Preview

- Overview
- Traditional animation
- Keyframe animation
- Procedural animation
- Motion paths
- Articulated animation
- Collision detection
- Dynamics
- Animation languages
- Animation systems
Traditional Animation Overview

- **Traditional animation process**
  - Animator creates a *storyboard* that outlines the story
    - Just enough sketches to be able to summarize the story
  - Animator draws a series of “key” frames
    - Identify all important poses among characters and objects in every scene
  - Junior artists draw all the *in between* key frames
    - Called “inbetweening” or “tweening”
  - Pre-viewing done with flip charts and incomplete images
  - Each *frame* generated and photographed separately
  - First done with pencil drawings
  - When all is ready, final color drawings done

Two ½ D

- Scene background doesn’t change much (or at all) from frame to frame; why re-draw it?
  - Draw background separately
  - Draw foreground on transparent *celluloid* sheet
  - Mount foreground over the background and photograph
  - Called *cel animation* (began in 1915)
- **Multiplane cameras** evolved from *cel animation*
  - Disney built 7-plane camera in 1937
    - Planes at varying distances apart, can slide in plane for panning
    - Scenes painted in oils on the glass
    - Used in *Snow White* and later classics
  - 2 neighboring planes moving in opposite directions can give impression of rotation
Principles of Traditional Animation*

- **Squash and stretch**: shape distortion
- **Timing**: can affect sense of object and personality
- **Anticipation**: sets up expectation of coming action
- **Staging**: presenting an idea so it is unmistakably clear
- **Follow through and overlapping action**: make end of an action very clear as well as its relation to next action.
- **Straight-ahead action and pose-to-pose action**: choices
- **Slow in and out**: varying inbetween spacing changes effect
- **Arcs**: visual path for action needs to be natural
- **Exaggeration**: helps to clarify action, make it more “real”
- **Secondary action**: one action leads to another
- **Appeal**: hardest part

*Lasseter, J., Principles of traditional animation applied to 3D computer animation, Siggraph ‘87.*
Squash and Stretch

- Rigid shape during motion isn’t very “realistic”
- Better to exaggerate near discontinuities

Squash and Stretch 2

- Squash and stretch can also make fast action more realistic and less jerky or strobing
  - Top image: slow movement; overlap makes animation smooth
  - Middle image: very fast motion; can get strobing or jerky motion
  - Bottom image: stretching object so frame positions overlap yields same speed, but smoother
Timing Matters a Lot

- Speed of action can make huge difference in perceived meaning of the action
  - Audience should
    - anticipate an action
    - understand the action and what it means
    - see and understand the reaction to the action
  - Too much time for any or all of these, audience loses attention
  - Too little time, audience misses the action or its effects
- Timing defines the weight of an object
  - heavy objects accelerate and decelerate more slowly

Timing and Emotion

- Emotional state of a character can be inferred from timing as much as anything.
- Consider two key frames of a head: one looking over left shoulder, the other over the right
  - 0 inbetweens: head hit by tremendous force
  - 1 inbetween: head hit by brick or rolling pin
  - 2 inbetweens: character has a nervous tic or muscle spasm
  - 3 inbetweens: character is dodging a brick
  - 4 inbetweens: character is giving a brisk order: “Move it!”
  - 5 inbetweens: character is more friendly: “Come on over”
  - 6 inbetweens: character sees a beautiful woman or a hunk
  - 7 inbetweens: character tries to get a better look at something
  - 8 inbetweens: character is searching for something
  - 9 inbetweens: character is deep in thought
Actions

• Every action should have 3 parts: anticipation, staging, reaction
• Anticipation
  – include something to be sure audience is looking at the right character for the action that is to occur
• Staging
  – present the action so its goal is completely clear
  – only one idea at a time
• Follow through and overlapping action
  – the action should complete with any appropriate follow through and lead to the next action with reasonable overlap

Slow In and Out

• Uniform spacing isn’t realistic
  – vary inbetween timing and
  – use squash and stretch

FIGURE 9. Timing chart for ball bounce.
Traditional Computer Animation

- Computer animation software
  - provides tools for interactive specification and previewing of 2D, 2½D and 3D animation
  - 3D tools are now very powerful
- Originally were 3 major approaches
  - Image-based key frame animation
  - Parametric key frame animation
  - Procedural animation

Image-based Keyframe Animation

- Identify corresponding points in adjacent key frames
- Linearly interpolate the intervening positions.
- Easy to do, once you have correspondences
- Linear interpolation is not very realistic; cubic splines often used
- Can get more shape changes by introducing new points
Parametric Keyframe Animation

• Can also interpolate parameters of the model rather than just location information
• Parameters could represent almost anything:
  – position: x(t), y(t), z(t)
  – size: radius(t)
  – visualization parameters: color, texture mapping, etc.
• Each key frame needs to identify the parametric value(s) associated with it, so can interpolate between them
• Generally, some form of spline interpolation is preferred, often cubic

Procedural Animation

• The motion/shape/characteristics of an object can be controlled by a procedure (or procedures).
• A motion procedure is invoked once per frame and it determines the new parameters for the object for that frame:
  – can use physically correct equations of motion that take weight, gravity, mass, speed, etc. into account
  – can use physically impossible shape transformations (morphing)
  – can use anything you can program!
Motion Paths

• An object may need to follow a specified path in space
  – perhaps, pre-defined
  – perhaps, generated dynamically based on conditions
• Speed
  – could be constant
  – determined procedurally based on the path (is it going uphill or downhill? is it rough terrain or smooth terrain?)
  – based on other factors such as visibility, other objects, etc.
• Is the path on a surface or in space?
• Does the path imply the object’s orientation?

Motion Path Example

• Consider a simple motion path defined by a sequence of positions in space:
  \[ P_i = (x_i, y_i, z_i) \]
• Draw a (spline?) curve through the points
• Move an object’s position along the curve at some speed which translates to distance per frame
• Can use tangent to the curve to rotate the object so it is heading along the curve
• Relatively easy to create a parametric quadratic or cubic spline through these points
  – and have the object follow the curve
Camera Animation

- Often desirable to move a camera through a scene
  - Specify a motion path for the eye point
  - Specify how other parameters (such as those in `gluLookAt`) should change with respect to the eye
    - could have the eye to lookAt vector be tangent to the curve
    - could have the lookAt point be fixed location

Articulated animation

- Consider a hierarchically defined complex object whose parts can move separately (humanoid)
  - Entire body can be moving
  - Parts can be moving as well
    - some parts may be determining the body motion (legs)
    - some parts may move independent of the body motion, but are still constrained characteristics of the model
- How is it done at the low level?
  - Based on a scene graph hierarchy
  - Some nodes in hierarchy are joints with degrees of freedom represented by joint angles
  - Joint transformations cannot violate constraints on joint angles
Collision detection

- Collision detection is a big deal in real-time
  - brute force is $n^2$ problem
  - need to use hierarchical bounding box and spatial subdivision techniques
  - special care needs to be taken for small fast objects
    - They could pass over another object in one frame
    - Need a test to make sure that the path of an object does not intersect another object in the frame

Kinematic Motion Specification

- Kinematics, or forward kinematics
  - calculate new position of each (part of) an object based on its current position, motion specification and constraints
- Inverse kinematics
  - given current position of articulated body, and desired “final” position (like a key frame) and the constraints, calculate intermediate positions
  - example: animator interactively positions the hand at desired next position, software calculates the required joint angles for the hand, the forearm, the upper arm, the shoulder, etc.
  - requires nonlinear programming
Dynamics

- Kinematics and inverse kinematics do not take physics into account (accept via joint constraints)
  - mass, gravity, inertia, friction, etc.
- More realistic animation is achieved by creating software to simulate these physical laws

Advanced Topics

- Animation languages and systems
- Motion capture animation
- Autonomous behavior
  - avoidance/attraction heuristics
  - swarming
  - other group behavior
- Event-driven procedural animation
- Real-time animation
  - virtual worlds
- Facial animation
- Morphing