CS130 : Computer Graphics

Animation

Tamar Shinar
Computer Science & Engineering
UC Riverside

Types of animation

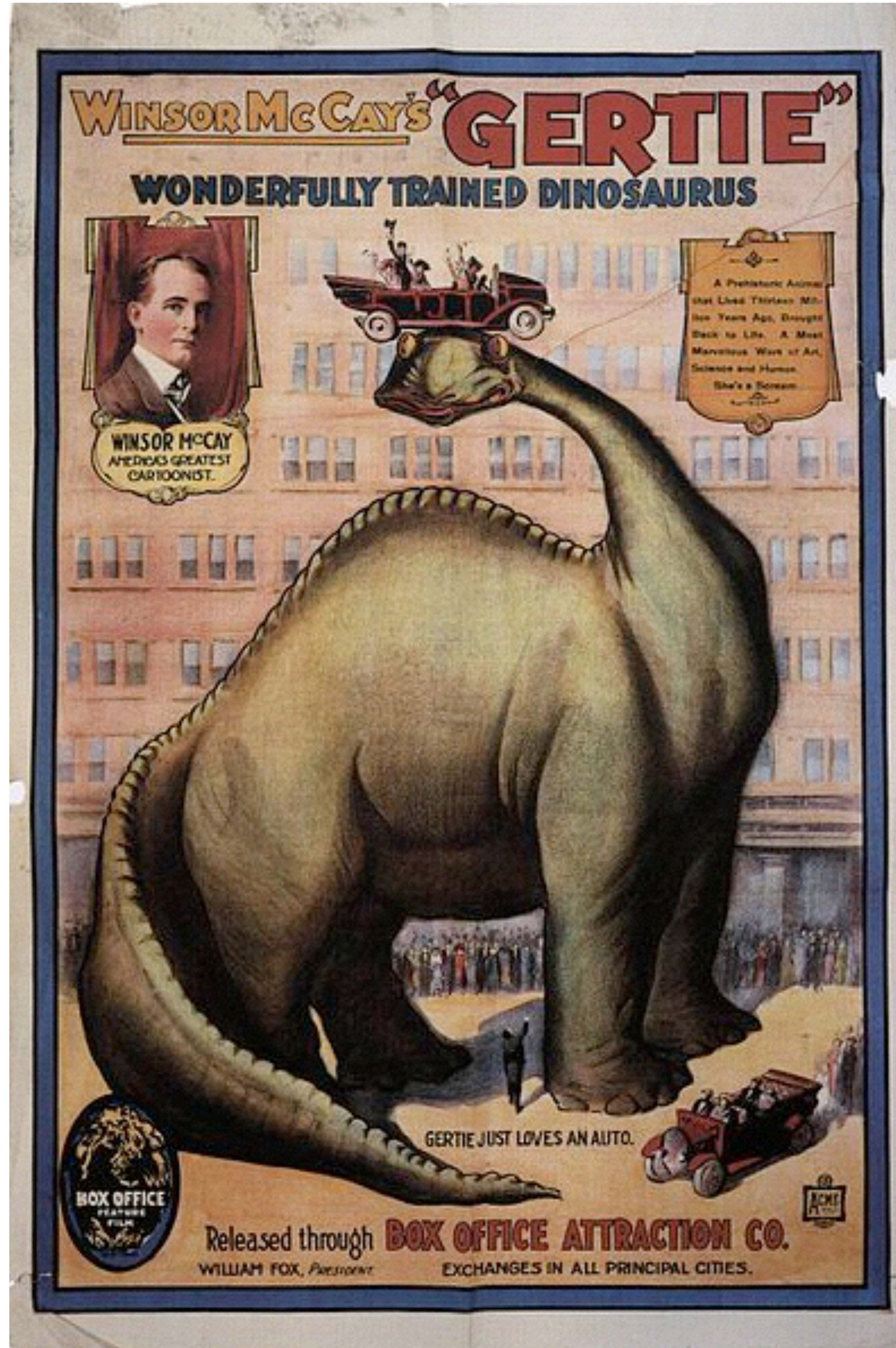
- keyframing
- rotoscoping
- stop motion
- procedural
- simulation
- motion capture

history

Gertie the Dinosaur

1914
12 minutes
hand drawn
keyframe animation
registration
cycling

link

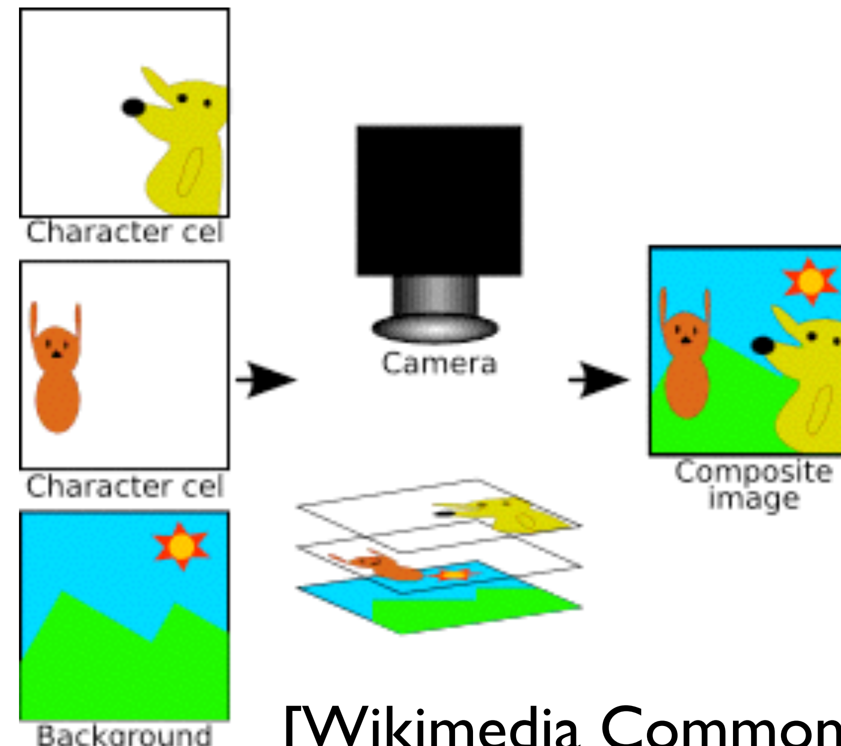


Traditional animation

Cels

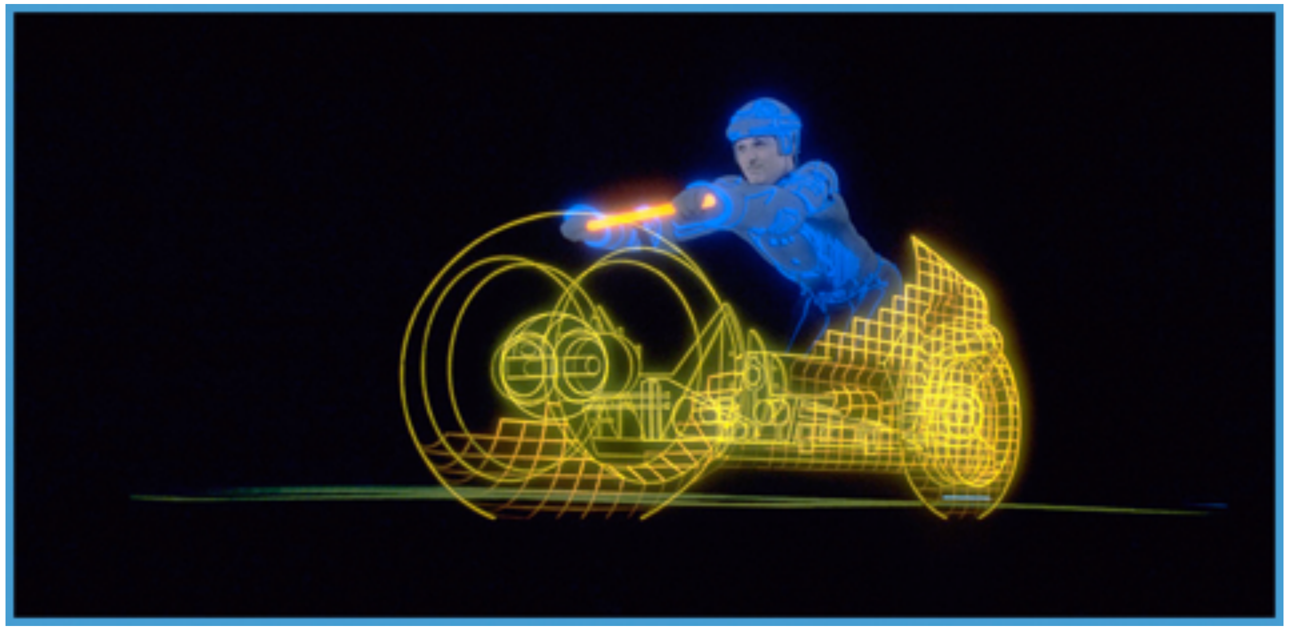
<u>Multiplane camera</u>

Sleeping Beauty, Disney, 1959

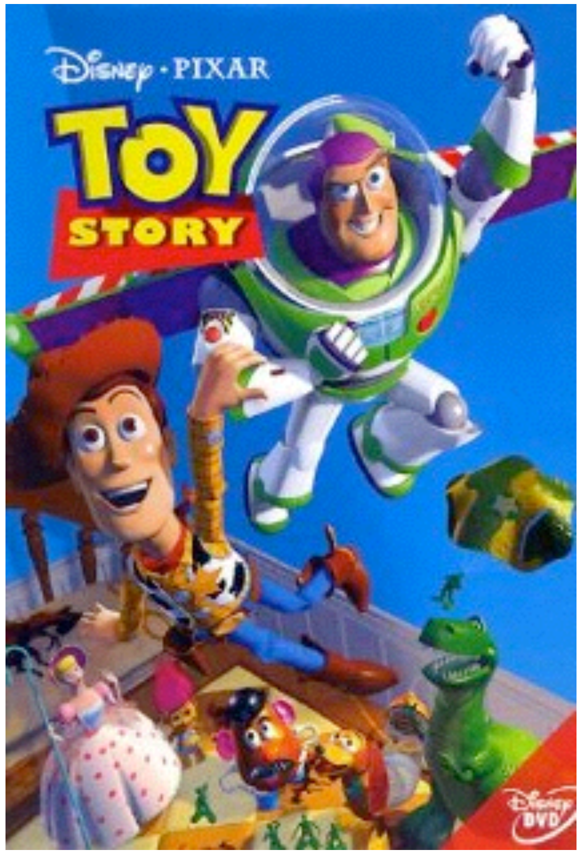


[Wikimedia Commons]

Realistic 3D animation



- Disney's Tron, 1981
- Pixar's Toy Story, 1995, first 3D feature



Performance capture

Rise of the Planet of the Apes, 2011

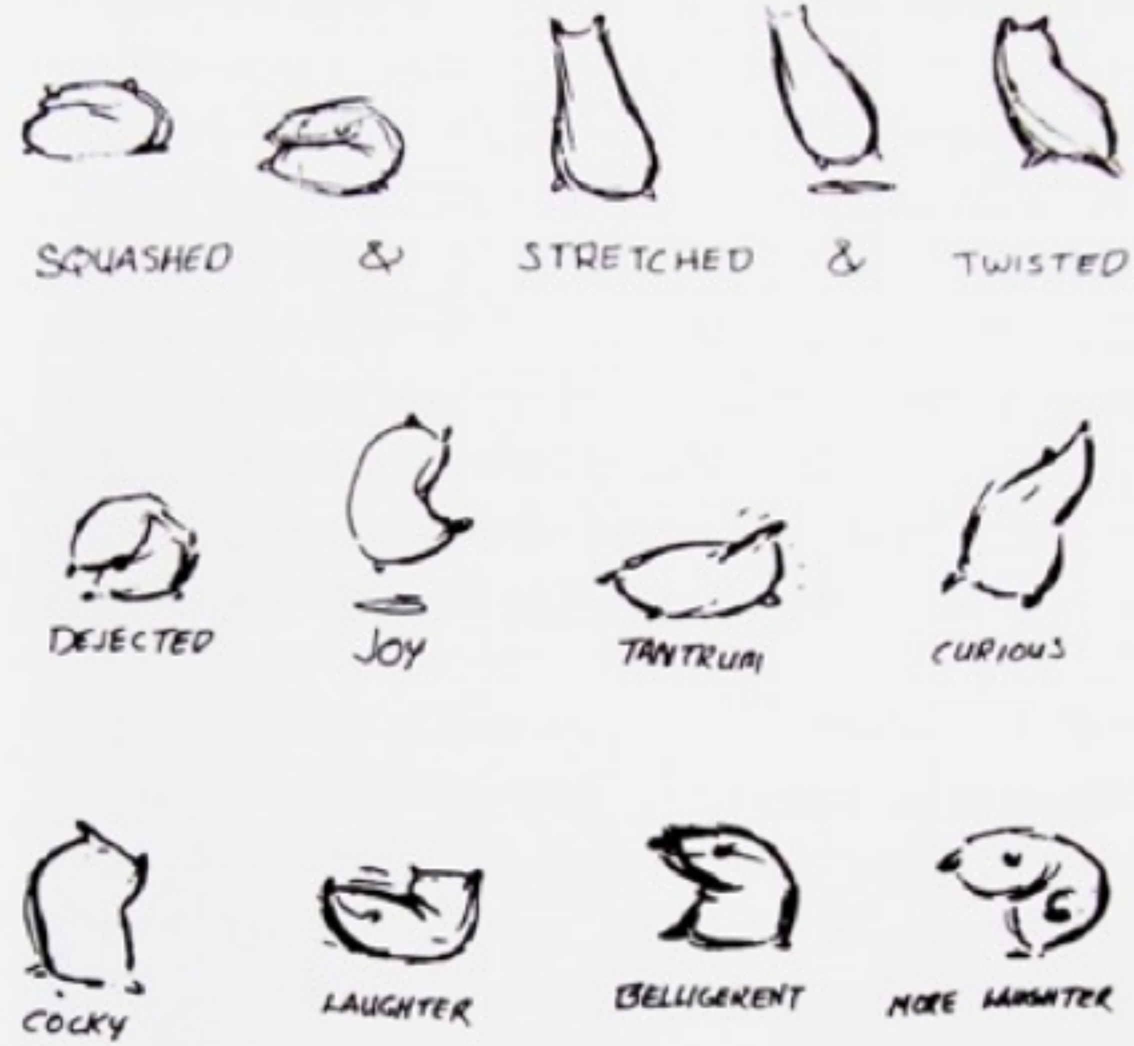
Lord of the Rings, 2001

Avatar, 2009

Disney's Paperman

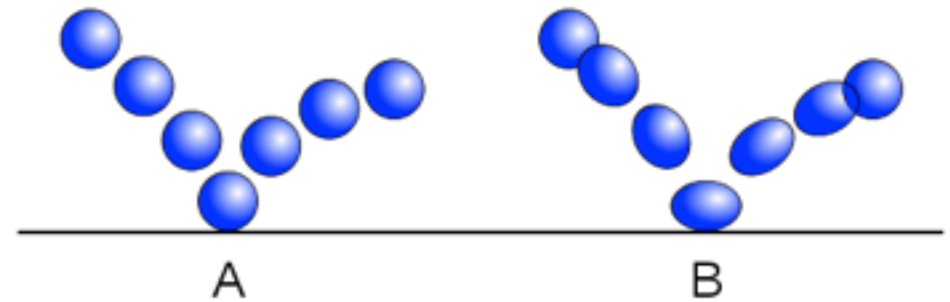
Paperman and the Future of 2D Animation

animation principles



The famous half-filled flour sack, guide to maintaining volume in any animatable shape, and proof that attitudes can be achieved with the simplest of shapes.

12 principles of animation

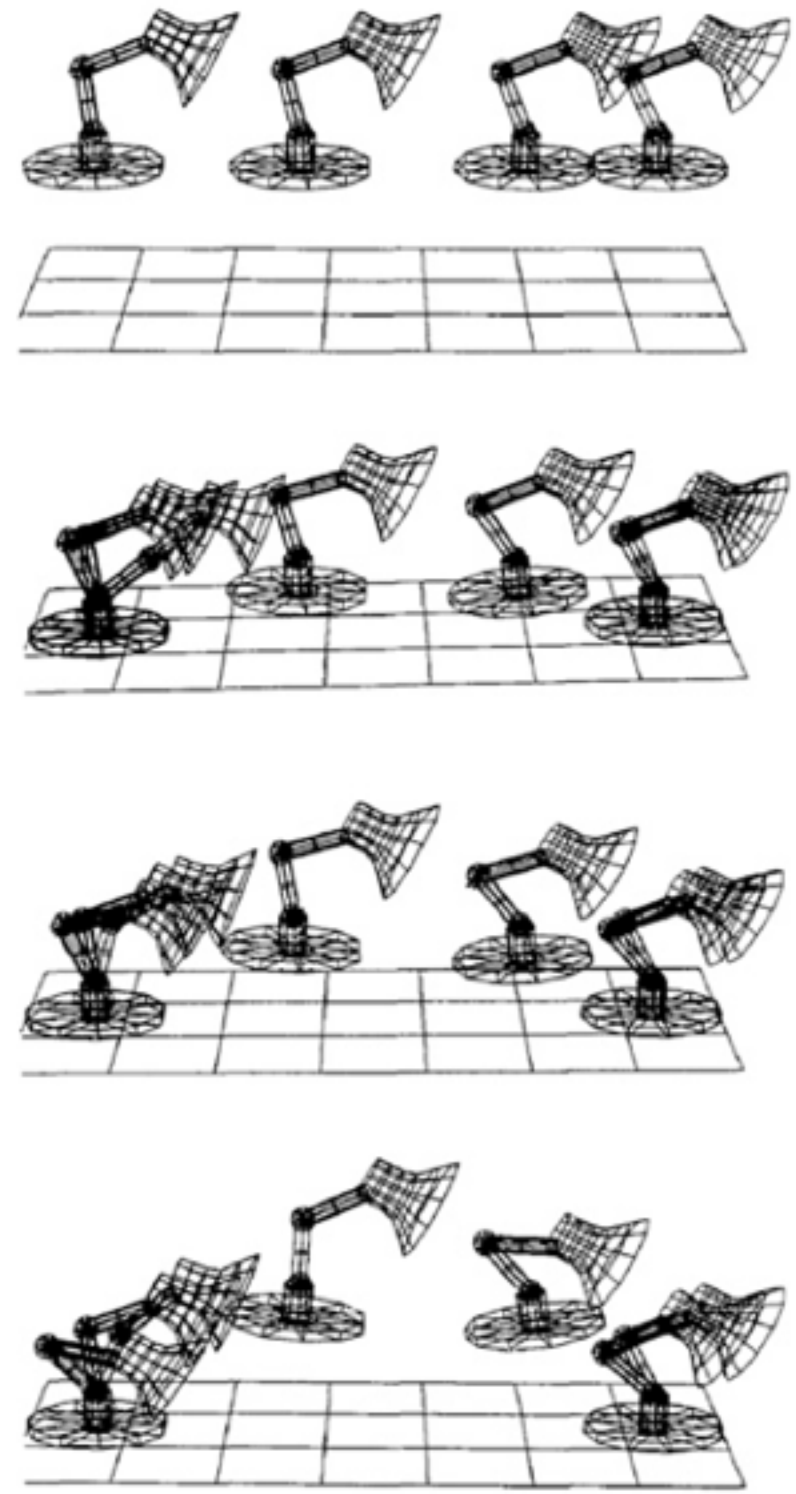


1. Squash and stretch
2. Anticipation
3. Staging
4. Straight ahead action and pose to pose
5. Follow through and overlapping action
6. Slow in and slow out
7. Arcs
8. Secondary action
9. Timing
10. Exaggeration
11. Solid drawing
12. Appeal

[Lasseter 87]

Physics-based animation

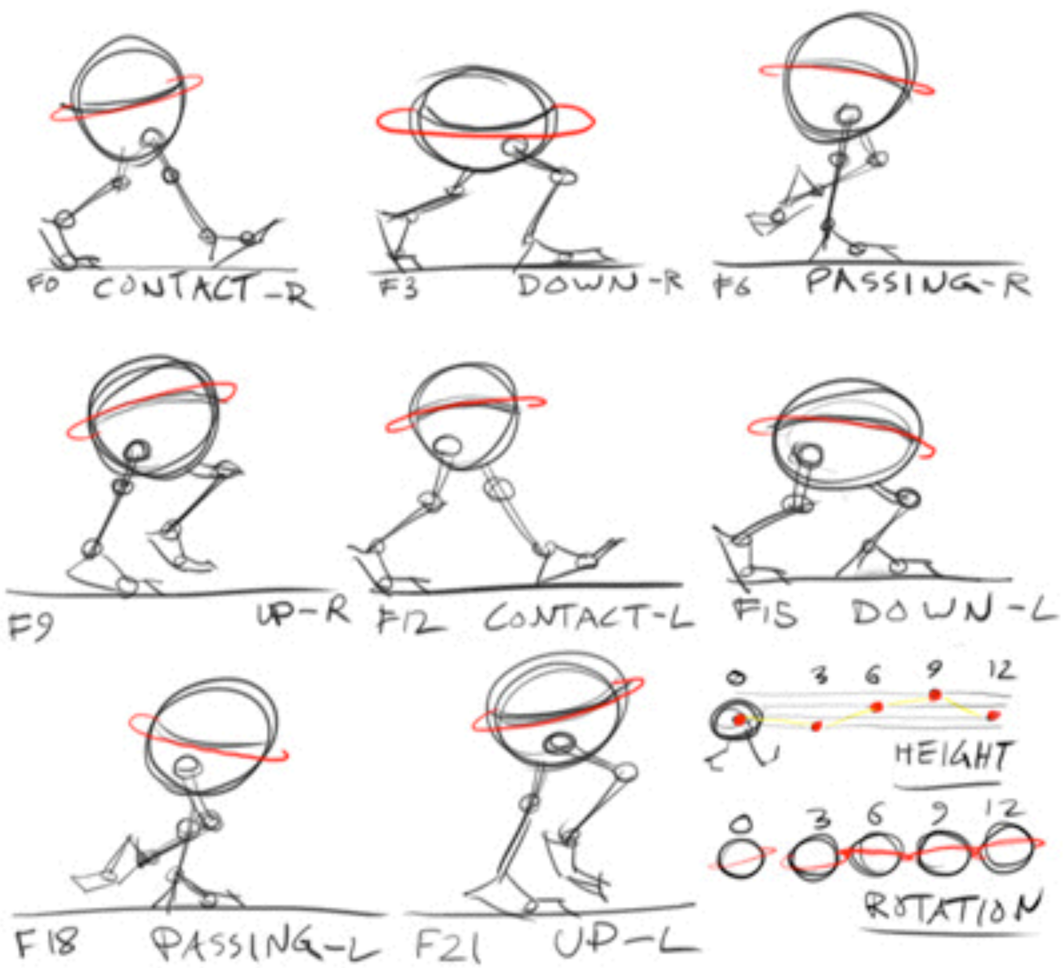
- Many animation principles follow from underlying physics
  - anticipation, follow through, secondary action, squash and stretch, ...
- *Spacetime Constraints,* Witkin and Kass 1988



keyframe animation

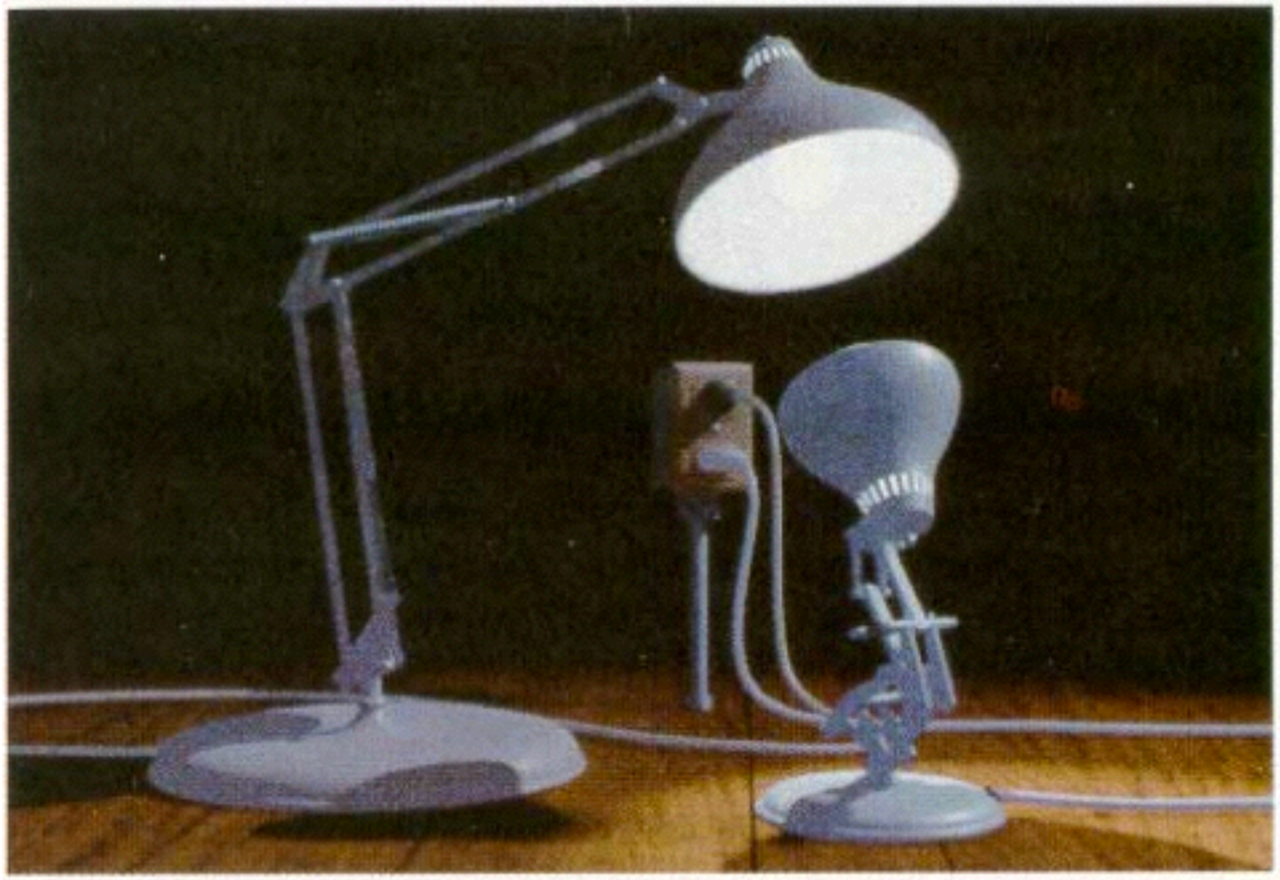
Keyframe animation

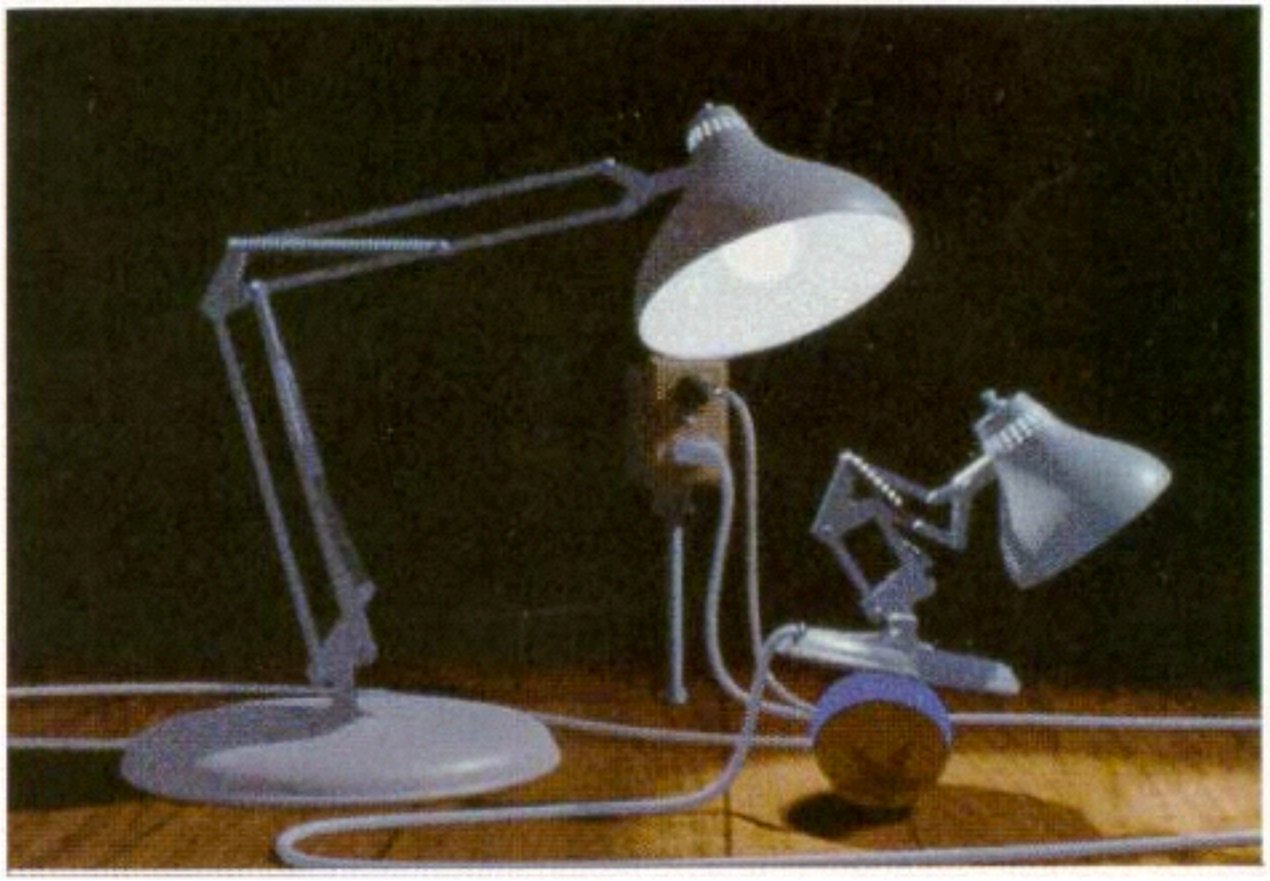
- draw a series of poses
- fill in the frames in between (“inbetweening”)
  - computer animation uses interpolation

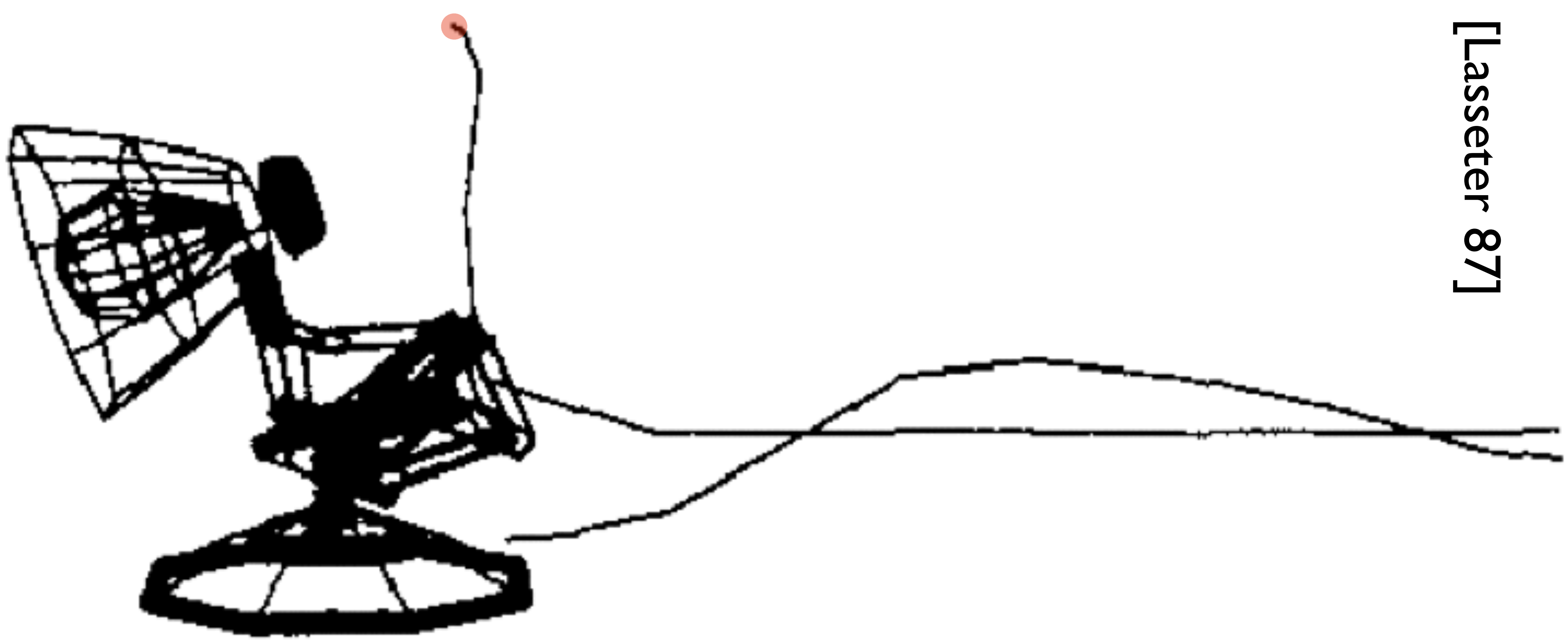


http://anim.tmog.net

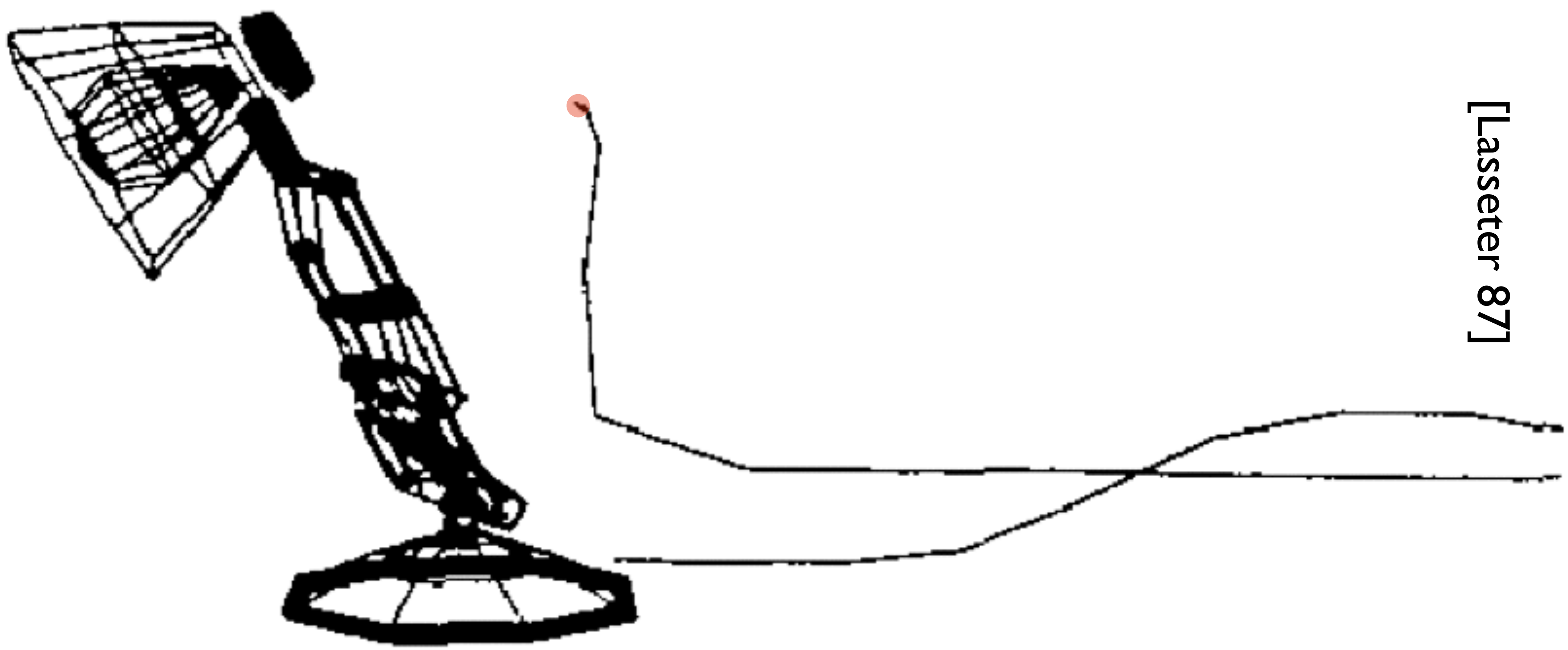
Luxo Jr.



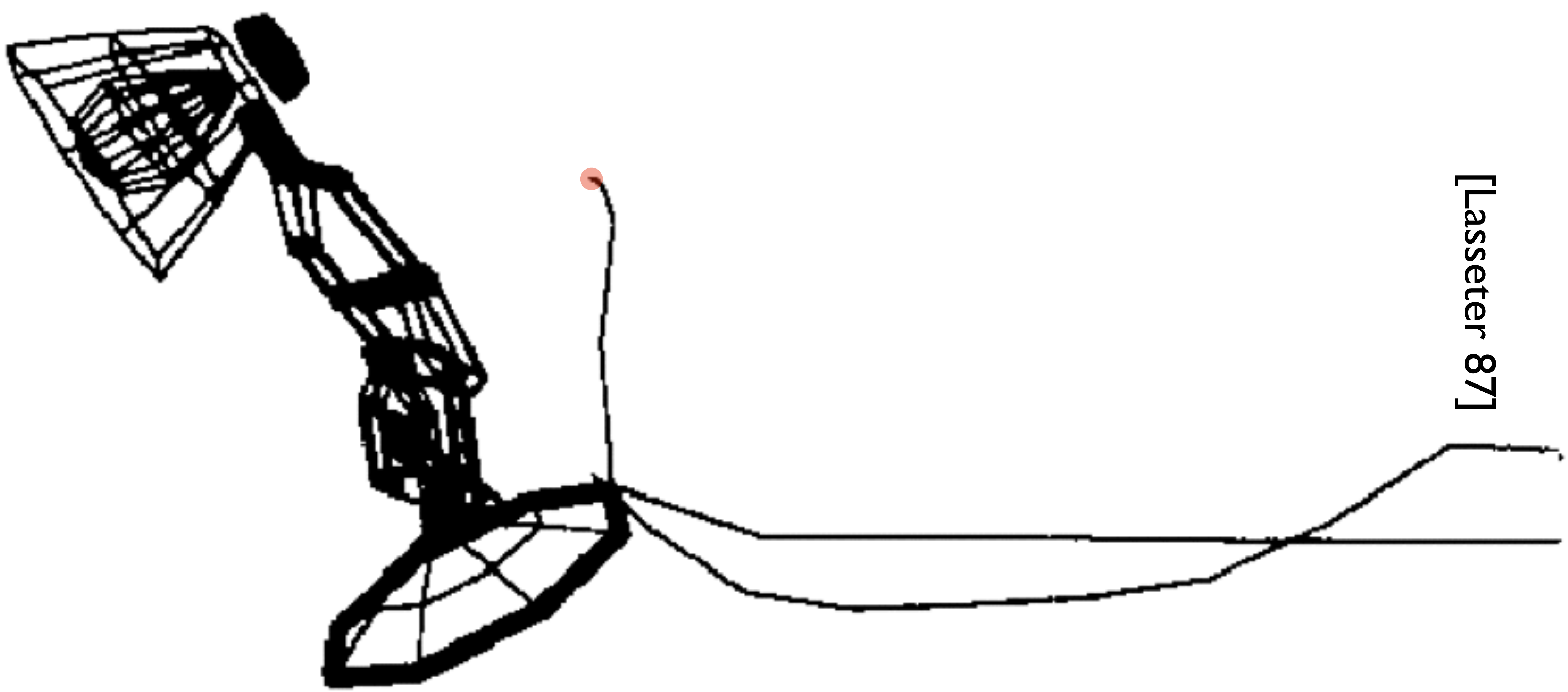




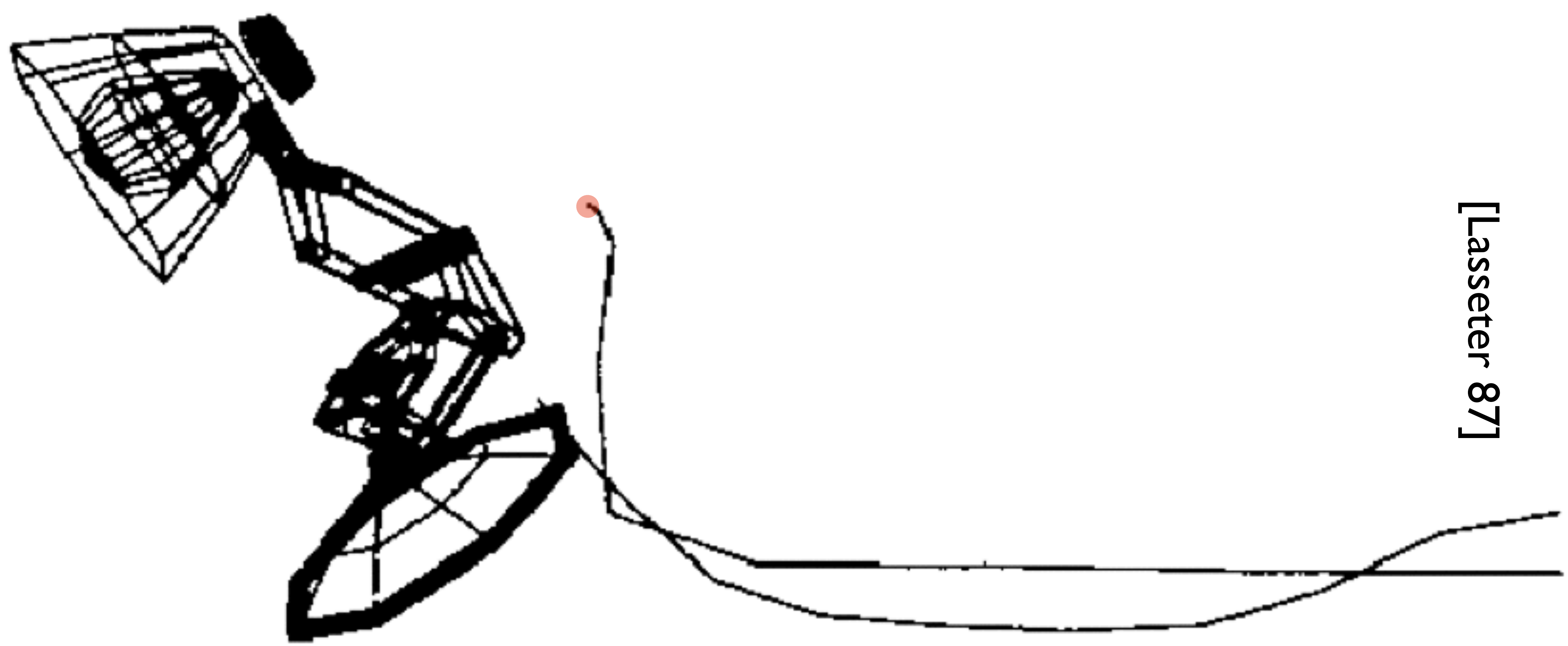
[Lasseter 87]



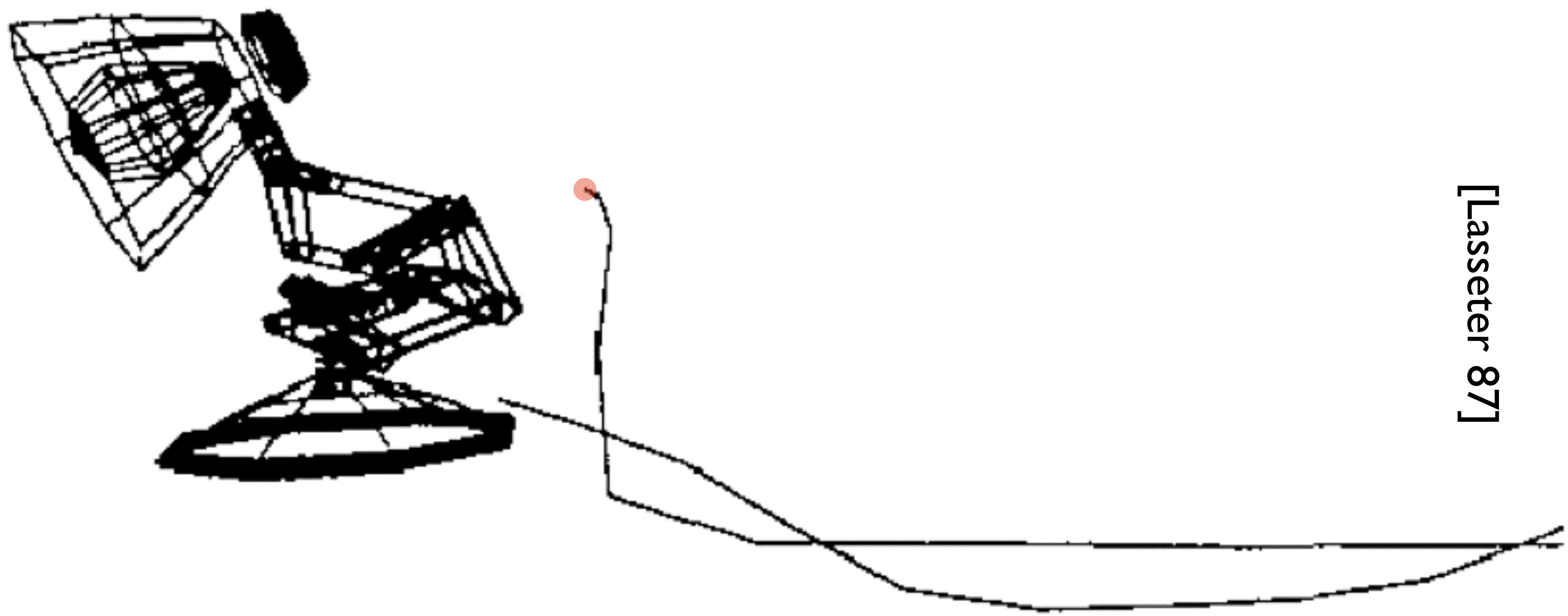
[Lasseter 87]



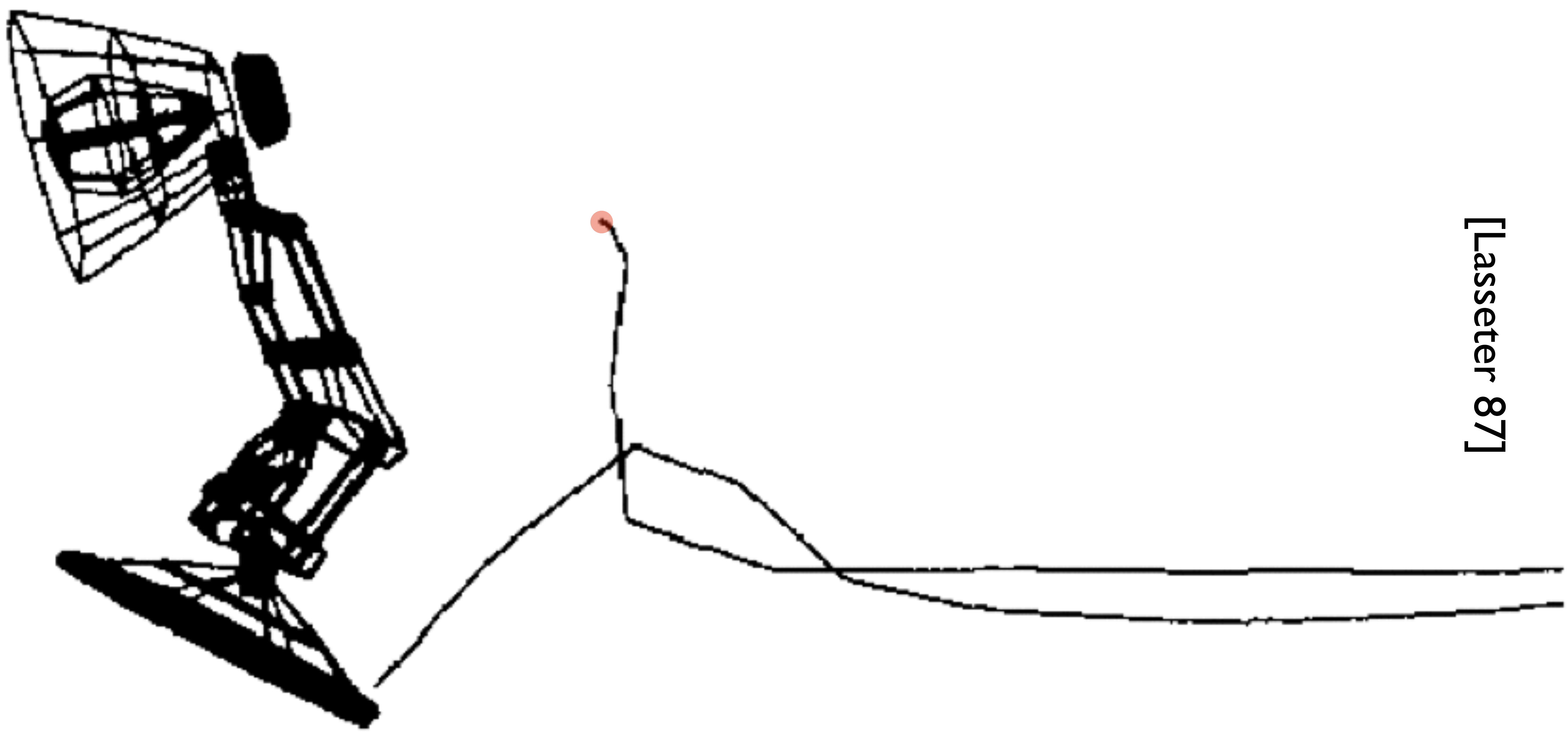
[Lasseter 87]



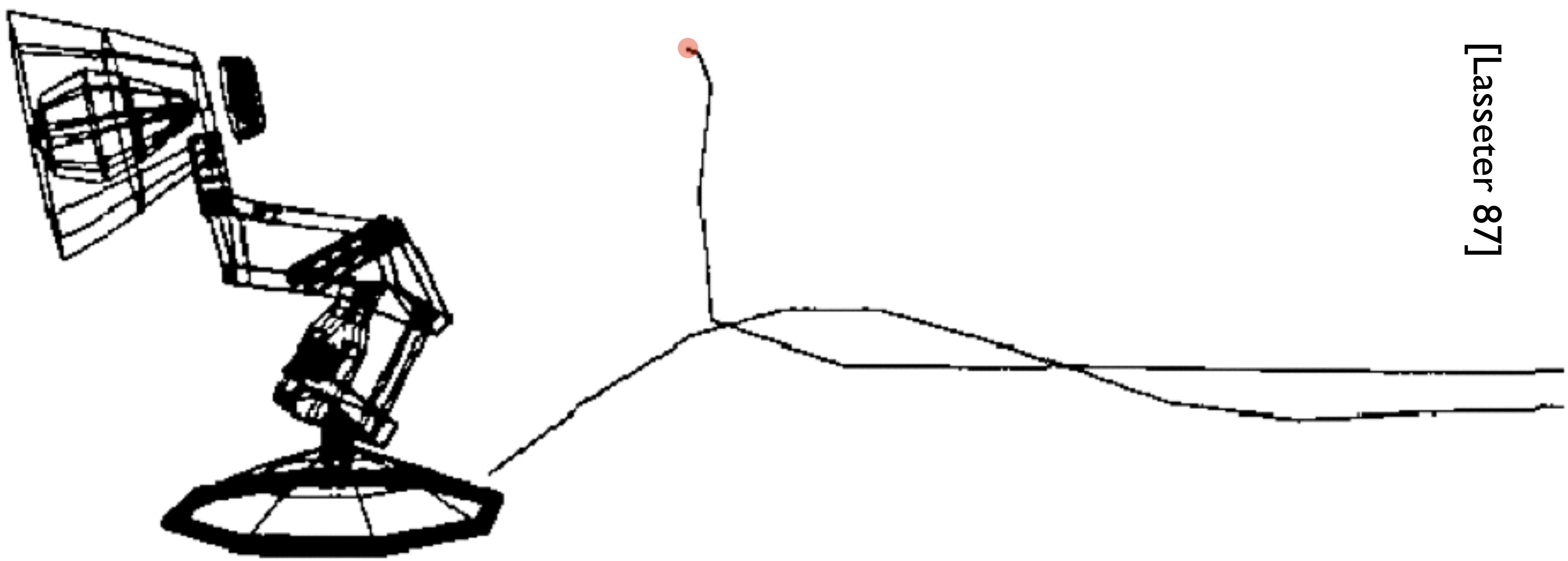
[Lasseter 87]



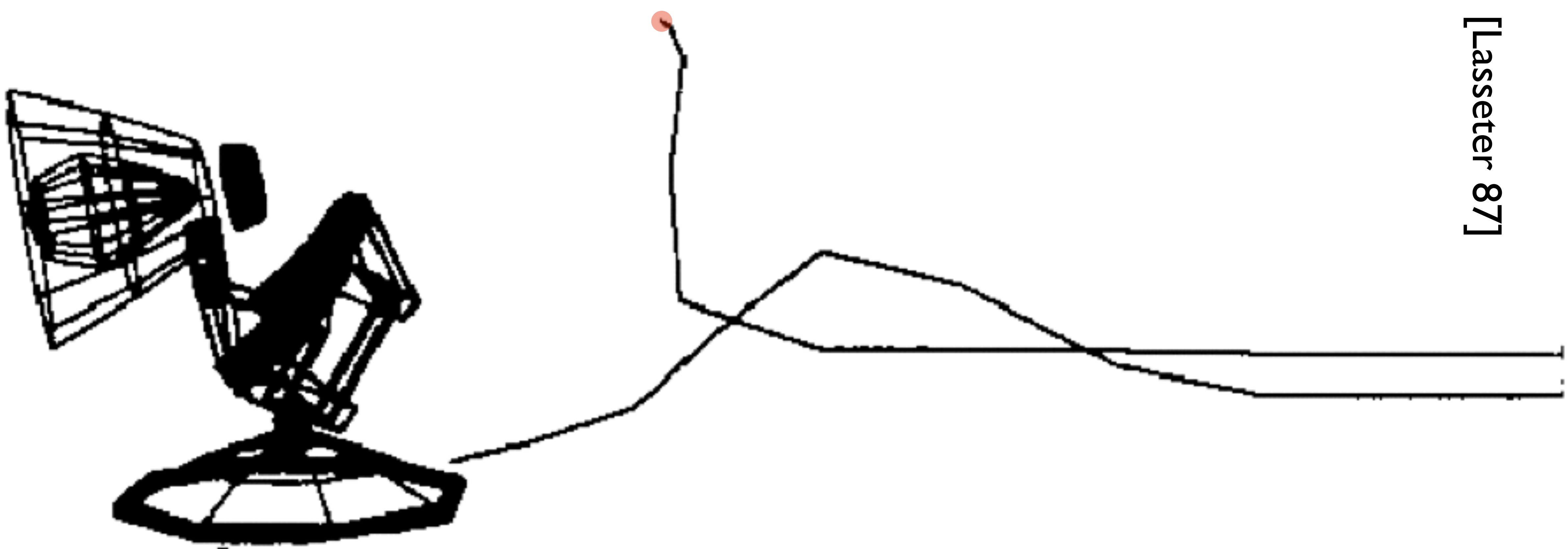
[Lasseter 87]



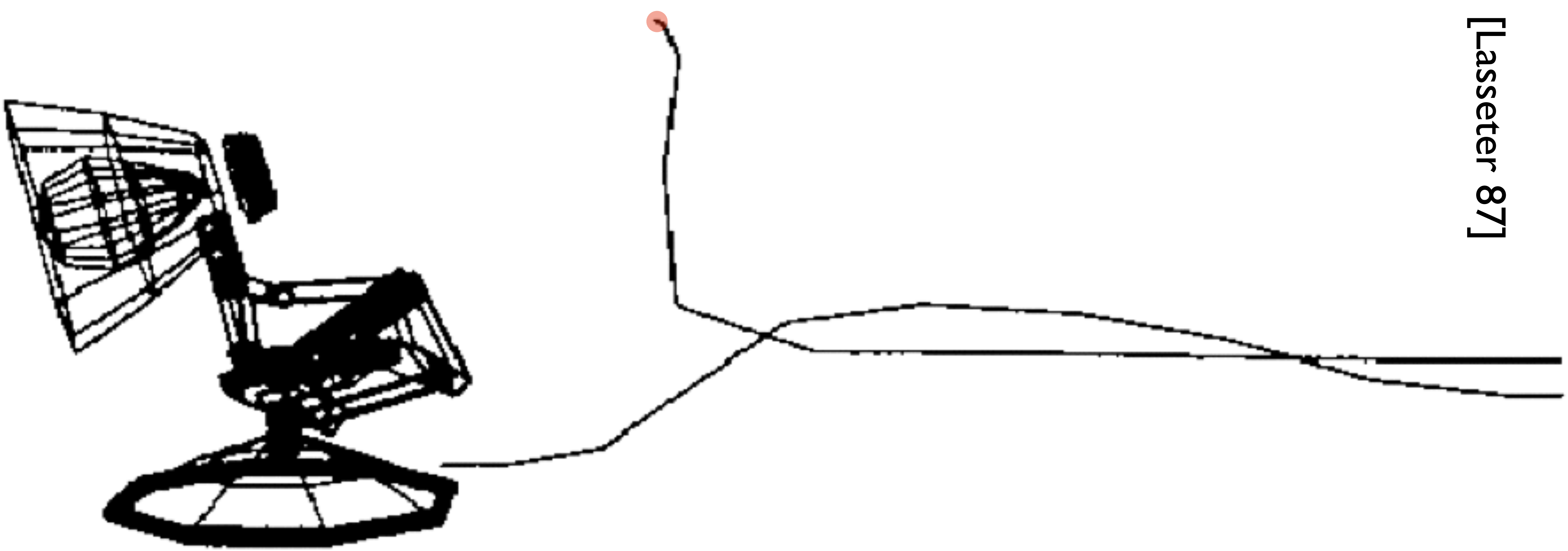
[Lasseter 87]



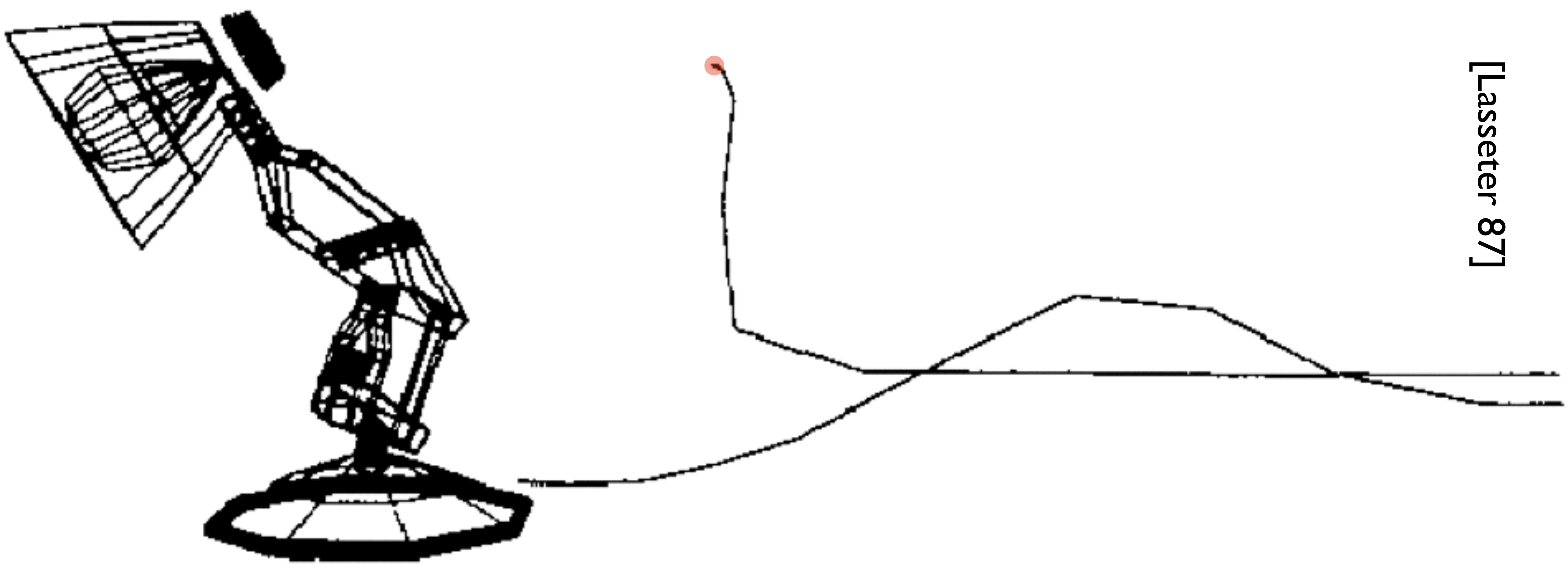
[Lasseter 87]



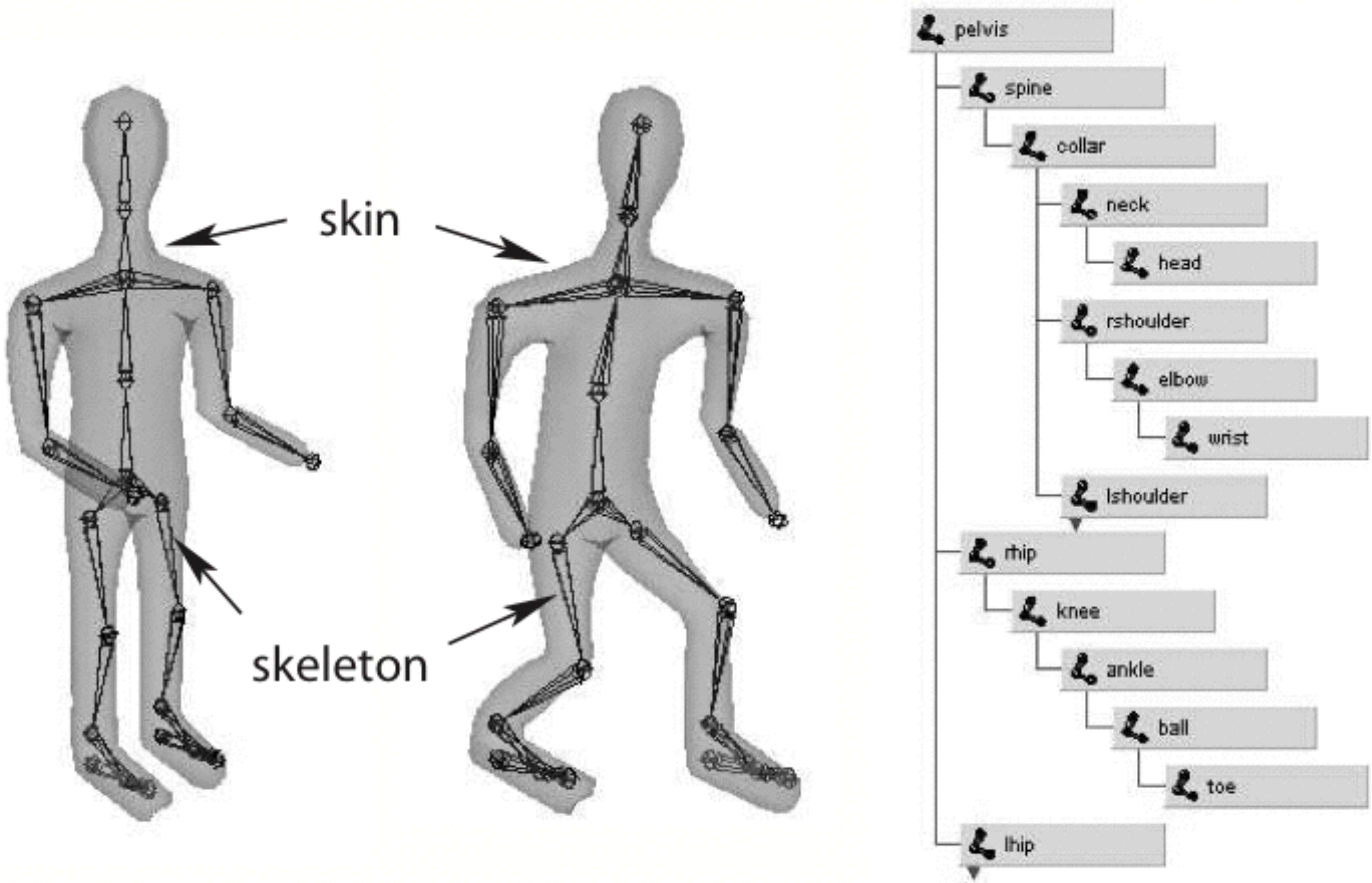
[Lasseter 87]



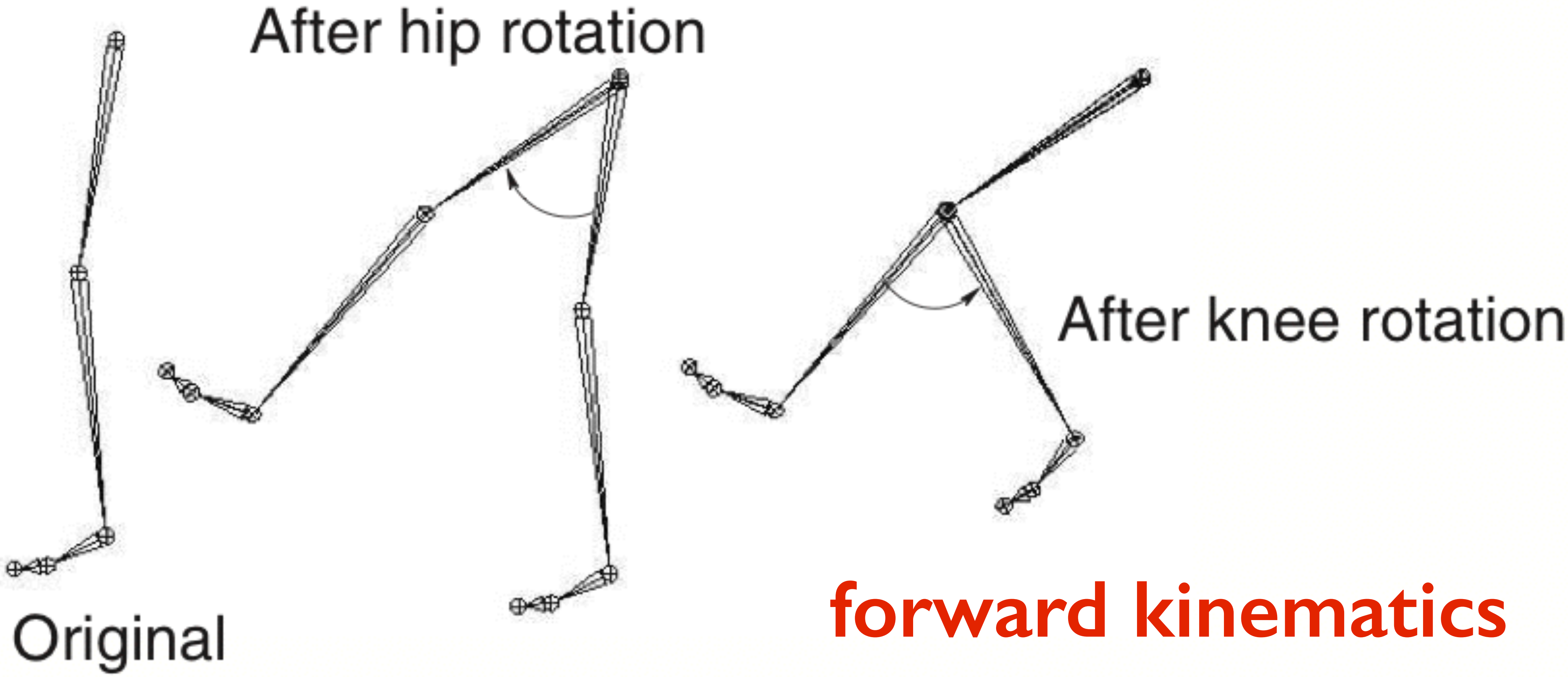
[Lasseter 87]



[Lasseter 87]



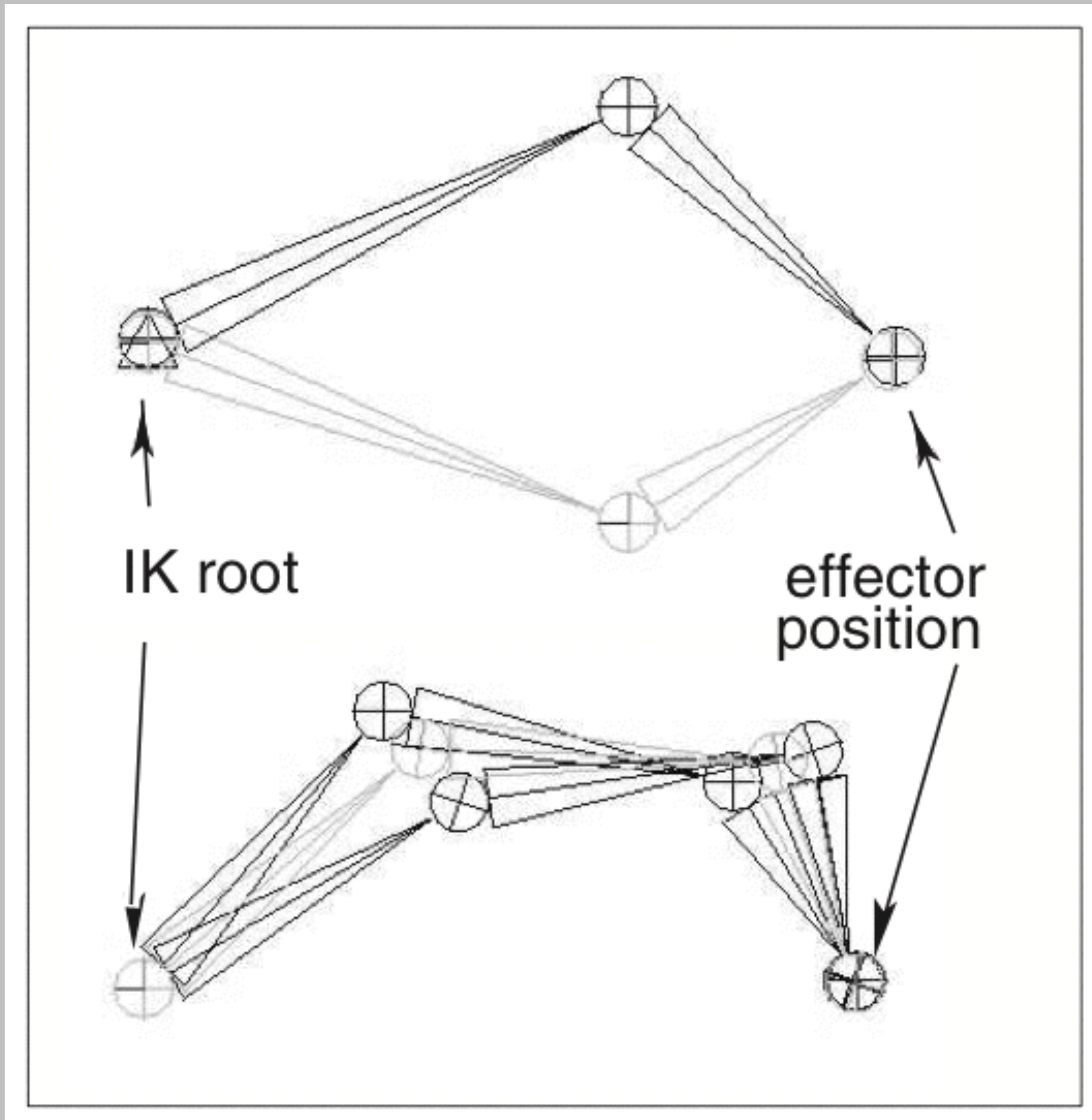
[Shirley and Marschner]



forward kinematics

inverse kinematics

[Shirley and Marschner]

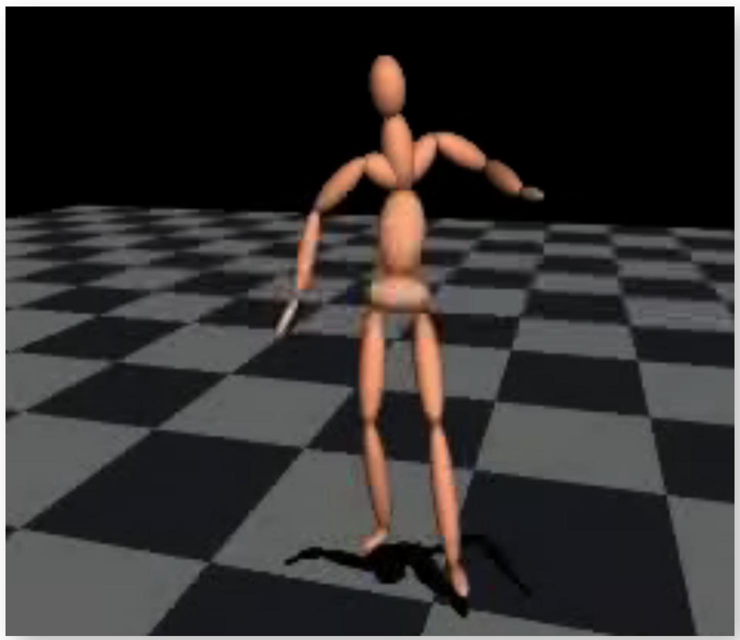


multiple possible states of joints

[Shirley and Marschner]

inverse kinematics

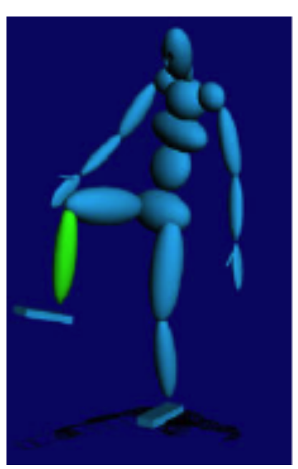
Keyframe character DOFs

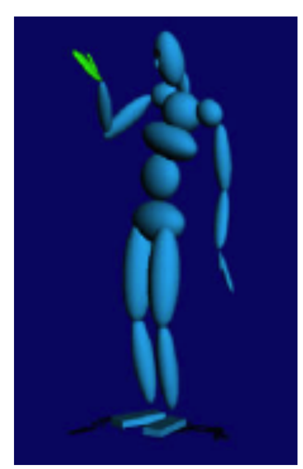


3 translational DOFs

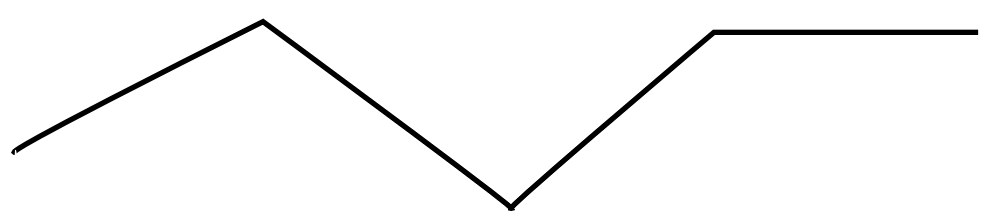
48 rotational DOFs

Each joint can have up to 3 DOFs

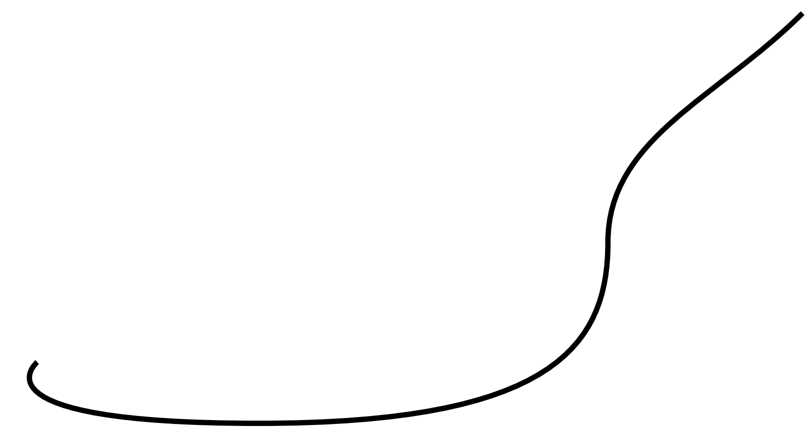




Interpolation of keyframes

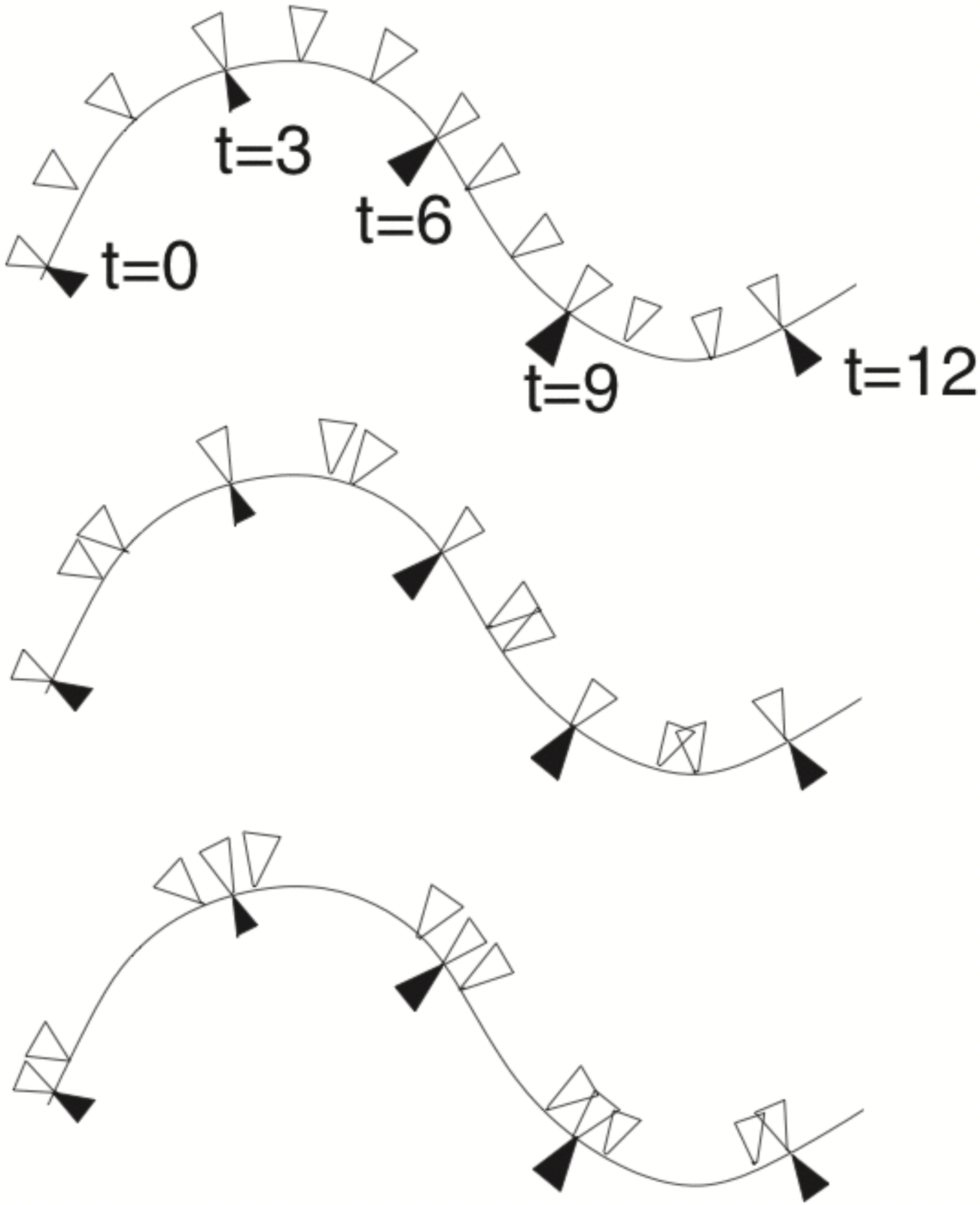


linear interpolation



spline interpolation

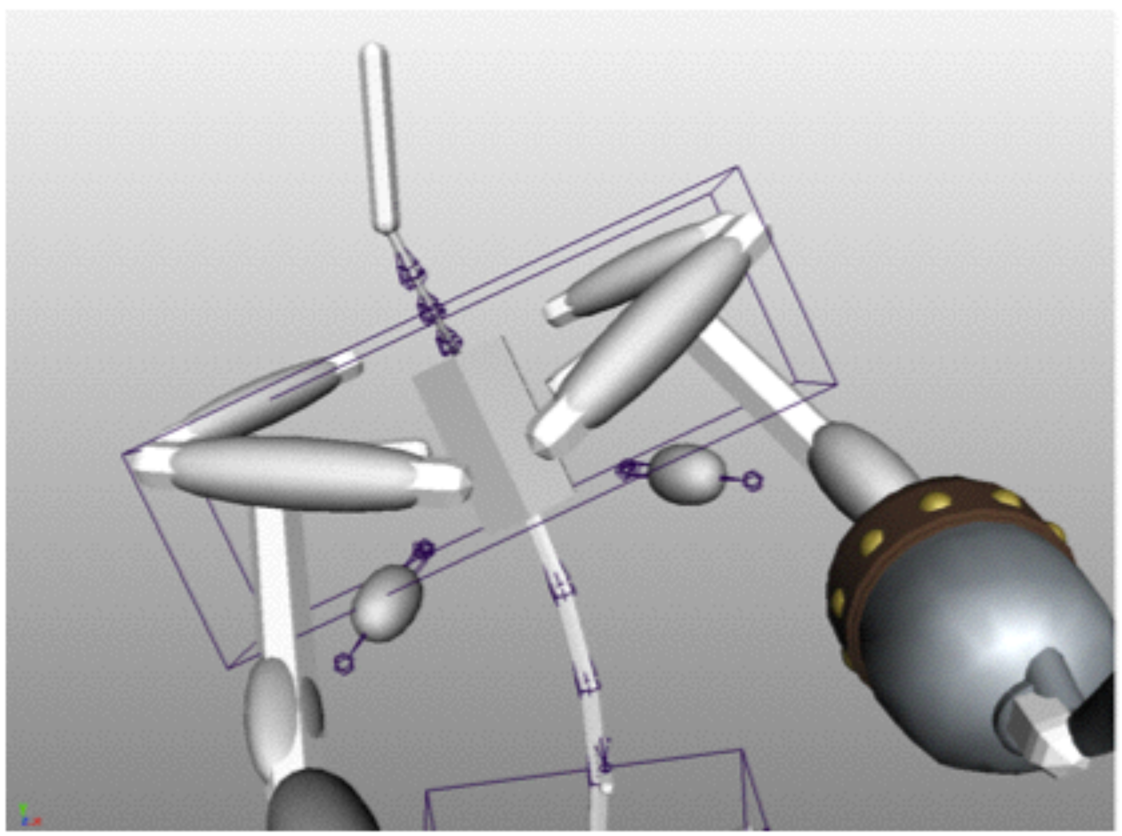
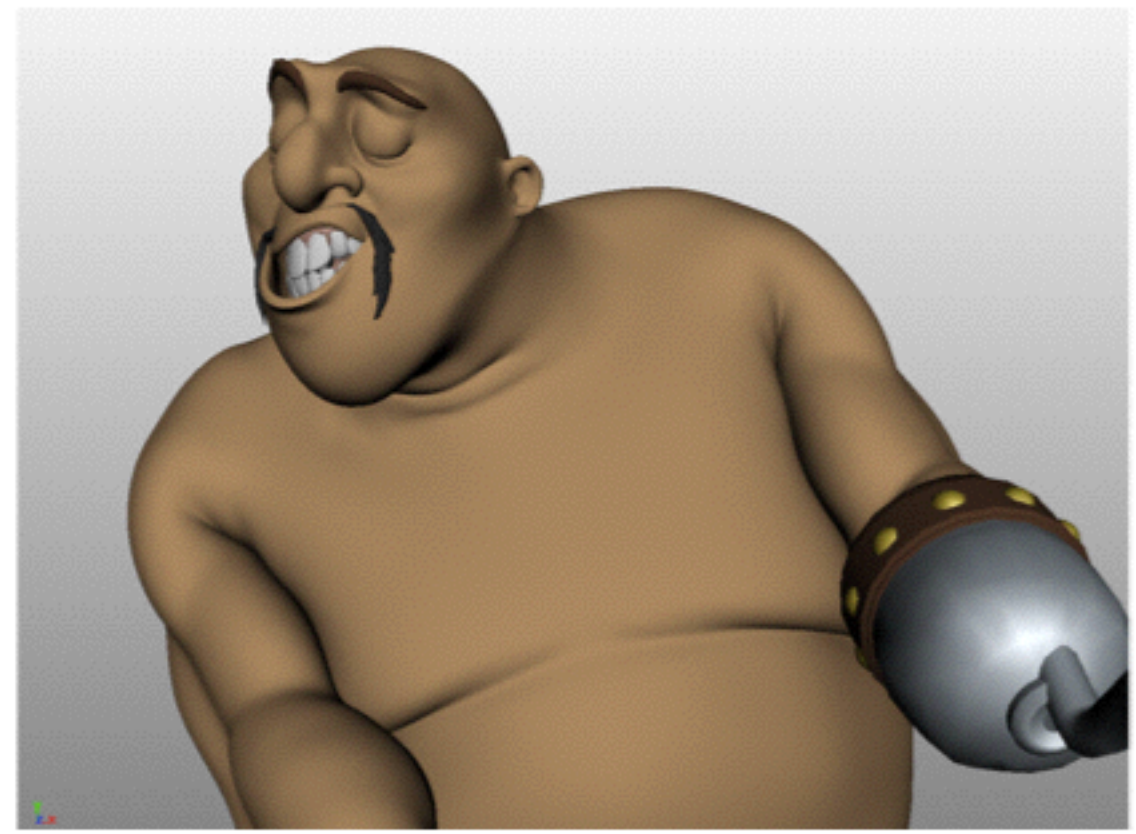
Straightforward to interpolate position but what about orientation?



need to consider
both
shape of motion
and
speed of motion

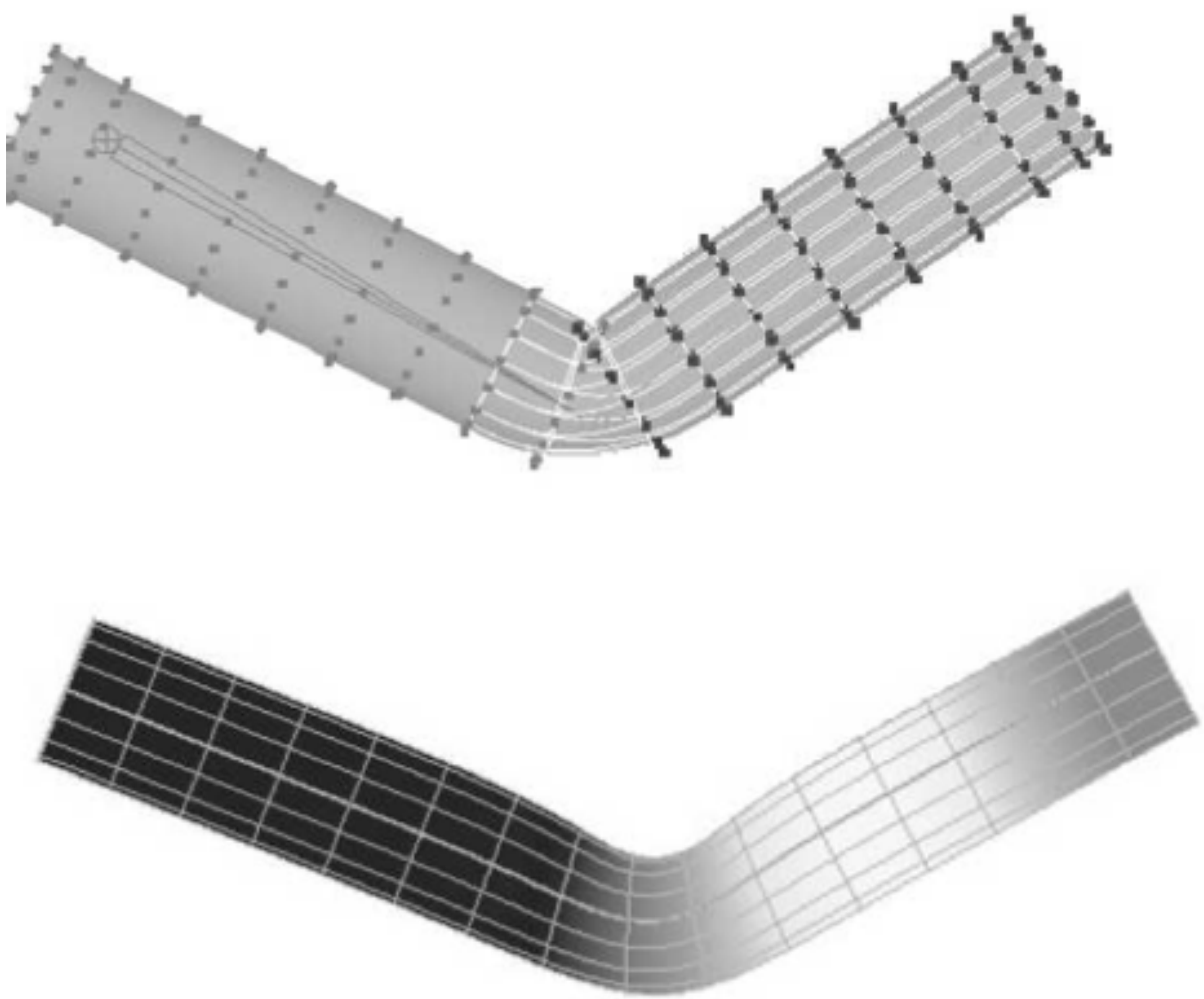
[Shirley and Marschner]

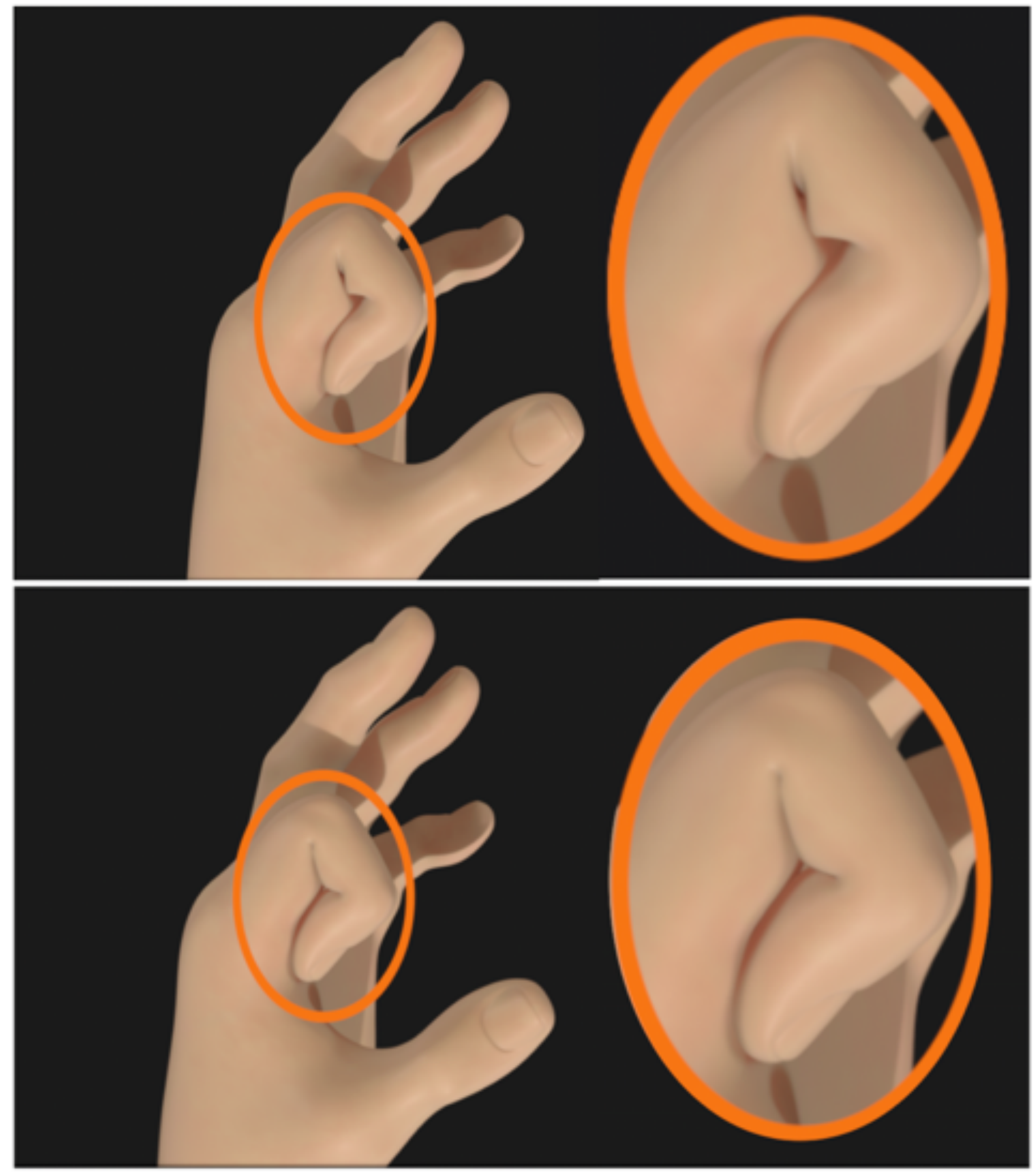
Character Skinning

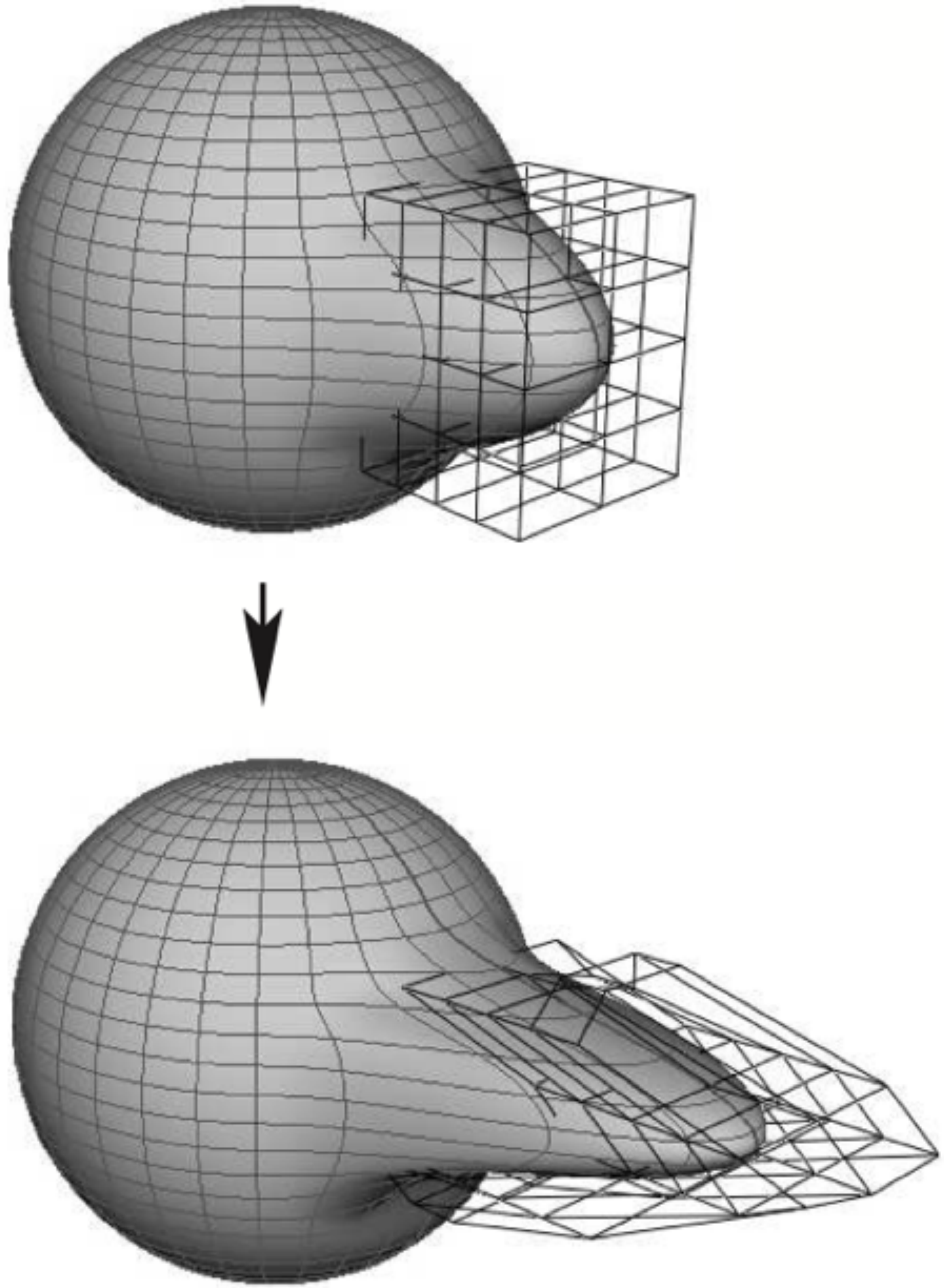
[McAdams et al. 2011]

Character Skinning





[McAdams et al. 2011]



free form deformation

[Sederberg 1986]

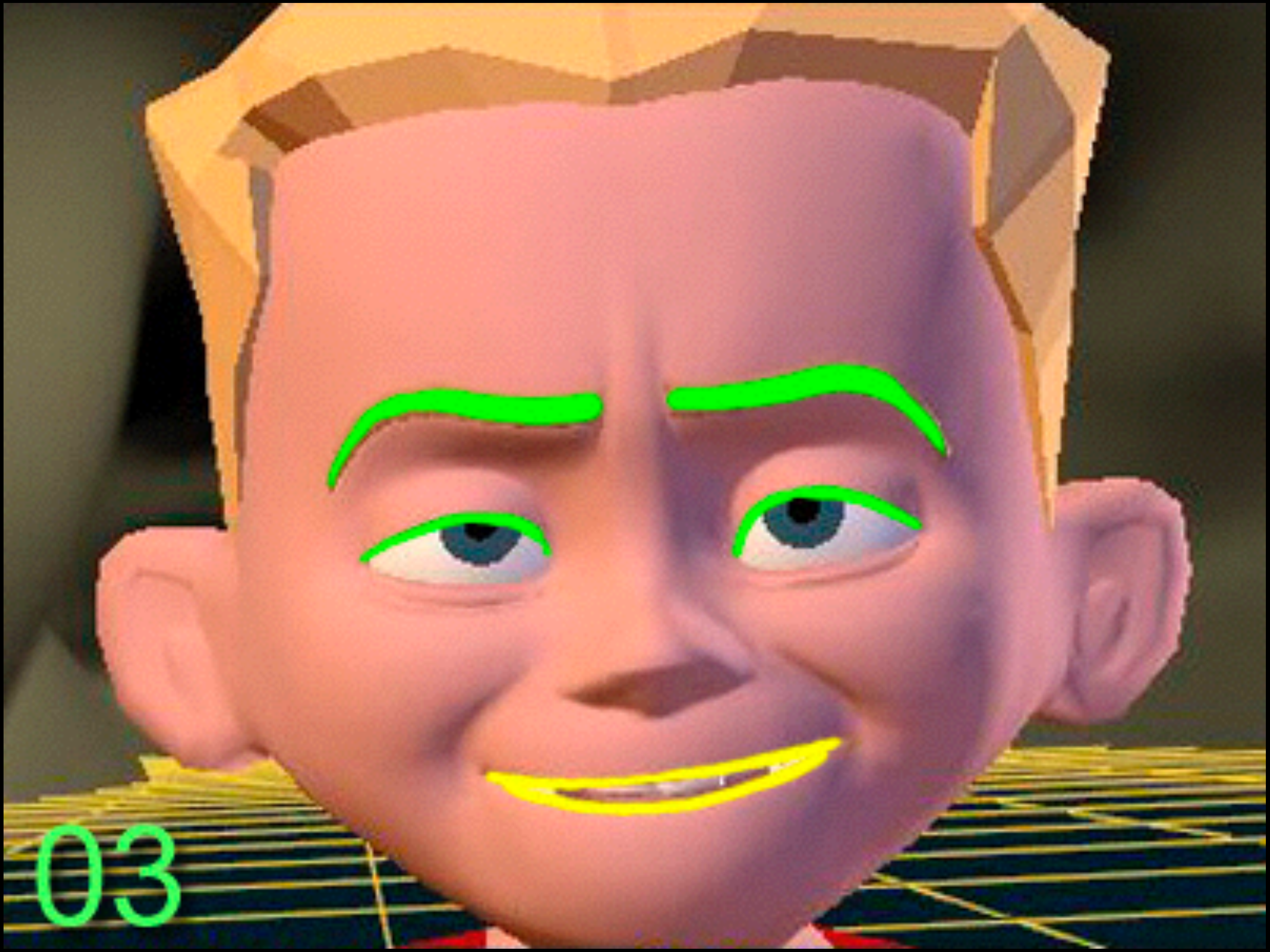
[Shirley and Marschner]

facial animation

http://www.navone.org/HTML/Tutorial_DashTake.htm


01

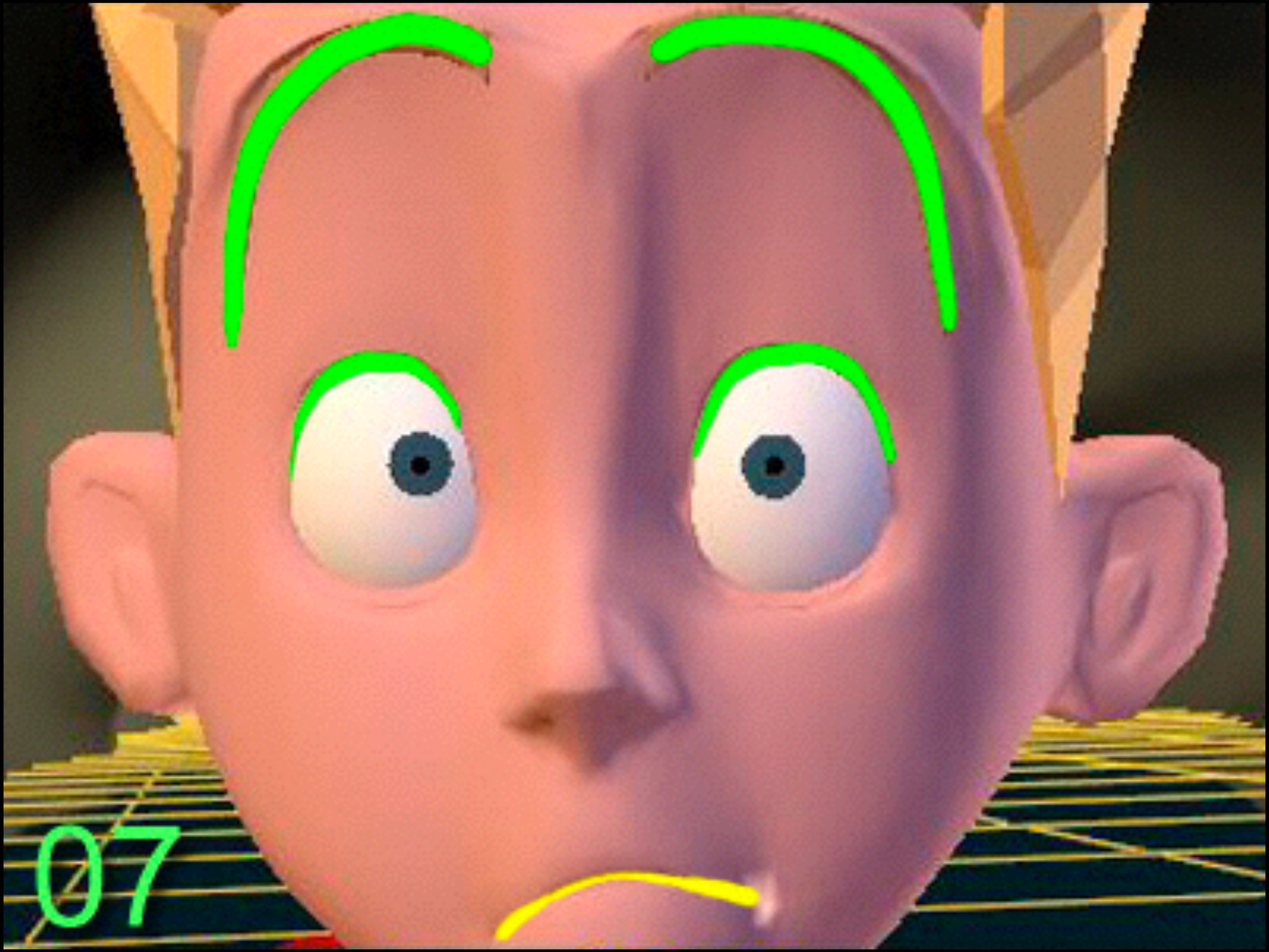

02

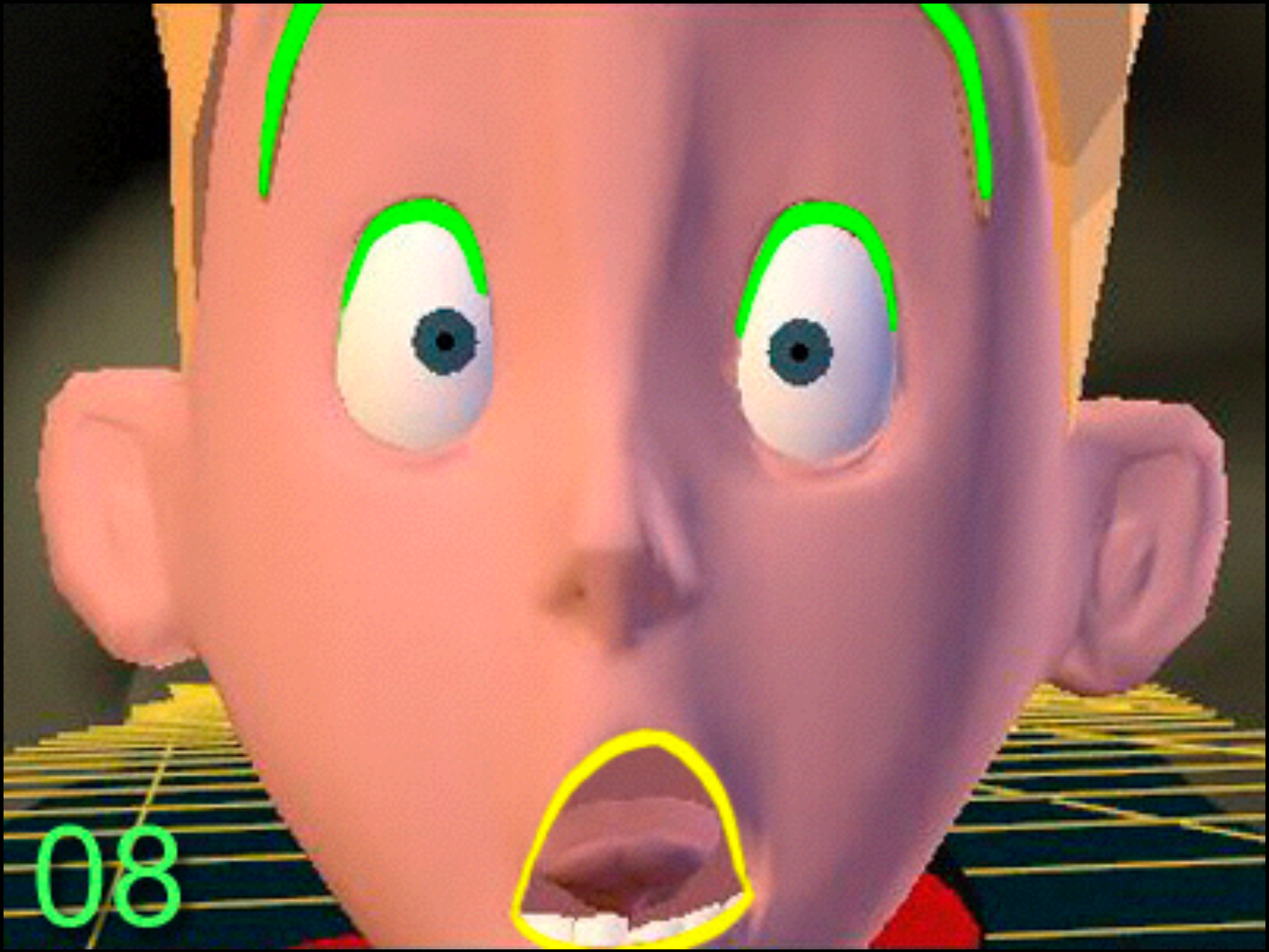

03

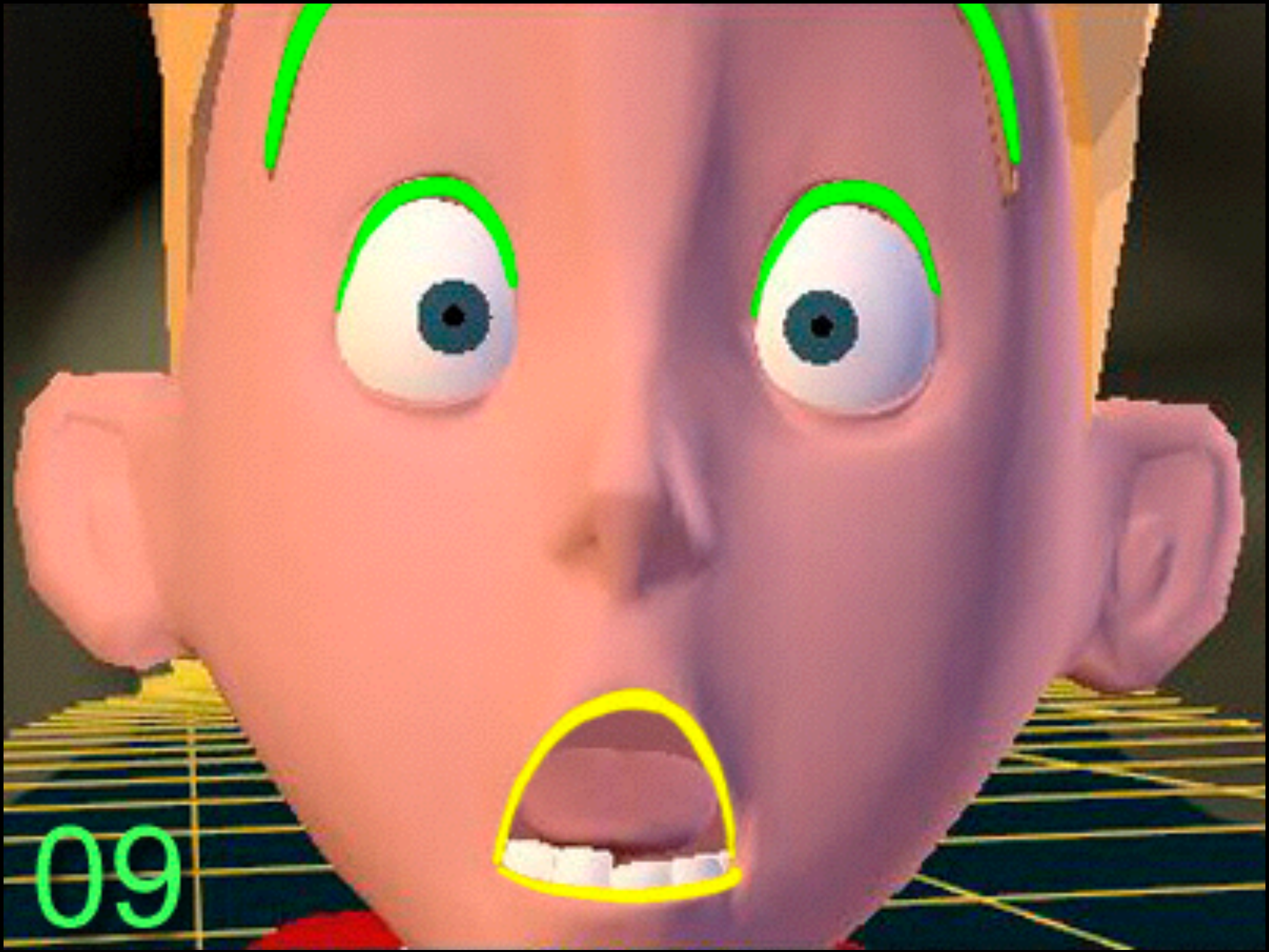

04

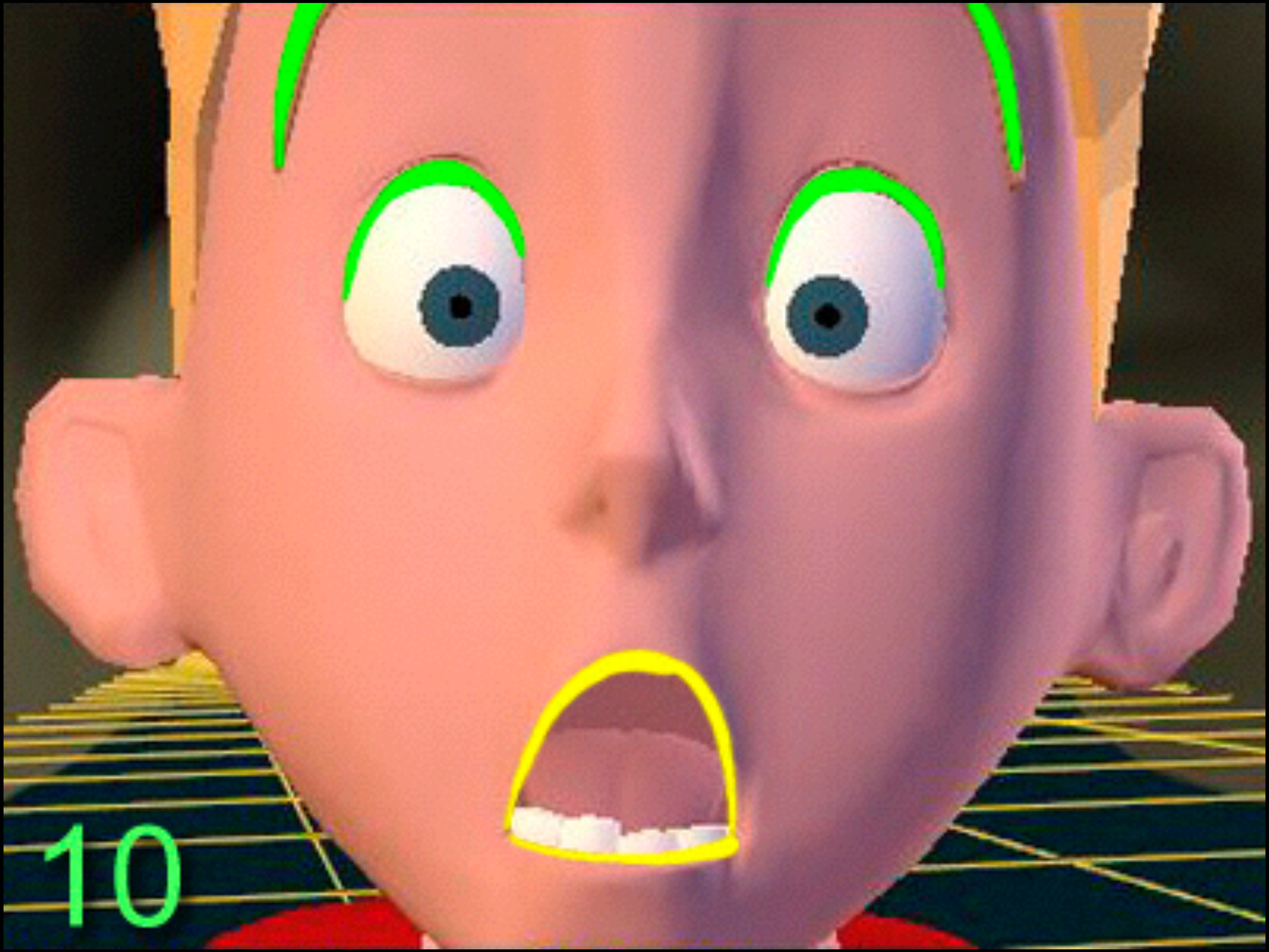

05


06

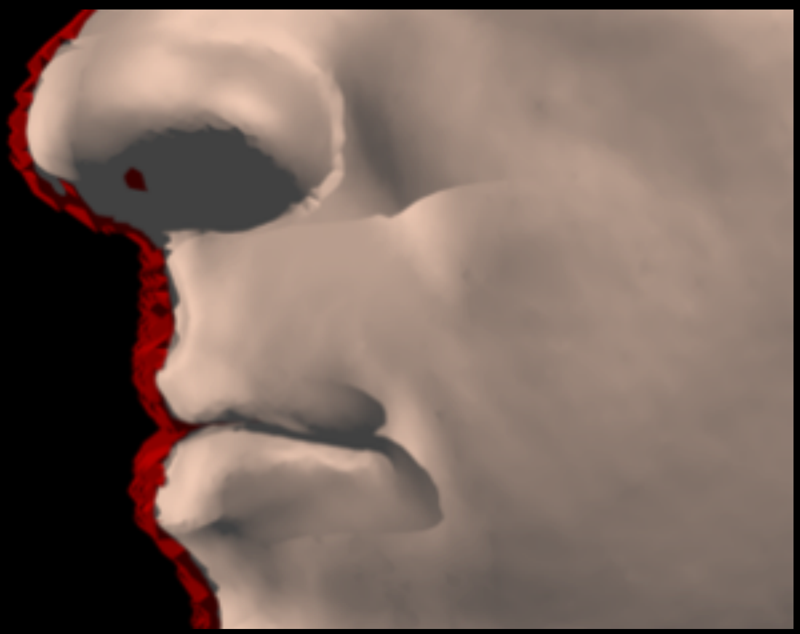

07

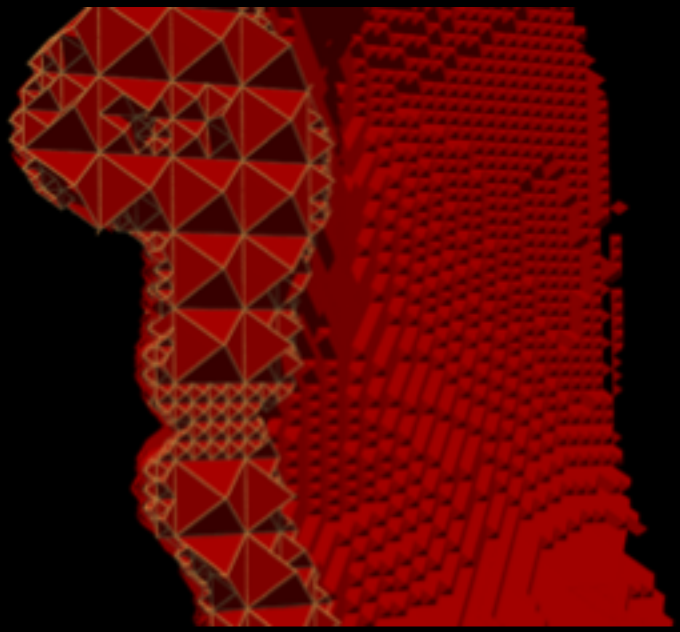

08


09


10

Facial animation

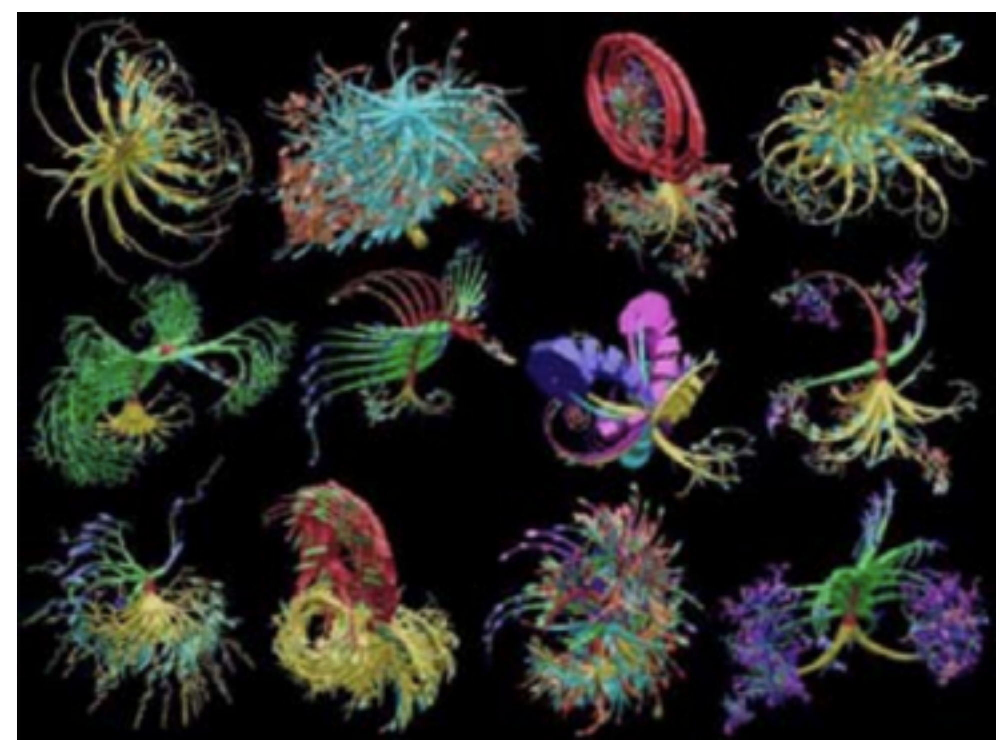




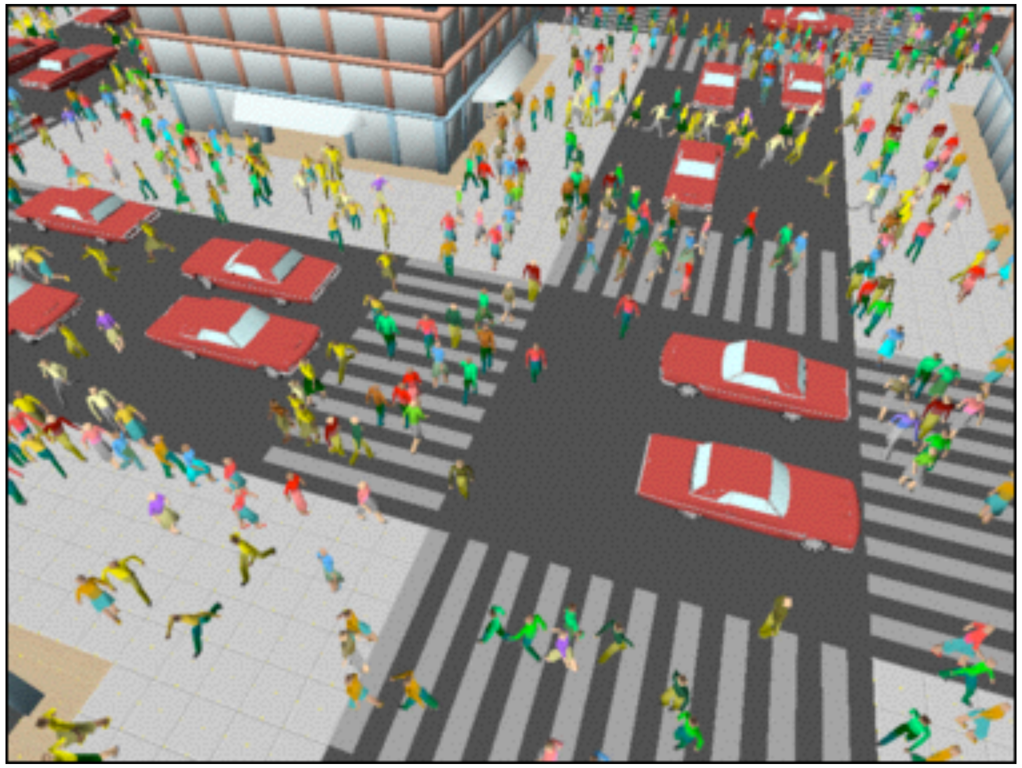
procedural animation

Artificial life

- plants - movement and growth
- evolving artificial life



Crowd simulation

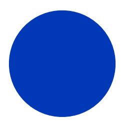


[Treuille et al. 2006]

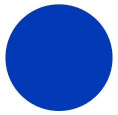
physics-based animation

Particles

Particle: basic dynamic object

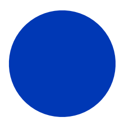


Particle: basic dynamic object



mass m

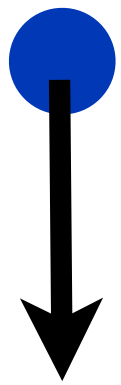
Particle: basic dynamic object



mass m

3 dof $\vec{X} = (x, y, z)$

Particle: basic dynamic object



mass m

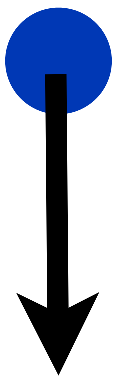
3 dof

$$\vec{X} = (x, y, z)$$

forces: e.g., gravity

$$\vec{F} = -m\vec{g}$$

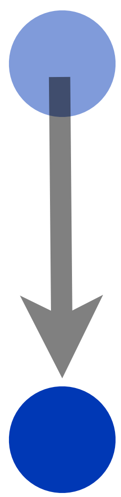
Particle: basic dynamic object



Equations of motion:
Newton's 2nd Law

$$\vec{F} = m\vec{a}$$

Particle: basic dynamic object



Equations of motion:
Newton's 2nd Law

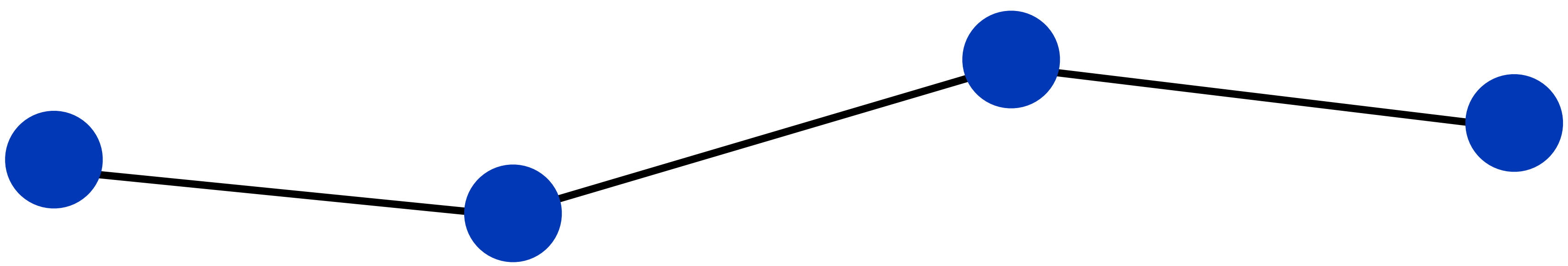
$$\vec{F} = m\vec{a}$$

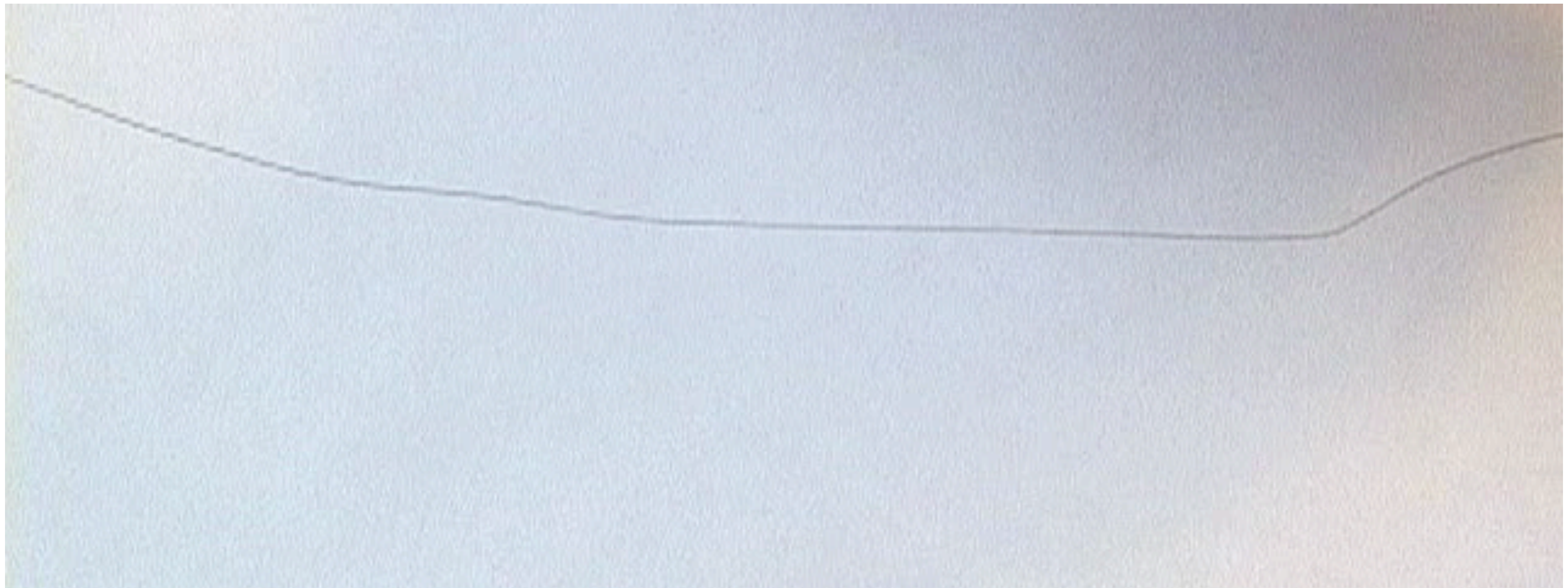
$$\frac{d\vec{x}}{dt} = \vec{v}$$
$$m\frac{d\vec{v}}{dt} = \vec{F}$$

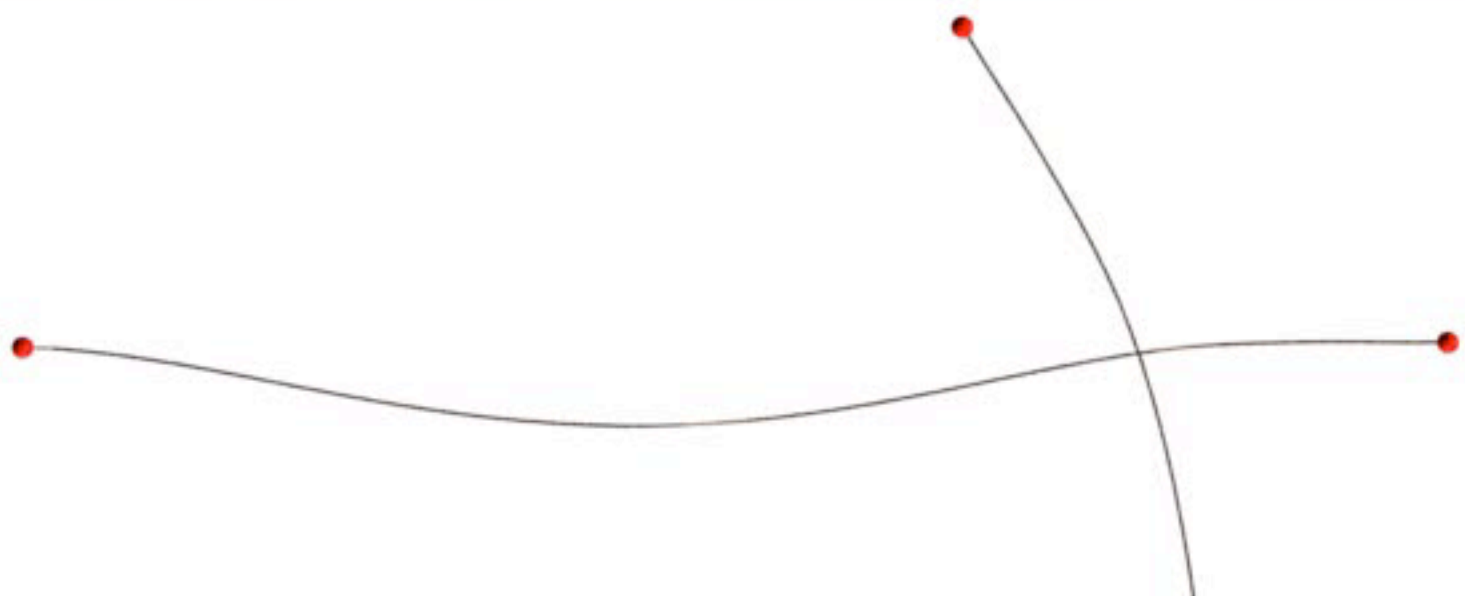
System of ODEs

Deformable bodies

Connect a bunch of particles into a <u>1D line segment</u> with springs



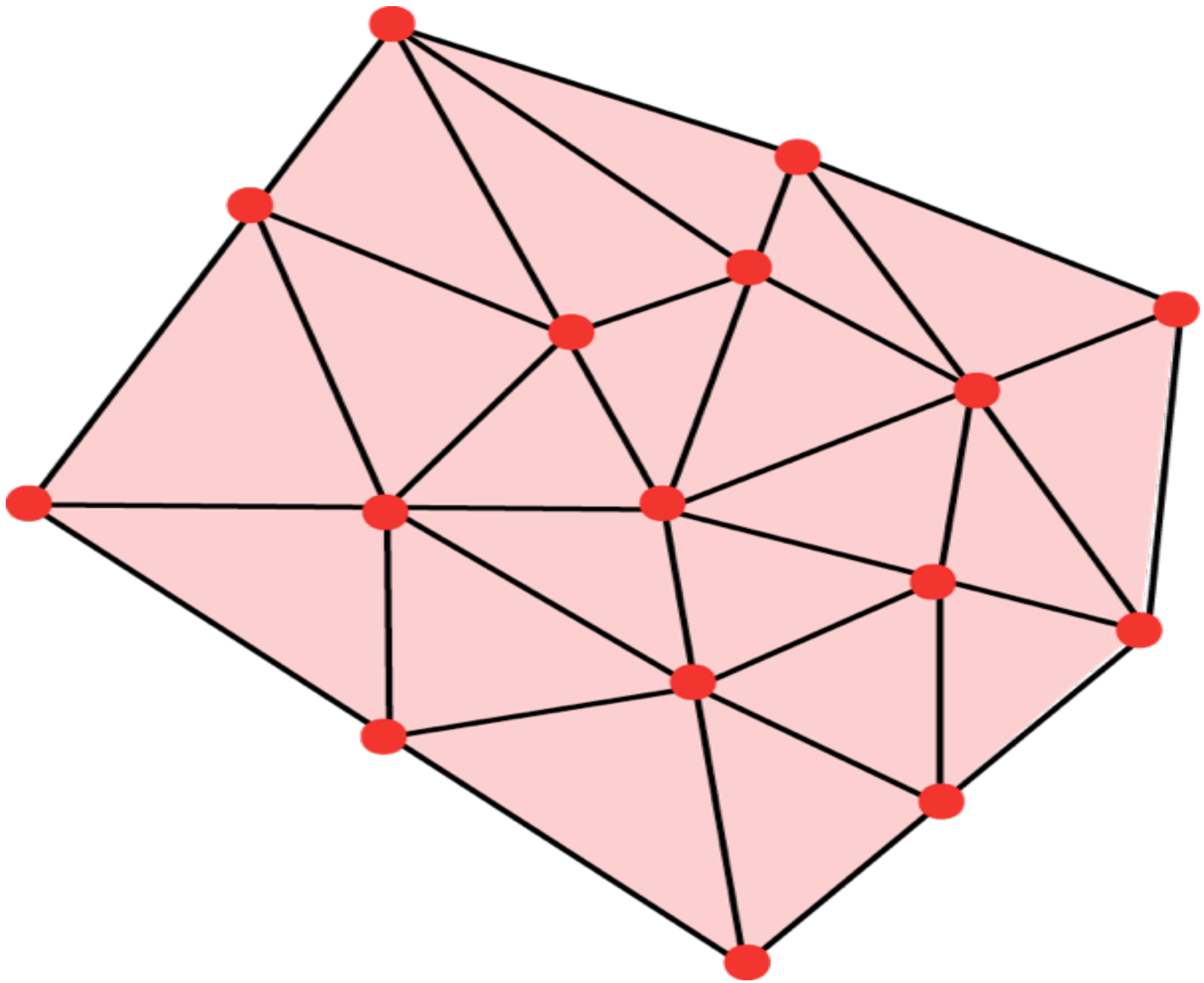




A Mass Spring Model for Hair Simulation

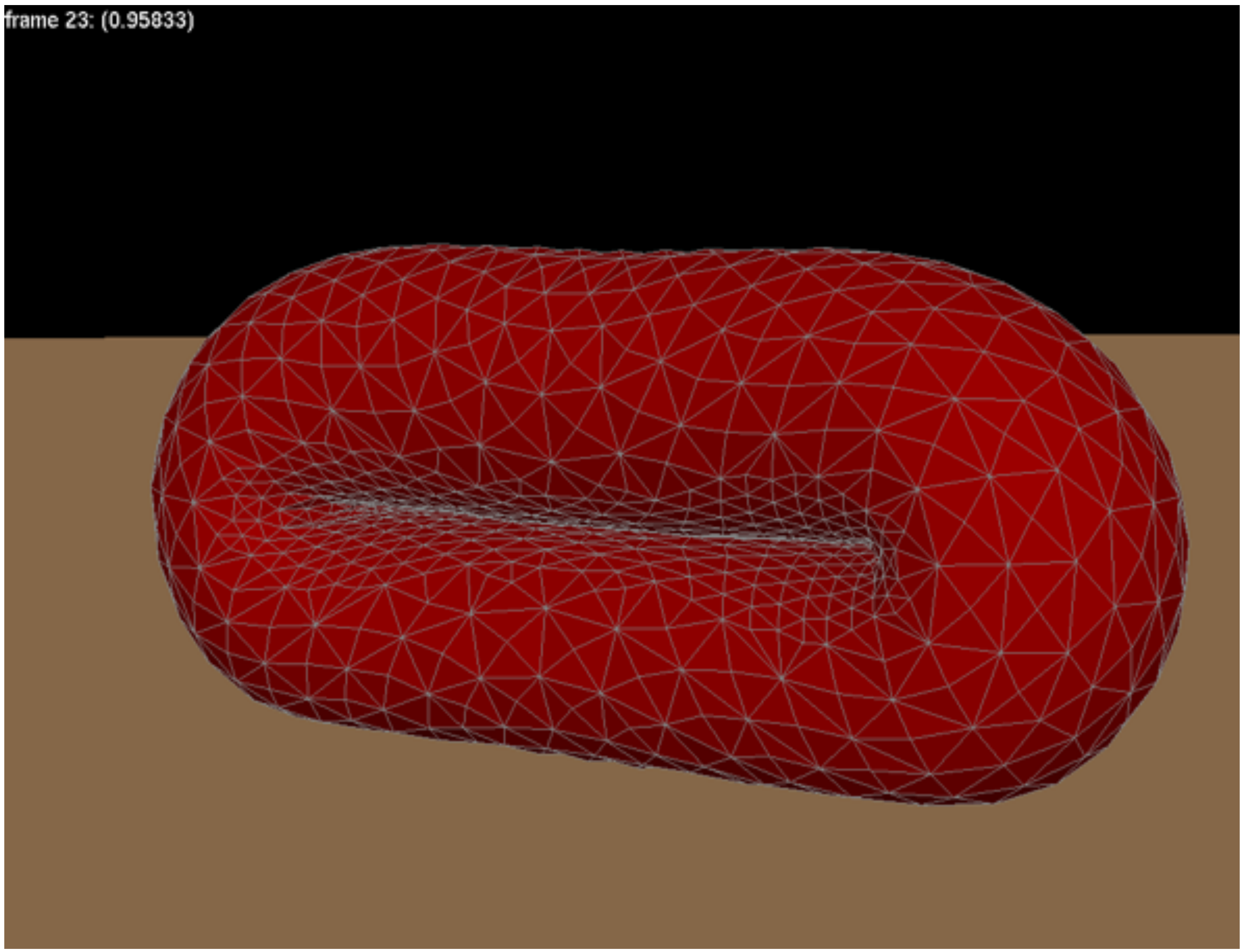
Selle, A., Lentine, M., G., and Fedkiw, R. ACM Transactions on Graphics SIGGRAPH 2008, ACM TOG 27, 64.1-64.11 (2008)

Connect a bunch of particles into a <u>2D mesh</u>

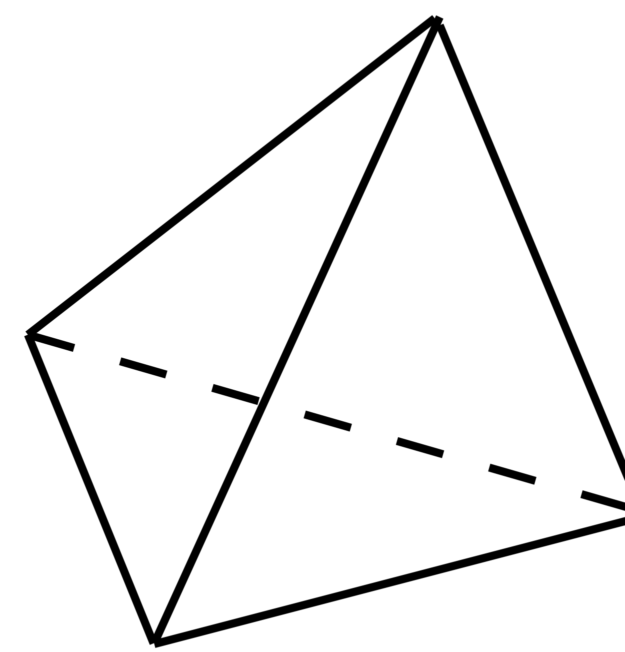


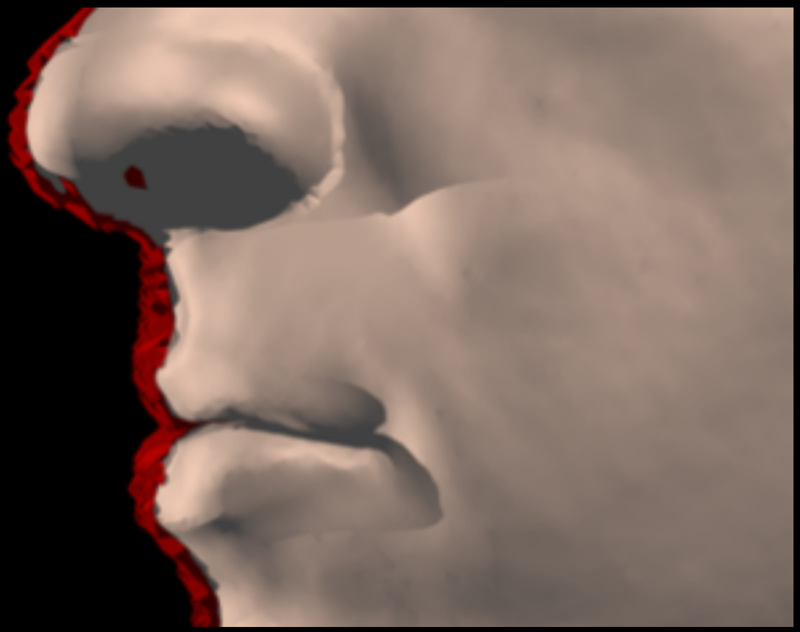
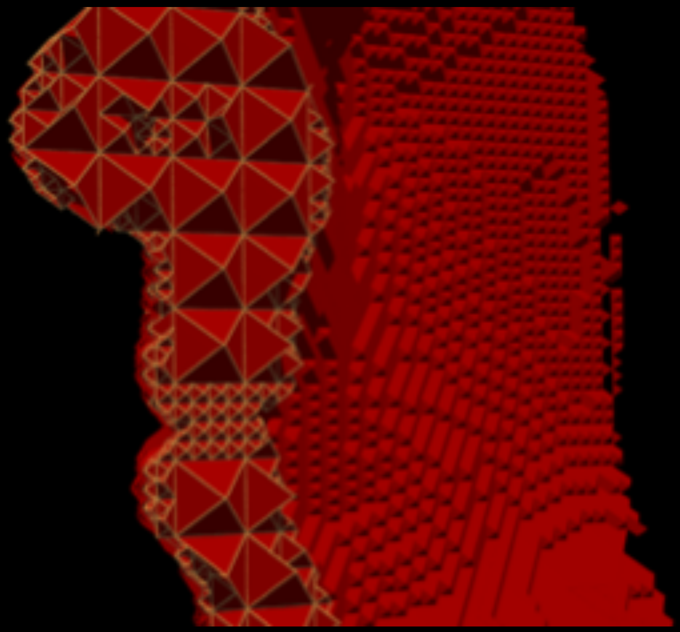
Selle, A., Su, J., Irving, G., and Fedkiw, R. IEEE Transactions on Visualization and Graphics (TVCG) 15(2) 339-350

Connect a bunch of particles into a 3D mesh

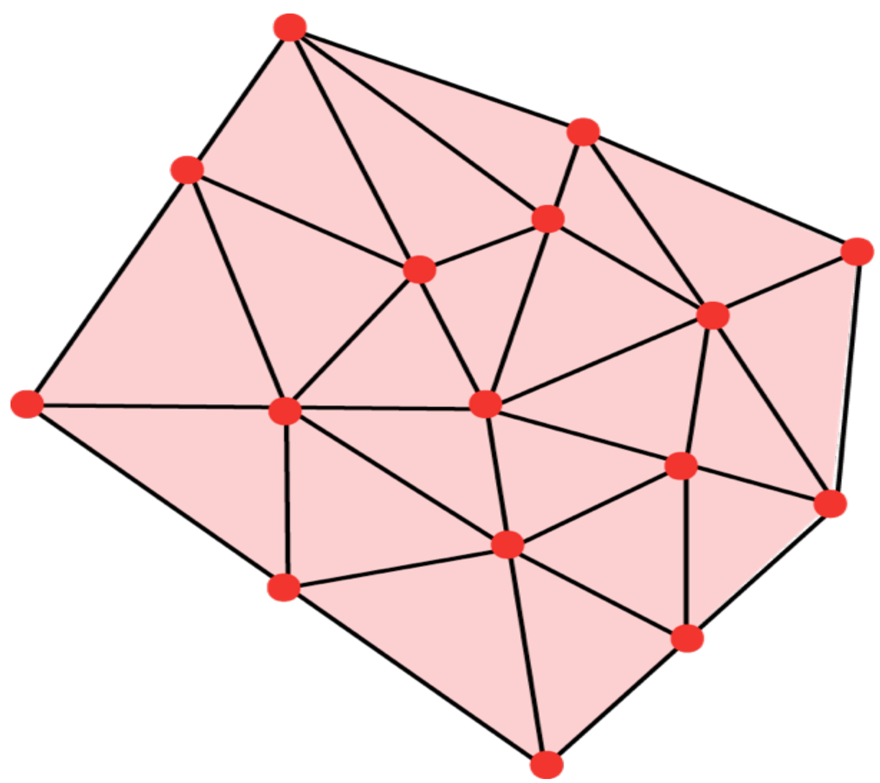


tetrahedron




Deformable bodies: equations of motion



Equations of motion:
Newton's 2nd Law

$$\vec{F} = m\vec{a}$$

$$\frac{d\vec{x}}{dt} = \vec{v}$$
$$m\frac{d\vec{v}}{dt} = \vec{F}$$

System of PDEs

contains spatial derivatives

Rigid bodies

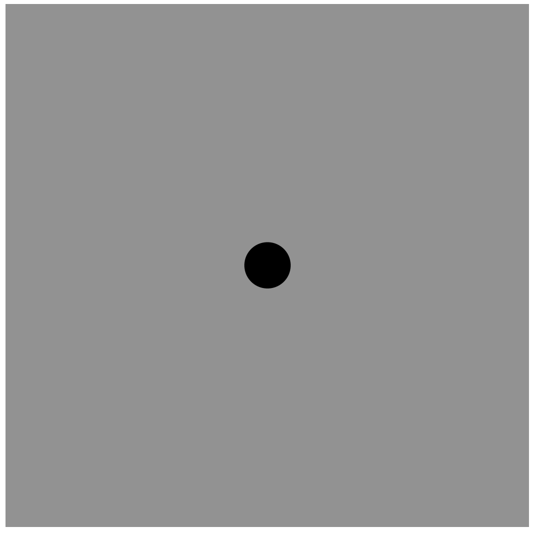
Rigid bodies

6 dofs

forces and torques

elastic collisions

ODEs



$$(\vec{X}, \vec{\Omega})$$

$$(\vec{F}, \vec{\tau})$$

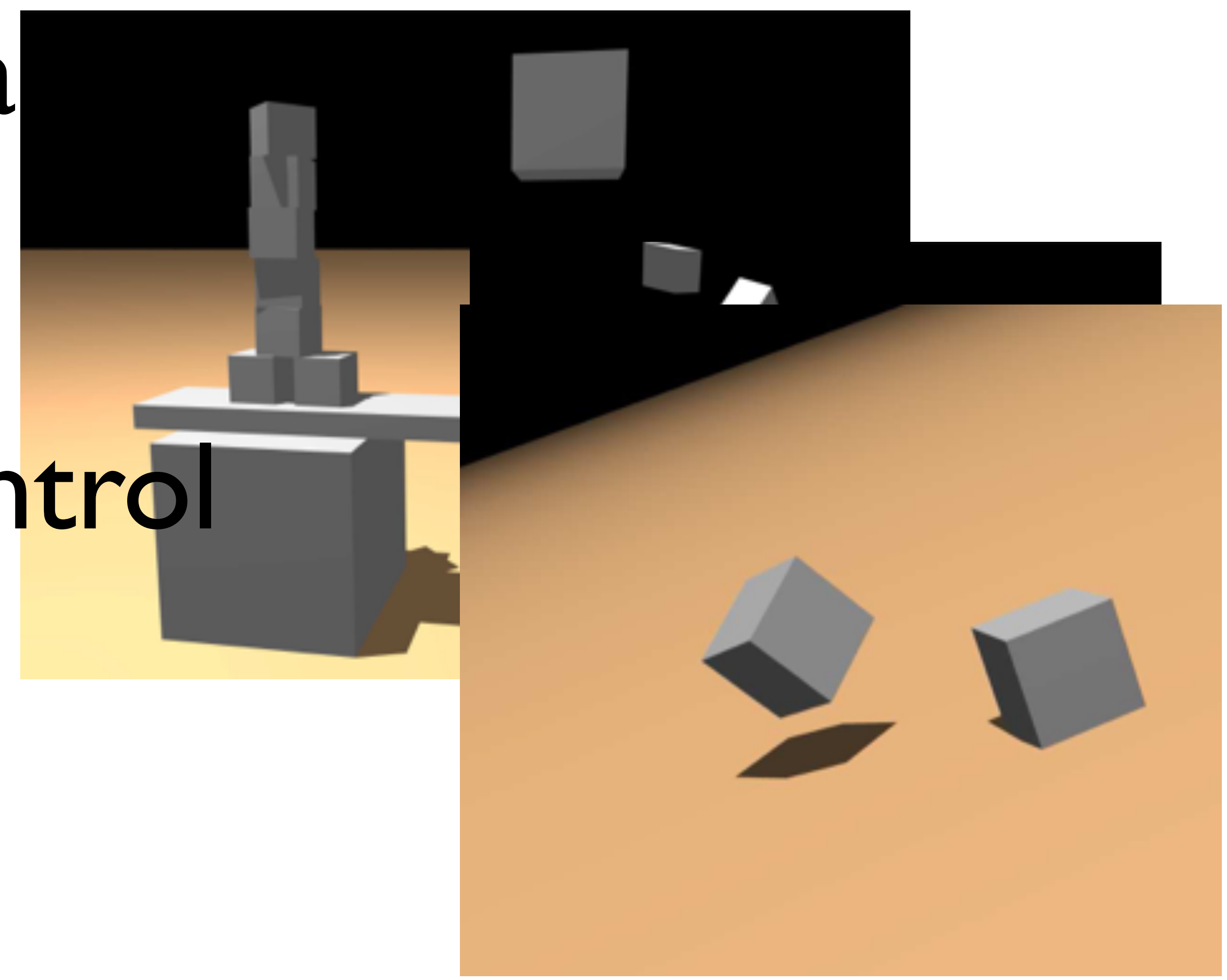
Rigid body phenomena

stacking

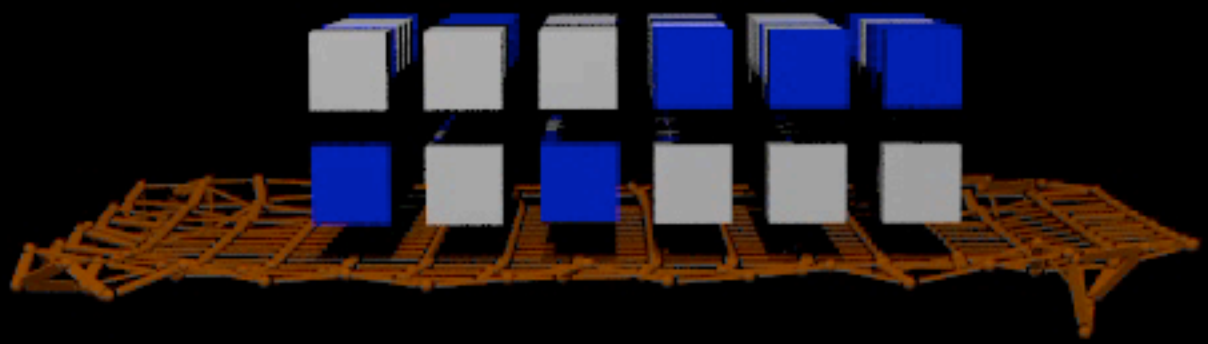
collisions, conta

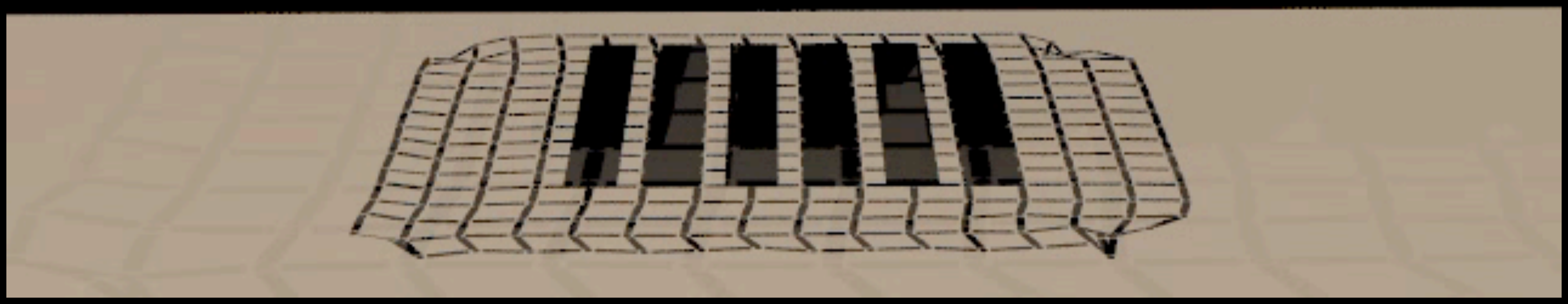
friction

articulation, control



Articulated rigid bodies





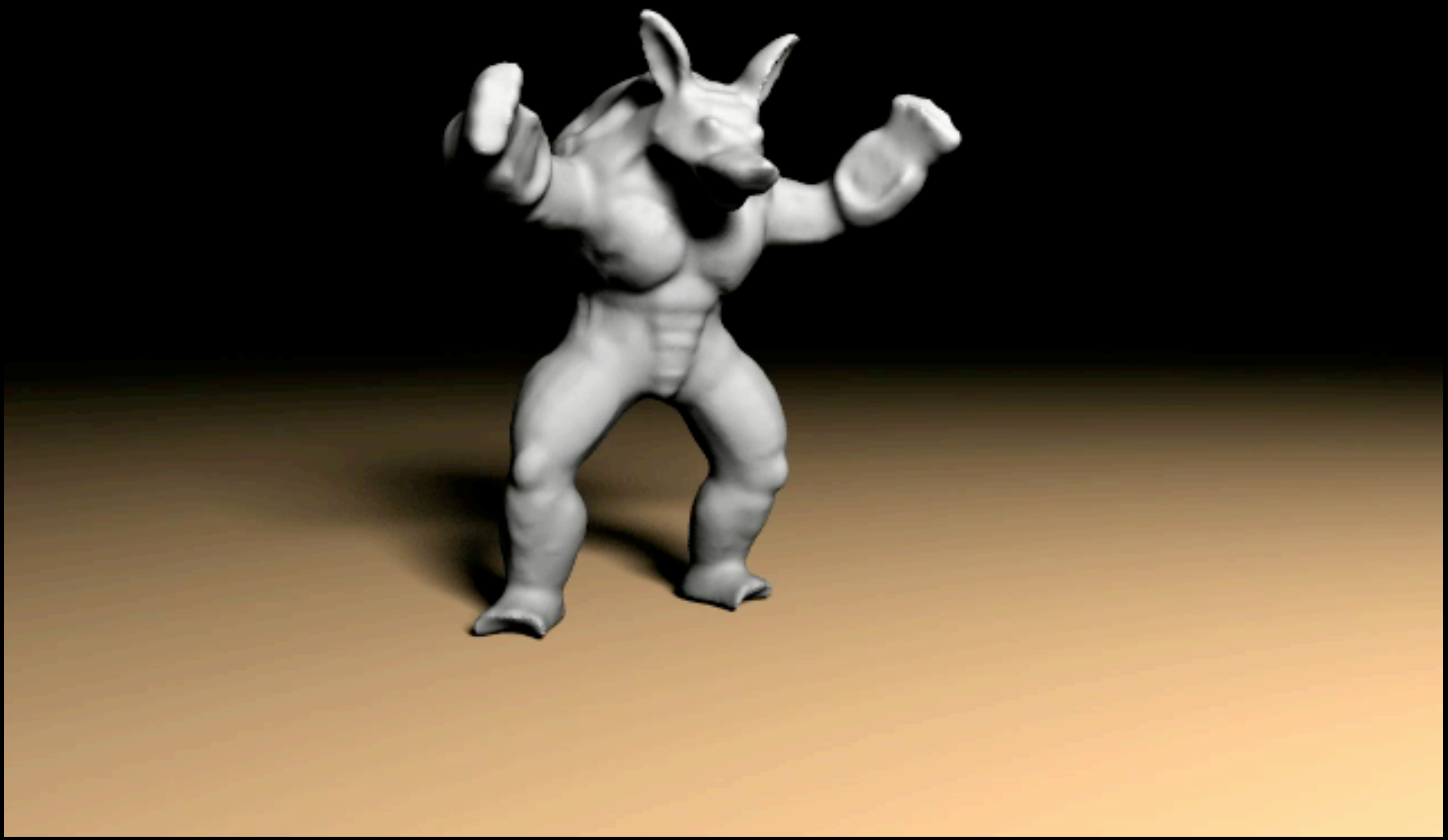
Rachel Weinstein, Joey Teran and Ron Fedkiw

Rigid body simulation

[Weinstein et al 2006]

Rigid and deformable solids coupled together...

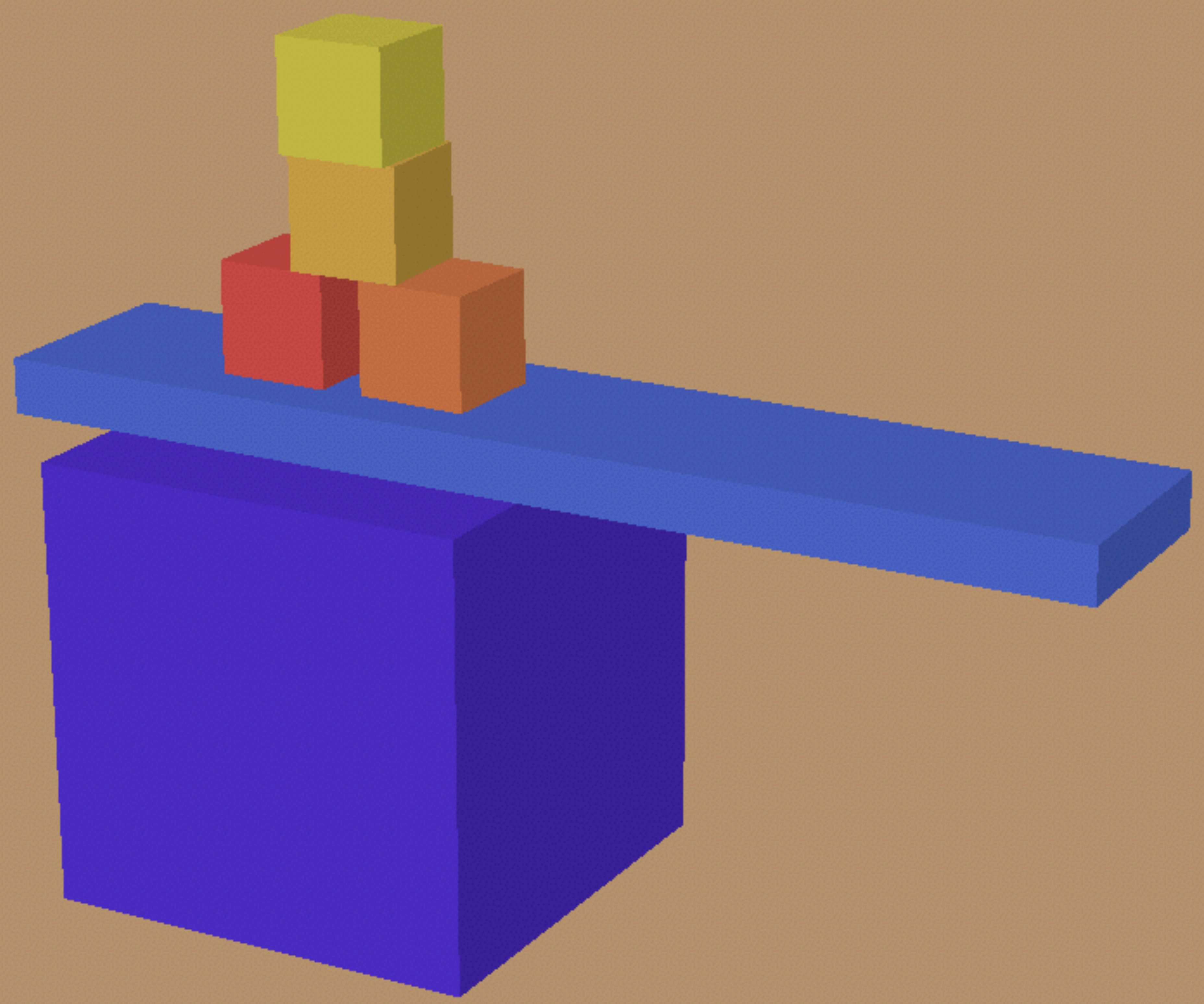
Fracture

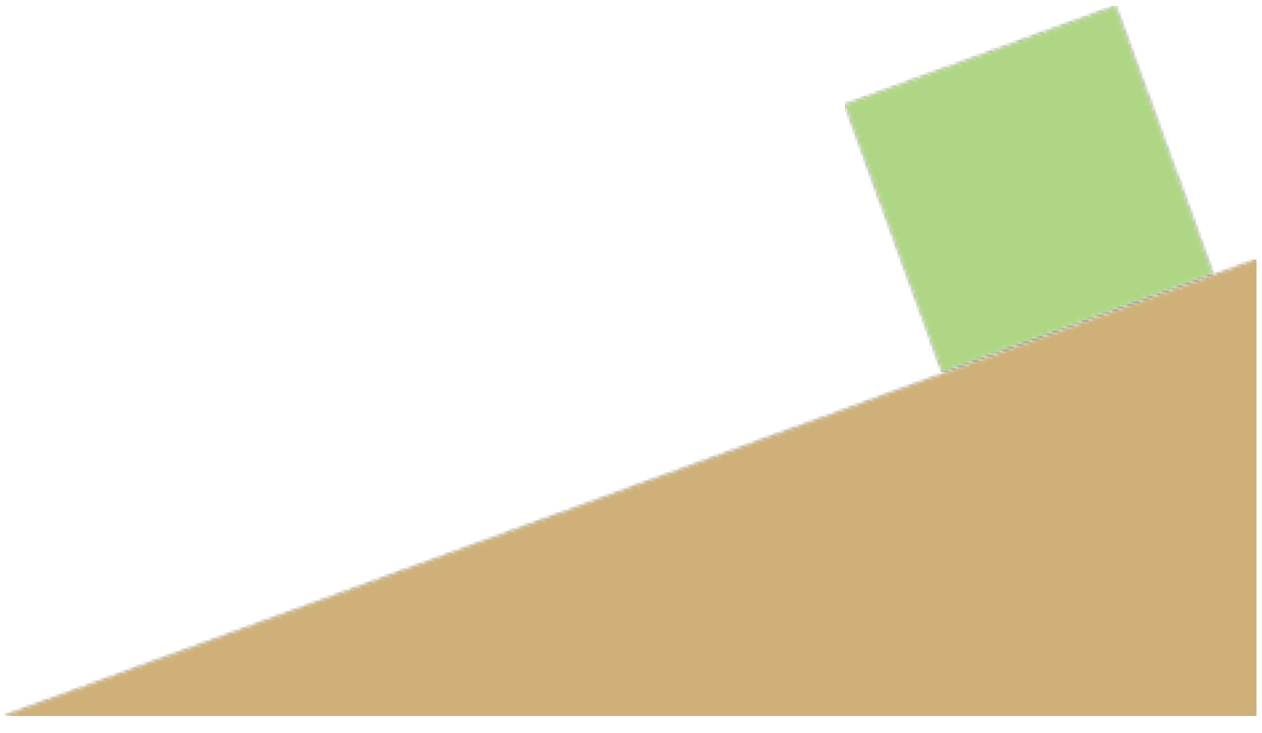


[Molino et al. 2004]

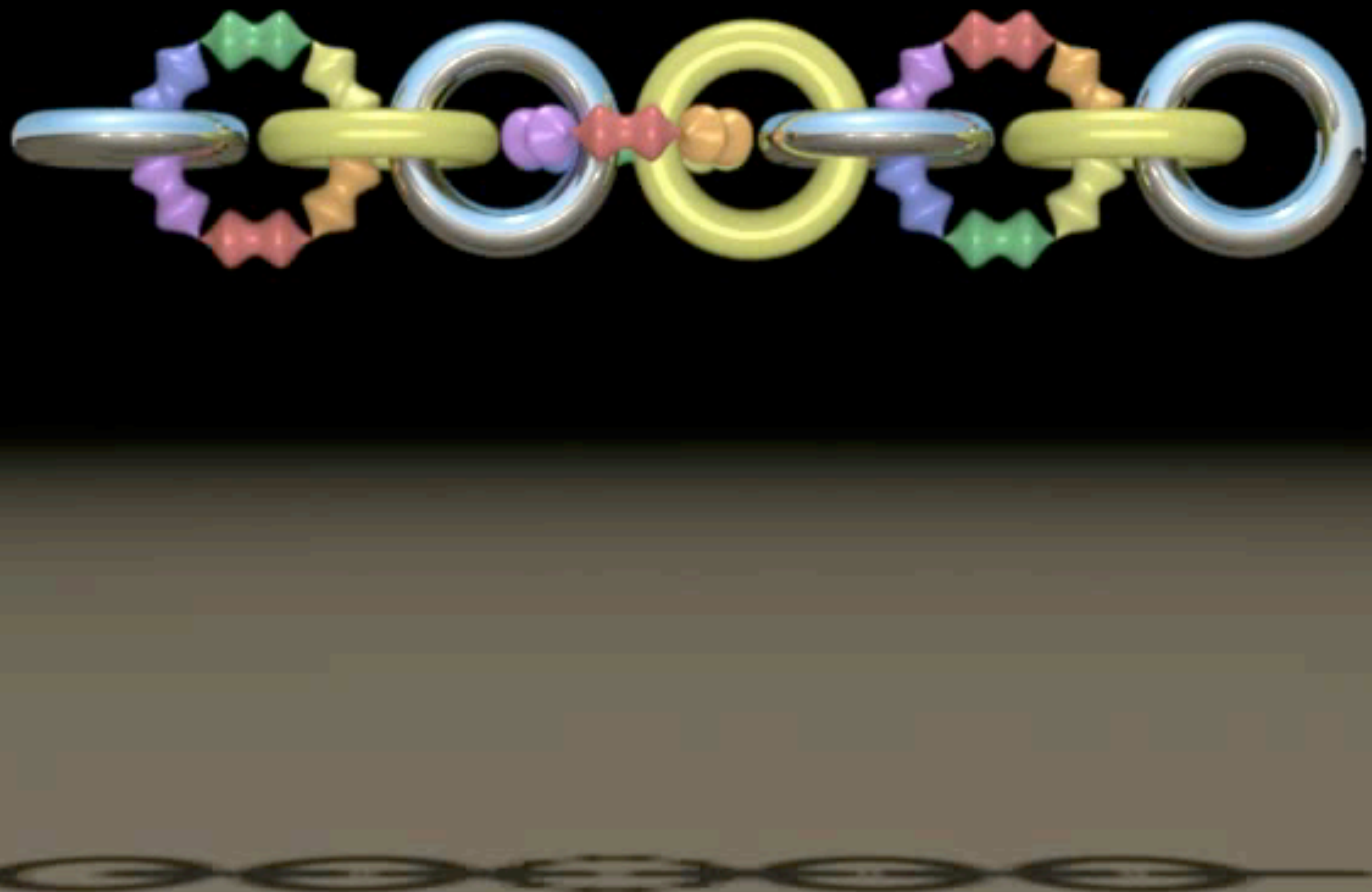
Contact and collision

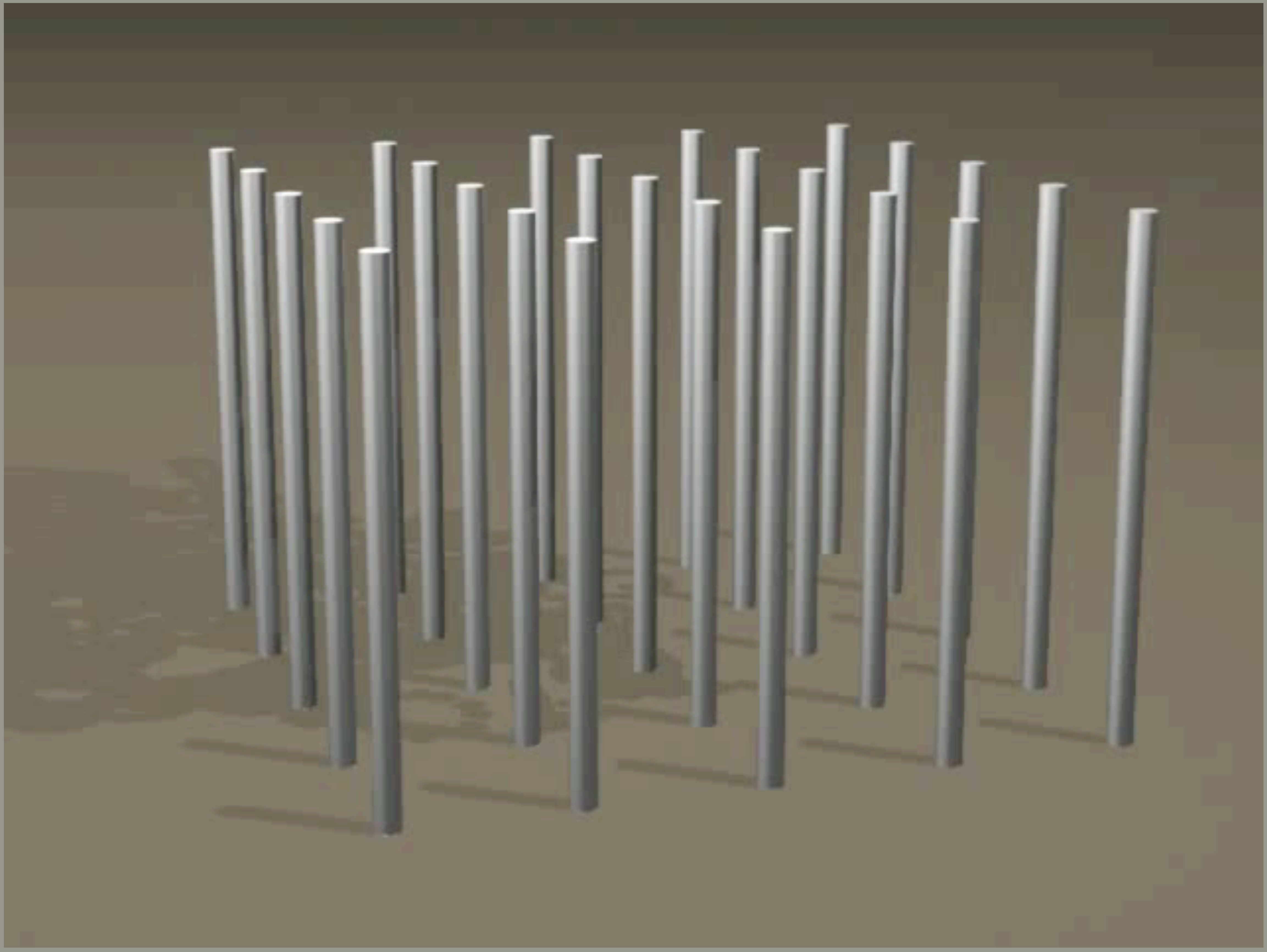
frame 25: (1.04167)

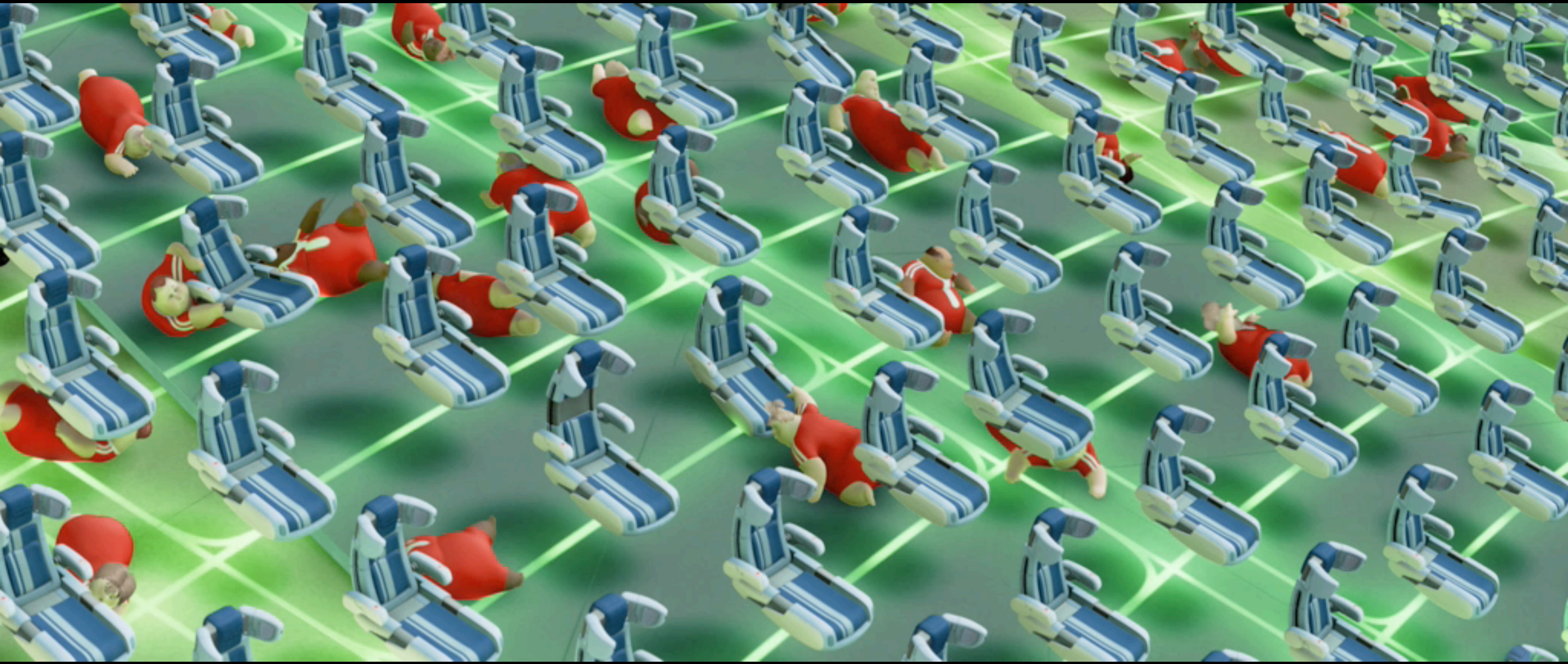




Simultaneous resolution of contact, elastic deformation, articulation constraints



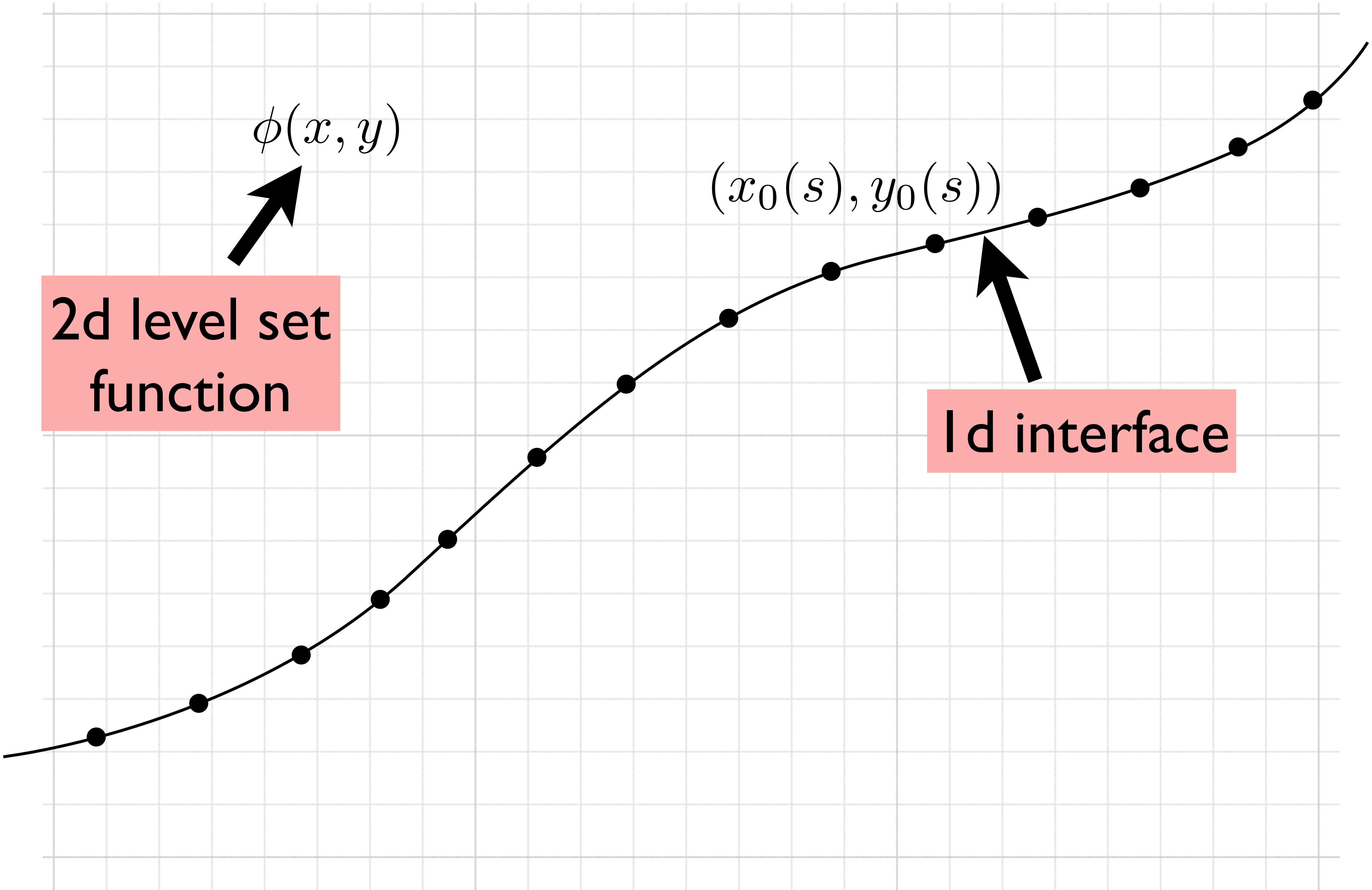




our rigid/deformable simulator in Pixar's *WALL-E*

Fluid simulation

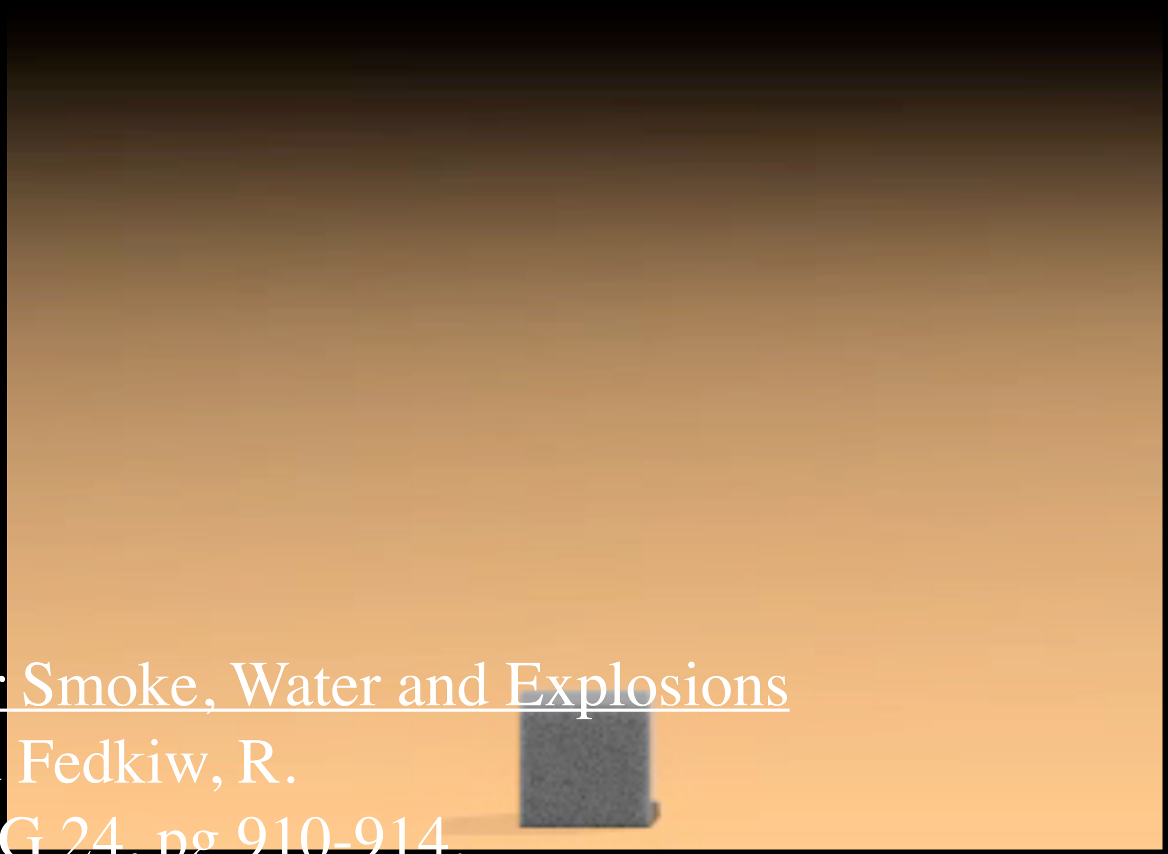
In fluid simulation, we often use a grid-based representation



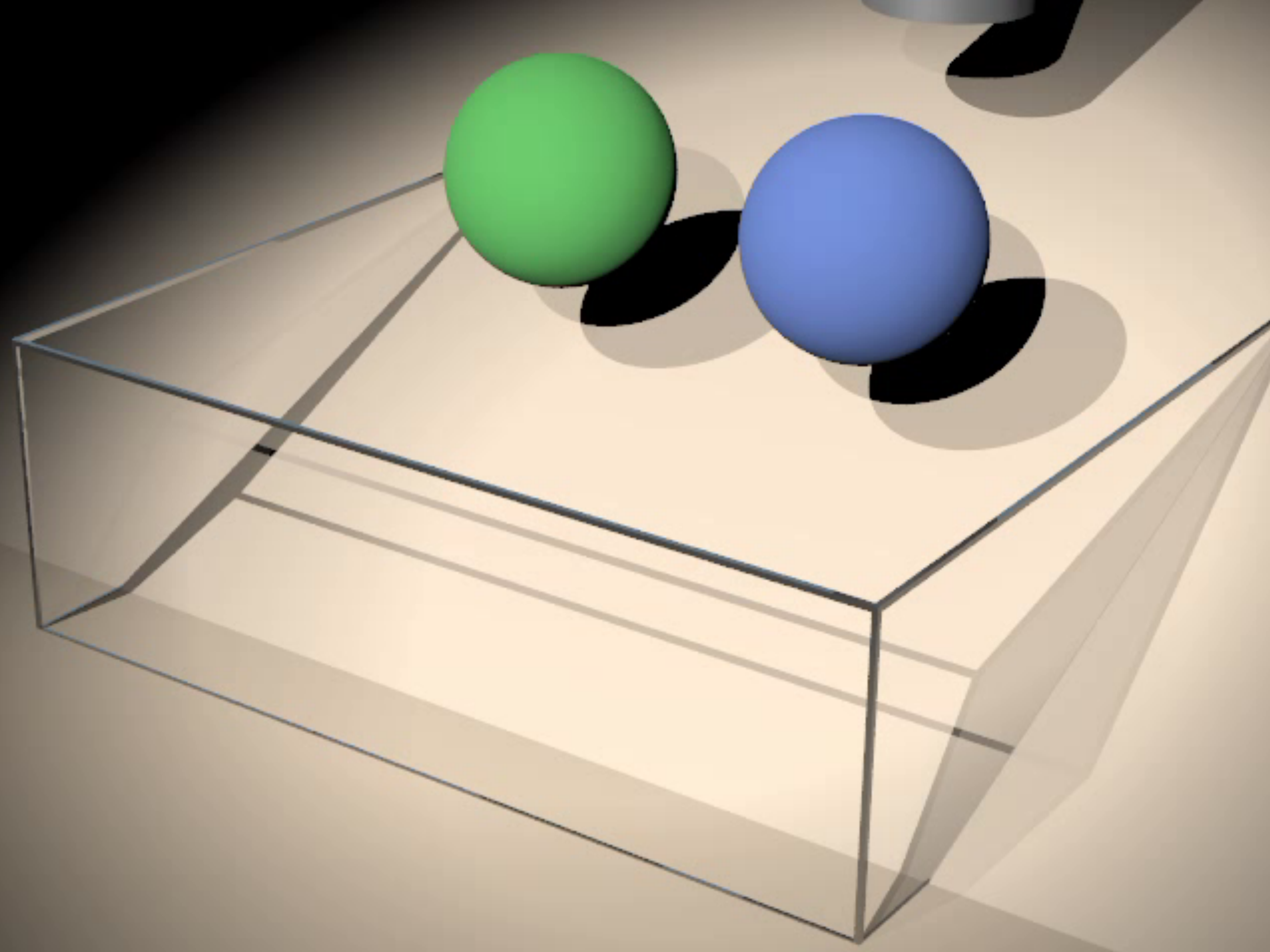
Fluid equations of motion: Navier-Stokes equations

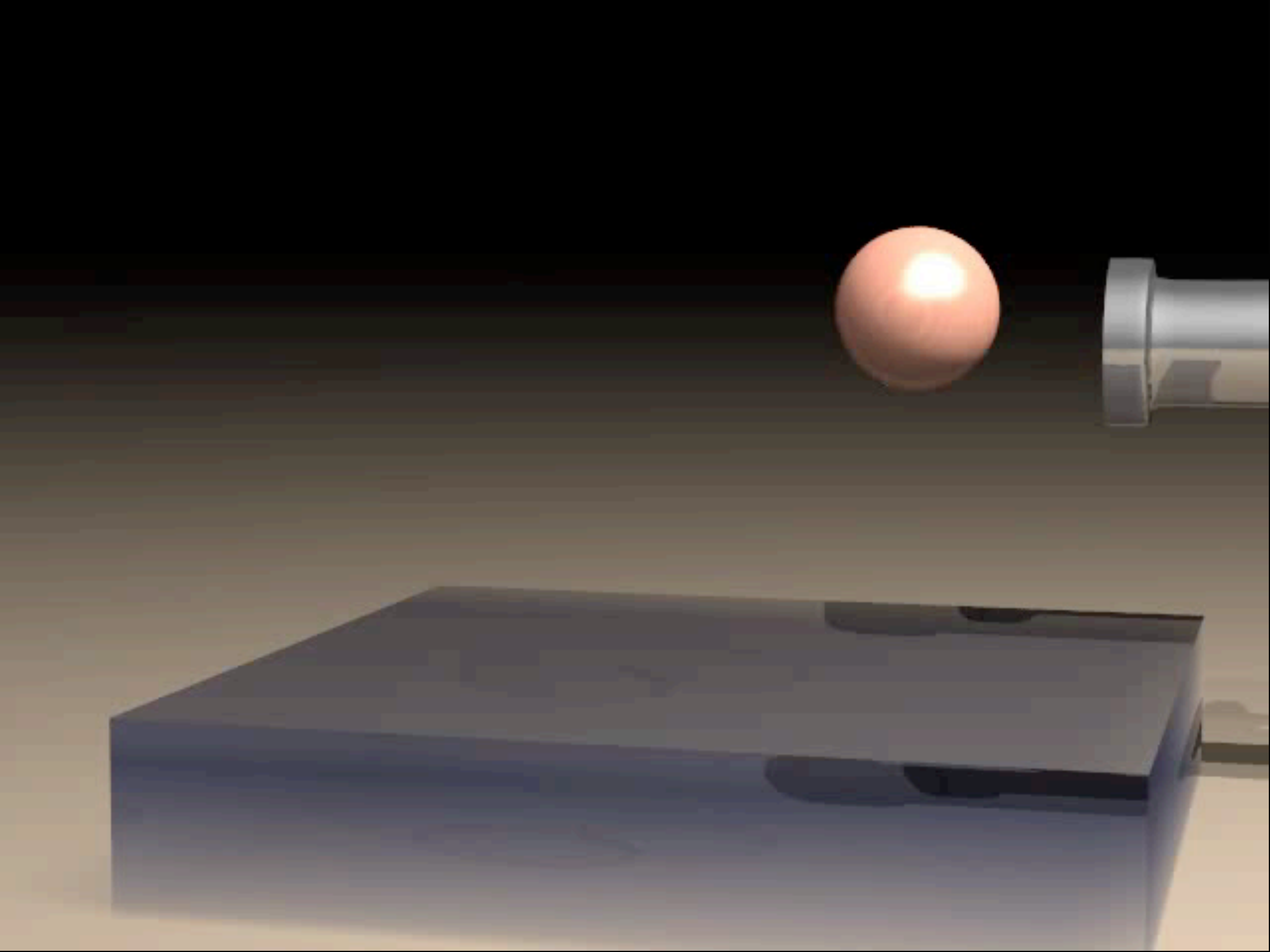
$$\vec{F} = m\vec{a}$$

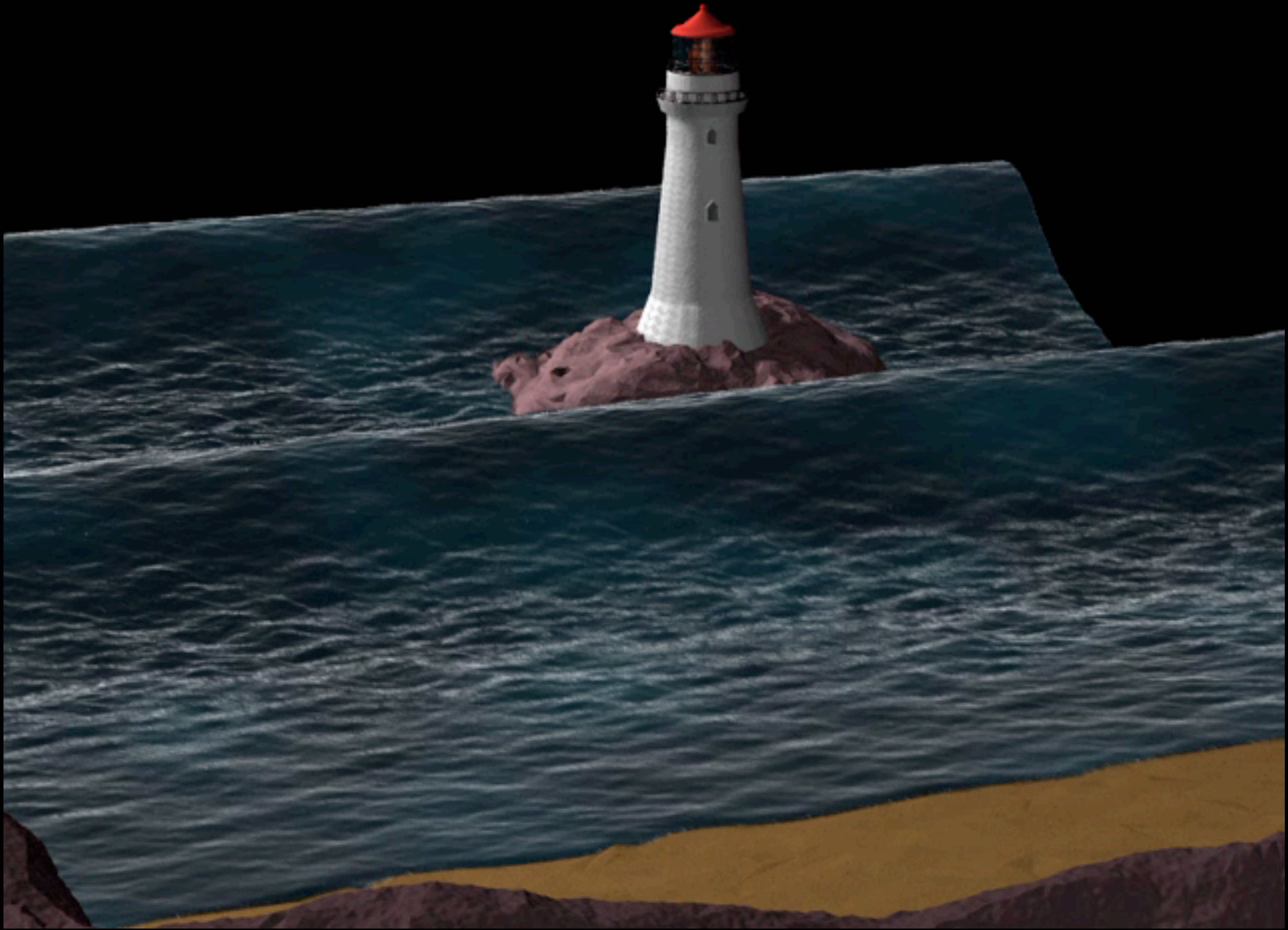
$$\rho(\mathbf{u}_t + \mathbf{u} \cdot \nabla \mathbf{u}) = \mu \triangle \mathbf{u} - \nabla p + \mathbf{f}$$



[A Vortex Particle Method for Smoke, Water and Explosions]
Selle, A., Rasmussen, N. and Fedkiw, R.
SIGGRAPH 2005, ACM TOG 24, pg 910-914.





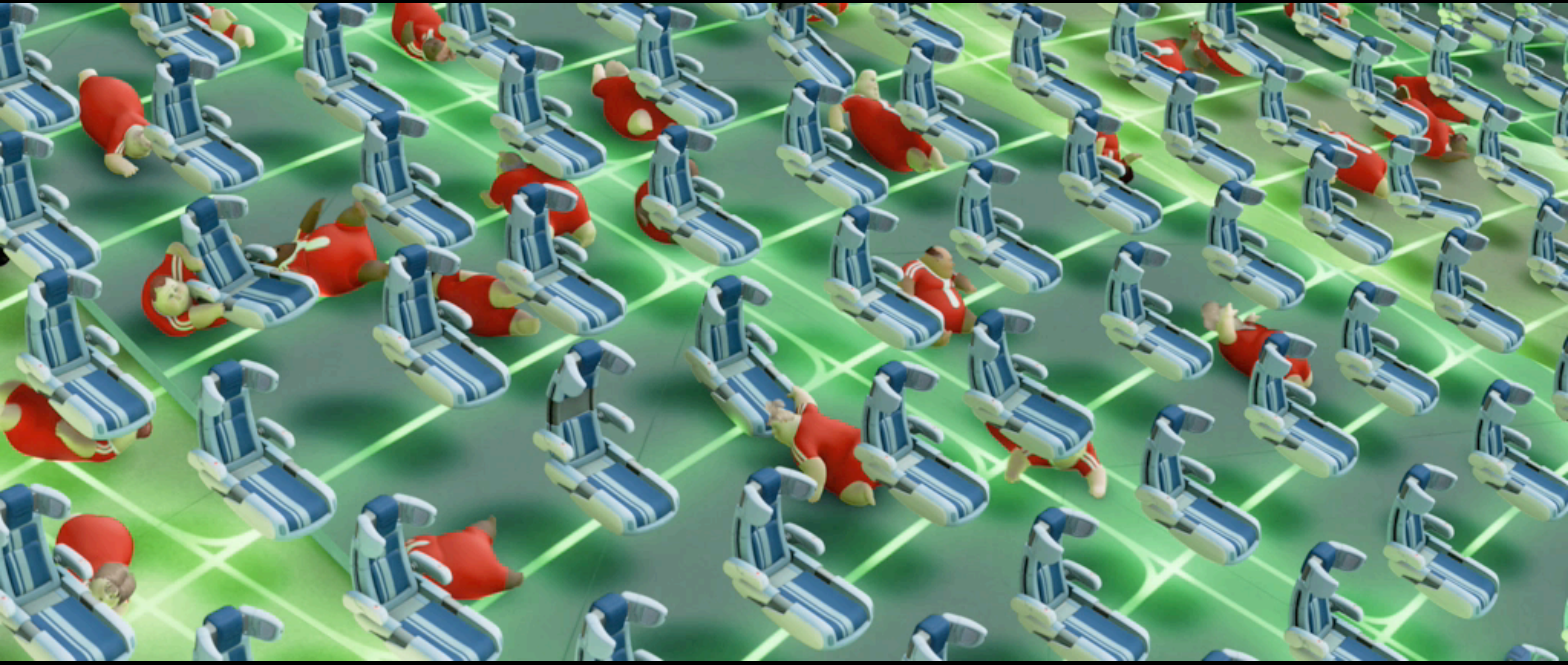


Two-way Coupled SPH and Particle Level Set Fluid Simulation

Losasso, F., Talton, J., Kwatra, N. and Fedkiw, R. IEEE TVCG 14, No. 4 (2008)

Control of virtual character

[Shinar et al. 2008]



rigid/deformable simulator in Pixar's *WALL-E*