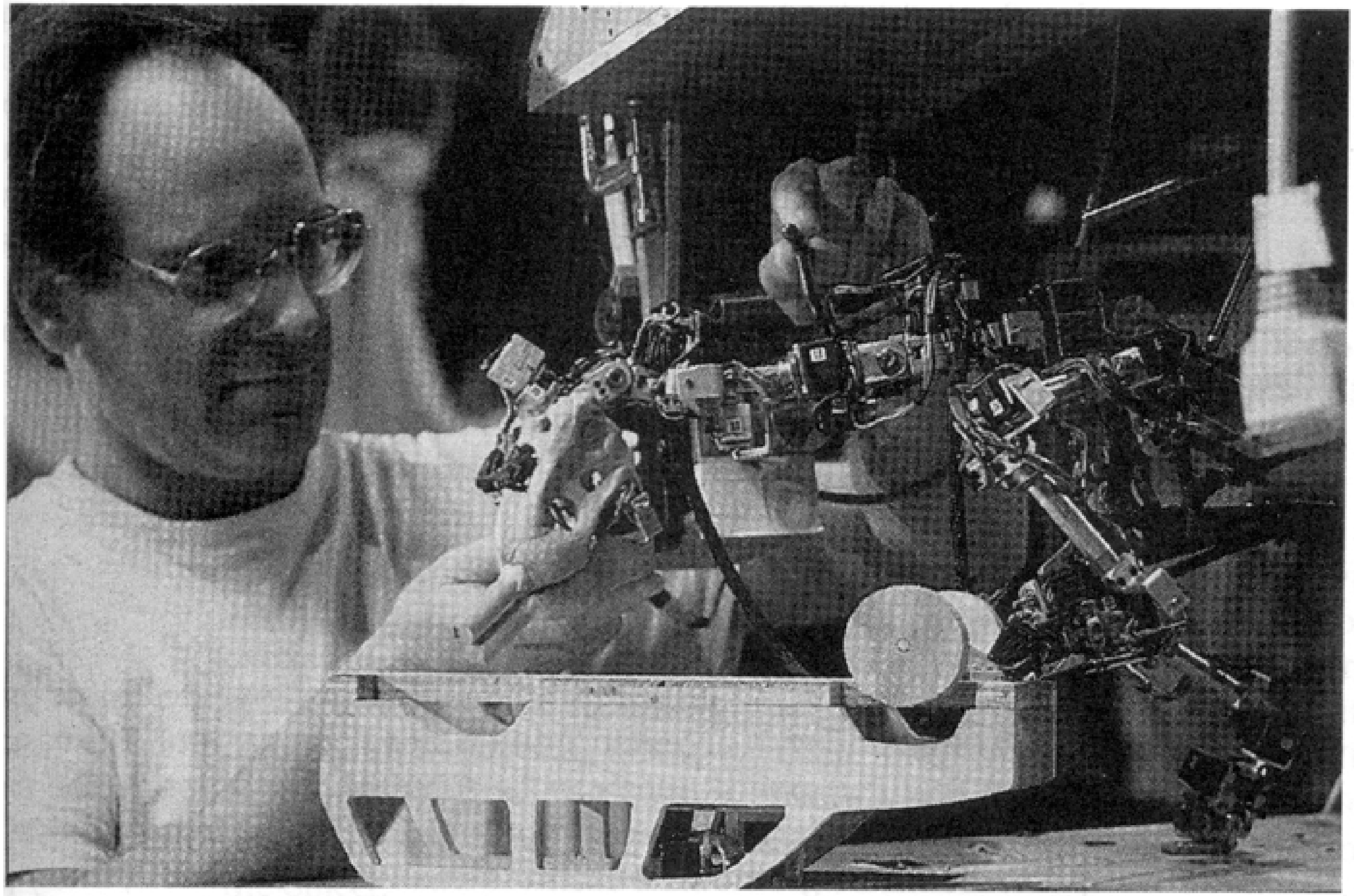


Interpolating orientation gives greater realism. Notice that the tangent to the motion path gives a great cue to the orientation of the object.

From “The computer in the visual arts”, Spalter, 1999

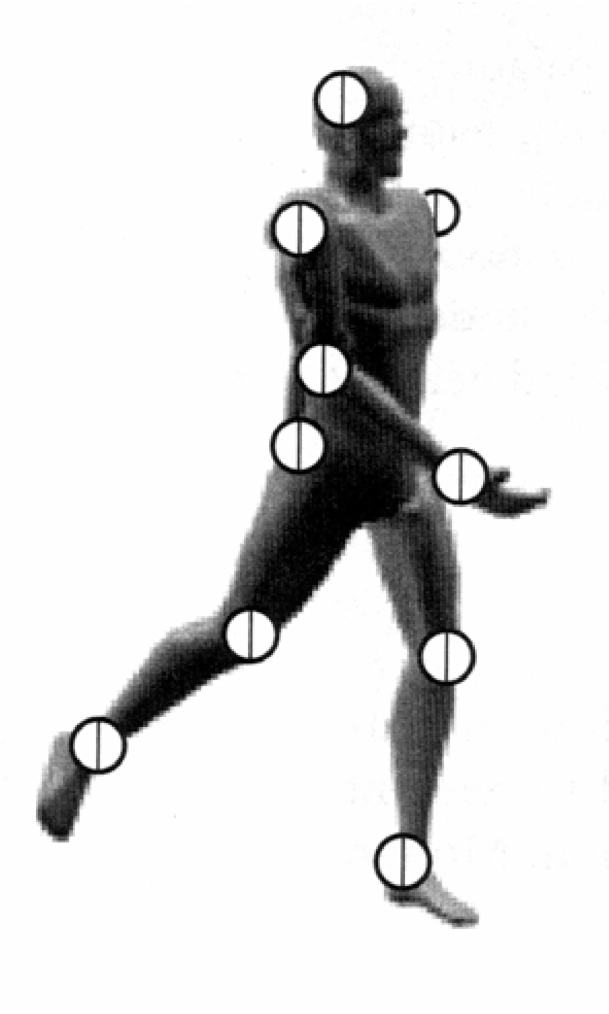
Stop motion

- Very important traditional animation technique
- Put model in position, photograph, move, photograph, etc. e.g. “Seven voyages of Sinbad”, “Clash of the titans”, etc.
  - Model could be
    - plastic
    - linkage
    - clay, etc.
- Model work is still very important e.g. “Men in Black”
- Computerizing model work is increasingly important
  - issue: where does configuration of computer model come from?

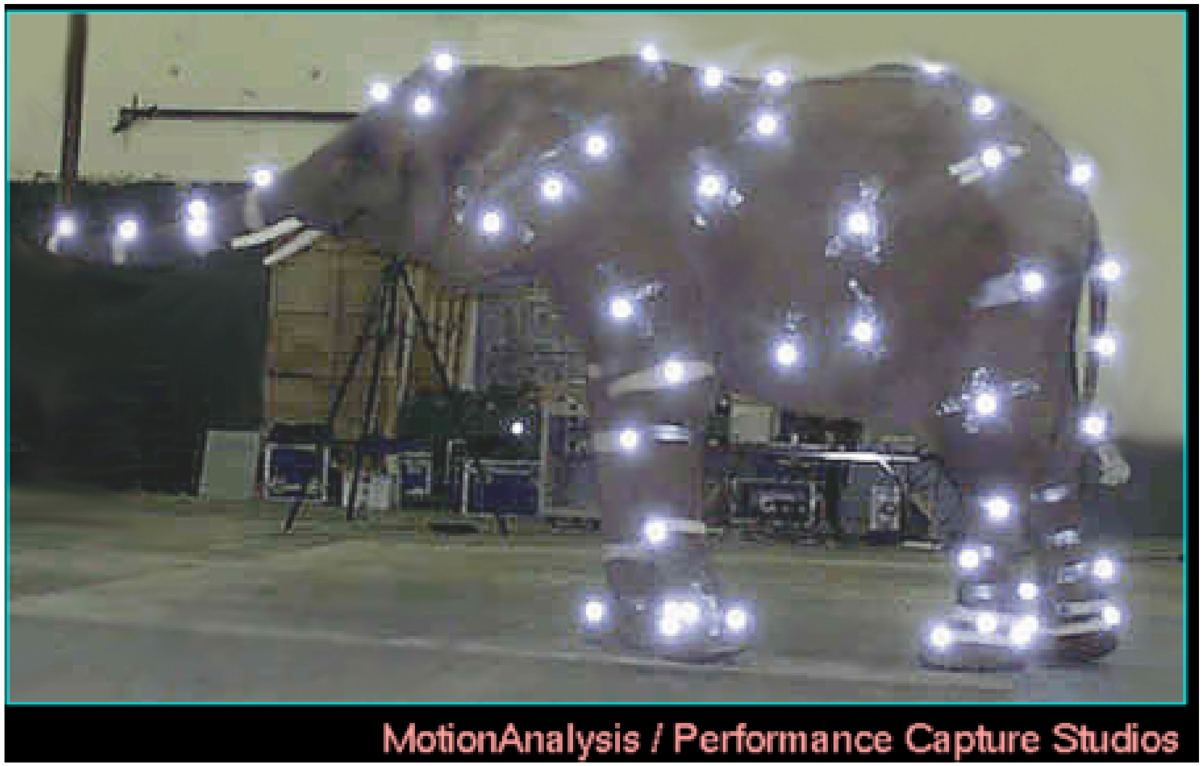


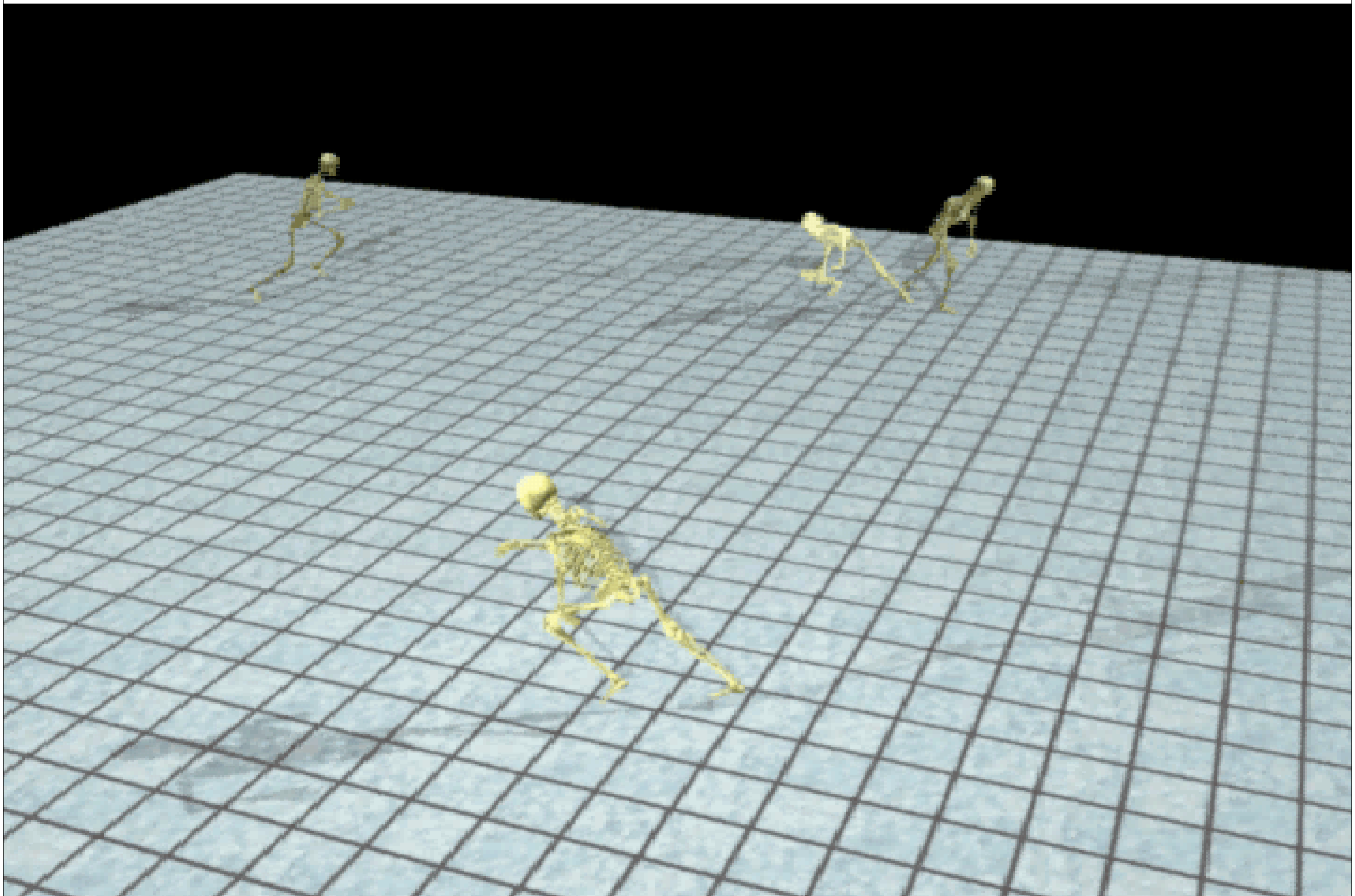
From “The computer Image”,Watt and Policarpo, 1998

Motion capture



- Instrument a person or something else, perhaps by attaching sensors
- Measure their motion
- Link variables that give their configuration to variables that give configuration of a computer model

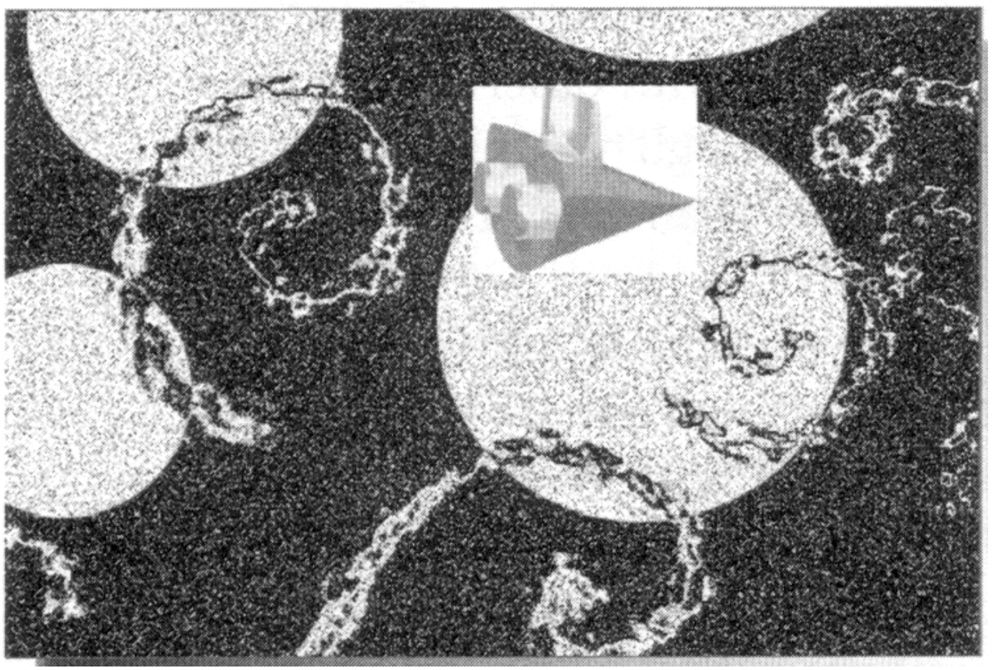

MotionAnalysis / Performance Capture Studios



[redacted]

Compositing

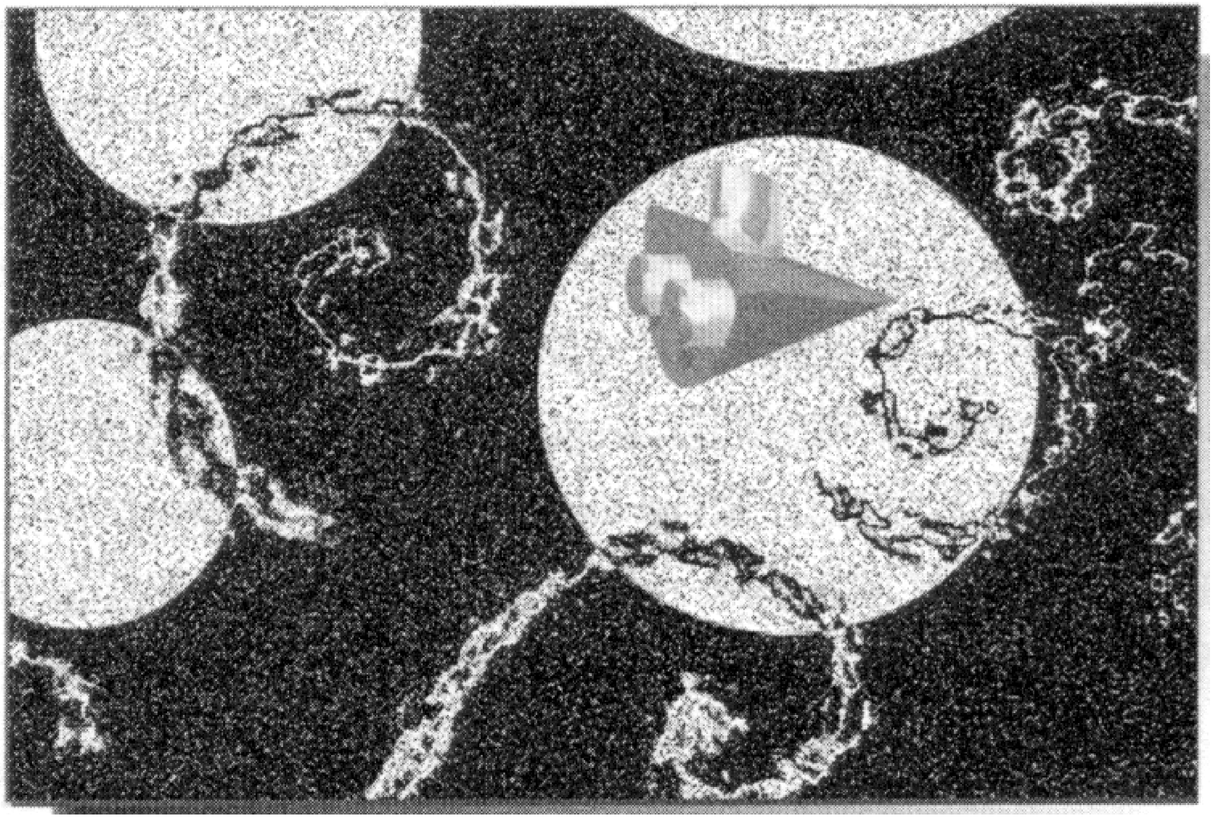
- Overlay one image/film on another
  - variety of types of overlay



Simple overlay - spaceship pixels replace background pixels

From “The computer in the visual arts”, Spalter, 1999

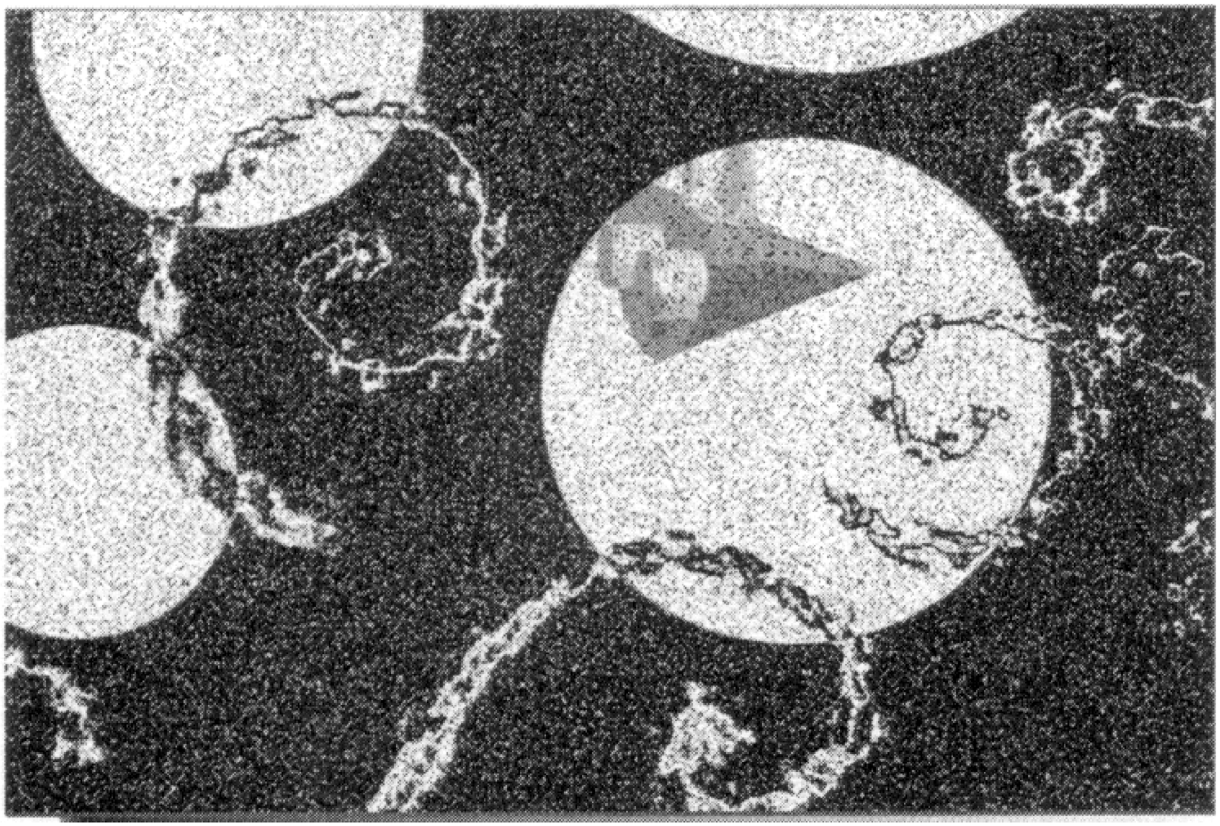
Compositing



Spaceship pixels replace background pixels if they are not white (white is “dropped out”)

From “The computer in the visual arts”, Spalter, 1999

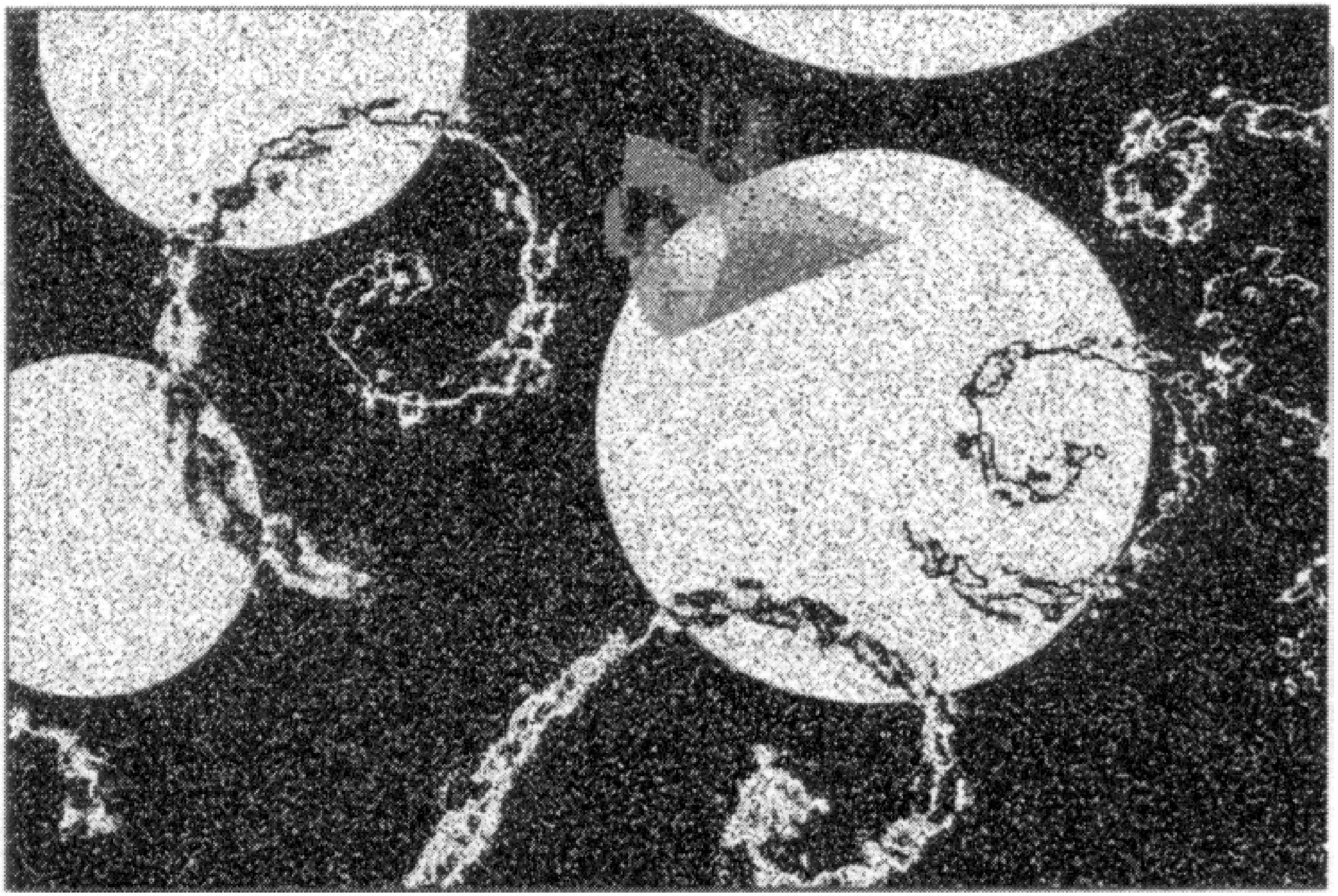
Compositing



Spaceship pixels replace background pixels if they are darker

From “The computer in the visual arts”, Spalter, 1999

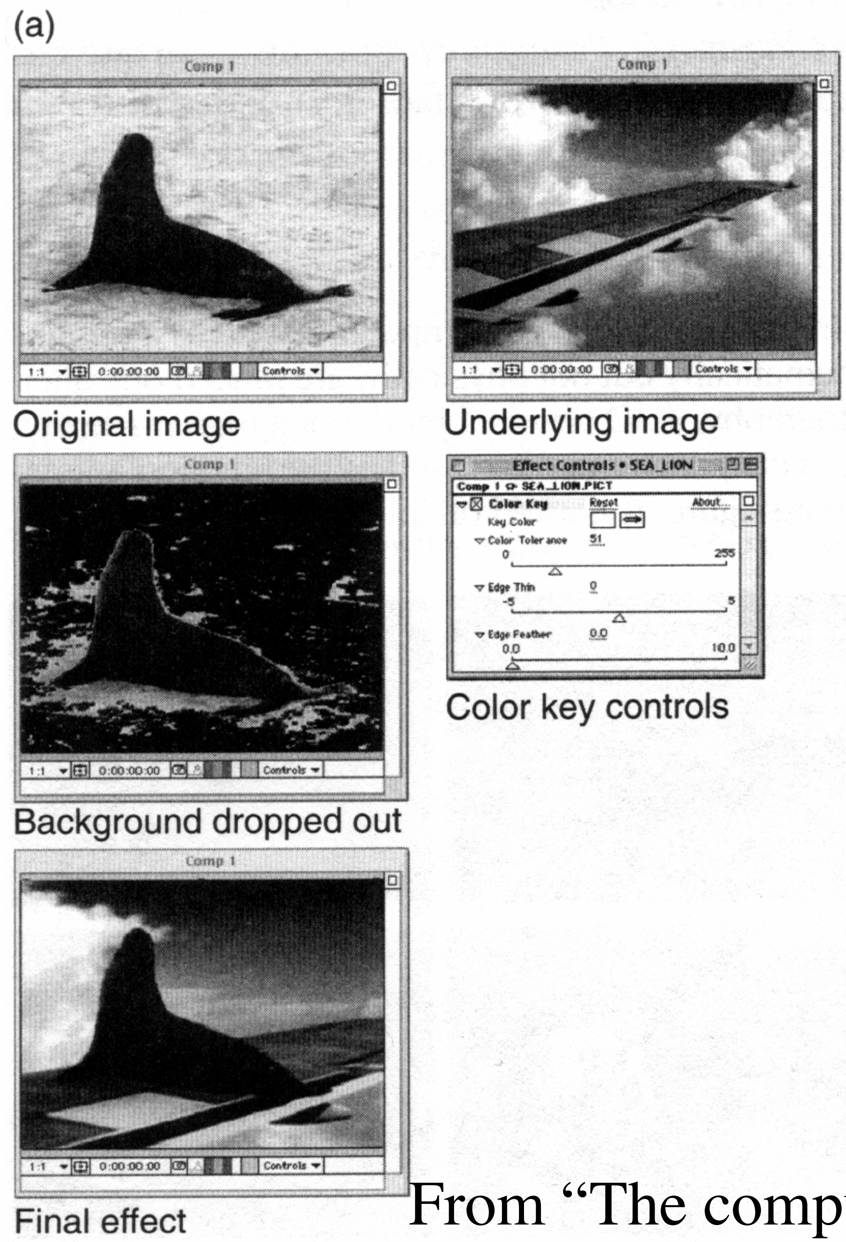
Compositing



Light areas are more transparent - blending

From “The computer in the visual arts”, Spalter, 1999

Compositing

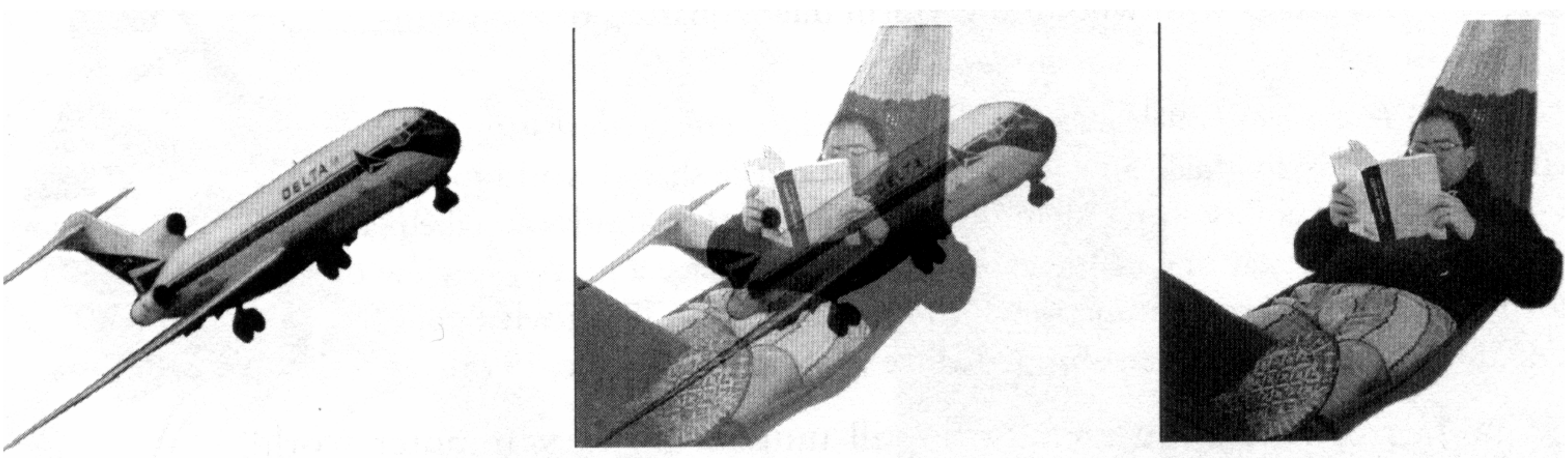


- Note that human intervention might be required to remove odd pixels, if the background doesn't have a distinctive colour
- One can buy sets of images which have been segmented by hand.

From “The computer in the visual arts”, Spalter, 1999

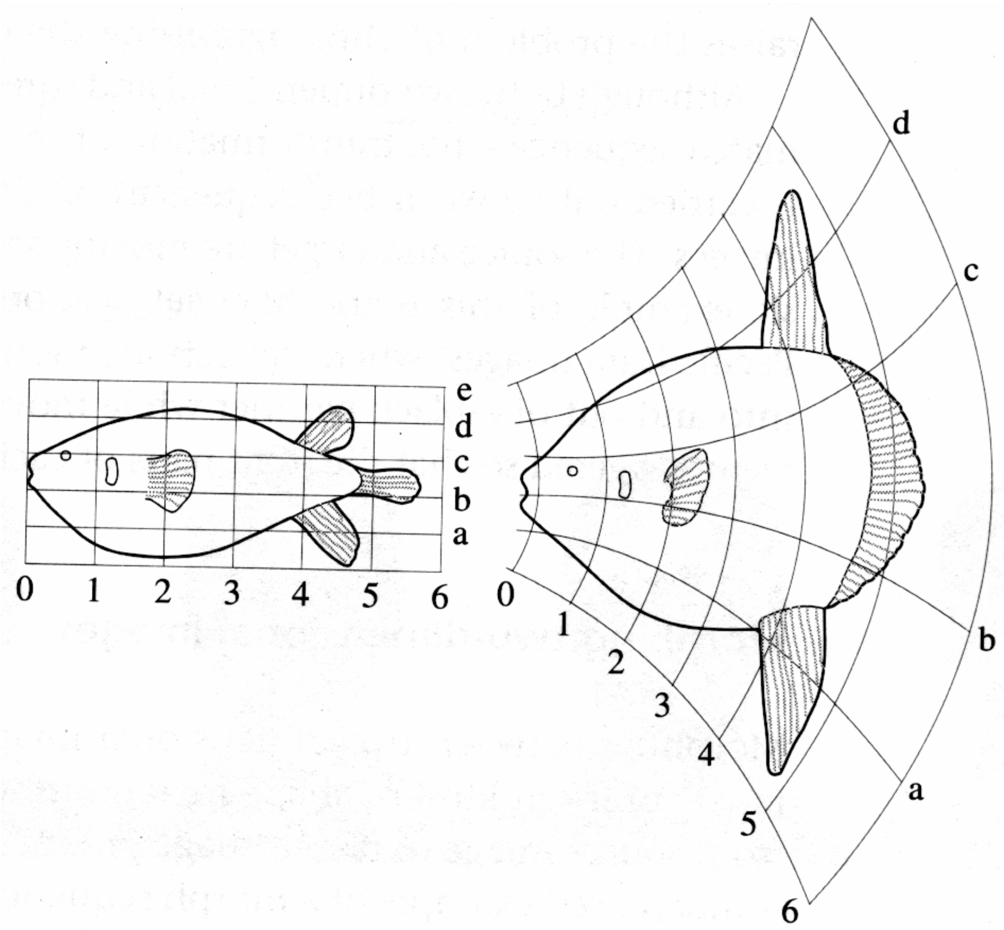
Morphing

- Simple blending doesn't work terribly well for distinct shapes
- Idea: map the one shape to the other, while blending



From "The computer Image", Watt and Policarpo, 1998

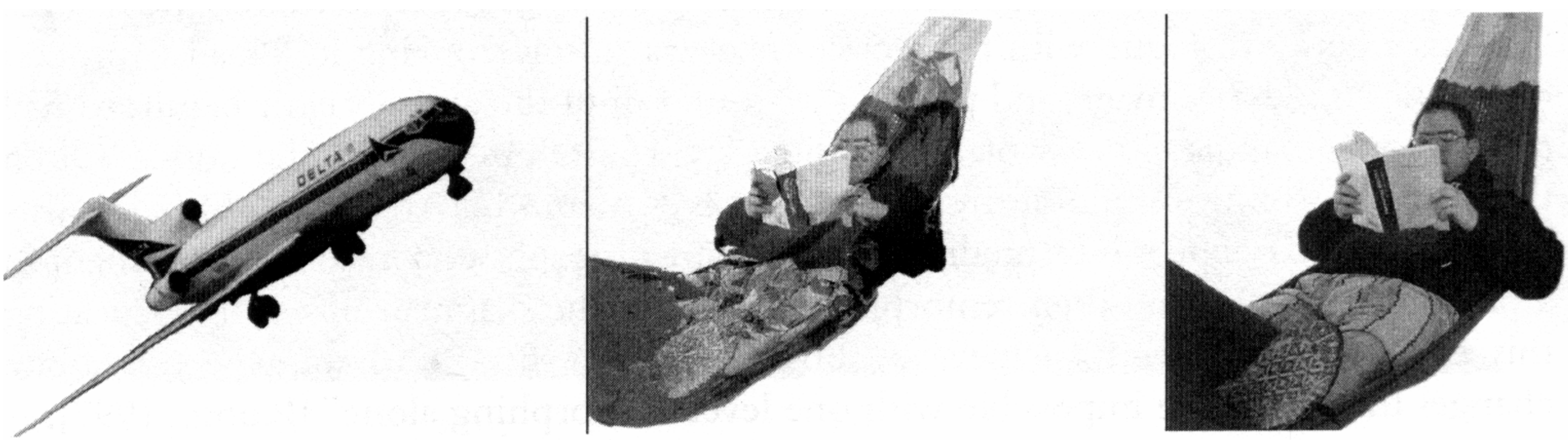
Morphing



From "On growth and Form", D'Arcy Thompson

Morphing

- Another use for the deformation encoding shown earlier
- From “The computer Image”,
- Watt and Policarpo, 1998



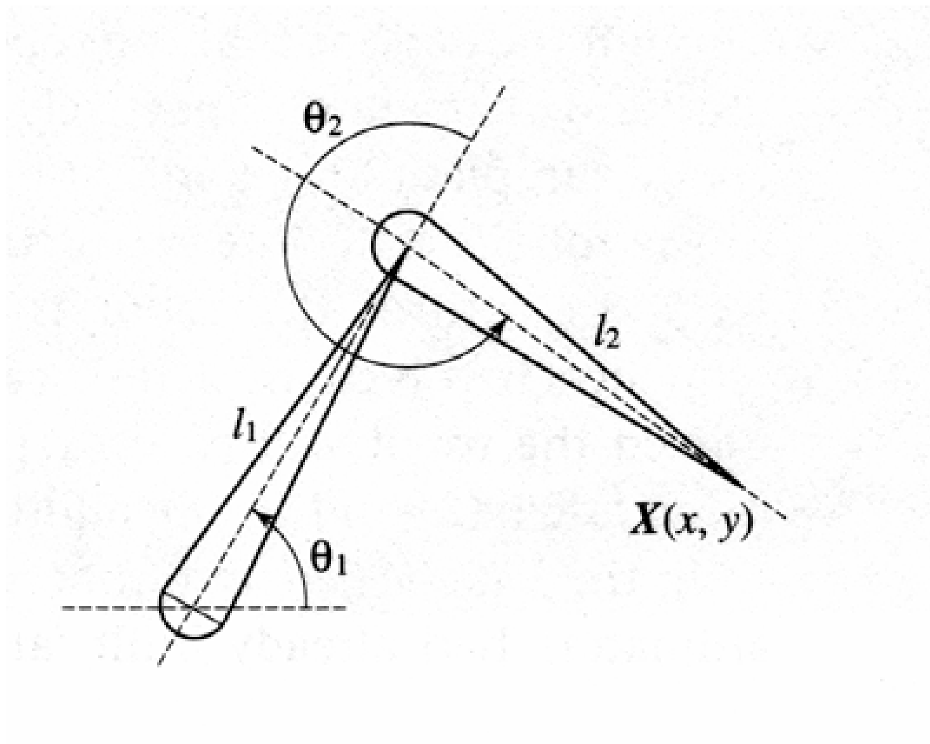
Morphing

(a) (b) (c) (d) (e)

From "The computer Image",
Watt and Policarpo, 1998

Procedural animation

- Kinematics
  - the configuration of a chain given its state variables
  - e.g. where is the end of the arm if angles are given?
- Inverse kinematics
  - the state variables that yield the configuration
  - e.g. what angles put the end of the arm here?

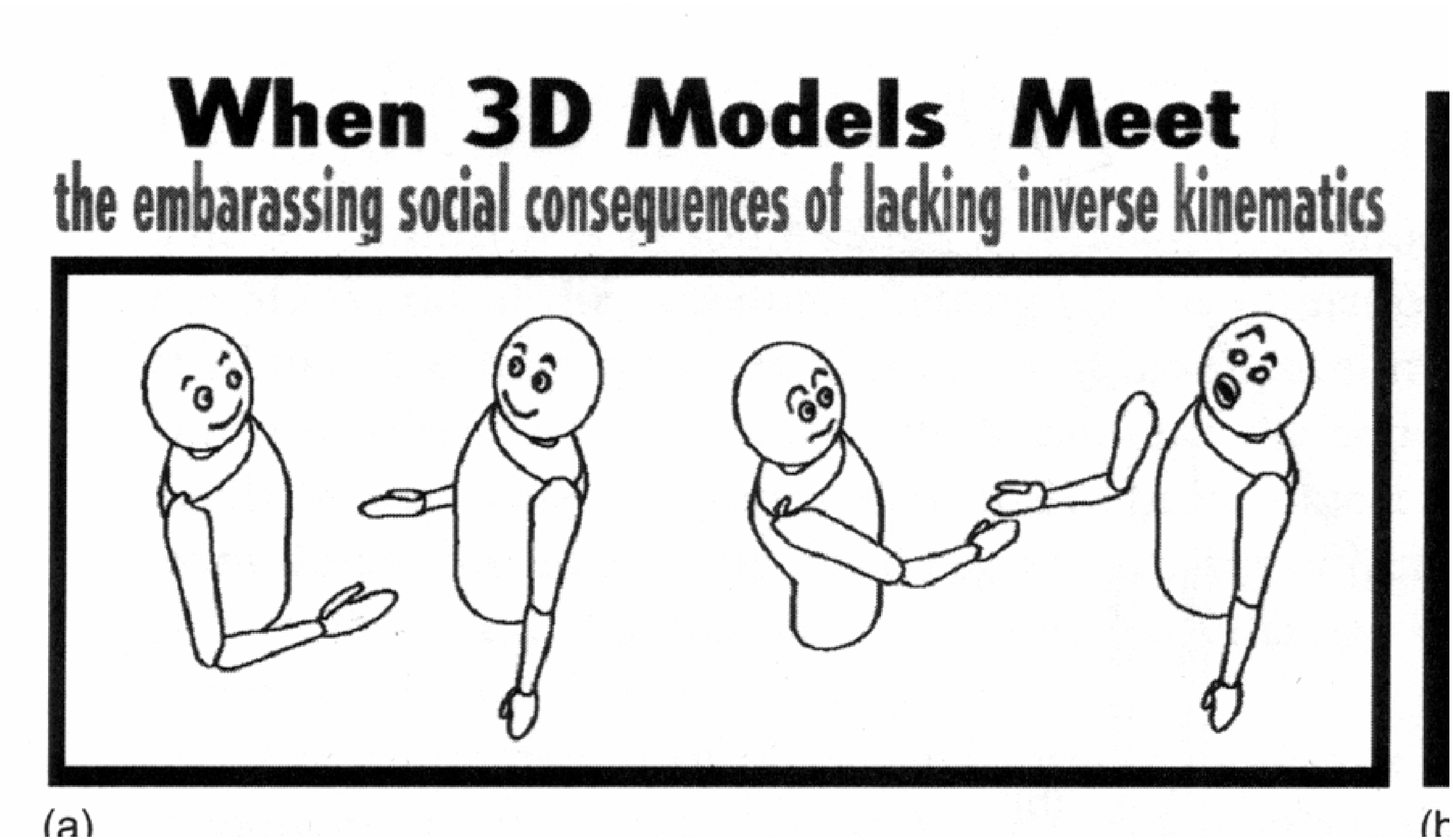


From “The computer Image”,

Inverse Kinematics

From “The computer Image”, Watt and Policarpo, 1998

Inverse Kinematics



From "The computer in the visual arts", Spalter, 1999

Inverse kinematics

- Endpoint position and orientation is: $\underline{e}(\underline{\theta})$
- Central Question: how do I modify the configuration variables to move the endpoint in a particular direction?

$$\delta \underline{e} = \begin{pmatrix} \frac{\partial e_1}{\partial \theta_1} & .. & \frac{\partial e_1}{\partial \theta_k} \\ .. & .. & .. \\ \frac{\partial e_6}{\partial \theta_1} & .. & \frac{\partial e_6}{\partial \theta_k} \end{pmatrix} \delta \underline{\theta} = J \delta \underline{\theta}$$

- J is the Jacobian
- If rank(J) < 6, then
  - some movements aren't possible
  - or more than one movement results in the same effect
- If k>6 then the chain is redundant
  - more than one set of variables will lead to the same configuration

Procedural animation

- Generate animations using procedural approach
  - e.g. “Slice and dice” existing animations to produce a more complex animation
  - e.g. use forward kinematics and a hierarchical model (doors swinging in our original hierarchical model)
  - e.g. construct a set of forces, etc. and allow objects to move under their effects.
    - particle models
    - waves
    - collision and ballistic models
    - spring mass models
    - control - flocking, etc.

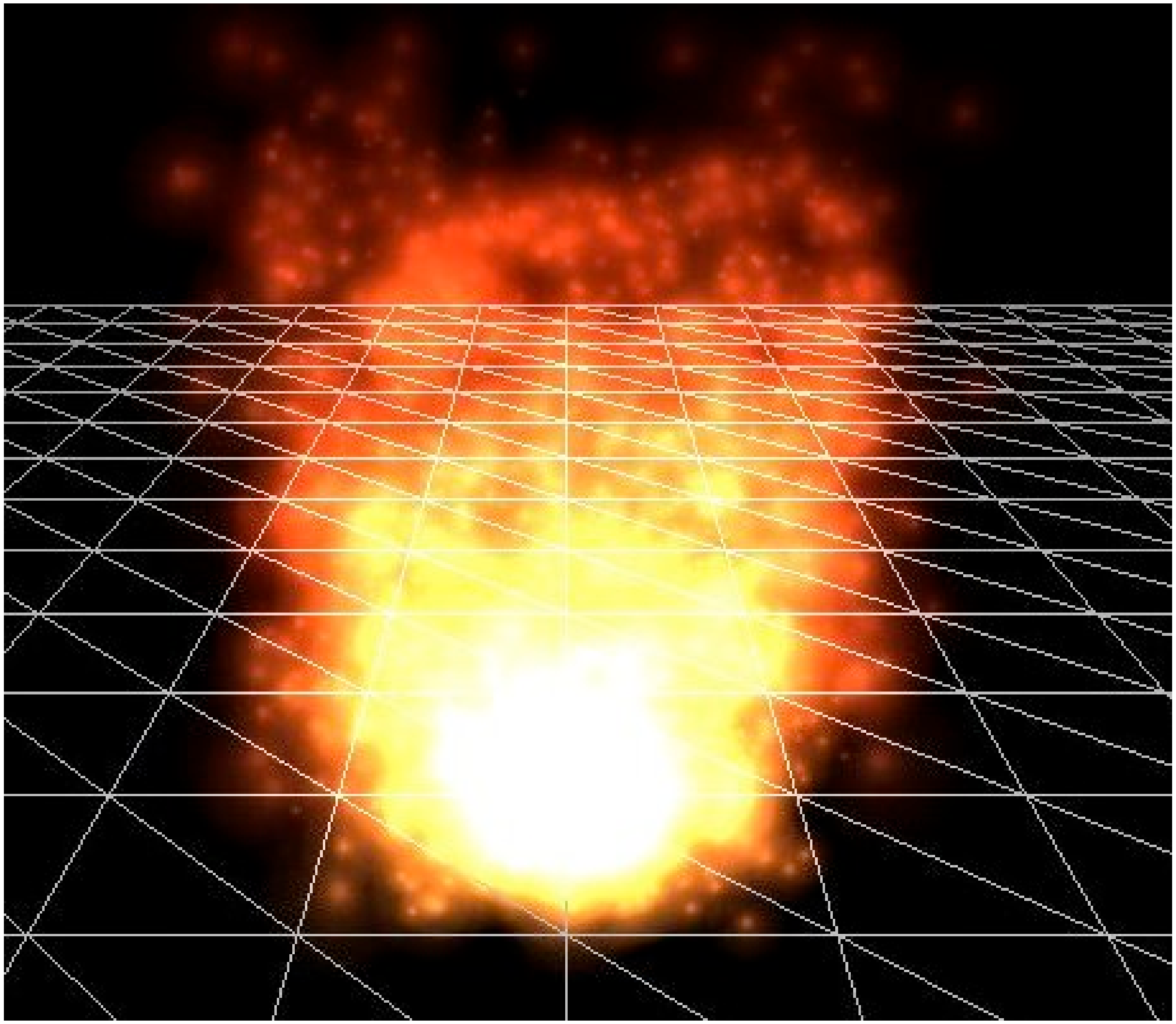
Procedural Dynamics - Particle systems

- There is a source of particles
  - move under gravity, sometimes collisions
  - sometimes other reactions
- Example: fireworks
  - particles chosen with random colour, originating randomly within a region, fired out with random direction and lasting for a random period of time before they expire
    - or explode, generating another collection of particles,etc
- Example: water
  - very large stream of particles, large enough that one doesn't see the gap
- Example: grass
  - fire particles up within a tapered cylinder, let them fall under gravity, keep a record of the particle's trail.

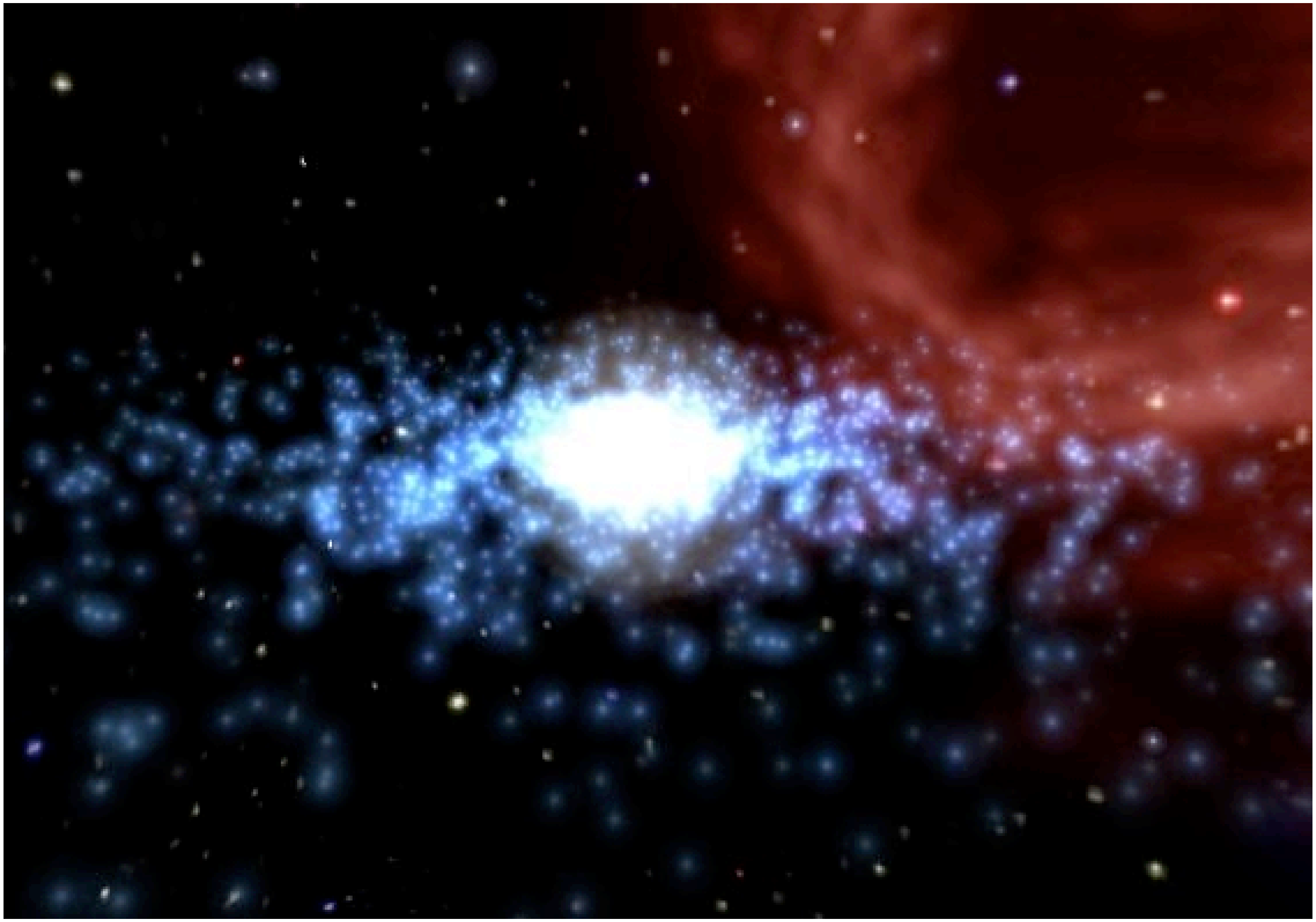
Particle Torch

Now replace particle centers with small blobs of colour in the image plane

http://www.arch.columbia.edu/manuals/Softimage/3d_learn/GUIDED/PARTICLES/p_first.htm



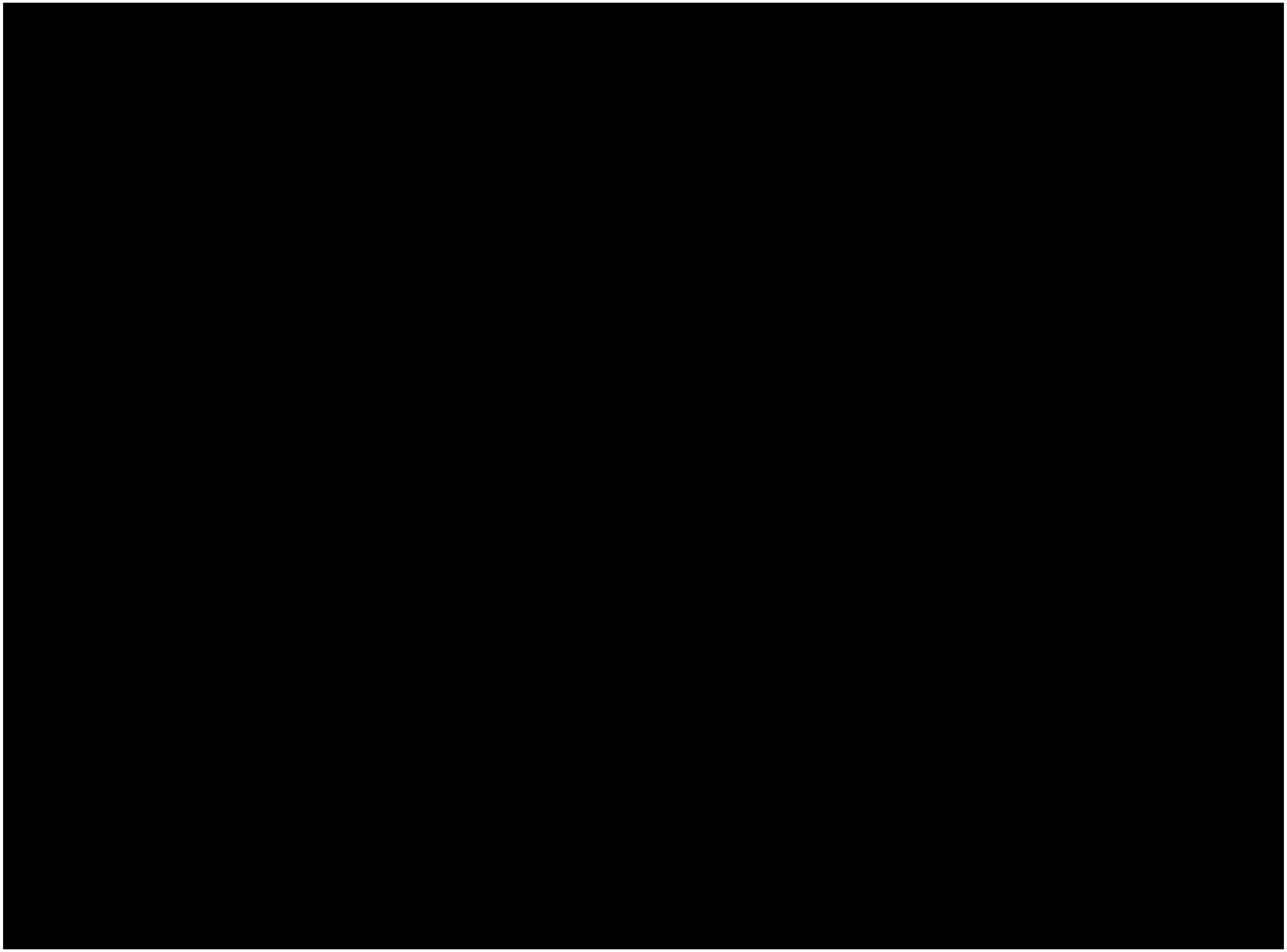
By John Tsiombikas from Wikipedia



By John Tsiombikas from Wikipedia

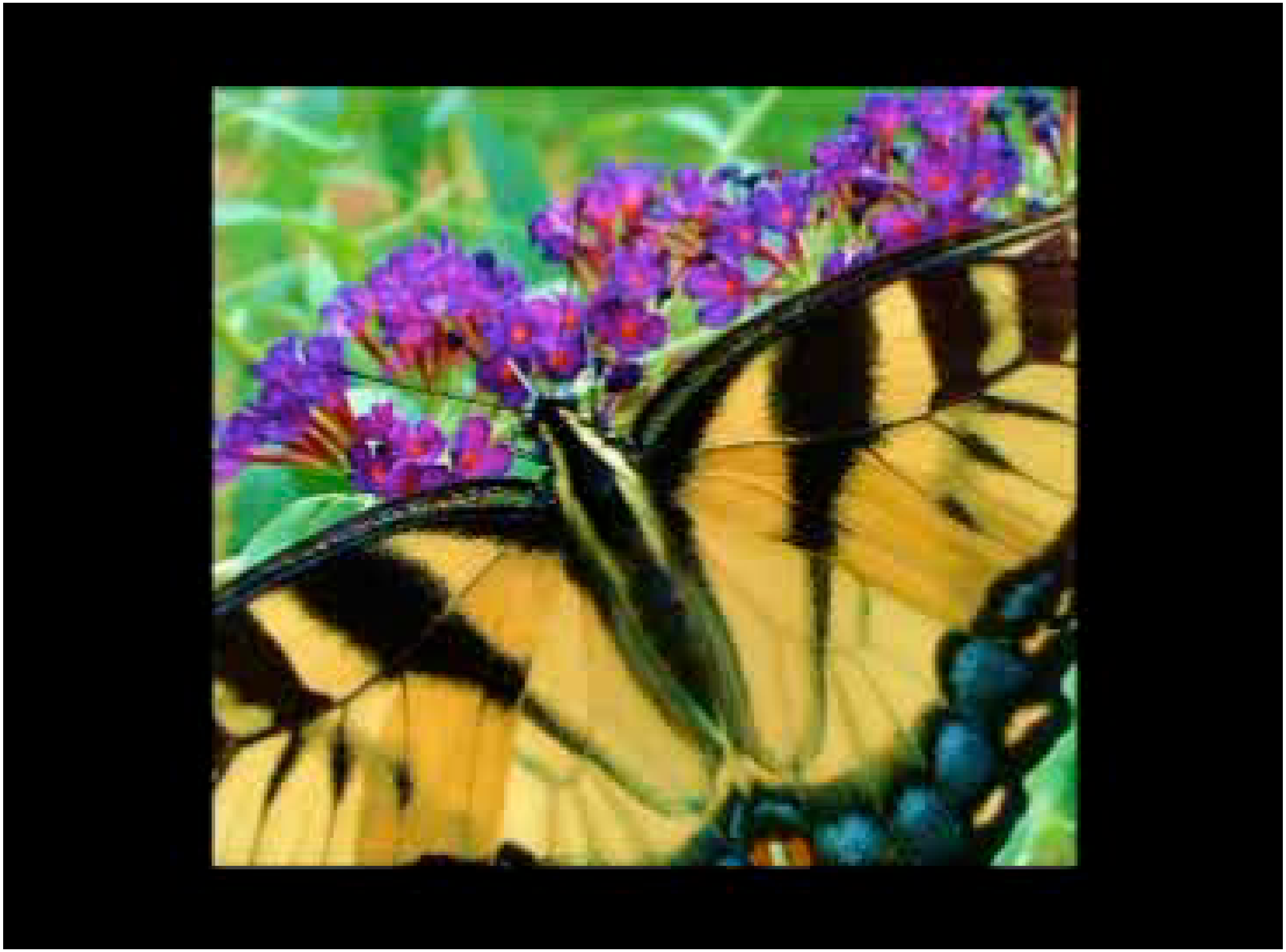
Commercial particle systems (wondertouch)

Commercial particle systems (wondertouch explosions)

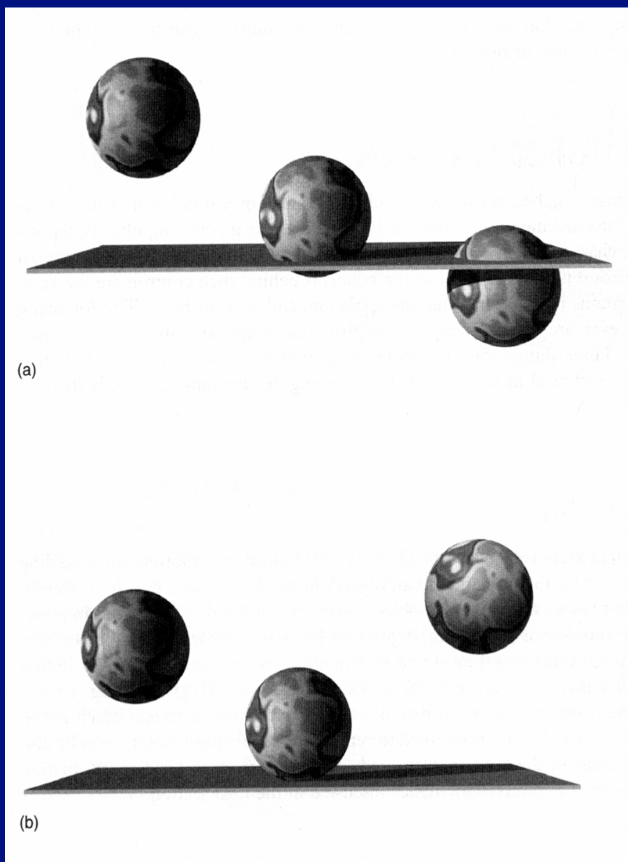


Commercial particle systems (wondertouch water)

Commercial particle systems (wondertouch distortions)



Ballistic + Collision



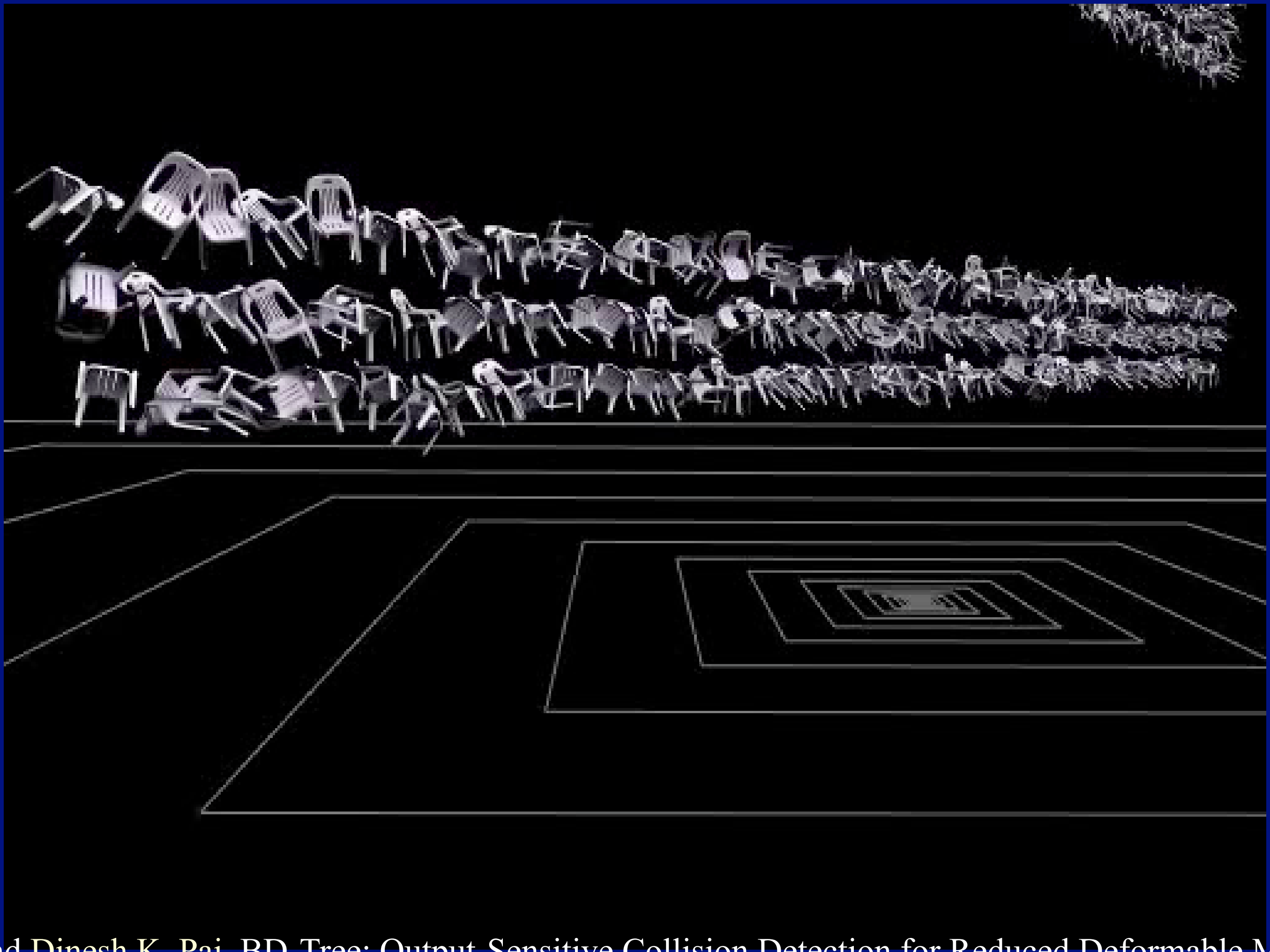
- Objects move freely under gravity until they collide.
- For accurate physical models, order in which collisions occur is important.

Collisions - detection

- Particles are straightforward
  - -ish (geometry is easy)
  - issues: undetected collisions
    - strategies:
      - identify safe bounds within which to advance time, search
        - use priority queue
        - but this may force quite small time steps
      - potential barrier
        - but this may force quite small time steps; stiffness
        - backward Euler helps, but only within limits
- Rigid objects more difficult
  - geometry: hierarchy of bounding spheres
  - strategies remain the same

12,201 chairs;
218,568,714 triangles

Collision: SOA



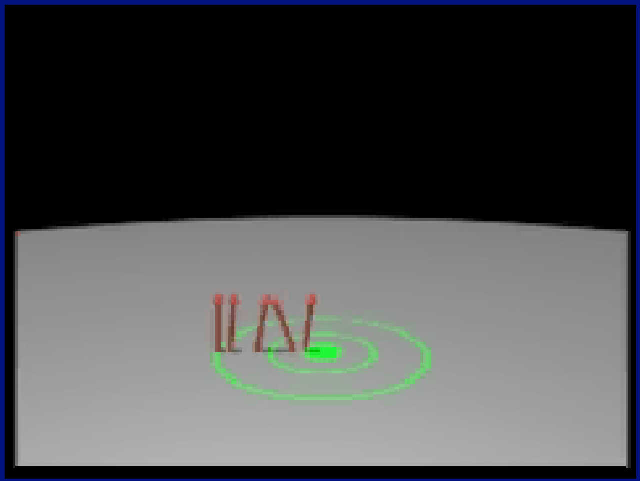
Doug L. James and Dinesh K. Pai, BD-Tree: Output-Sensitive Collision Detection for Reduced Deformable Models, ACM Transactions on Graphics (ACM SIGGRAPH 2004), 23(3), 2004.

Collisions - resolution

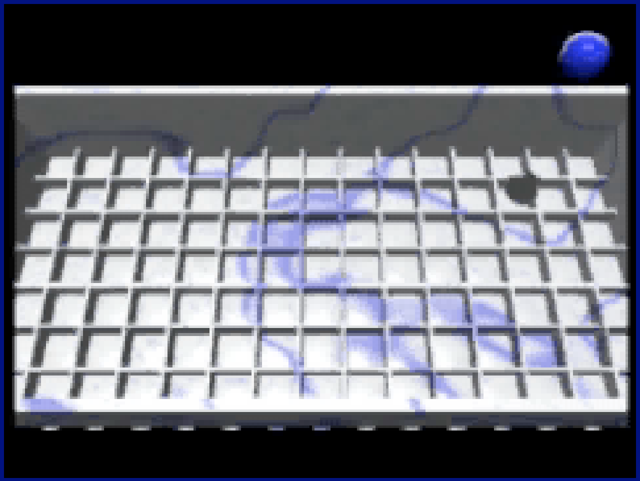
- Strategies:
  - potential field
  - explicit collision model
    - state_out=F(state_in, physical parameters)
    - typical physical parameters:
      - friction, coefficient of restitution
  - data driven
    - match inputs to data, read off outputs
- Collisions
  - produce randomness in motion
  - are a mechanism to control the motion

Control via collisions

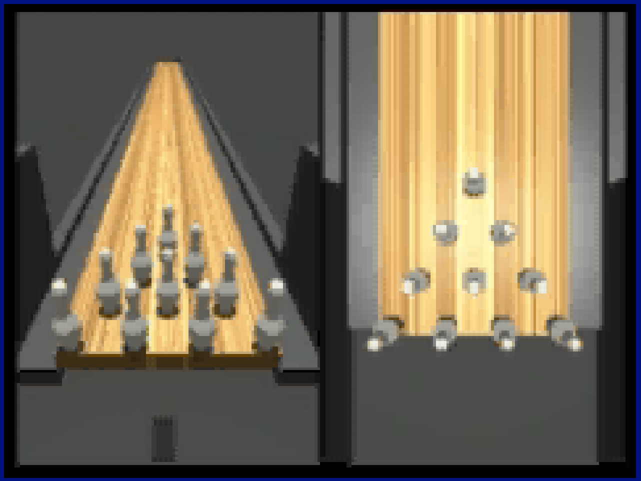
- Collisions are an important source of randomness
  - particularly in the case of sharp edges, rotation -> dice
  - physical parameters typically vary over space
    - Idea: modify physical parameters at collisions to produce desired outcome
      - Issues:
        - extremely complex search
        - requires very fast simulation
          - Notice: each object can be advanced different timesteps



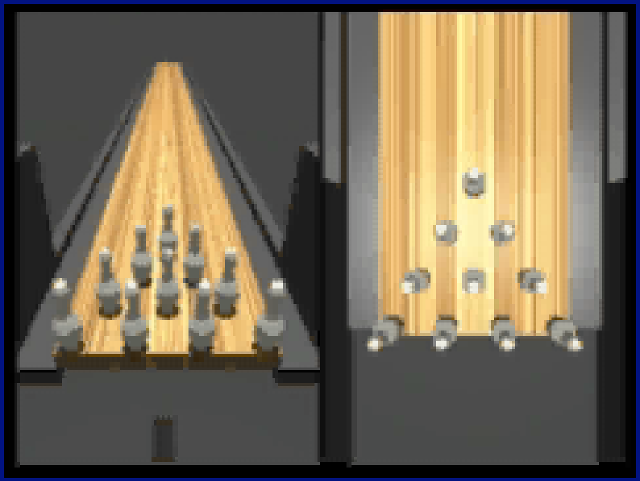
Stephen Chenney and D.A.Forsyth, "Sampling Plausible Solutions to Multi-Body Constraint Problems". SIGGRAPH 2000 Conference Proceedings, pages 219-228, July 2000.



Stephen Chenney and D.A.Forsyth, "Sampling Plausible Solutions to Multi-Body Constraint Problems". SIGGRAPH 2000 Conference Proceedings, pages 219-228, July 2000.



Stephen Chenney and D.A.Forsyth, "Sampling Plausible Solutions to Multi-Body Constraint Problems". SIGGRAPH 2000 Conference Proceedings, pages 219-228, July 2000.



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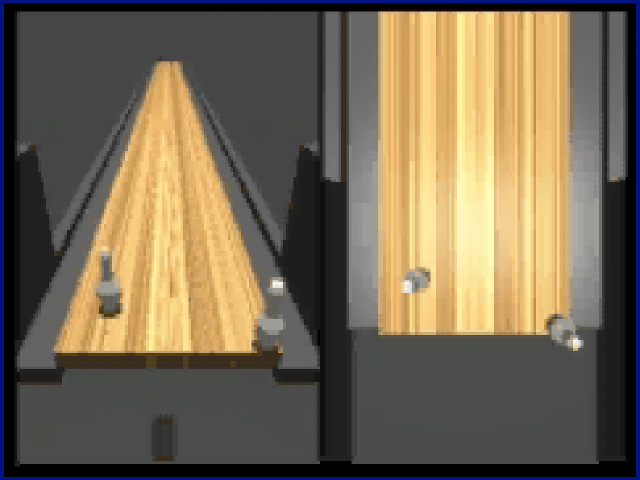
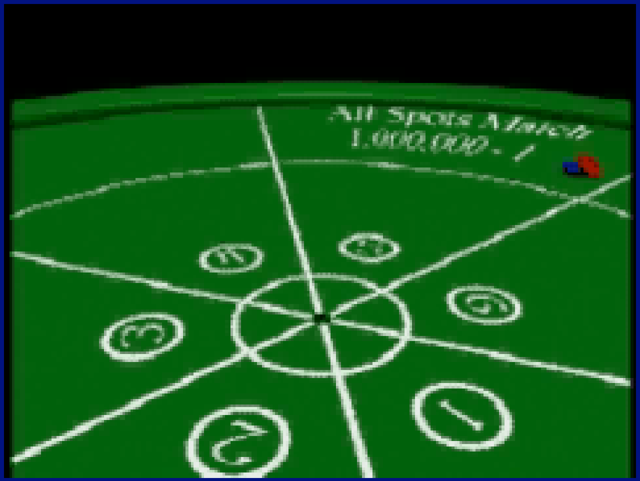
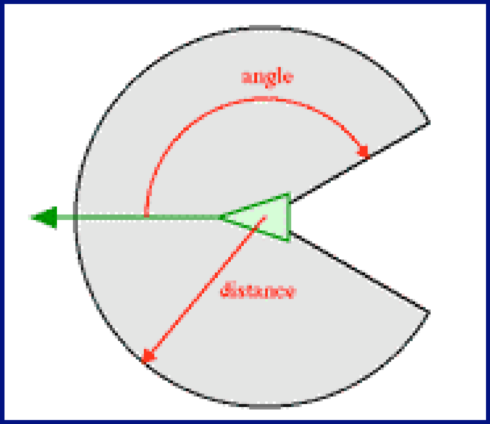


Stephen Chenney and D.A.Forsyth, "Sampling Plausible Solutions to Multi-Body Constraint Problems". SIGGRAPH 2000 Conference Proceedings, pages 219-228, July 2000.



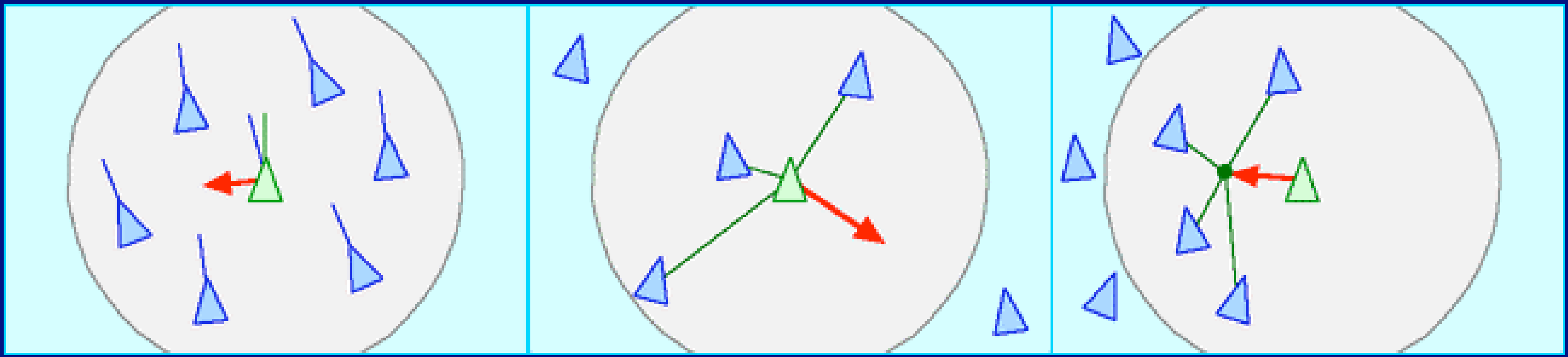
Stephen Chenney and D.A.Forsyth, "Sampling Plausible Solutions to Multi-Body Constraint Problems". SIGGRAPH 2000 Conference Proceedings, pages 219-228, July 2000.

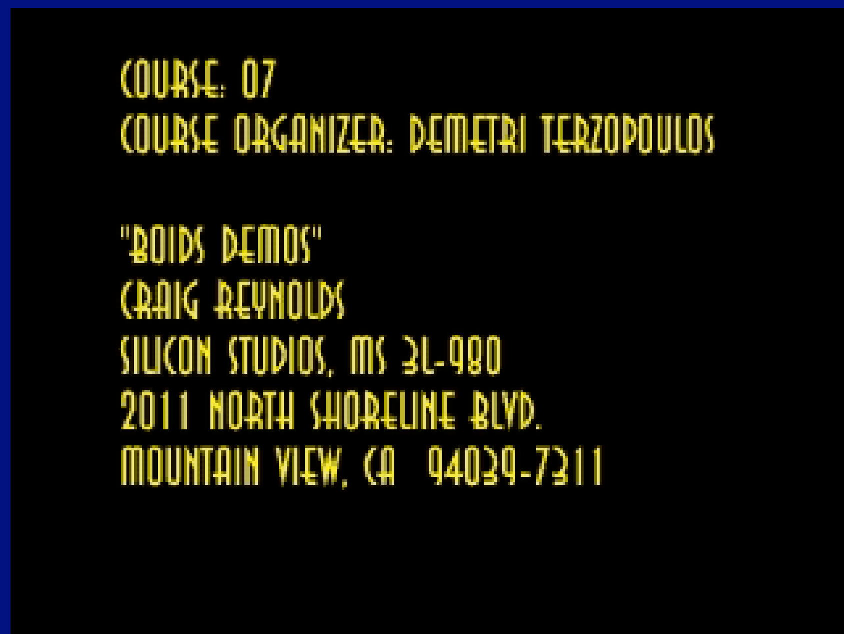
Flocking - Boids



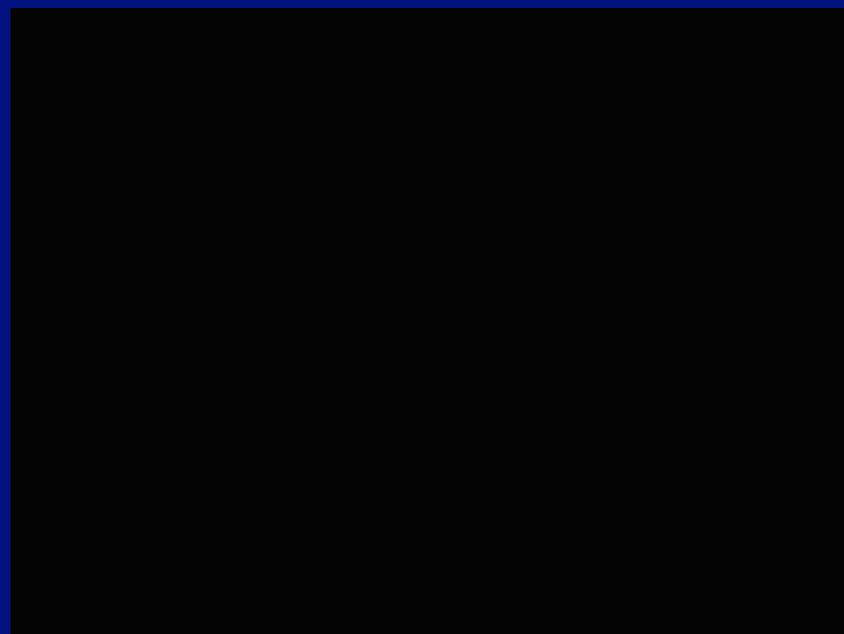
- We'd like things to move in schools
  - and not hit each other, objects
  - abstraction: particle with rocket with maximum force
- 3 goals
  - How to accelerate?
    - each goal gives an acceleration; weighted sum
    - accumulate in priority order until acceleration exceeds threshold,
      - then cut back last

Alignment Separation Cohesion





http://www.red.com/cwr/boids.html



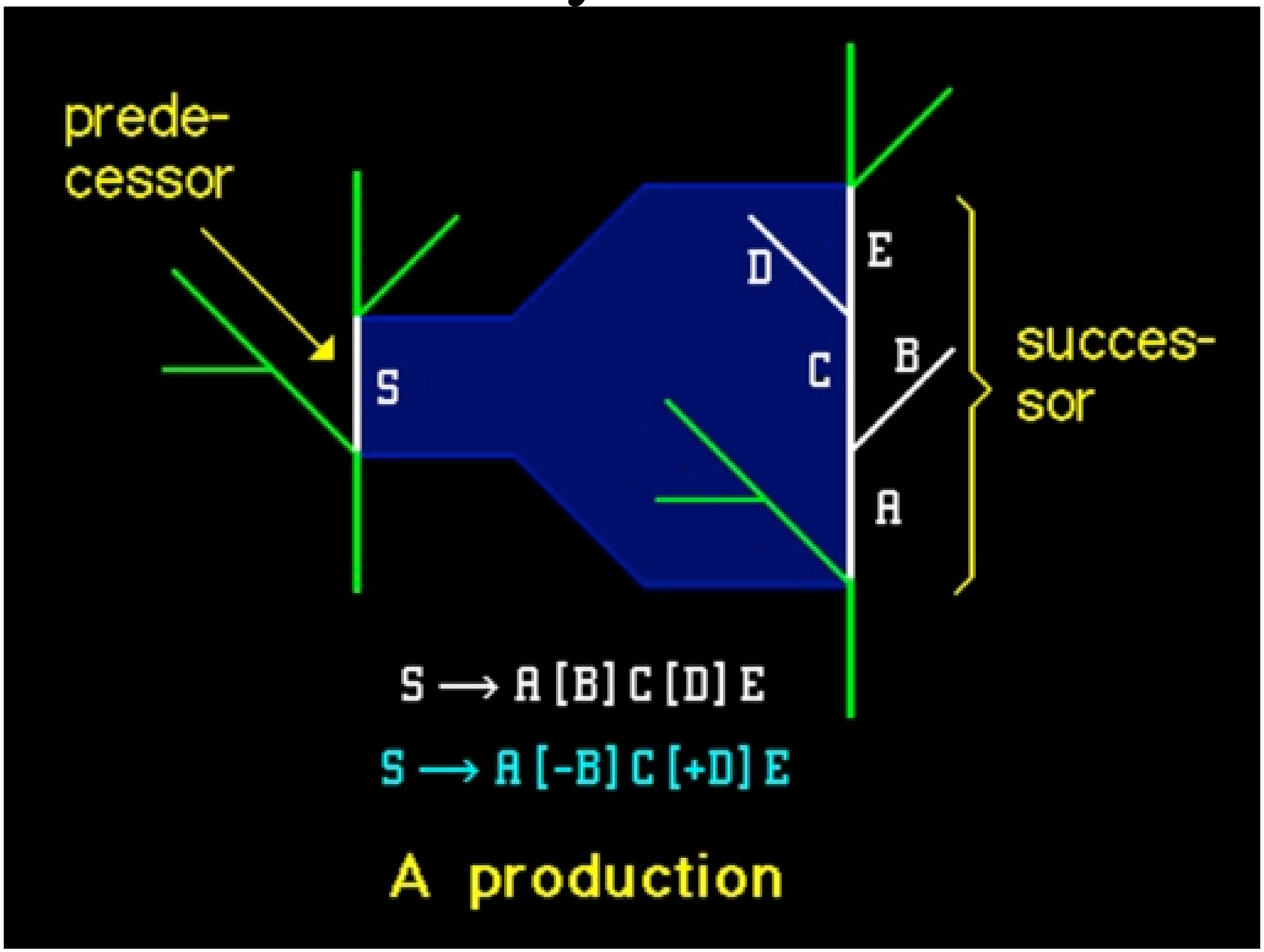
http://www.red.com/cwr/boids.html

Procedural Animation: L-systems

- Formal grammar, originally due to Lindenmayer
  - {Variables, Constants, Initial state, Rules}
  - Plants by:
    - Constants are bits of geometry,
    - rules appropriately chosen

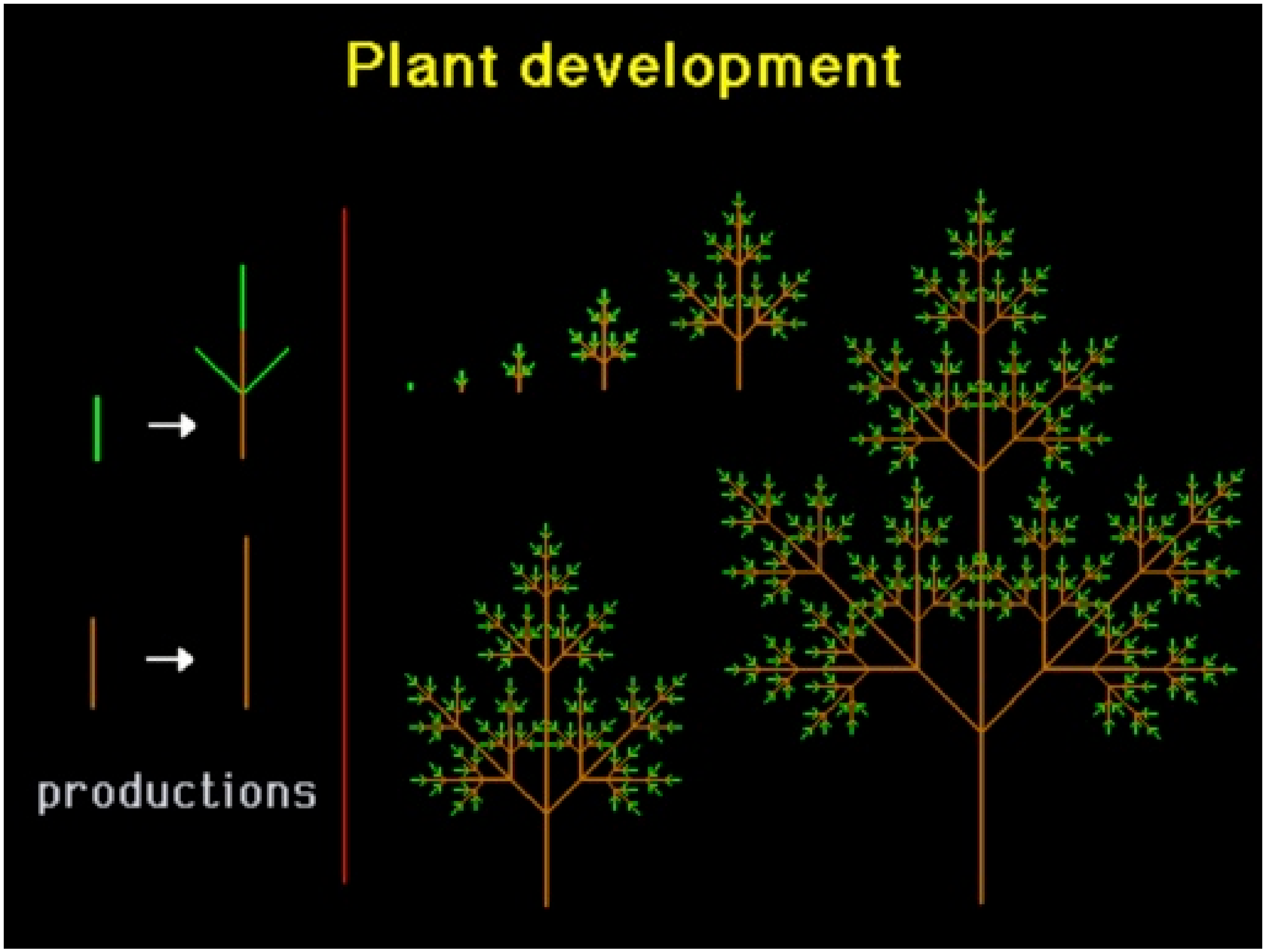
Figure from wikipedia entry

L-Systems



Prusinkiewicz, Hammel, Mech http://www.cpsc.ucalgary.ca/projects/bmv/vmm/title.html

L-Systems

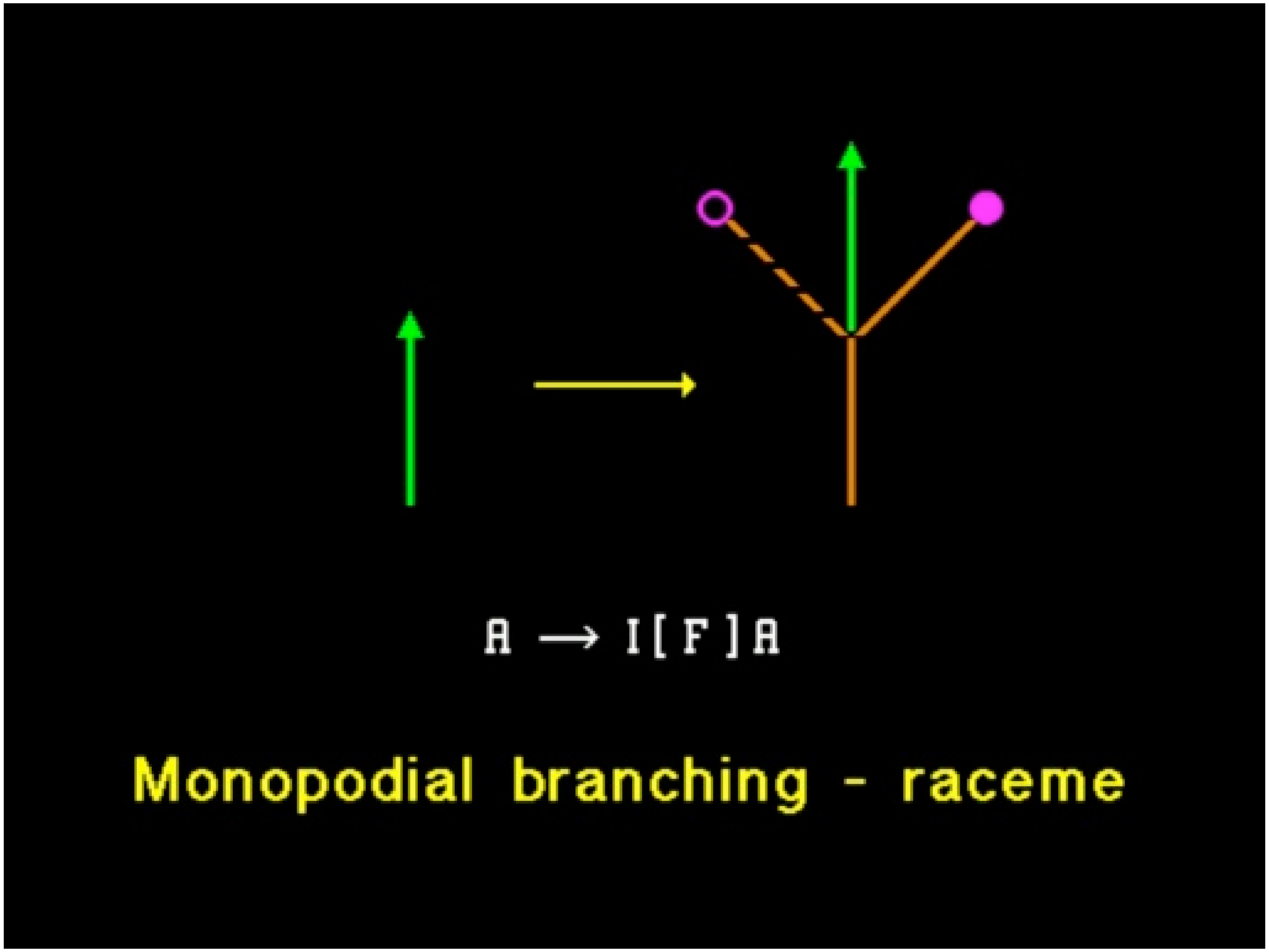


Prusinkiewicz, Hammel, Mech http://www.cpsc.ucalgary.ca/projects/bmv/vmm/title.html

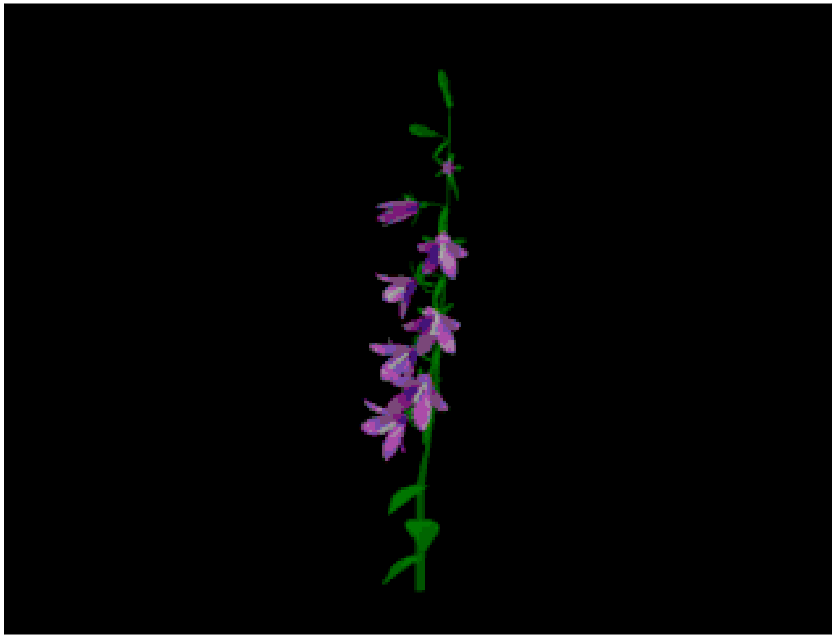
L-System plant growing

Prusinkiewicz, Hammel, Mech http://www.cpsc.ucalgary.ca/projects/bmv/vmm/title.html

Flowers at side branches

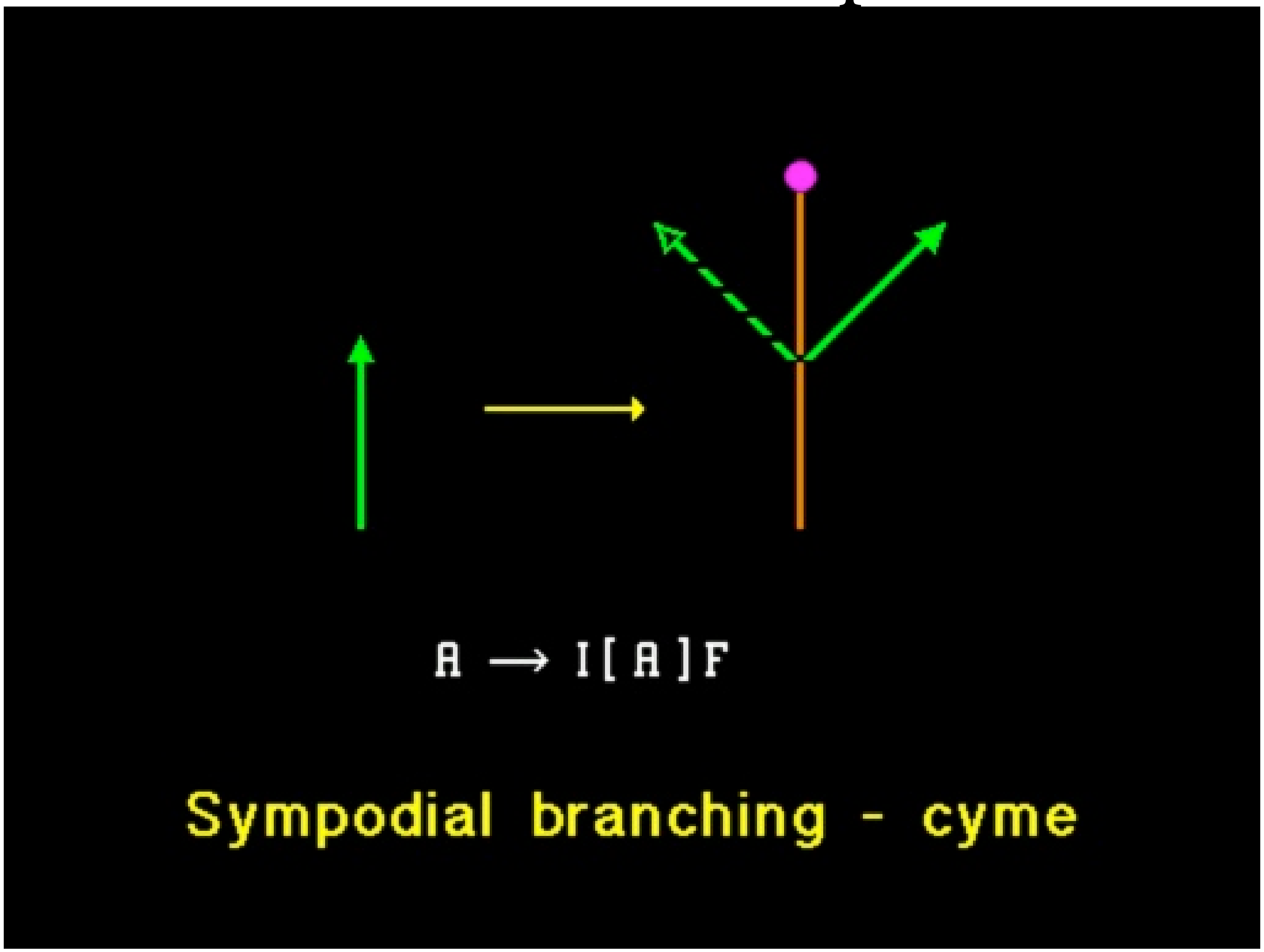


Prusinkiewicz, Hammel, Mech http://www.cpsc.ucalgary.ca/projects/bmv/vmm/title.html

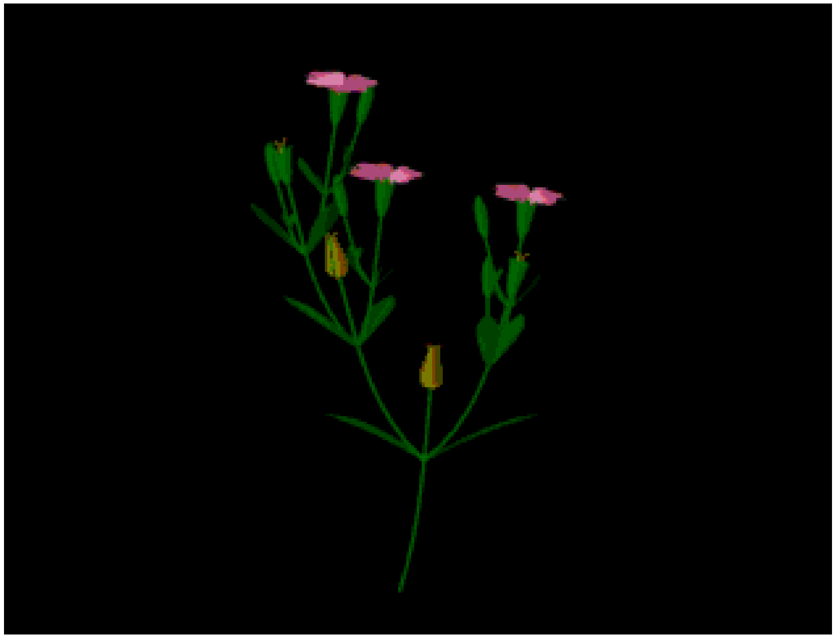


Prusinkiewicz, Hammel, Mech http://www.cpsc.ucalgary.ca/projects/bmv/vmm/title.html

Flowers at the apex



Prusinkiewicz, Hammel, Mech http://www.cpsc.ucalgary.ca/projects/bmv/vmm/title.html



Prusinkiewicz, Hammel, Mech http://www.cpsc.ucalgary.ca/projects/bmv/vmm/title.html