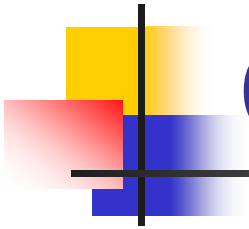
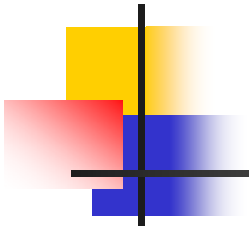


Computer Animation

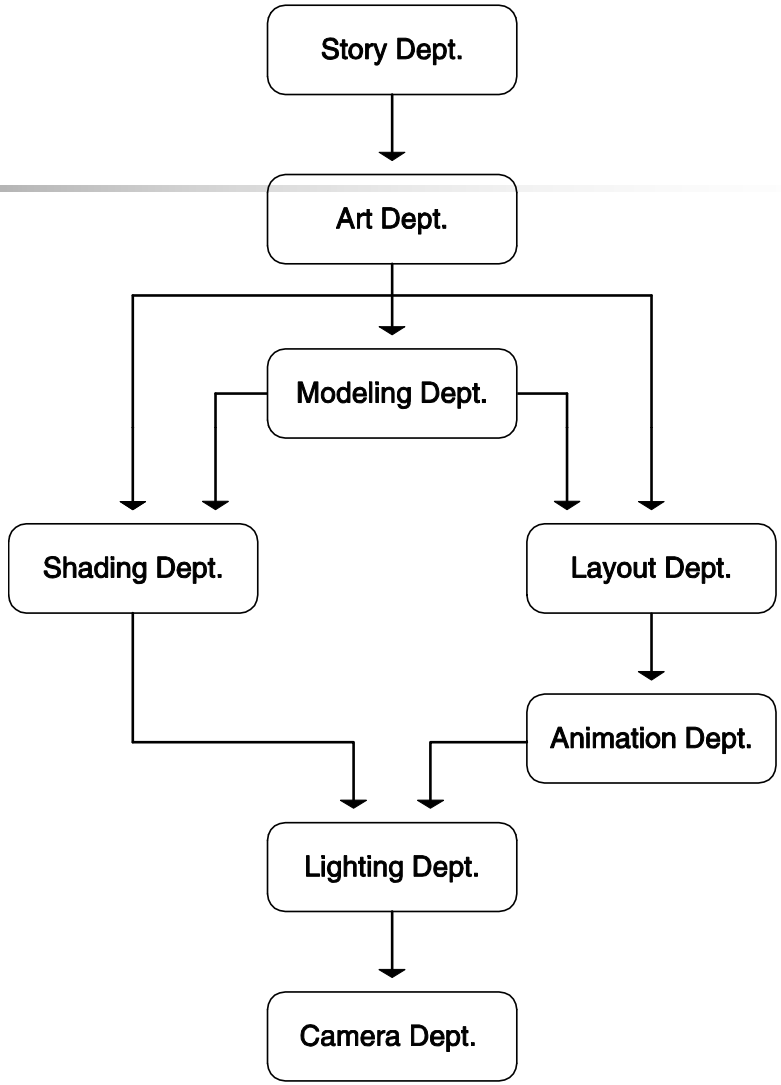
- **Feature-length films**:
- **Games**:
- **Desktop Animations:**

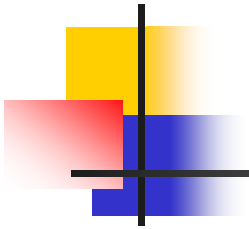


Computer Animation motion control

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

Computer Animation Production

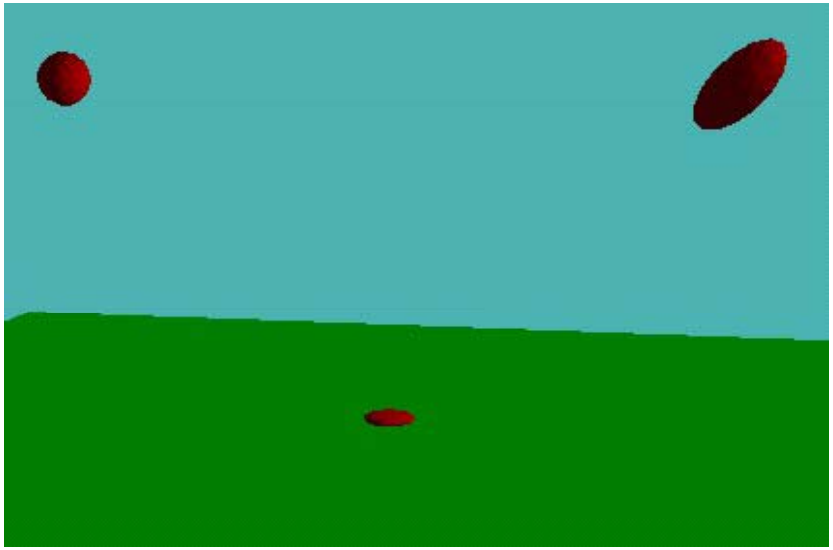


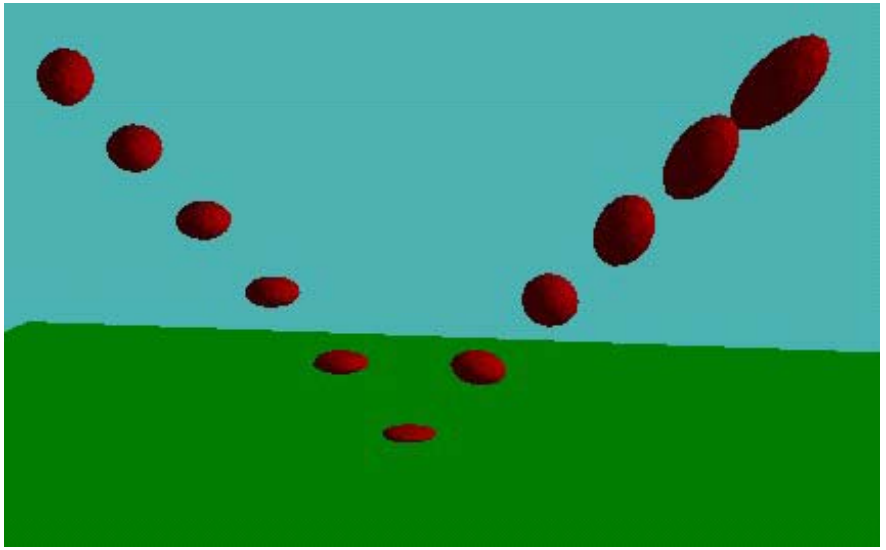


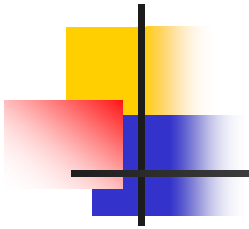
Keyframing

- 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



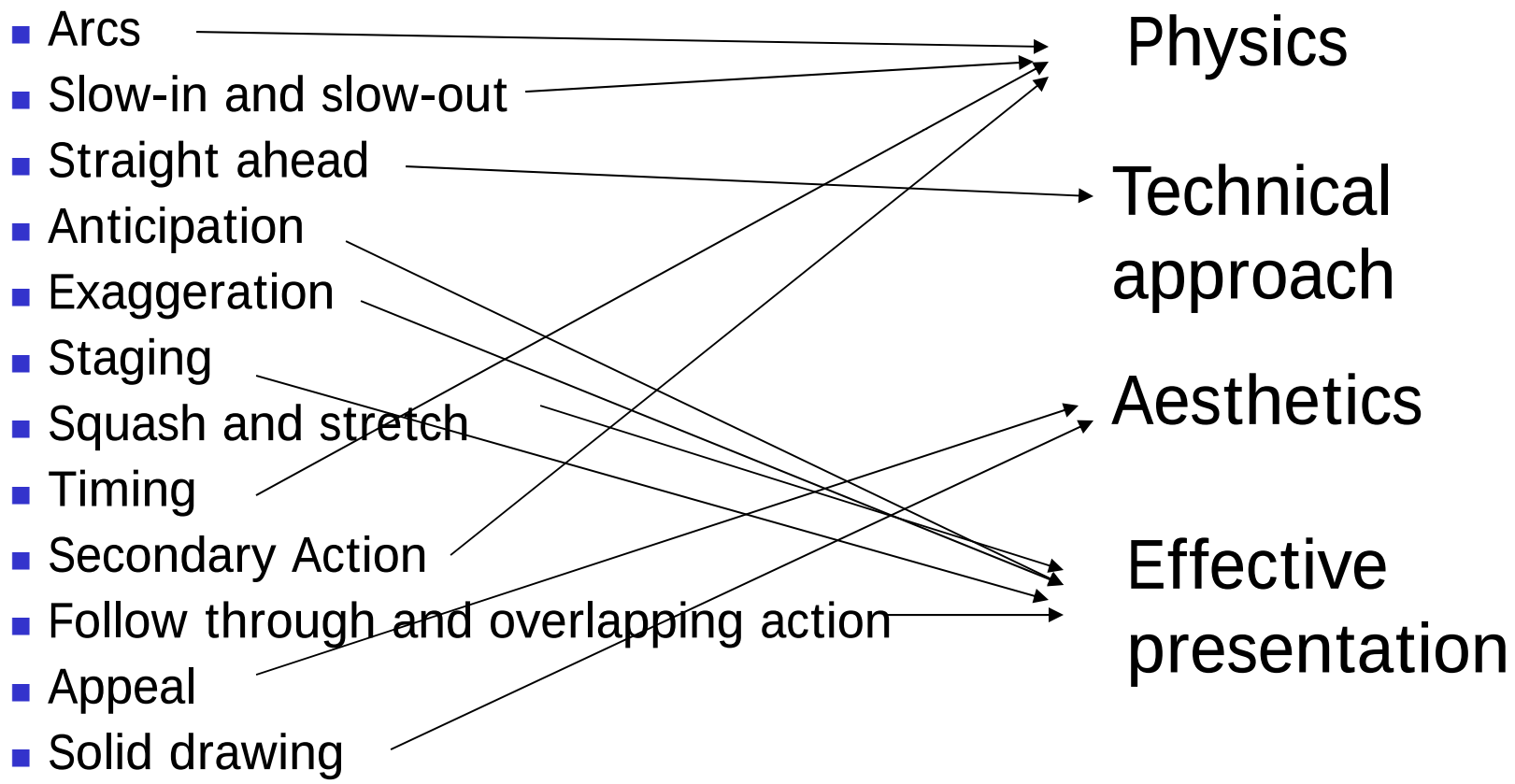


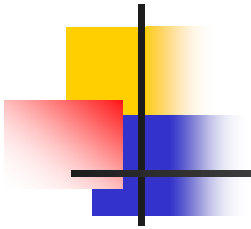


Keyframe...anything

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

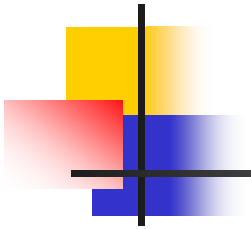
Principles of Animation





Interpolation

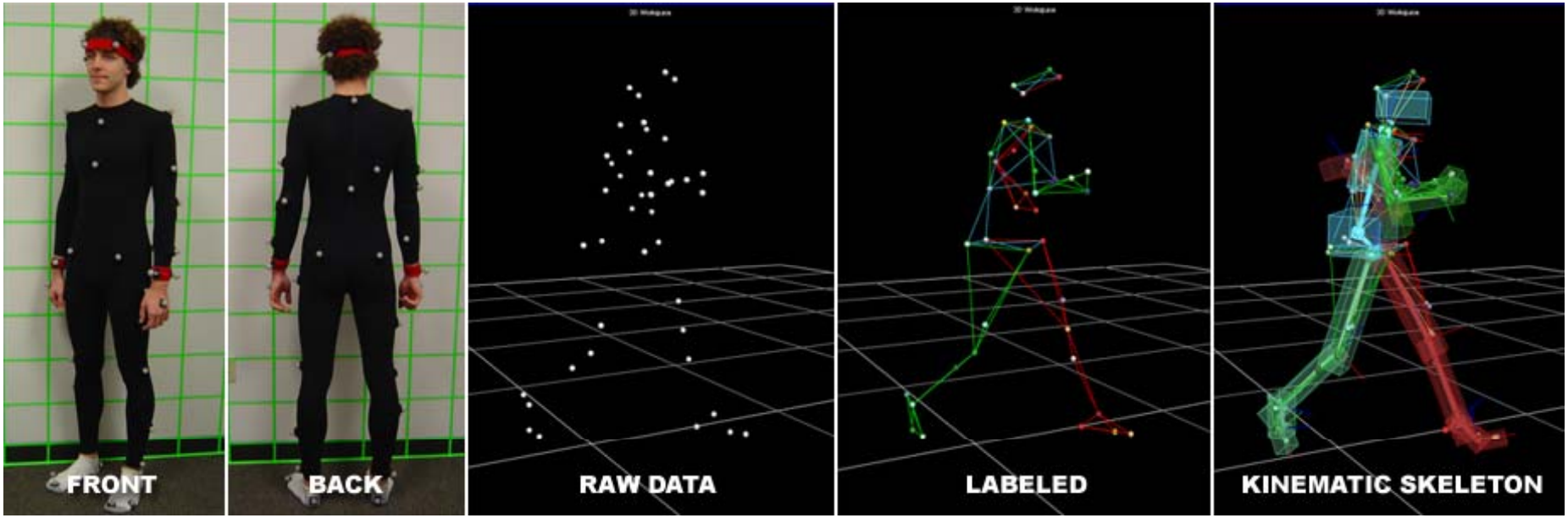
- Linear or cubic (e.g. Hermite, Bezier, etc.)
- Interpolation of orientation (rotation) takes special care: quaternions
- Need to estimate arc-length
- Control acceleration/deceleration: ease-in, ease-out

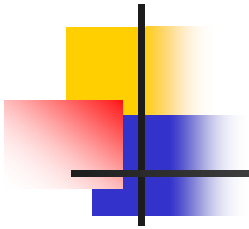


Mocap

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

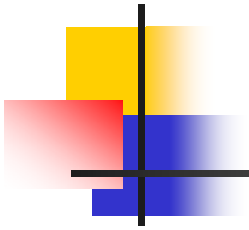
Mocap





Procedural Animation

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

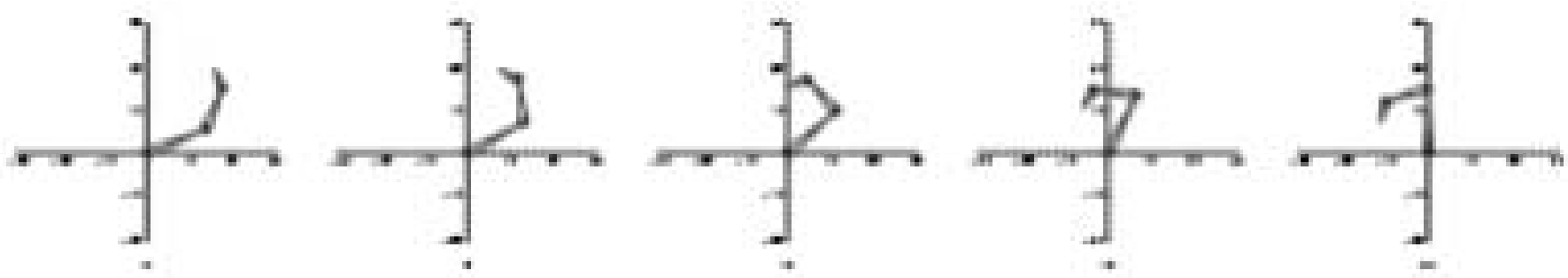


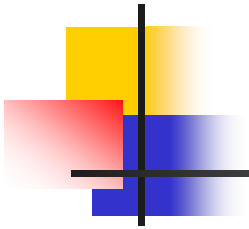
Kinematics of articulated figures

- Forward kinematics

- Inverse kinematics
  - Pseudo-inverse of the Jacobian
  - Cyclic Coordinate Descent
  - others...

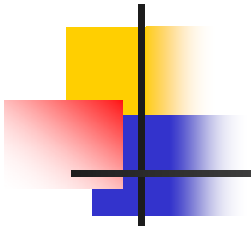
Kinematics of articulated figures





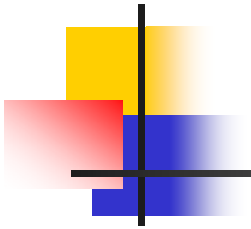
Physically based simulation

- 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 $f = k_s(length - restLength)$
- Viscosity: damping $f = k_d \partial(length - restLength)$
- Friction: static & kinetic $f = k_{sf} f_n$ $f = k_{kf} f_n$
- Wind field
- Impulse force of contact
- Fictional forces



Forces ->

$$f = ma$$

$$a = \frac{f}{m}$$

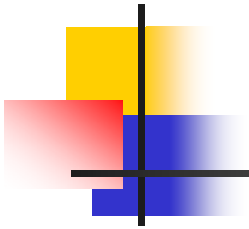
- Update

$$v(t+1) = v(t) + a\Delta t$$

- Integration

$$p(t+1) = p(t) + v\Delta t$$

- Numerical integration
- Runge-Kutta, Implicit Euler, etc.

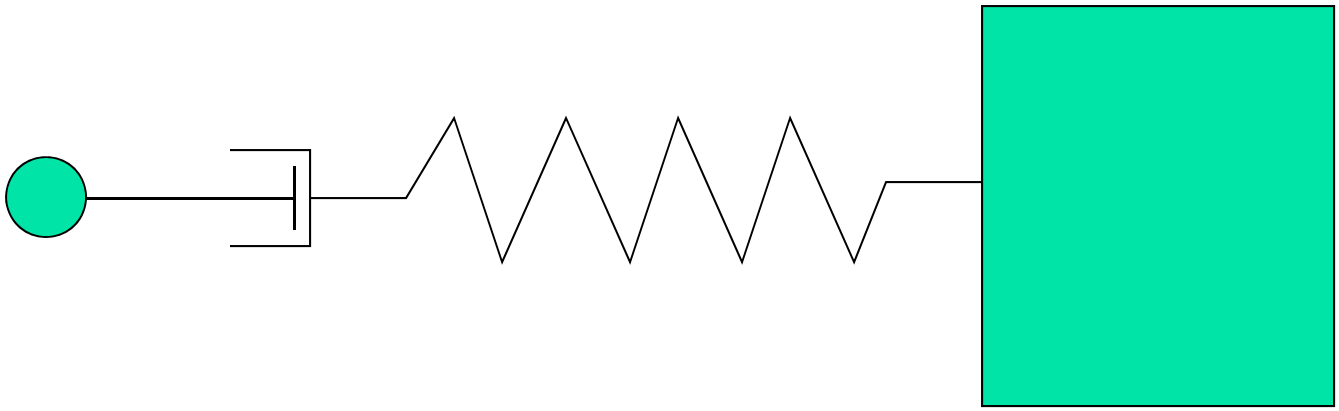


Spring-damper-mass system

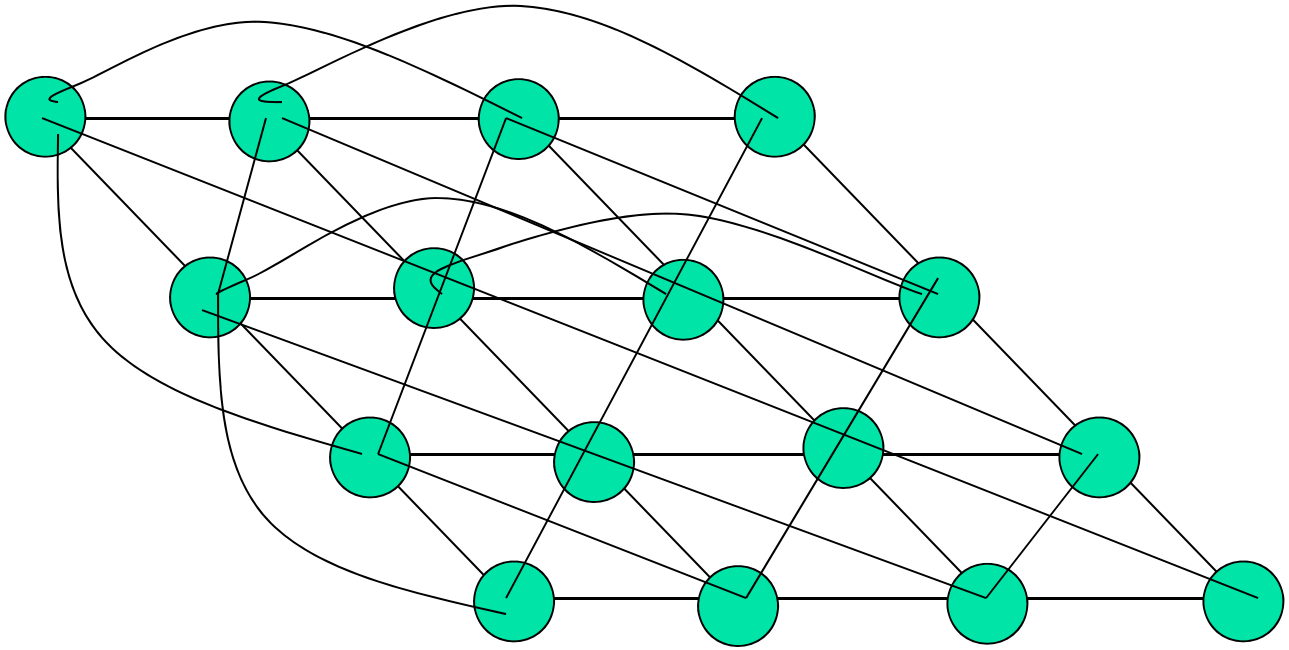
- Collection of point masses connected by springs and dampers
- Model cloth, flexible body dynamics
- Tricky to set constants and connections

Spring-damper-mass system

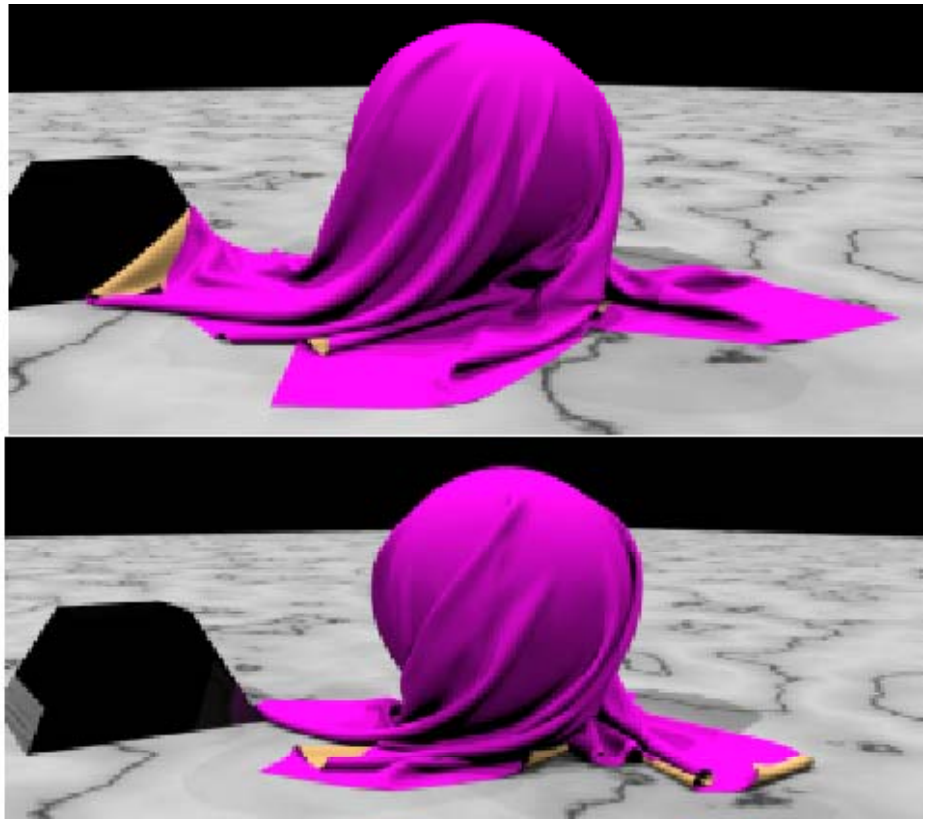
$$f = k_s(l - l_{rest}) - k_d\dot{l}$$

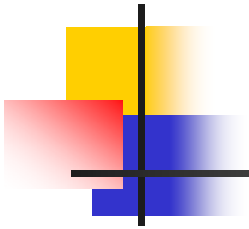


Spring-damper-mass system



Spring-damper-mass system

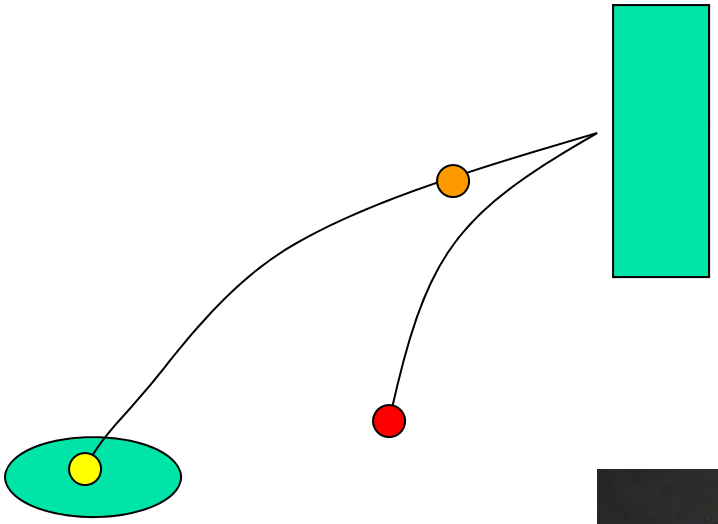


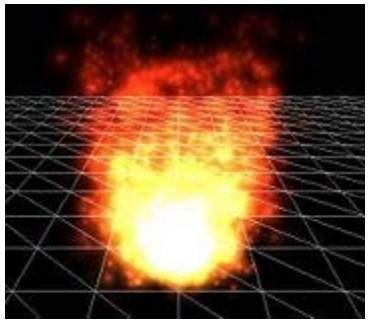


Particle system

- Collection of point masses
- No interaction between point masses
- Interact with environment

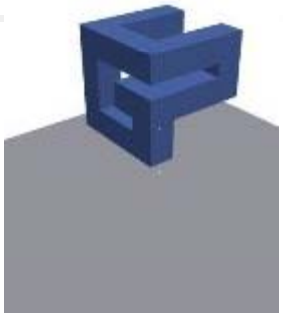
Particle system

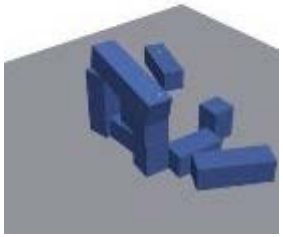




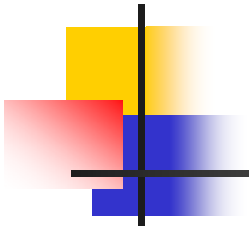
Rigid body dynamics

- Inertia tensor
- Conservation of momentum
- Coefficient of restitution
- Impulse force of collision

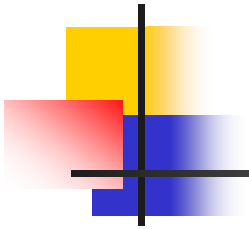




Forward dynamics of articulated linkage



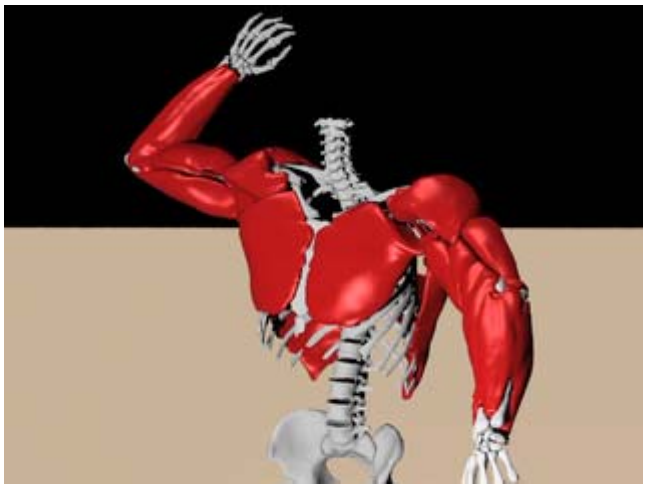
- Featherstone equations
- Traverse linkage forming inertia tensor

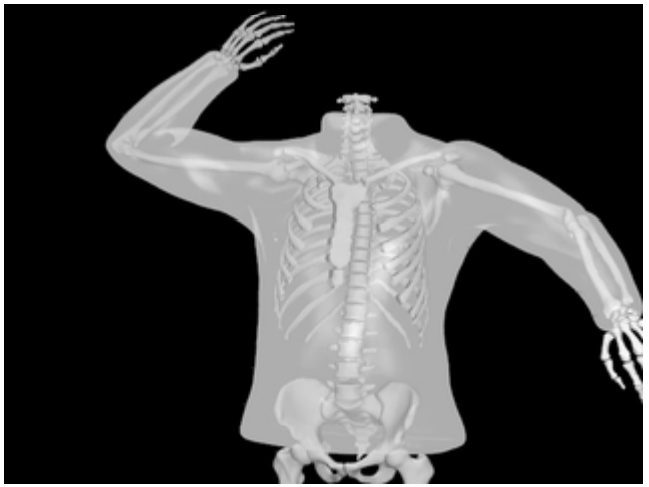


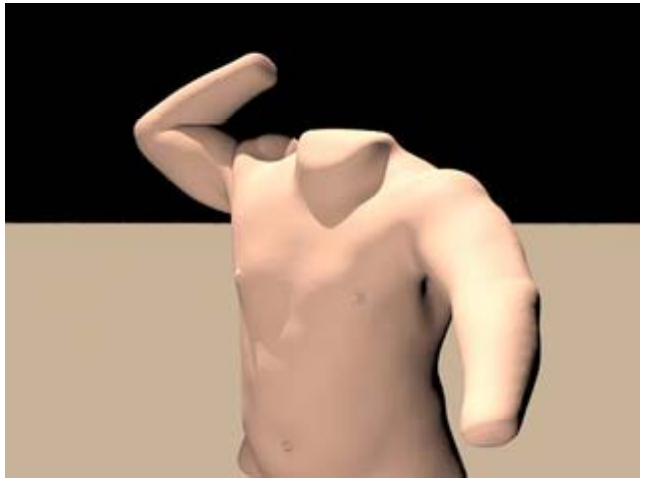
Human figure animation

- 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