Animation
(web version)

CS 4620 Lecture 20

Animation

- Industry production process leading up to animation
- What animation is
- How animation works (very generally)
- Artistic process of animation
- Further topics in how it works

What is animation?

- Modeling = specifying shape
- Animation = specifying shape as a function of time
  - Just modeling done once per frame?
  - Need smooth, concerted movement
- Controlling shape = the technical problem
- Using shape controls = the artistic problem

Approaches to animation

- Straight ahead
  - Draw/animate one frame at a time
  - Can lead to spontaneity, but is hard to get exactly what you want
- Pose-to-pose
  - Top-down process:
    - Plan shots using storyboards
    - Plan key poses first
    - Finally fill in the in-between frames

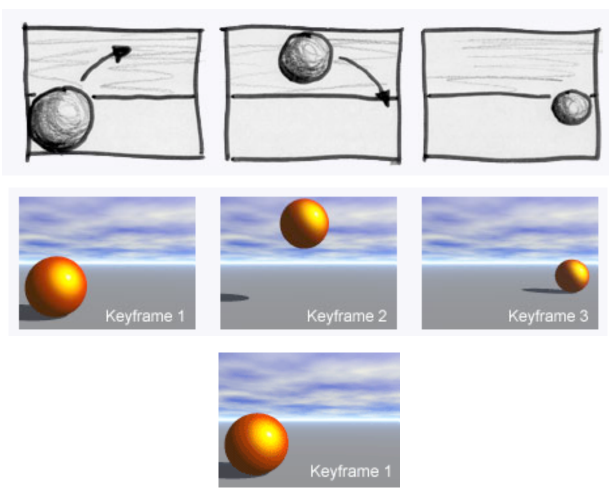
Pose-to-pose animation planning

- First work out poses that are key to the story
- Next fill in animation in between

Keyframe animation

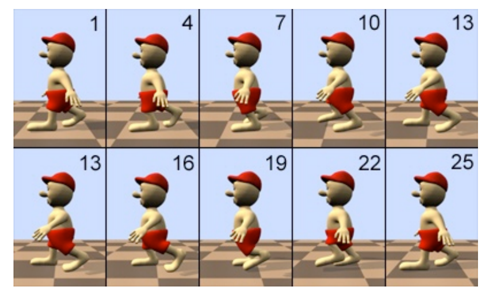
- Keyframing is the technique used for pose-to-pose animation
  - Head animator draws key poses—just enough to indicate what the motion is supposed to be
  - Assistants do "in-betweening" and draws the rest of the frames
  - In computer animation substitute "user" and "animation software"
  - *Interpolation* is the principal operation

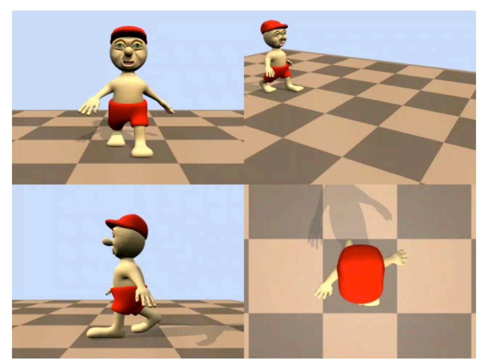
Keyframe animation



[Bryce Tutorial http://www.cadtutor.net/dd/bryce/anim/anim.html]

Walk cycle





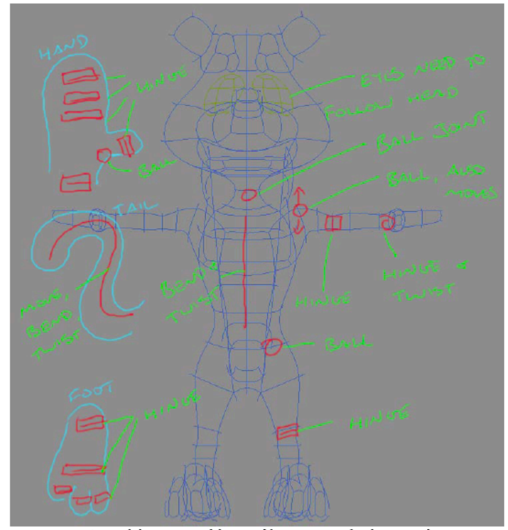
[Christopher Lutz http://www.animationsnippets.com]

Controlling geometry conveniently

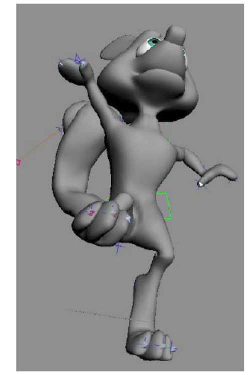
- Could animate by moving every control point at every keyframe
  - This would be labor intensive
  - It would also be hard to get smooth, consistent motion
- Better way: animate using smaller set of meaningful *degrees of freedom* (DOFs)
  - Modeling DOFs are inappropriate for animation
    - E.g. "move one square inch of left forearm"
  - Animation DOFs need to be higher level
    - E.g. "bend the elbow"

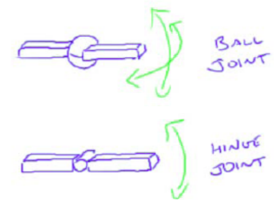
Character with DOFs

[Greenberg/Pellacini | CIS 565]



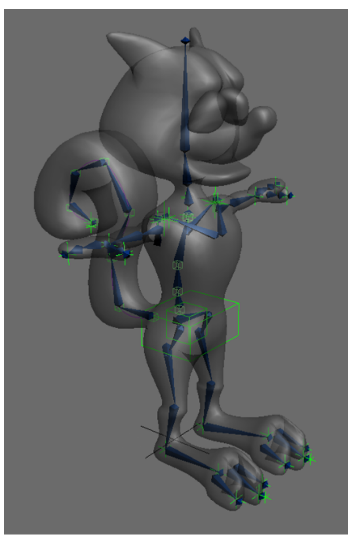
A visual description of the possible movements for the squirrel





Rigged character

[CIS 565 staff]



- Surface is deformed by a set of *bones*
- Bones are in turn controlled by a smaller set of *controls*
- The controls are useful, intuitive DOFs for an animator to use

The artistic process of animation

- What are animators trying to do?
  - Important to understand when designing animation tools
- Basic principles are universal across media
  - 2D hand-drawn animation
  - 2D computer animation
  - 3D computer animation
- John Lasseter, **Principles of Traditional Animation Applied to 3D Computer Animation**, *Computer Graphics (SIGGRAPH 87)*, pp. 35-44, 21:4, July 1987.
- The following slides follow the examples from Michael Comet's very nice discussion on the page:

  http://www.comet-cartoons.com/toons/3ddocs/charanim

Animation principles: timing

- Speed of an action is crucial to the impression it makes
  - examples with same keyframes, different times:

[Michael B. Comet]

60 fr: looking around

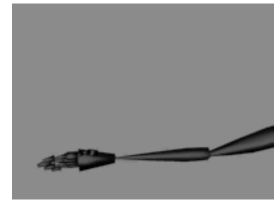
30 fr: "no"

5 fr: just been hit

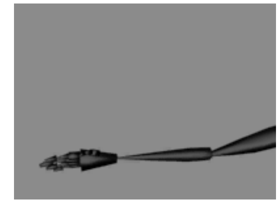
Animation principles: ease in/out

- Real objects do not start and stop suddenly
  - animation parameters shouldn't either

[Michael B. Comet]



straight linear interp.



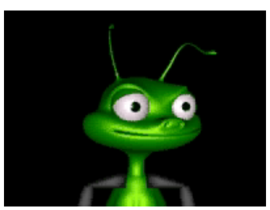
ease in/out

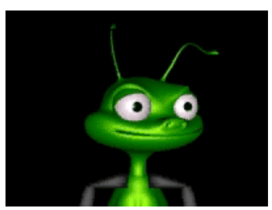
  - a little goes a long way (just a few frames acceleration or deceleration for "snappy" motions)

Animation principles: moving in arcs

- Real objects also don't move in straight lines
  - generally curves are more graceful and realistic

[Michael B. Comet]

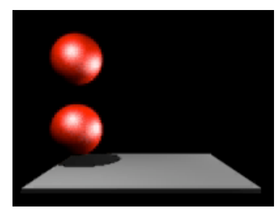




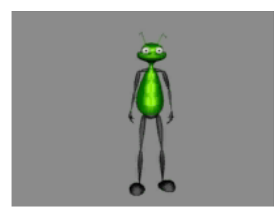
Animation principles: anticipation

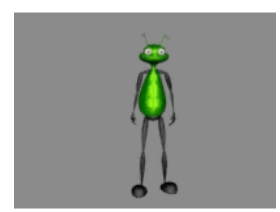
- Most actions are preceded by some kind of "wind-up"

[Michael B. Comet]



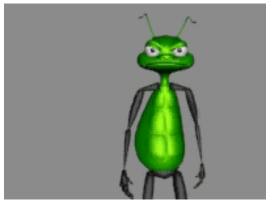
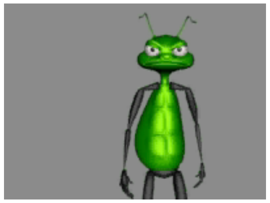
[Michael B. Comet]





Animation principles: exaggeration

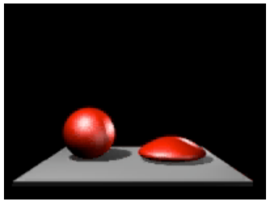
- Animation is not about exactly modeling reality
- Exaggeration is very often used for emphasis

[Michael B. Comet]

Animation principles: squash & stretch

- Objects do not remain perfectly rigid as they move
- Adding stretch with motion and squash with impact:
  - models deformation of soft objects
  - indicates motion by simulating exaggerated "motion blur"



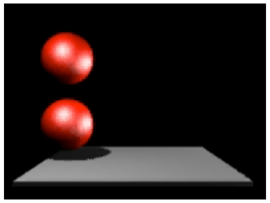
[Michael B. Comet]

Animation principles: squash & stretch

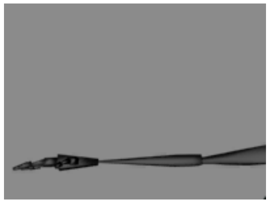
[Cook, Porter, Carpenter 1984]

Animation principles: follow through

- We've seen that objects don't start suddenly
- They also don't stop on a dime



[Michael B. Comet]



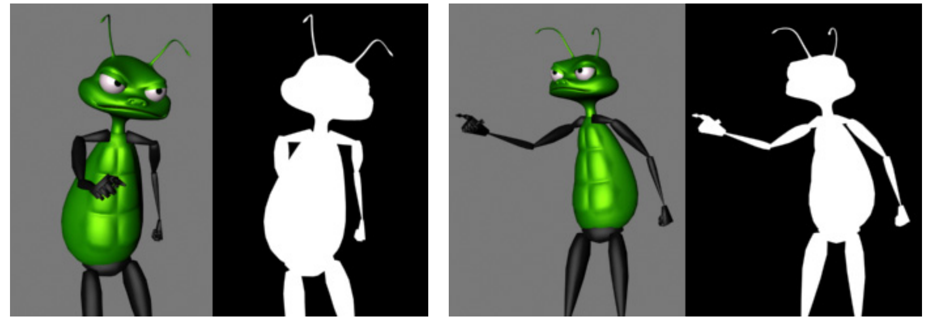
[Michael B. Comet]

Anim. principles: overlapping action

- Usually many actions are happening at once

[Michael B. Comet]

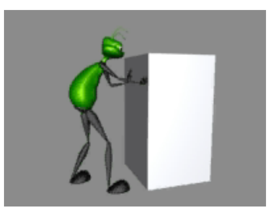
Animation principles: staging

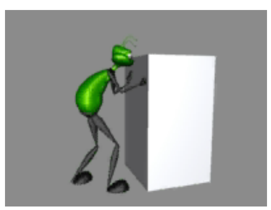


- Want to produce clear, good-looking 2D images
  - need good camera angles, set design, and character positions

[Michael B. Comet]

Principles at work: weight





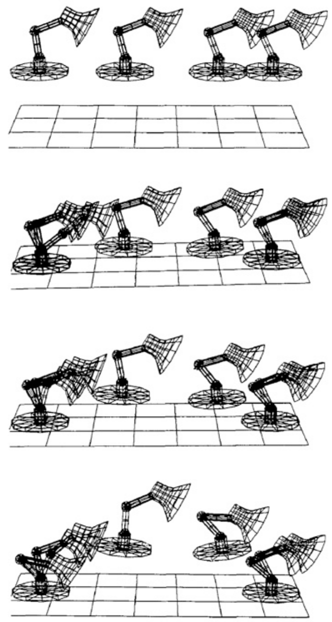
[Michael B. Comet]

Extended example: Luxo, Jr.

© Pixar/Disney

Computer-generated motion

- Interesting aside: many principles of character animation follow indirectly from physics
- Anticipation, follow-through, and many other effects can be produced by simply minimizing physical energy
- Seminal paper: "Spacetime Constraints" by Witkin and Kass in SIGGRAPH 1988

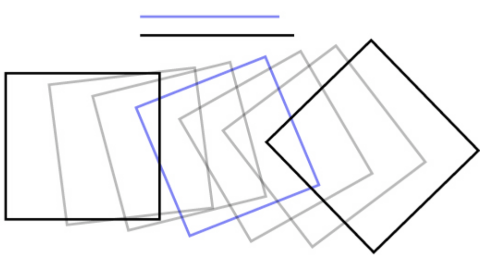


Controlling shape for animation

- Start with *modeling DOFs* (control points)
- *Deformations* control those DOFs at a higher level
  - Example: move first joint of second finger on left hand
- *Animation controls* control *those* DOFs at a higher level
  - Example: open/close left hand
- Both cases can be handled by the same kinds of deformers

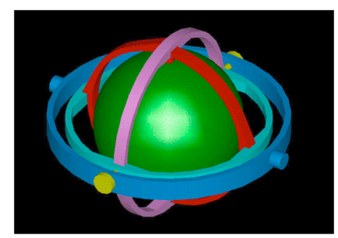
Rigid motion: the simplest deformation

- Move a set of points by applying an affine transformation
- How to animate the transformation over time?
  - Interpolate the matrix entries from keyframe to keyframe?
    - This is fine for translations but bad for rotations



Parameterizing rotations

- Euler angles
  - Rotate around x, then y, then z
  - Problem: gimbal lock
    - If two axes coincide, you lose one DOF

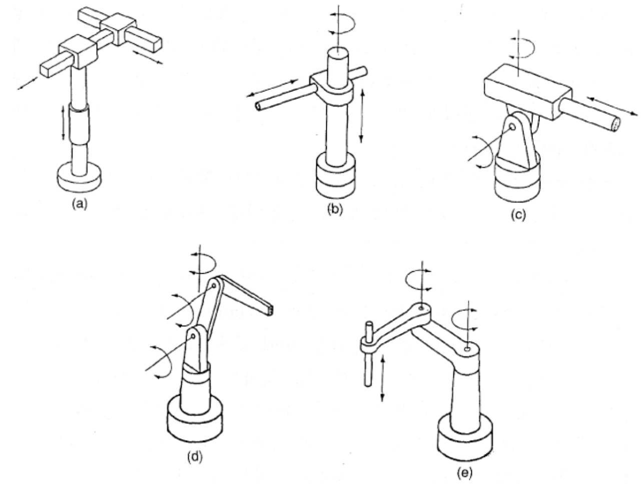


- Unit quaternions
  - A 4D representation (like 3D unit vectors for 2D sphere)
  - Good choice for interpolating rotations
- These are first examples of motion control
  - Matrix = deformation
  - Angles/quaternion = animation controls

Hierarchies and articulated figures

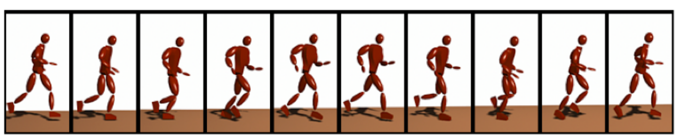
- Robot assignment as an example
  - Small number of animation controls control many transformations
  - Constraint: the joints hold together
- Robotics as source of math. Methods
  - Forward kinematics
  - Inverse kinematics

Articulation in robotics



a. rectangular or cartesian
b. cylindrical or post-type
c. spherical or polar
d. joint-arm or articulated
e. SCARA (selective compliance assembly robot arm)

Motion capture



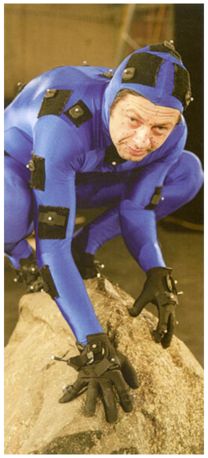
- A method for creating complex motion quickly: measure it from the real world

[thanks to Zoran Popović for many visuals]

Motion capture in movies

[Final Fanatsy]

Motion capture in movies



[*The Two Towers* | New Line Productions]

Motion capture in games

Magnetic motion capture

- Tethered
- Nearby metal objects cause distortions
- Low freq. (60Hz)

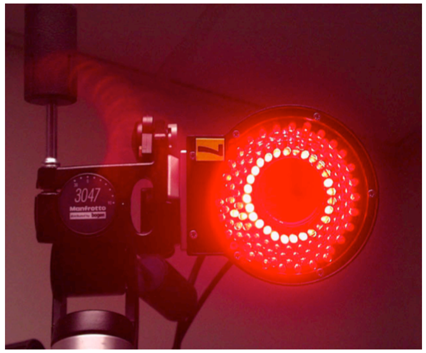
Mechanical motion capture

- Measures joint angles directly
- Works in any environment
- Restricts motion

Optical motion capture

- Passive markers on subject

Retroreflective markers



Cameras with IR illuminators

- Markers observed by cameras
  - Positions via triangulation

Optical motion capture

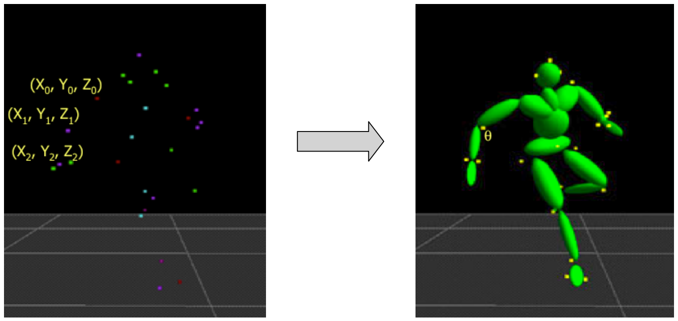
- 8 or more cameras
- Restricted volume
- High frequency (240Hz)
- Occlusions are troublesome

Inertial motion capture

Inertial motion capture

From marker data to usable motion

- Motion capture system gives inconvenient raw data
  - Optical is "least information" case: accurate position but:
    - Which marker is which?
    - Where are the markers are relative to the skeleton?



Motion capture data processing

- Marker identification: which marker is which
  - Start with standard rest pose
  - Track forward through time (but watch for markers dropping out due to occlusion!)
- Calibration: match skeleton, find offsets to markers
  - Use a short sequence that exercises all DOFs of the subject
  - A nonlinear minimization problem
- Computing joint angles: explain data using skeleton DOFs
  - A inverse kinematics problem per frame!

Motion capture in context

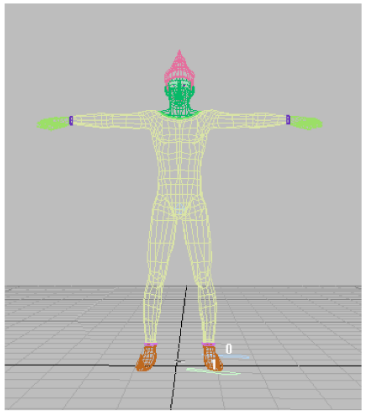
- Mocap data is very realistic
  - Timing matches performance exactly
  - Dimensions are exact
- But it is not enough for good character animation
  - Too few DOFs
  - Noise, errors from nonrigid marker mounting
  - Contains no exaggeration
  - Only applies to human-shaped characters
- Therefore mocap data is generally a starting point for skilled animators to create the final product

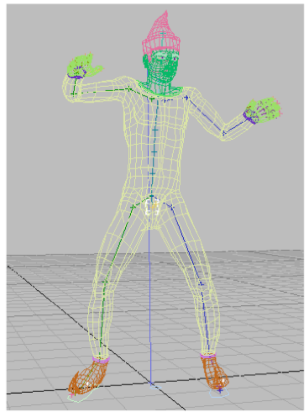
Basic surface deformation methods

- Mesh skinning: deform a mesh based on an underlying skeleton
- Blend shapes: make a mesh by combining several meshes
- Both use simple linear algebra
  - Easy to implement—first thing to try
  - Fast to run—used in games
- The simplest tools in the offline animation toolbox

Mesh skinning

- A simple way to deform a surface to follow a skeleton





[Sébastien Dominé | NVIDIA]

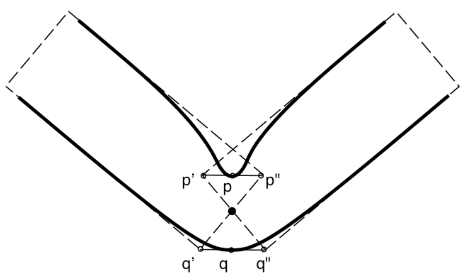
Mesh skinning math: setup

- Surface has control points $\mathbf{p}_i$
  - Triangle vertices, spline control points, subdiv base vertices
- Each bone has a transformation matrix M_j
  - Normally a rigid motion
- Every point–bone pair has a weight w_{ij}
  - In practice only nonzero for small # of nearby bones
  - The weights are provided by the user

Mesh skinning math

- Deformed position of a point is a weighted sum
  - of the positions determined by each bone's transform alone
  - weighted by that vertex's weight for that bone

$$\mathbf{p}'_i = \sum_j w_{ij} M_j \mathbf{p}_i$$



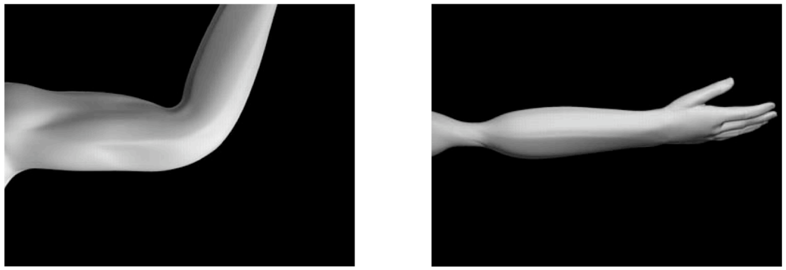
[Lewis et al. SIGGRAPH 2000]

Mesh skinning

- Simple and fast to compute
  - Can even compute in the vertex stage of a graphics pipeline
- Used heavily in games
- One piece of the toolbox for offline animation
  - Many other deformers also available

Mesh skinning: classic problems

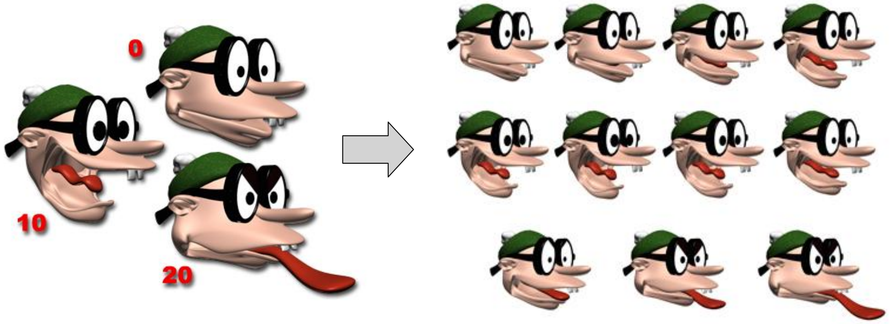
- Surface collapses on the inside of bends and in the presence of strong twists
  - Average of two rotations is not a rotation!
  - Add more bones to keep adjacent bones from being too different, or change the blending rules.



[Lewis et al. SIGGRAPH 2000]

Blend shapes

- Another very simple surface control scheme
- Based on interpolating among several key poses
  - Aka. blend shapes or morph targets



[3D Studio Max example]

Blend shapes math

- Simple setup
  - User provides key shapes—that is, a position for every control point in every shape: $\mathbf{p}_{ij}$ for point i, shape j
  - Per frame: user provides a weight w_j for each key shape
    - Must sum to 1.0
- Computation of deformed shape

$$\mathbf{p}'_i = \sum_j w_j \mathbf{p}_{ij}$$

- Works well for relatively small motions
  - Often used for for facial animation
  - Runs in real time; popular for games

