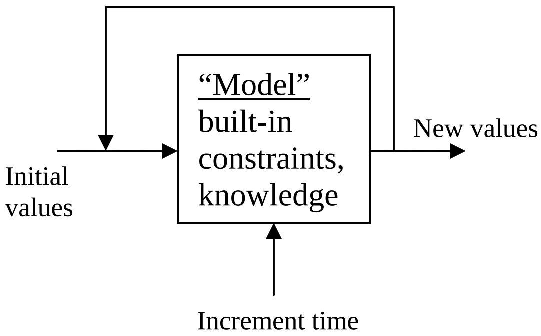
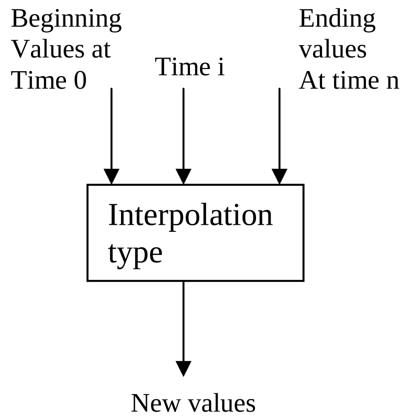
# Introduction to Procedural Animation




## As Simulation

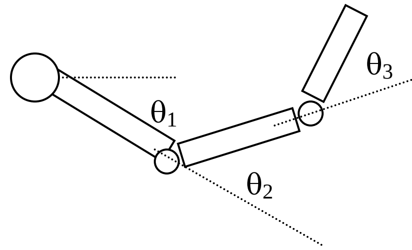
Physical World

- Basic Physics
  - Spring-damper-mass model (flexible objects, cloth, clothes)
  - Particle systems
  - Rigid body dynamics
  - Flexible body dynamics
- Natural Phenomena
  - Plants
  - Clouds
  - Water
  - Fire

Human (and other) Figures

- Kinematic linkages: forward kinematics, inverse kinematics
- Walking
- Reaching
- Skin deformation
- Facial animation
  - Emotions, Expressions
  - Conversational animation, gestures
  - Lip-sync animation
- Behavior
  - Path planning
  - Task Planning
  - Flocking
  - Prey-preditor
  - crowds

## Kinematics v. Dynamics




Kinematics – position, velocity
Dynamics – forces, acceleration

## Articulated Figure kinematics

Linked appendages
Constrained to remain attached to each other
Reduce dimensionality of positioning linkages
from 6 degrees of freedom for each linkage
to one joint angle per joint angle

Forward Kinematics
Specify: T, $\theta_1$, $\theta_2$, $\theta_3$
Solve for: position and rotation of each linkage

Inverse Kinematics
Specify: desired goal position of "end effector"
Solve for: joint angles
Compute direction vector from end effector to goal position: dP
Compute, for each joint, effect on end effector position of incremental change to joint angle: cross product of joint axis and vector from joint to end effector. Collect these in J
Solve for change in joint angles, weighted by J, that produces dP
$dP = J\, d\Theta$

**Basic Physics**

F=ma

Accumulate forces in a vector: $f = \Sigma f_i$

Compute acceleration: $a = f/m$

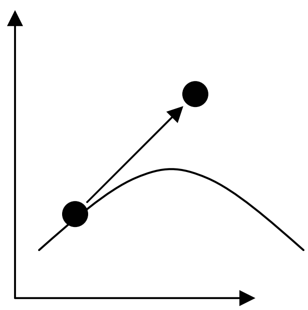
Update velocity: $v' = v+a*dt$ ; $v_{ave} = (v + v')/2$

Update position: $p' = p + v_{ave}*dt$

BASIC ISSUE

What's the best way to update discrete approximation to continuous process?

e.g., force of gravity continually varies for moving objects over time interval



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**Basic Physics (continued)**

Forces – based on position and/or velocity
- Spring: $f = k_s*(L_c-L_r)$
- Damper: $f = k_d*dL_c$
- Viscosity: $f = k_v*v$
- Gravity: $f = G(m_1*m_2)/d^2$
- Earth gravity: $a = g$
- Virtual forces to maintain constraints (e.g., non-penetration)
- Impulse force due to collision

Momentum: P=mv
- dP = F

Rotational force: torque
- Rotation matrix, R(t)
- Angular velocity, $\omega(t)$
- Angular acceleration, $\alpha(t)$
- Inertia tensor, I(t)

Angular momentum
- $L(t) = I(t)\omega(t)$

Energy minimization
- e.g., of deformed surface