



## Basic Animation Techniques

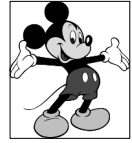
- Traditional (frame by frame)
- Keyframing
- Procedural techniques
- Behavioral techniques (e.g., flocking)
- Performance-based (motion capture)
- Physically-based (dynamics)

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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)
- 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



Source: Wikipedia and Disney

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## Traditional Animation Process

- Story board: sequence of sketches with story



A Bug's Life [Pixar, 1998]

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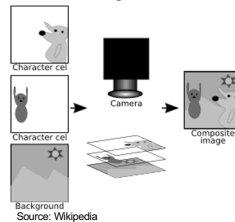
## Traditional Animation Process

- 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

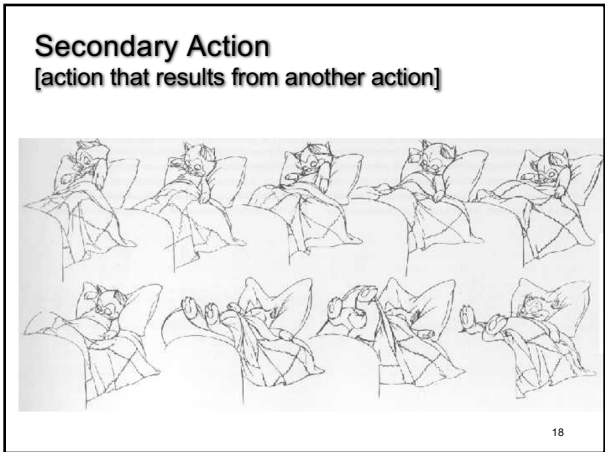
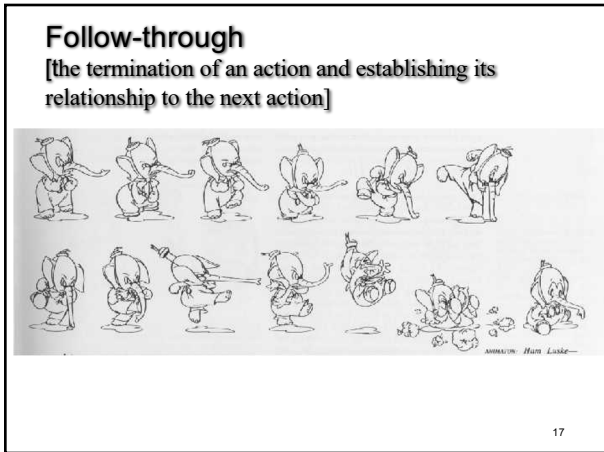
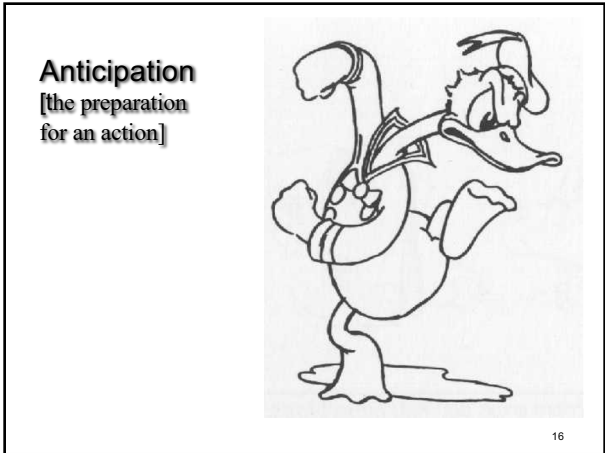
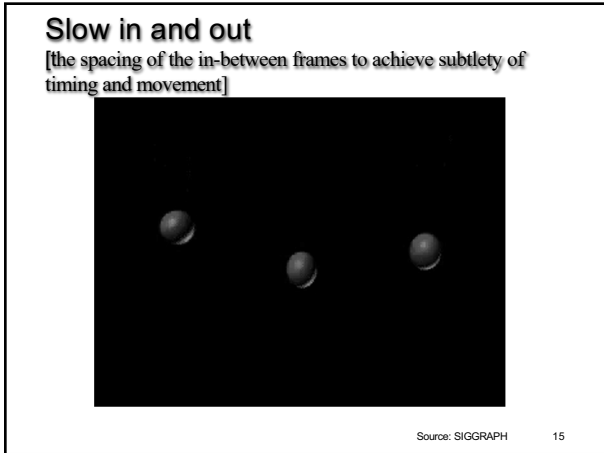
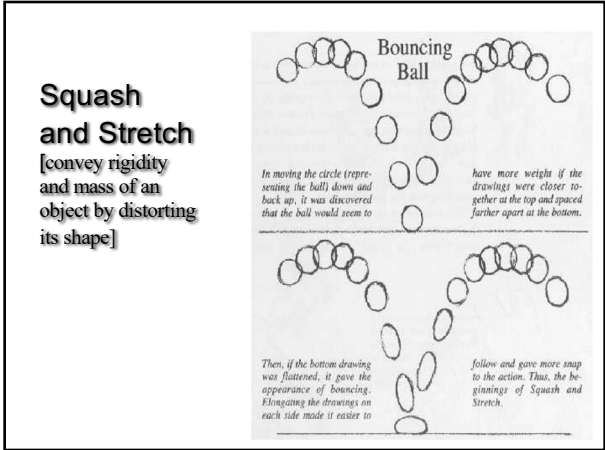
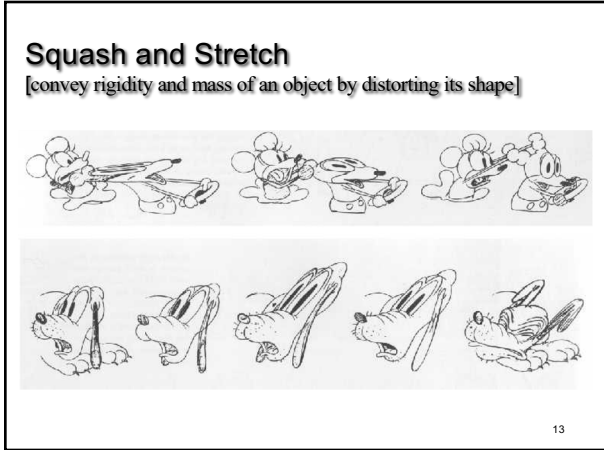
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## Principles of Traditional Animation [Lasseter, SIGGRAPH 1987]

- 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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## 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

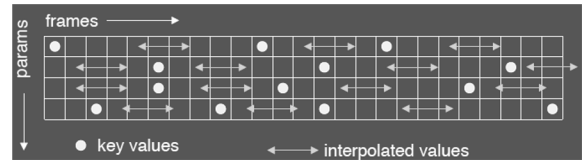
- Hard to interpolate hand-drawn keyframes
  - Computers don't help much
- The situation is different in 3D computer animation:
  - Each keyframe is defined by a bunch of parameters (state)
  - Sequence of keyframes = points in high-dimensional state space
- Computer inbetweening interpolates these points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

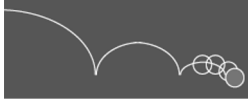
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## Interpolation

- 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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