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

- Story Dept.
  - Art Dept.
    - Modeling Dept.
      - Shading Dept.
      - Layout Dept.
        - Animation Dept.
          - Lighting Dept.
            - Camera Dept.
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
Keyframe... anything

- 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
  \[ f = G \frac{m_1 m_2}{d^2} \]

- Spring
  \[ f = k_s (\text{length} - \text{restLength}) \]

- Viscosity: damping
  \[ f = k_d \partial (\text{length} - \text{restLength}) \]

- Friction: static & kinetic
  \[ f = k_{sf} f_n \]

- Wind field

- Impulse force of contact
  \[ f = k_{kf} f_n \]

- Fictional forces
Forces - >

\[ f = ma \]

\[ a = \frac{f}{m} \]

- Update

- Integration

\[ v(t + 1) = v(t) + a\Delta t \]

\[ p(t + 1) = p(t) + v\Delta t \]

- 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
Spring-damper-mass system

\[ f = k_s (l - l_{rest}) - k_d \dot{l} \]
Spring-damper-mass system
Spring-damper-mass system
Particle system

- Collection of point masses
- No interaction between point masses
- Interact with environment
Particle system
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
Human figure animation
Facial animation

- Expressions
- Lip-sync animation
- Emotion
Behavioral animation

- Flocking
- Prey-preditor model
- Crowds
- Emotion
- Personality