CSCI 480 Computer Graphics
Lecture 19

Keyframe Animation

Traditional Animation
Keyframe Animation
Computer Animation
[Angel 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.

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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

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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

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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?
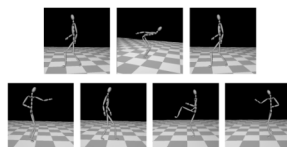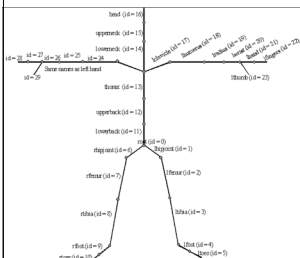
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Animation vs Modeling

- 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...

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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

- Film runs at 24 frames per second (fps)
  - That's 1440 pictures to draw per minute
  - 1800 fpm for video (30fps)

Source: Wikipedia and Disney

- 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
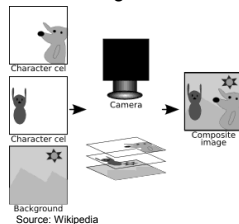
Character cel
Character cel
Camera
Composite image
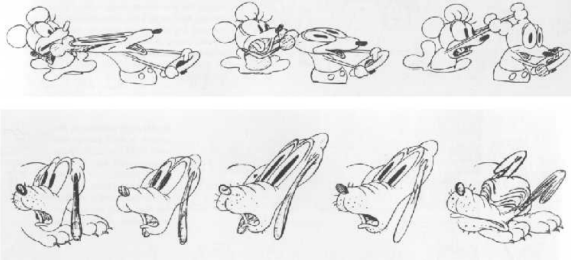Background
Source: Wikipedia

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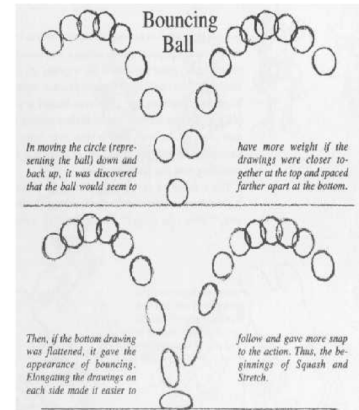
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Squash and Stretch
[convey rigidity and mass of an object by distorting its shape]

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

Bouncing Ball

In moving the circle (representing the ball) down and back up, it was discovered that the ball would seem to have more weight if the drawings were closer together at the top and spaced farther apart at the bottom.

Then, if the bottom drawing was flattened, it gave the appearance of bouncing. Elongating the drawings on each side made it easier to follow and gave more snap to the action. Thus, the beginnings of Squash and Stretch.

Slow in and out
[the spacing of the in-between frames to achieve subtlety of timing and movement]
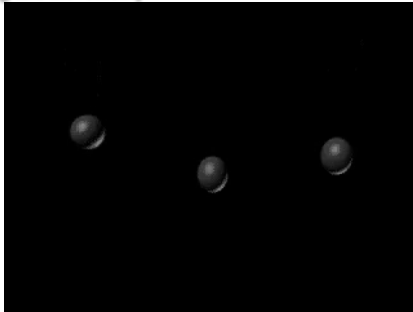
Source: SIGGRAPH   15

Anticipation
[the preparation for an action]
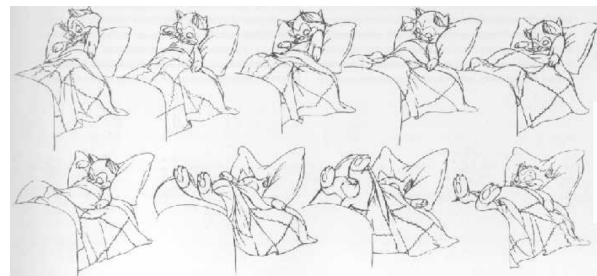

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Follow-through
[the termination of an action and establishing its relationship to the next action]

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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
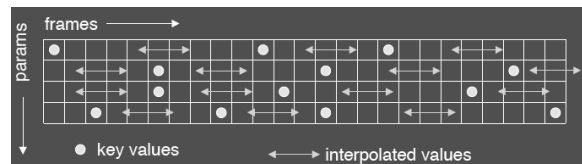
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Keyframing: Issues

- 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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