Animation

Traditional Animation
Keyframe Animation

Interpolating Rotation
Forward/Inverse Kinematics

Overview

- Animation techniques
  - Performance-based (motion capture)
  - Traditional animation (frame-by-frame)
  - Keyframing
  - Physically based (dynamics)
- Modeling issues
  - Rotations
  - Inverse kinematics

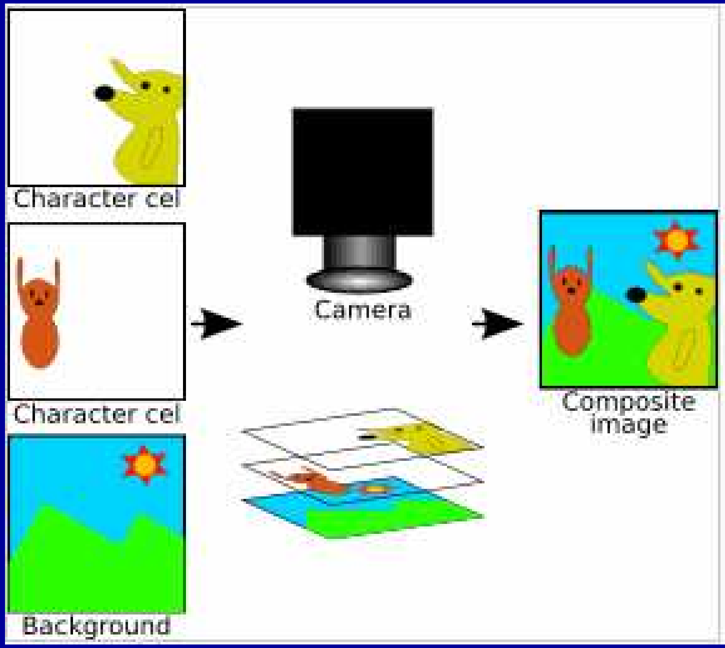
Overview

- Animation techniques
  - Performance-based (motion capture) } last class
  - Traditional animation (frame-by-frame) } today
  - Keyframing
  - Physically based (dynamics) } next class

- Modeling issues
  - Rotations } today
  - Forward / Inverse kinematics

Traditional Cel Animation

- Each frame is drawn by hand



- Film runs at 24 frames per second (fps)
  - That's 1440 pictures to draw per minute
- Artistic issues:
  - Artistic vision has to be converted into a sequence of still frames
  - Not enough to get the stills right--must look right at full speed
    - » Hard to "see" the motion given the stills
    - » Hard to "see" the motion at the wrong frame rate

Traditional Animation: The Process

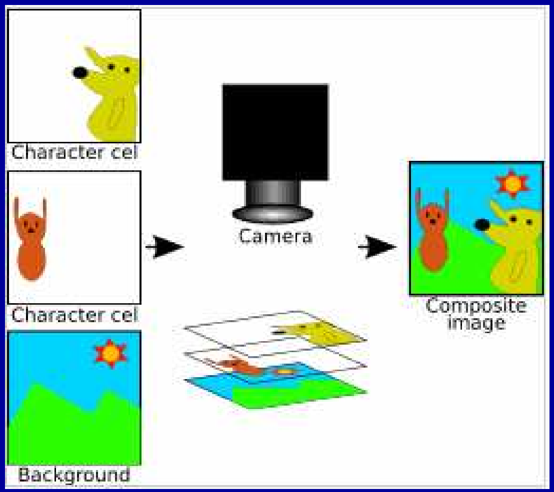
- Story board
  - Sequence of drawings with descriptions
  - Story-based description
- Voice Recording
  - Preliminary soundtrack or "scratch track" is recorded
  - To synchronize animation later
- Animatic or Story Reel
  - Pictures of the storyboard synchronized with the soundtrack
  - To work out timing issues
- Design
  - Design and draw characters from different angles
  - Statues and maquettes can be produced
- Animation

Traditional Animation: The Process

- Turtle Hill Example
  - Story board
  - Animatic
  - Final Animation

Traditional Animation: The Process

- Key Frames
  - Draw a few important frames in pencil
    - » beginning of jump, end of jump and a frame in the air
- Inbetweens
  - Draw the rest of the frames
- Painting
  - Redraw onto clear sheet of plastic called a *cel*, color them in



- Use one layer for background, one for object
  - Draw each separately
  - Stack them together on a copy stand
  - Transfer onto film by taking a photograph of the stack

- Can have multiple animators working simultaneously on different layers, avoid re-drawing and flickering

Principles of Traditional Animation
[Lasseter, SIGGRAPH 1987]

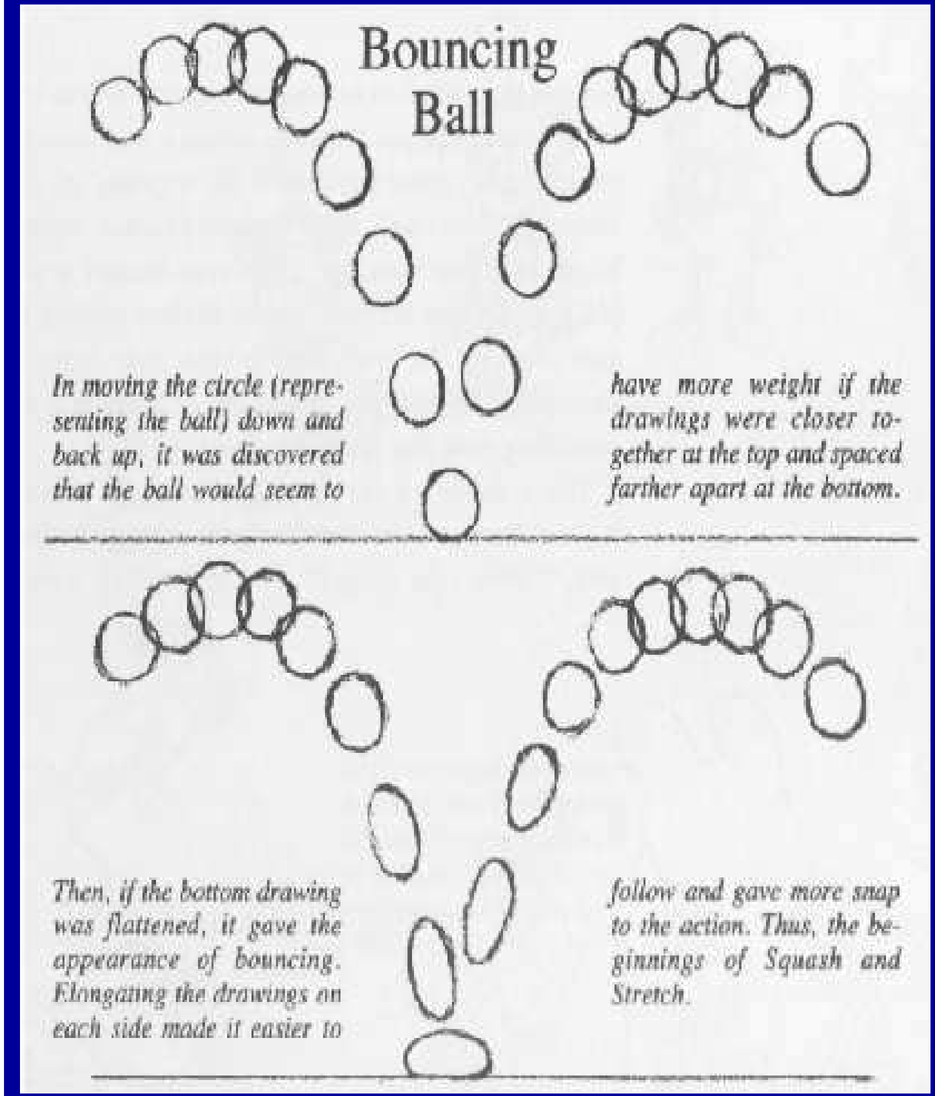
- Stylistic conventions followed by Disney's animators and others

- From experience built up over many years
  - Squash and stretch -- use distortions to convey flexibility
  - Timing -- speed conveys mass, personality
  - Anticipation -- prepare the audience for an action
  - Followthrough and overlapping action -- continuity with next action
  - Slow in and out -- speed of transitions conveys subtleties
  - Arcs -- motion is usually curved
  - Exaggeration -- emphasize emotional content
  - Secondary Action -- motion occurring as a consequence
  - Appeal -- audience must enjoy watching it

Principles of Traditional Animation

Squash and Stretch

Use distortions to convey flexibility



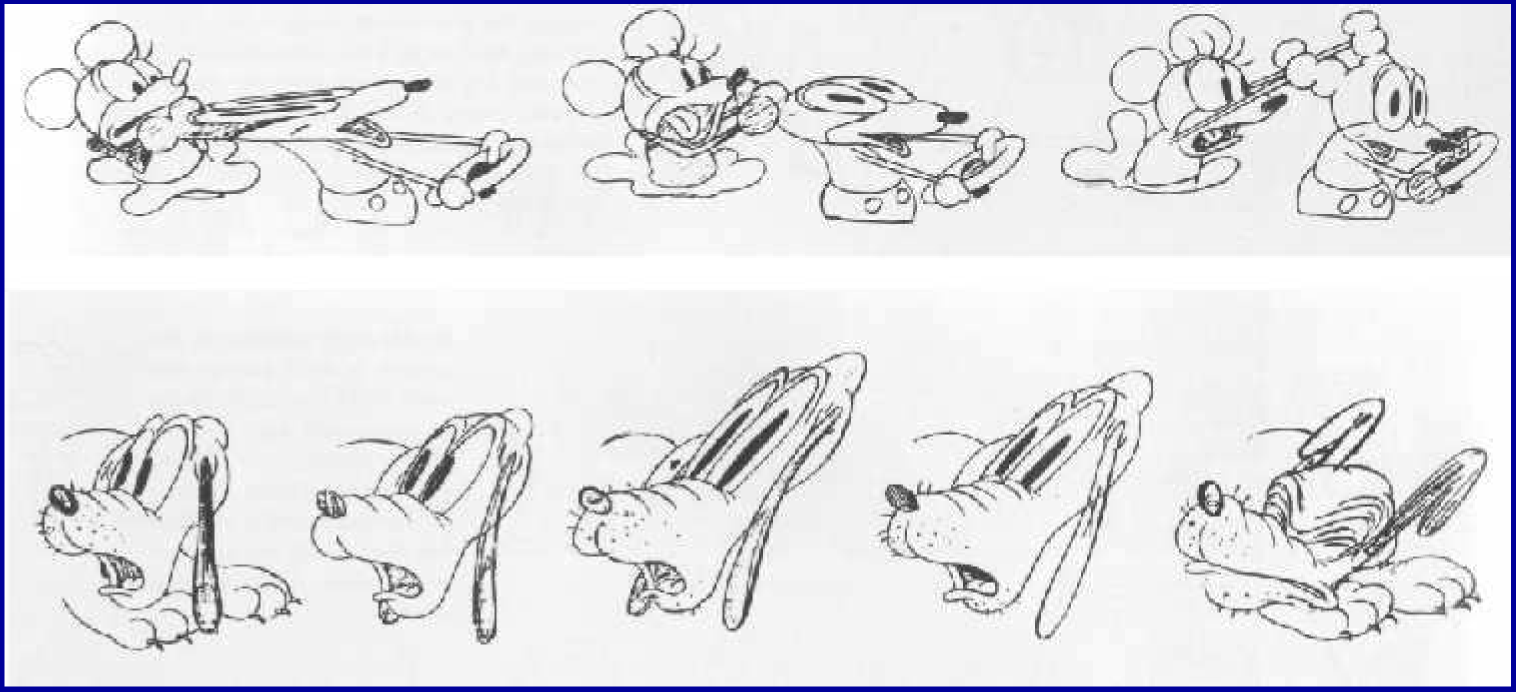
Defines the rigidity of the material

Gives the sense that the object is made out of a soft, pliable material.

Elongating the drawings before and after the bounce increases the sense of speed, makes it easier to follow and gives more snap to the action.

Squash and Stretch

Use distortions to convey flexibility



Timing & Motion

Speed conveys mass, personality

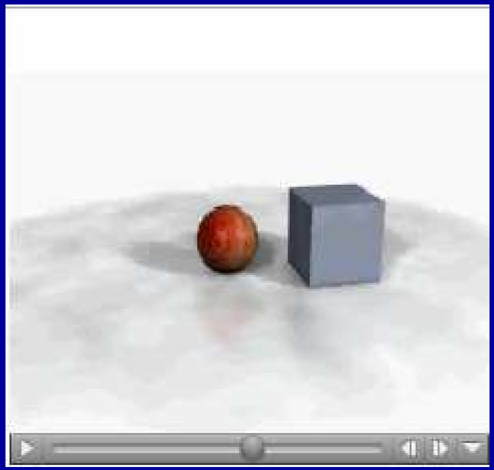
A heavier object takes a greater force and a longer time to accelerate and decelerate

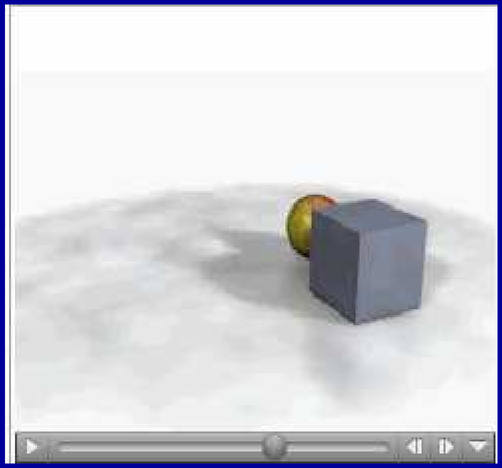
A larger object moves more slowly than a smaller object and has greater inertia

Motion also can give the illusion of weight

For example, consider a ball hitting a box

http://www.siggraph.org/education/materials/HyperGraph/animation/character_animation/principles/timing.htm





Timing & Motion

Timing can also indicate an emotional state

Consider a scenario with a head looking first over the right shoulder and then over the left shoulder

No in-betweens - the character has been hit by a strong force and its head almost snappedd off
One in-betweens - the character has been hit by something substantial, .e.g., frying pan
Two in-betweens - the character has a nervous twitch
Three in-betweens - the character is dodging a flying object
Four in-betweens - the character is giving a crisp order
Six in-betweens - the character sees something inviting
Nine in-betweens - the character is thinking about something
Ten in-betweens - the character is stretching a sore muscle

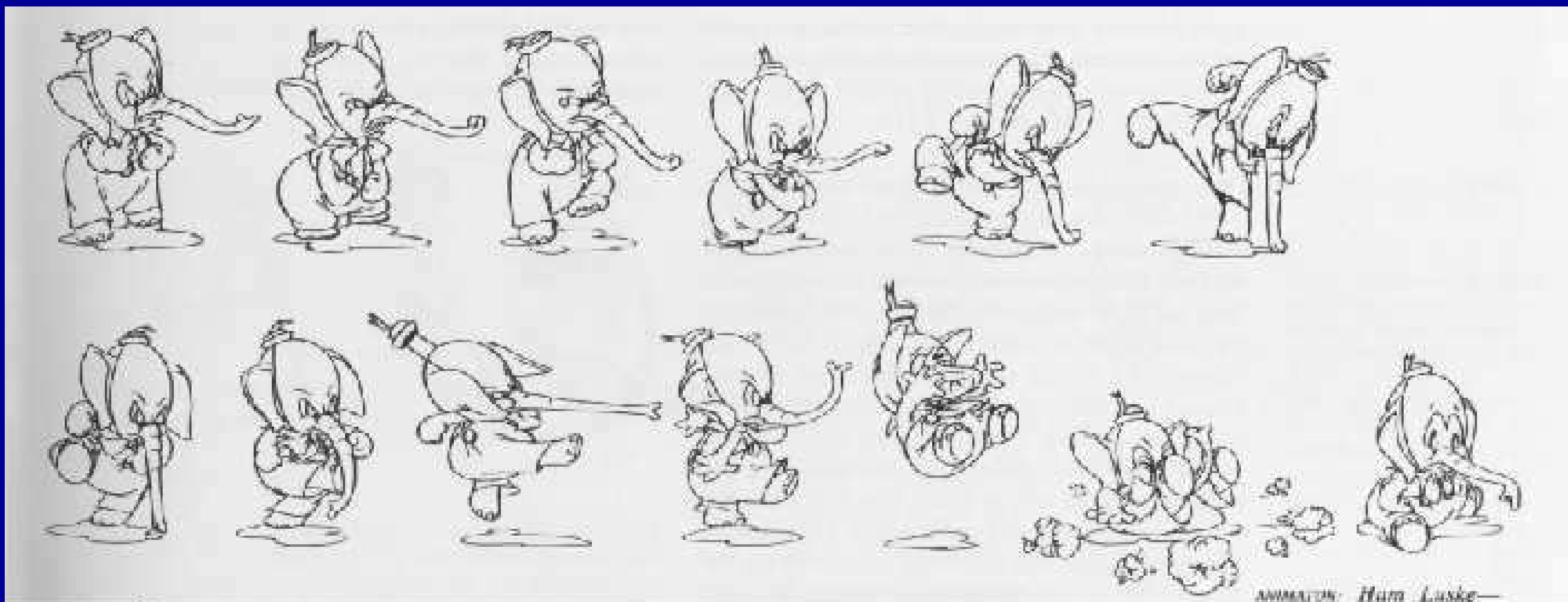
Anticipation

Prepare the audience for an action

Don’t surprise the audience
Direct their attention to what’s important

Follow Through and Overlapping Action

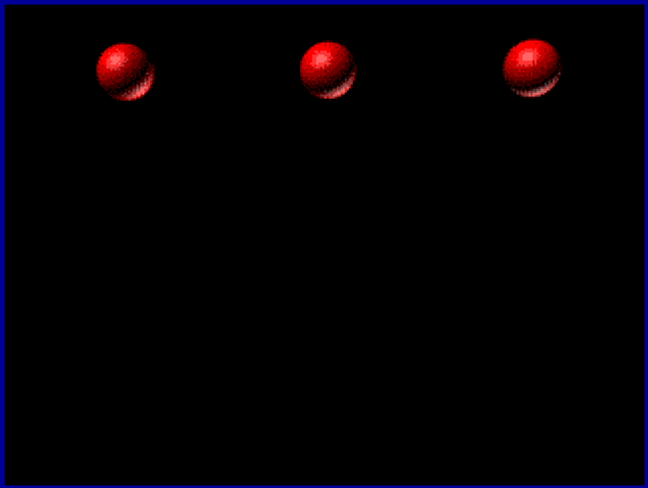
The termination of an action and establishing its relationship to the next action



Audience likes to see resolution of action
Discontinuities are unsettling

Slow in and out

Speed of transitions conveys subtleties

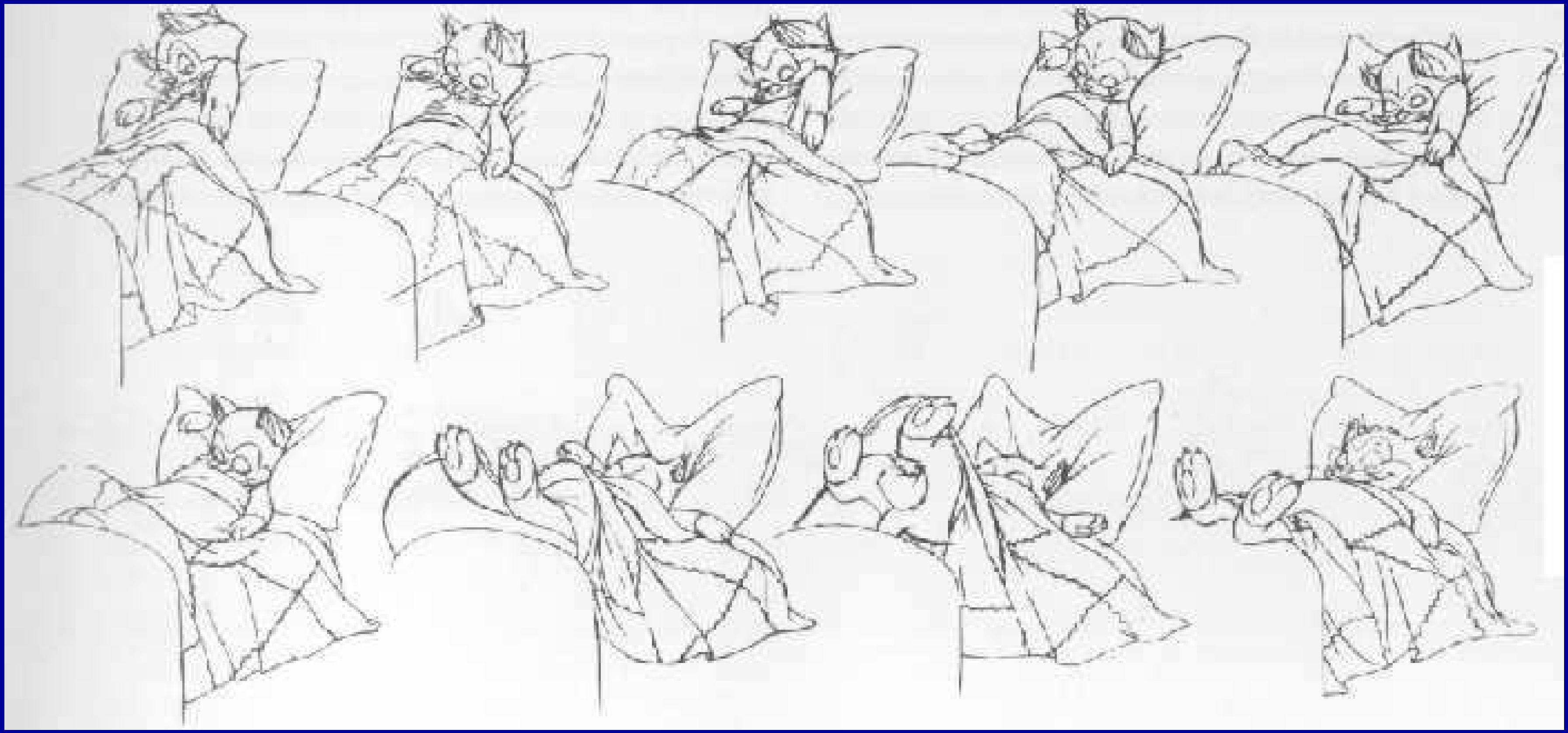


http://www.siggraph.org/education/materials/HyperGraph/animation/character_animation/principles/bouncing_ball_example_of_slow_in_out.htm

The ball on the left moves at a constant speed with no squash/stretch.
The ball in the center does slow in and out with a squash/stretch.
The ball on the right moves at a constant speed with squash/stretch.

Secondary Action

Motion occurring as a consequence



Computer Assisted Animation

- Computerized Cel painting
  - Digitize the line drawing, color it using digital paint
  - Widely used in production (little hand painting any more)
  - e.g. *Lion King*
- Graphics Tablet
  - For outline drawing

- Cartoon Inbetweening
  - Automatically interpolate between two drawings to produce inbetweens (*a la* morphing)
  - Hard to get right
    - » inbetweens often don't look natural
    - » what are the parameters to interpolate? Not clear...
    - » not used very often

3D Computer Animation

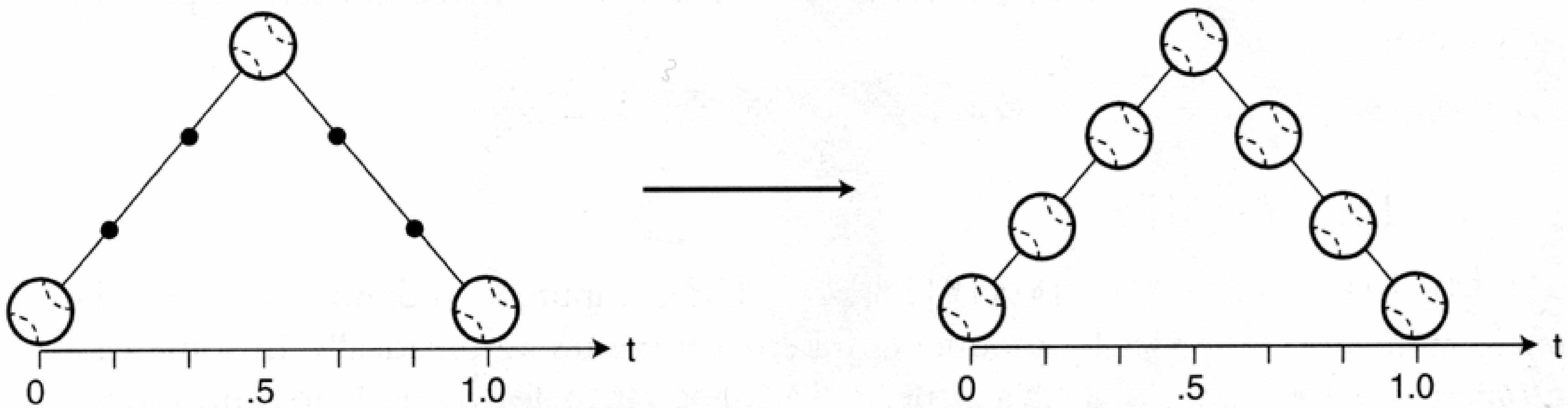
- Generate the images by rendering a 3-D model
- Vary the parameters to produce the animation
- Brute force
  - Manually set the parameters for each and every frame
  - For an *n* parameter model: $60 \times 24 \times n = 1440n$ values per minute
- Traditional keyframing
  - Lead animators draw the important frames
  - Assistant animators draw the inbetweens
- Computer keyframing
  - Lead animators create the important frames with 3-D computer models
  - Computers draw the inbetweens

Interpolation

- Hard to interpolate hand-drawn keyframes
  - Computers don't help much
- The situation is different in 3D computer animation:
  - Each keyframe is a defined by a bunch of parameters (state)
  - Sequence of keyframes = points in high-dimensional state space
- Computer inbetweening interpolates these points
- How? splines

Keyframing Basics

Figure 10.5 Inbetweening with linear interpolation. Linear interpolation creates inbetween frames at equal intervals along straight lines. The ball moves at a constant speed. Ticks indicate the locations of inbetween frames at regular time intervals (determined by the number of frames per second chosen by the user).



Keyframing Basics

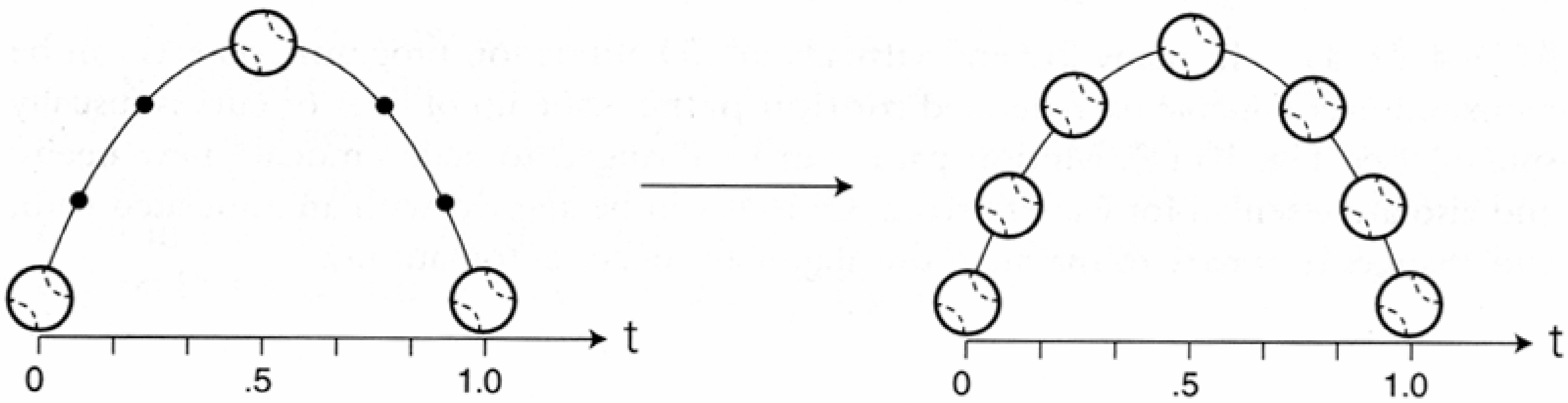


Figure 10.9 **Inbetweening with nonlinear interpolation.** Nonlinear interpolation can create equally spaced inbetween frames along curved paths. The ball still moves at a constant speed. (Note that the three keyframes used here and in Fig. 10.10 are the same as in Fig. 10.4.)

Keyframing Basics

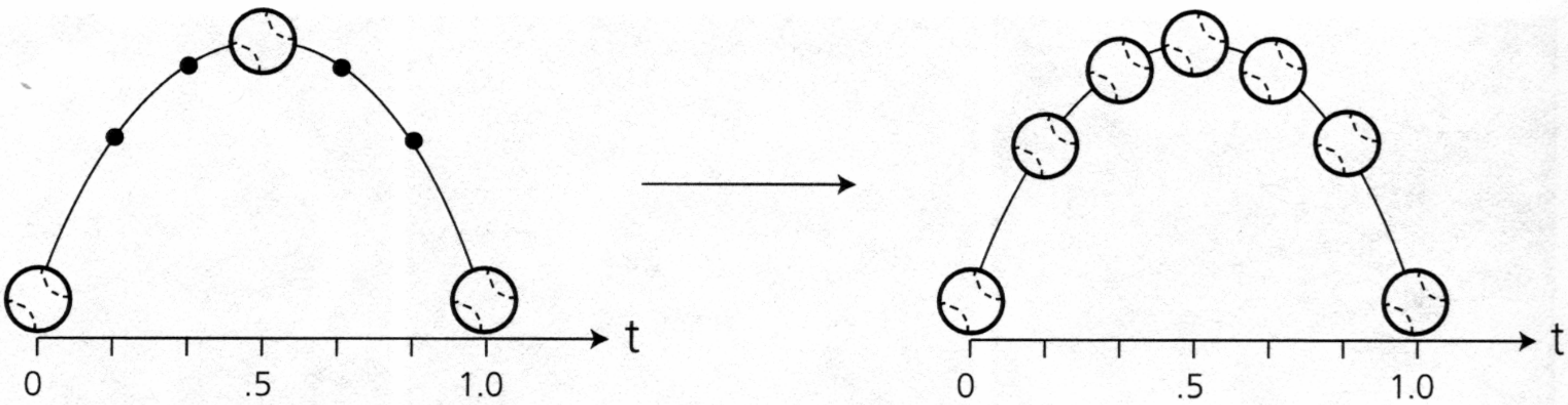
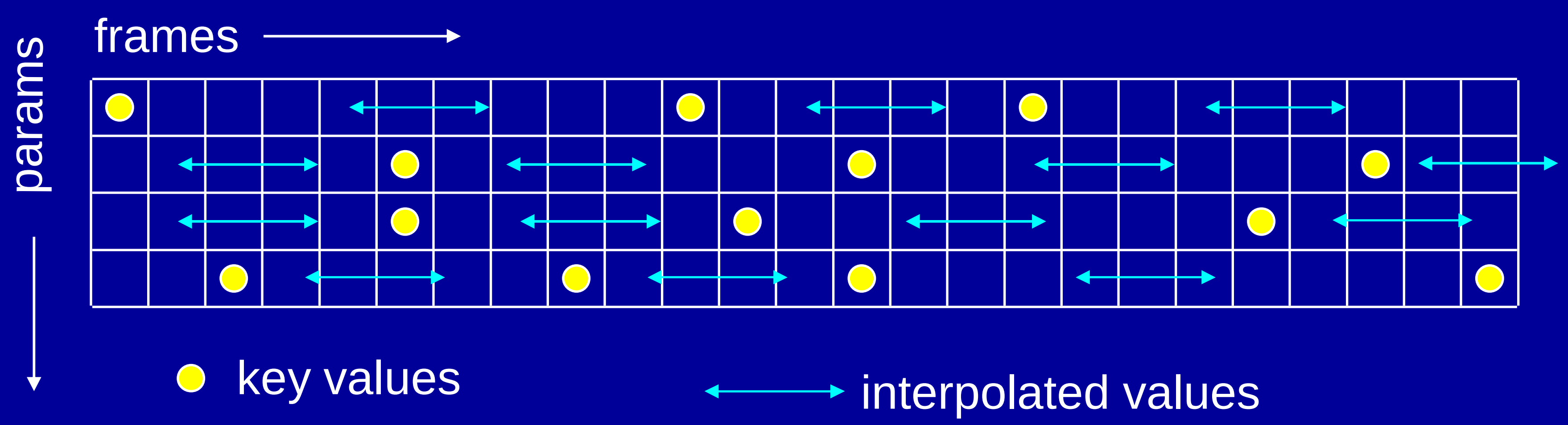


Figure 10.10 Inbetweening with nonlinear interpolation and easing. The ball changes speed as it approaches and leaves keyframes, so the dots indicating calculations made at equal time intervals are no longer equidistant along the path.

Keyframing Basics

- For each variable, specify its value at the “important” frames. Not all variables need agree about which frames are important.
- Hence, *key values* rather than key frames
- Create path for each parameter by interpolating key values



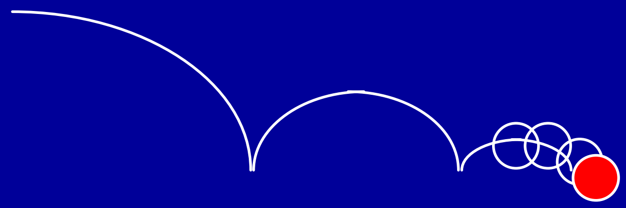
Keyframing: Issues

- What should the key values be?
- When should the key values occur?
- How can the key values be specified?
- How are the key values interpolated?
- What kinds of BAD THINGS can occur from interpolation?
  - Invalid configurations (pass through objects)
  - Unnatural motions (painful twists/bends)
  - Jerky motion

How Do You Interpolate Between Keys?

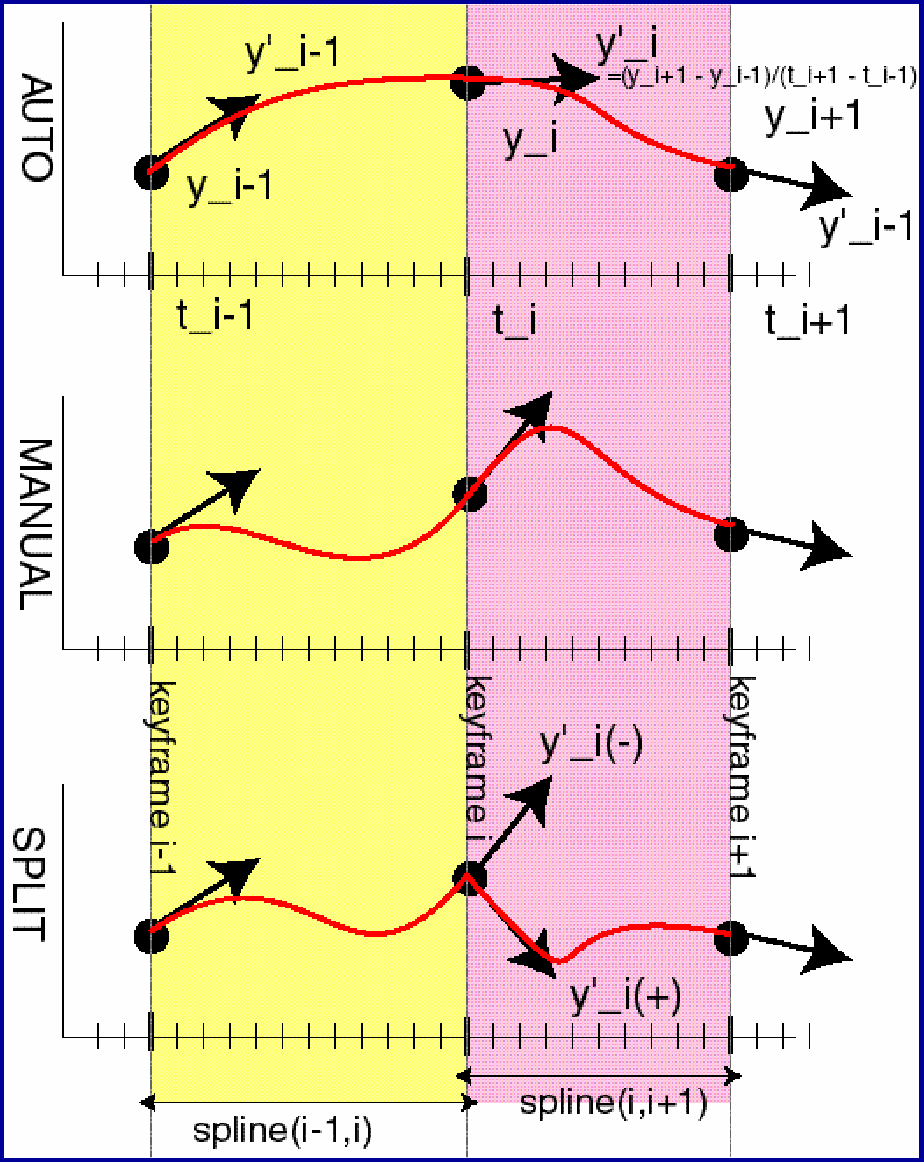
- What kind of spline might we want to use?

Hermite is good



- What kind of continuity do we want?

How Do You Interpolate Between Keys?



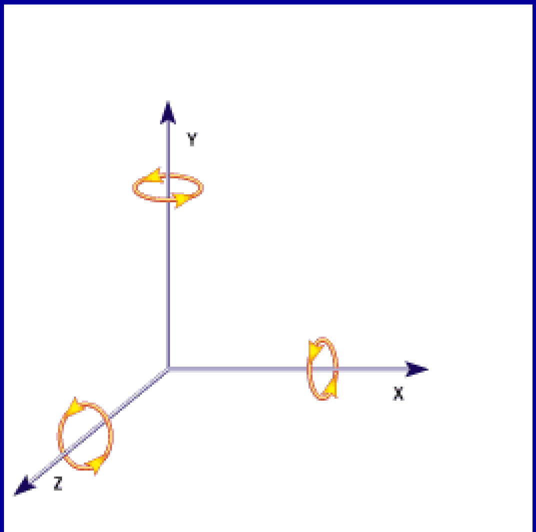
Maya Demo

Maya Demo - Ball

Problems with Interpolation

- Splines don’t always do the right thing
- Classic problems
  - –Important constraints may break between keyframes
    - » feet sink through the floor
    - » hands pass through walls
  - –3D rotations
    - » Euler angles don’t always interpolate in a natural way
- Classic solutions:
  - –More keyframes!
  - –Quaternions help fix rotation problems

Interpolating Rotations



Euler angles

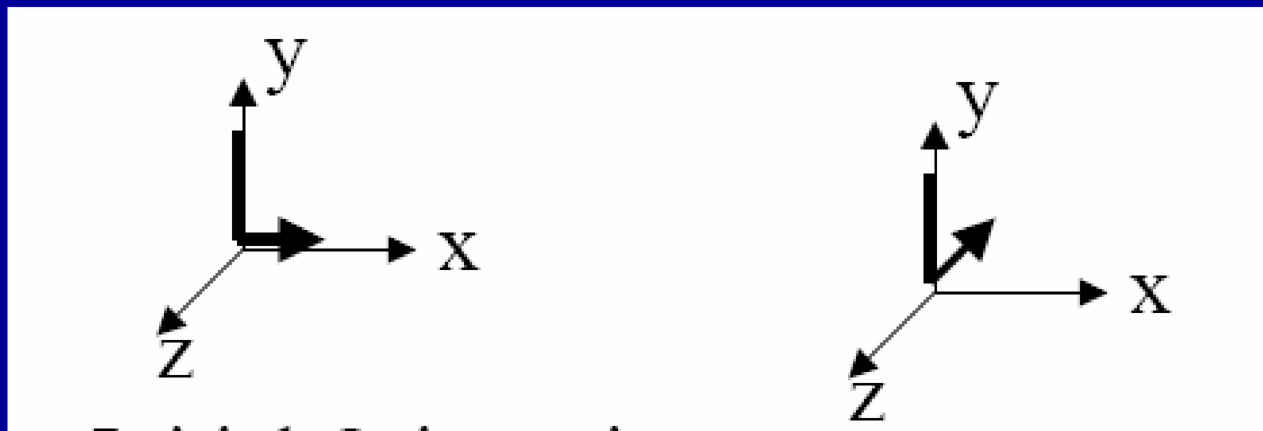
Q: What kind of compound rotation do you get by successively turning about each of the 3 axes at a constant rate?

A: Not the one you want

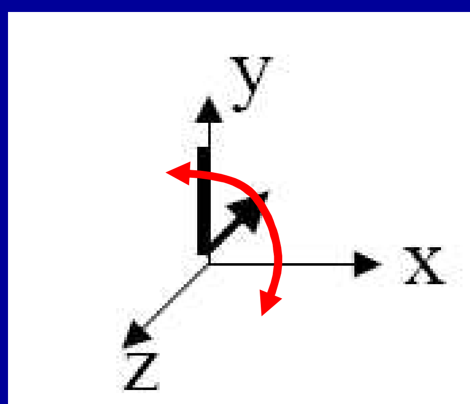
Euler Angles

- Good for single-axis rotations
- Awkward for other rotations

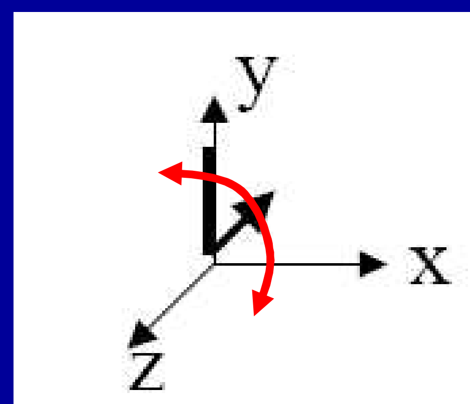
Gimbal Lock



(0, 90, 0)

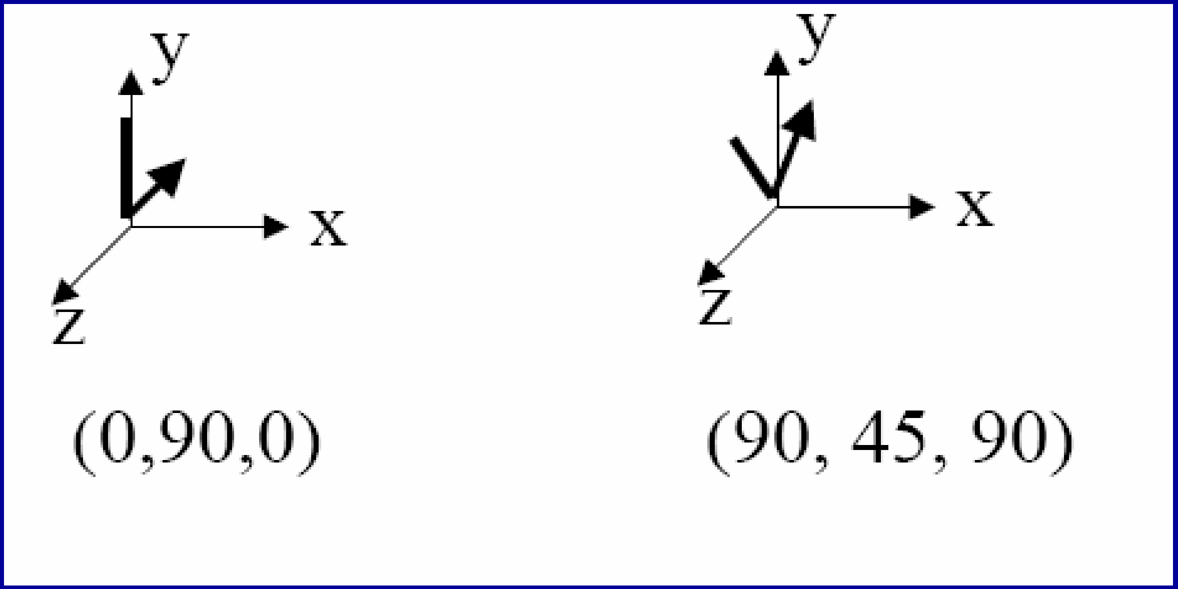


(+/-e, 90, 0)



(0, 90, +/-e)

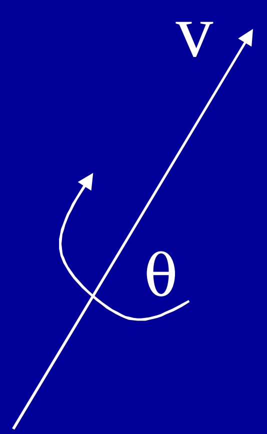
Gimbal Lock



90, 22.5, 90, but get 45, 67.5, 45

Quaternion Rotation

- A quaternion is a 4-D unit vector $q = [x\ y\ z\ w]$
  - It lies on the unit hypersphere $x^2+y^2+z^2+w^2=1$



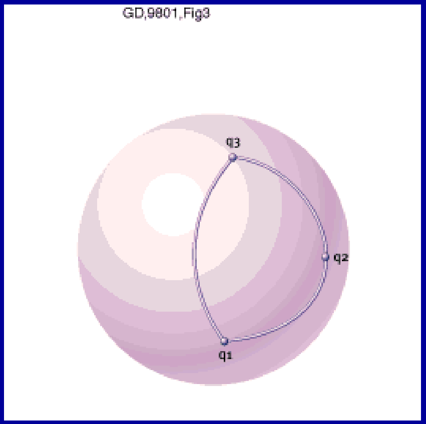
- For rotation about (unit) axis *v* by angle θ
  - vector part $(\sin\theta/2)\,v = [x\ y\ z]$
  - scalar part $\cos\theta/2 = w$

- The rotation matrix corresponding to a quaternion is

$$\begin{bmatrix} 1-2y^2-2z^2 & 2xy+2wz & 2xz-2wy \\ 2xy-2wz & 1-2x^2-2z^2 & 2yz+2wx \\ 2xz+2wy & 2yz-2wx & 1-2x^2-2y^2 \end{bmatrix}$$

Quaternion Rotation

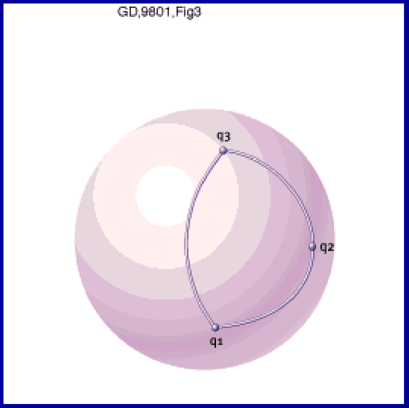
- We can think of rotations as lying on an n-D unit sphere



- Interpolating rotations means moving on 4-D sphere

Quaternion Interpolation

- Interpolating quaternions produces better results than Euler angles

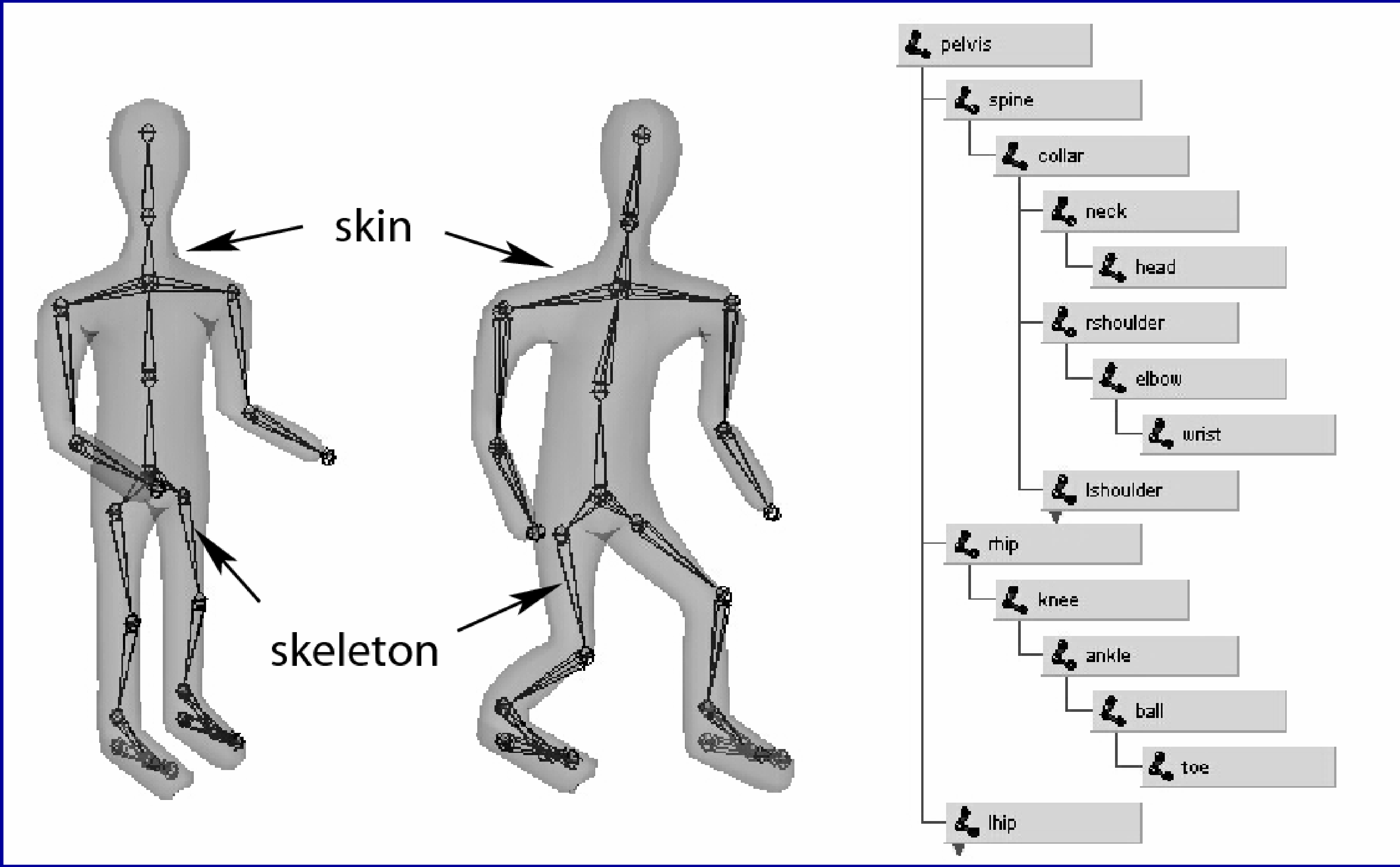


- Quaternion Interpolation
  - represent rotation as quaternion
  - SLERP: move with constant angular velocity along the great circle between the two points
  - convert to rotation matrix to apply the rotation

- Any rotation is given by 2 quaternions
  - pick the shortest SLERP

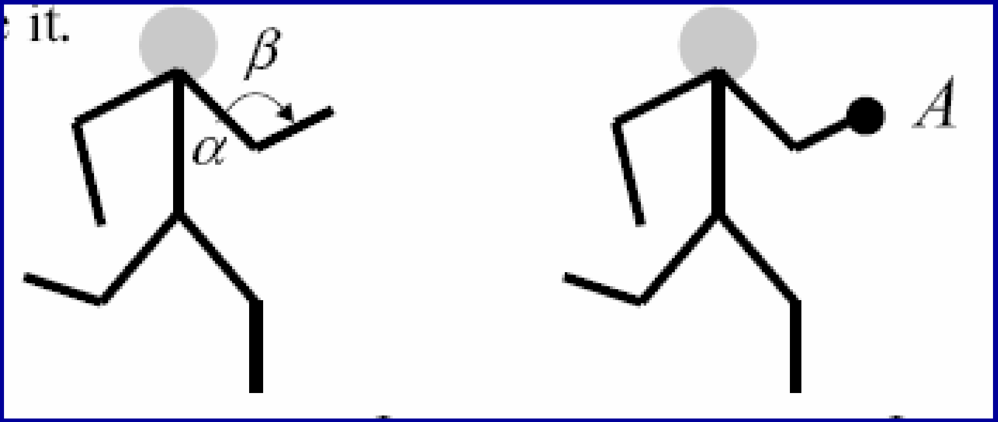
- Further information: Ken Shoemake in the Siggraph '85 proceedings (*Computer Graphics*, V. 19, No. 3, P.245)

Character Animation



Kinematics & Inverse Kinematics

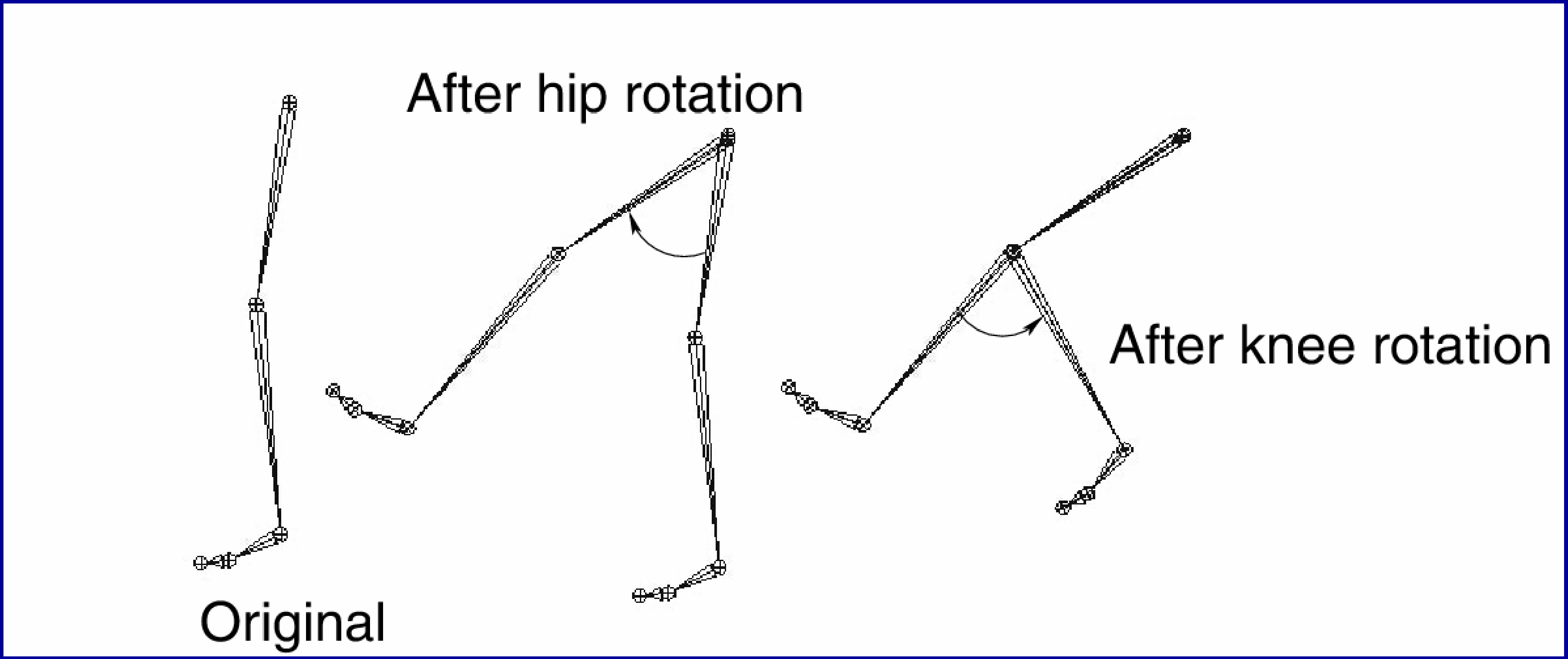
- We need help in positioning joints



Forward: $A = f(\alpha,\beta)$ Backward: $\alpha, \beta = f^{-1}(A)$

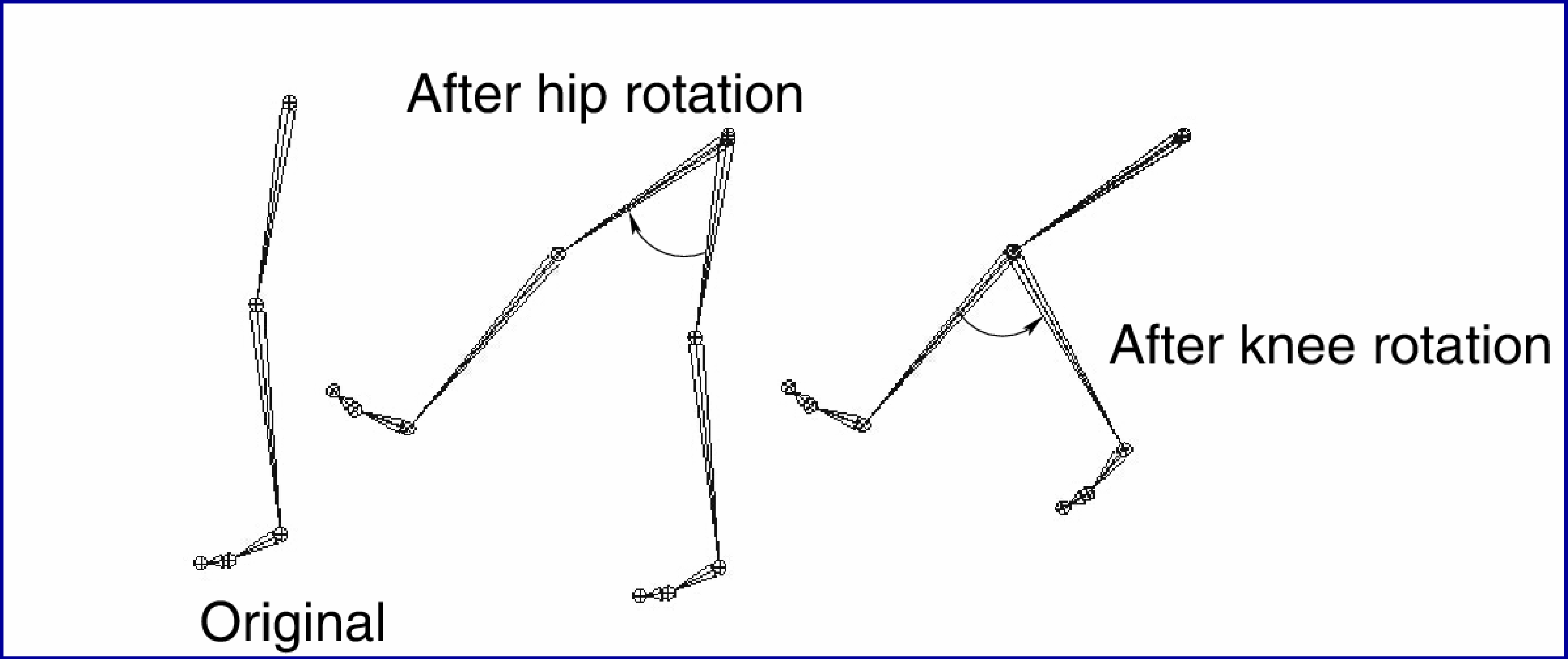
Kinematics & Inverse Kinematics

- We need help in positioning joints
- Forward Kinematics
  - animator controls all joint angles



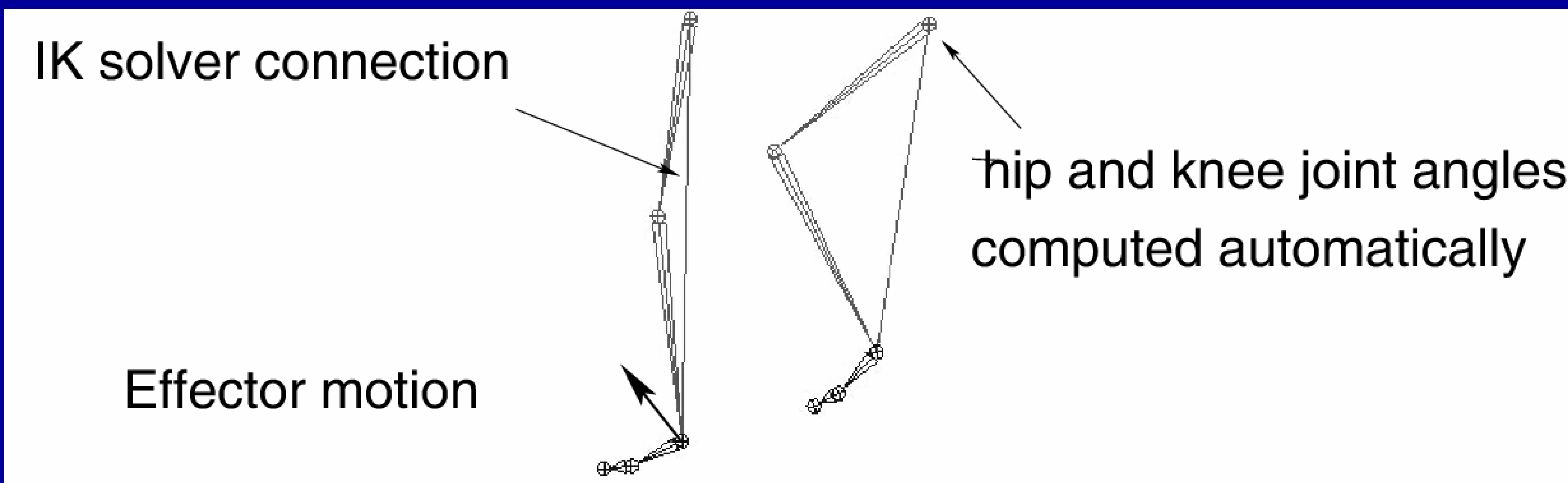
Kinematics & Inverse Kinematics

- We need help in positioning joints
- Forward Kinematics
  - animator controls all joint angles



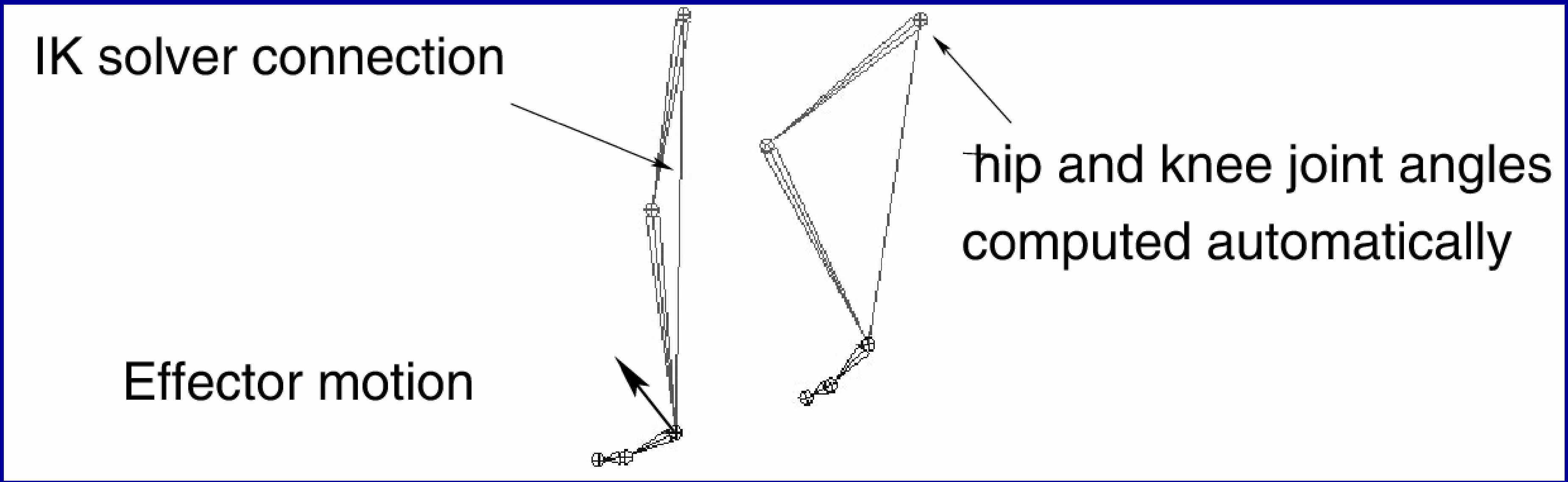
Kinematics & Inverse Kinematics

- Inverse kinematics
  - determine joint angles from positions
  - e.g. "calculate the hip, knee and foot parameters in order to put the foot here"
  - better for interaction
  - sometimes underdetermined (i.e. many combinations of joint angles to achieve a given end result)



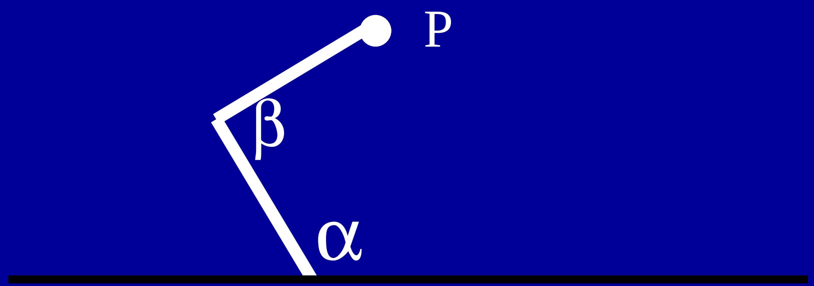
Kinematics & Inverse Kinematics

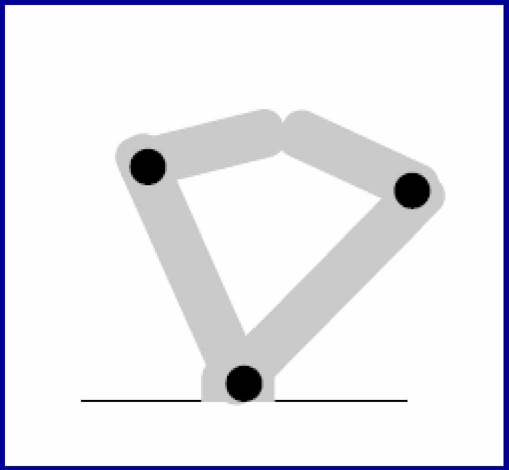
- Inverse kinematics
  - determine joint angles from positions
  - e.g. "calculate the hip, knee and foot parameters in order to put the foot here"
  - better for interaction
  - sometimes underdetermined (i.e. many combinations of joint angles to achieve a given end result)

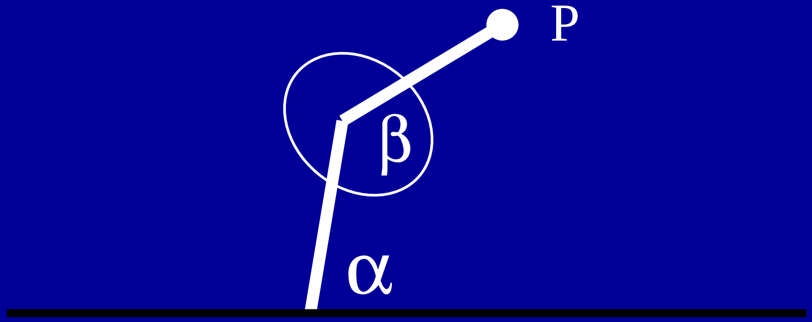


Kinematics & Inverse Kinematics

- Inverse kinematics
  - Closed form only for fairly simple mechanisms







Maya Demo

Maya Demo - Human