CSCI 480 Computer Graphics
Lecture 19

Keyframe Animation

Traditional Animation
Keyframe Animation
Computer Animation
[Ch. 10.6]

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Animation

"*There is no particular mystery in animation...it's really very simple, and like anything that is simple, it is about the hardest thing in the world to do.* "

Bill Tytla at the Walt Disney Studio,
June 28, 1937.

Computer Animation

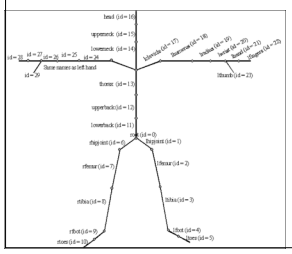
- Models have parameters:
  - polygon positions,
  - normals,
  - spline control points,
  - joint angles,
  - camera parameters,
  - lights,
  - color, etc.
- *n* parameters define an *n*-dimensional state space
- Values of *n* parameters = point in state space

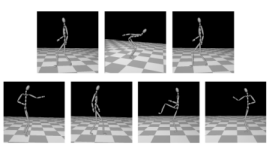
Computer Animation

- Animation defined by path through state space
- To produce animation:
  1. start at beginning of state space path
  2. set the parameters of your model
  3. render the image
  4. move to next point along state space path,
  5. Goto 2.
- Path usually defined by a set of motion curves (one for each parameter)
- Animation = specifying state space trajectory

Animation vs Modeling

- Modeling and animation are tightly coupled
  – Modeling: what are the control knobs and what do they do?
  – Animation: how to vary them to generate desired motions?





Animation vs Modeling

- Building models that are easy to control is a VERY important part of doing animation
  – Hierarchical modeling can help
- Where does modeling end and animation begin? Sometimes a fuzzy distinction...

Basic Animation Techniques

- Traditional (frame by frame)
- Keyframing
- Procedural techniques
- Behavioral techniques (e.g., flocking)
- Performance-based (motion capture)
- Physically-based (dynamics)

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Traditional Animation

Source: Wikipedia and Disney

- Film runs at 24 frames per second (fps)
  - That's 1440 pictures to draw per minute
  - 1800 fpm for video (30fps)
- Productions issues:
  - Need to stay organized for efficiency and cost reasons
  - Need to render the frames systematically
- Artistic issues:
  - How to create the desired look and mood while conveying story?
  - 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

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Traditional Animation Process

- Story board: sequence of sketches with story

A Bug's Life [Pixar, 1998]

Traditional Animation Process

- Key frames
  - Important frames
  - Motion-based description
  - Example: beginning of stride, end of stride
- Inbetweens: draw remaining frames
  - Traditionally done by (low-paid) human animators

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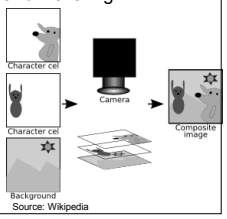
Layered Motion

- It's often useful to have multiple layers of animation
  - How to make an object move in front of a background?
  - Use one layer for background, one for object
  - Can have multiple animators working simultaneously on different layers, avoid re-drawing and flickering
- Transparent acetate allows multiple layers
  - Draw each separately
  - Stack them on a copy stand
  - Transfer onto film by taking a photograph of the stack



Source: Wikipedia

Principles of Traditional Animation
[Lasseter, SIGGRAPH 1987]

- Stylistic conventions followed by Disney's animators and others (but this is not the only interesting style, of course)
- 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

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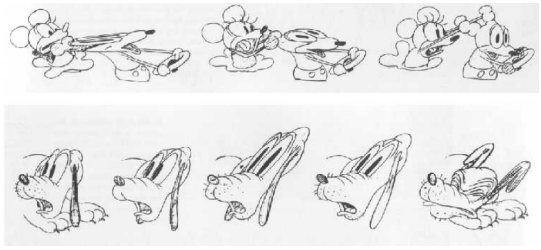
Squash and Stretch
[convey rigidity and mass of an object by distorting its shape]



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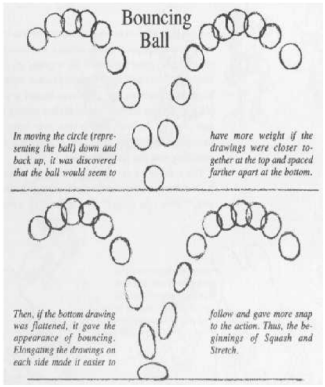
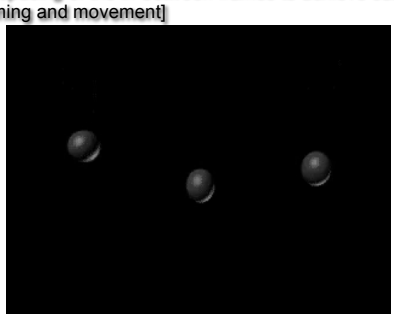
Squash and Stretch
[convey rigidity and mass of an object by distorting its shape]



Slow in and out
[the spacing of the in-between frames to achieve subtlety of timing and movement]



Source: SIGGRAPH

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Anticipation
[the preparation for an action]

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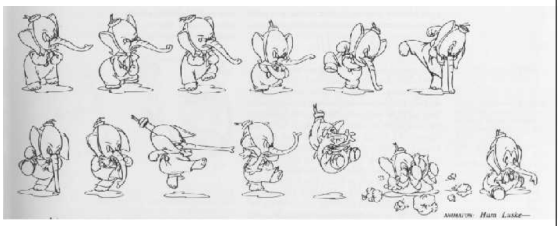
Follow-through
[the termination of an action and establishing its relationship to the next action]



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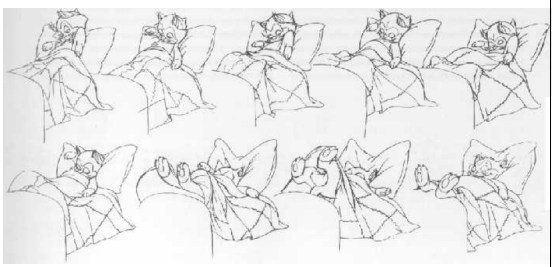
Secondary Action
[action that results from another action]



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Computer-Assisted Animations

- Computerized Cel painting
  - Digitize the line drawing, color it using seed fill
  - Eliminates cel painters
  - Widely used in production (little hand painting any more)
  - e.g. *Lion King*
- Cartoon Inbetweening
  - Automatically interpolate between two drawings to produce inbetweens (similar to morphing)
  - Hard to get right
    - inbetweens often don't look natural
    - what are the parameters to interpolate? Not clear...
    - not used very often

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True Computer Animations

- Generate images by rendering a 3D model
- Vary parameters to produce animation
- Brute force
  - Manually set the parameters for every frame
  - 1440n values per minute for n parameters
  - Maintenance problem
- Computer keyframing
  - Lead animators create important frames
  - Computers draw inbetweens from 3D(!)
  - Dominant production method

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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? You guessed it: splines

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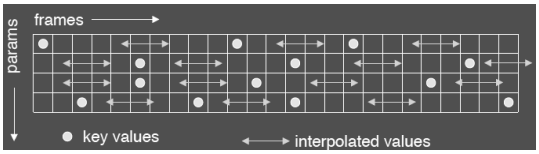
Keyframing Basics

- Despite the name, there aren't really keyframes, per se
- 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



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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

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Keyframing: Production Issues

- How to learn the craft
  - apprentice to an animator
  - practice, practice, practice
- Pixar starts with animators, teaches them computers and starts with computer folks and teaches them some art

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Interpolation

- Splines: non-uniform, C1 is pretty good
- Velocity control is needed at the keyframes
- Classic example: a ball bouncing under gravity
  - zero vertical velocity at start
  - high downward velocity just before impact
  - lower upward velocity after
  - motion produced by fitting a smooth spline looks unnatural
- What kind of spline might we want to use?

Hermite is good

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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

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Example: From Toy Story (1995)

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Scene from Toy Story 2

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Some Research Issues

- Inverse kinematics
  - How to plot a path through state space
  - Multiple degrees of freedom
  - Also important in robotics

Summary

- Traditional Animation
- Keyframe Animation
- Computer Animation

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