Animation Pipeline
Keyframing Introduction

COMPUTER ANIMATION
15-497/15-861
Producing an Animation

• Film runs at 24 frames per second (fps)
  – That’s 1440 pictures to create per minute
  – 1800 fpm for video (30fps)

• Productions issues:
  – Need to stay organized for efficiency and cost reasons
  – Need to create 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

A lesson you will painfully learn in this class!
Traditional Animation: The Process

• Story board
  – Sequence of drawings with descriptions
  – Story-based description

• Key Frames
  – Draw a few important frames as line drawings
    » For example, beginning of stride, end of stride
  – Motion-based description

• Inbetweens
  – Draw the rest of the frames
  – People who draw these don't get paid much

• Painting
  – Redraw onto acetate Cels, color them in
  – These people get paid even less

From http://www.animationartgallery.com/
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 together on a copy stand
  - Transfer onto film by taking a photograph of the stack

From http://www.animationartgallery.com/
Computer-Assisted Animation

• Computerized Cel painting
  – Digitize the line drawing, color it using seed fill
  – Eliminates cel painters (low rung on totem pole)
  – Widely used in production (little hand painting any more)
  – e.g. *Lion King*

• Cartoon Inbetweening
  – Automatically interpolate between two drawings to produce inbetweens (morphing)
  – Hard to get right
    » inbetweens often don’t look natural
    » what are the parameters to interpolate? Not clear...
    » not used very often
True Computer Animation

• Generate the images by rendering a 3-D model
• Vary the parameters to produce the animation
• Brute force
  – Manually set the parameters for each and every frame
  – For an \( n \) parameter model: \( 1440n \) values per minute
• Computer keyframing
  – Lead animators create the important frames with 3-D computer models
  – Unpaid computers draw the inbetweens
  – The dominant production method
Digital Production Pipeline

- Story
- Visual Development
- Character Design
- Storyboards
- Scene Layout
- Modeling
- Animation
- Shading and Texturing
- Lighting
- Rendering
- Post Production
Story

• Different types of stories
  – beginning/middle/end with conflict and resolution (drama)
    » Red’s Dream
  – sequences built around a situation
    » Mickey Mouse
  – String of Gags
    » Roadrunner

• Story is the most important part of any animation
  – 1 big, simple idea
  – the story you can tell in 2 sentences
  – Shorts are particularly hard to get right
Visual Development

• What look will your scenes have?
• Who are the characters and how do they look?
• Develop style
• Includes the creation of characters, environments (desert, swamp), props, etc.
• Involves painters, sculptors, illustrators, etc.

Lots of drawings pasted up on the wall!
Character Design

• After story come characters
• Consists mostly of drawings, or sculptures
  – body poses
  – facial expressions
  – key features from multiple points of view

Note the lack of computers at this stage!
Storyboards

• The film in outline form
  – specify the key scenes
  – specify the camera moves and edits
  – specify character gross motion

• Typically paper and pencil sketches on individual sheets taped on a wall

Still not very many computers…
Story Boarding (from “A Bug’s Life”)
What makes a good storyboard?

• Does the shot sequence
  – maintain continuity
  – not confuse the audience
  – contain variations in pacing
• Is the information clearly presented?
• Are the characters clearly portrayed?
• Is the story clear?
• Do you have the techniques necessary to pull it off?
• Can you do it with the time and $ you have?
Scene Layout

Design the scenes

• for example, build the room with an understanding of the camera pan
• create colors
• create textures
• create props
• keep in mind camera and character motion within the scene
• use placeholder geometry and start to design camera moves
Modeling

• Create geometric models of environment, props, characters

• Keep in mind the ultimate purpose of the model – feature film, game, etc.

• Set up internal skeleton and animation handles appropriately for that character’s behaviors
Scene from Toy Story II
From the “Making of Toy Story”
Post Production

- Sound track sync
- Titles
- Cuts and effects (dissolves, fades, etc)

Rendering

- Frames can take hours to render
- 1800 frames for a single minute of animation
- Pixar has a HUGE renderfarm
Animation Pipeline
Keyframing Introduction
What is a key?

• Hard to interpolate hand-drawn images
  – Computers don’t help much

• The situation is different in 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
What is a key?

• For a bouncing ball?
  – Position in 3D
  – Orientation?
  – Squishedness?

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.
What is a key?

- For a monster?
  - Position and orientation in 3D
  - Joint angles of the hierarchy
  - Deformations?
  - Facial features
  - Hair/fur???
  - Clothing???
Splines for Interpolation

• Splines: non-uniform, $C^1$ 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 continuity/control do we need?
How Do You Interpolate Between Keys?

\[ y'_i = \frac{(y_{i+1} - y_{i-1})}{(t_{i+1} - t_{i-1})} \]

\[ y_i = \text{spline}(i-1,i) \]

\[ y_{i+1} = \text{spline}(i,i+1) \]
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
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 walls)
  – Unnatural motions
    » Painful twists/bends
    » Going the “long way around”
  – Jerky motion
Keyframe Animation: 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

• Gives good control over motion

• Eliminates much of the labor of traditional animation
  – But still very labor-intensive

• Impractical for complex scenes with everything moving: grass in the wind, water, and crowd scenes, for example
Next Class

• Representation of joint angles
  – Euler angles
  – Quaternions

• Interpolation of quaternions

Very important for the first assignment!