Computer Animation

- Feature-length films:
- Games:
- Desktop Animations:

Computer Animation motion control

- Keyframing: “hand-crafted” animation
- Digitized motion: Motion Capture (mocap)
- Procedural animation: algorithms to control movement

Computer Animation Production

Keyframing

- Digital equivalent to traditional, hand-drawn animation
- Animator designs ‘keys’
- Selects interpolation technique and sets timing
- System does what traditionally was done by low-paid trainees - automatically computes in-between frames
**Keyframes**

- Transformations: scale, rotate, translate
- Shape: squash and stretch
- Color: e.g. of a flame
- Image (morphing)
- Any attribute or parameter

**Principles of Animation**

- Arcs
- Slow-in and slow-out
- Straight ahead
- Anticipation
- Exaggeration
- Staging
- Squash and stretch
- Timing
- Secondary Action
- Follow through and overlapping action
- Appeal
- Solid drawing

**Physics**

**Technical approach**

**Aesthetics**

**Effective presentation**

**Interpolation**

- Linear or cubic (e.g. Hermite, Bezier, etc.)
- Interpolation of orientation (rotation) takes special care: quaternions
- Need to estimate arc-length
- Control acceleration/deceleration: ease-in, ease-out
Mocap

- Several technologies: optical, mechanical, magnetic
- Research on ‘markerless’ mocap
- Hard to ‘retarget’ to new figure or imaginary creature

Procedural Animation

- Set initial conditions - run simulation
- Control is an issue
- Computational cost (e.g. real-time) is an issue

Kinematics of articulated figures

- Forward kinematics
- Inverse kinematics
- Pseudo-inverse of the Jacobian
- Cyclic Coordinate Descent
- others...
Kinematics of articulated figures

Physically based simulation

- Kinematics v. Dynamics
- Forces & mass -> acceleration -> velocity -> position
- Point mass, particle system
- Rigid body dynamics: add rotational dynamics: inertia tensor & torques
- Flexible body animation: elastic collisions

Forces

- Gravity \( f = \frac{G m_1 m_2}{d^2} \)
- Spring \( f = k_1 (\text{length} - \text{restLength}) \)
- Viscosity: damping \( f = k_2 (\text{length} - \text{restLength}) \)
- Friction: static & kinetic \( f = k_s f_x \)
- Wind field \( f = k_f f_x \)
- Impulse force of contact \( f = k_i f_x \)
- Fictional forces

Forces ->

\[ \begin{align*}
  f &= ma \\
  a &= \frac{f}{m}
\end{align*} \]

- Update \( v(t+1) = v(t) + a\Delta t \)
- Integration \( p(t+1) = p(t) + v\Delta t \)

- Numerical integration
- Runge-Kutta, Implicit Euler, etc.
Spring-damper-mass system

- Collection of point masses connected by springs and dampers
- Model cloth, flexible body dynamics
- Tricky to set constants and connections

\[ f = k_s(l - l_{\text{rest}}) - k_d \dot{l} \]
### Particle system
- Collection of point masses
- No interaction between point masses
- Interact with environment

### Rigid body dynamics
- Inertia tensor
- Conservation of momentum
- Coefficient of restitution
- Impulse force of collision

### Forward dynamics of articulated linkage
- Featherstone equations
- Traverse linkage forming inertia tensor
Human figure animation
- Kinematics of walking, reaching, sitting, standing
- Motion capture
- Modeling muscles - appearance, dynamics
- Dynamics of grasping, handling, lifting

Facial animation
- Expressions
- Lip-sync animation
- Emotion

Behavioral animation
- Flocking
- Prey-predator model
- Crowds
- Emotion
- Personality