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

Multiplane camera

Sleeping Beauty, Disney, 1959

[Image from 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
Paperman and the Future of 2D Animation

Disney’s Paperman
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
Physics-based animation

- Many animation principles follow from underlying physics
- anticipation, follow through, secondary action, squash and stretch, ...
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.
forward kinematics

After hip rotation

Original

After knee rotation

forward kinematics

IK solver connection

hip and knee joint angles computed automatically

Effector motion

inverse kinematics

[Shirley and Marschner]
forward kinematics

inverse kinematics

multiple possible states of joints

[Shirley and Marschner]
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
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 \quad 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
  
  $$\vec{F} = -mg$$
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 1D line segment with springs
A Mass Spring Model for Hair Simulation

Connect a bunch of particles into a 2D mesh
Connect a bunch of particles into a 3D mesh
Deformable bodies: equations of motion

Equations of motion: Newton’s 2nd Law

\[ \vec{F} = m \ddot{\vec{a}} \]

\[ \frac{d\vec{x}}{dt} = \vec{v} \]

\[ m \frac{d\vec{v}}{dt} = \vec{F} \]

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, contact
- 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
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

\[ \phi(x, y) \]

2d level set function

\( (x_0(s), y_0(s)) \)

1d interface
Fluid equations of motion: Navier-Stokes equations

\[ \vec{F} = m\vec{a} \]

\[ \rho(\vec{u}_t + \vec{u} \cdot \nabla \vec{u}) = \mu \Delta \vec{u} - \nabla p + \vec{f} \]
A Vortex Particle Method for Smoke, Water and Explosions
Selle, A., Rasmussen, N. and Fedkiw, R.
Two-way Coupled SPH and Particle Level Set Fluid Simulation

Control of virtual character

[Shinar et al. 2008]
rigid/deformable simulator in Pixar’s WALL-E