Lecture 20: Intro to Animation
Topics

History, goals and principles
Artist-driven animation: rigging, posing, keyframing
Computer aids: forward & inverse kinematics
Data-driven animation: motion capture

Procedural animation: physical simulation
Animation

“Bring things to life”

• Communication tool

• Aesthetic issues often dominate technical issues

An extension of modeling

• Represent scene models as a function of space

Output: sequence of images that when viewed sequentially provide a sense of motion

• Film: 24 frames per second

• Video: 30 fps

• Virtual reality: 90 fps
Historical Points in Animation
(slides courtesy Keenan Crane)
First Animation

(Shahr-e Sukhteh, Iran 3200 BCE)
History of Animation

(tomb of Khnumhotep, Egypt 2400 BCE)
History of Animation

(Phenakistoscope, 1831)
First Film

Originally used as scientific tool rather than for entertainment

Critical technology that accelerated development of animation

Edward Muybridge, “Sallie Gardner” (1878)
First Hand-Drawn Feature-Length Animation

Disney, "Snow White and the Seven Dwarfs" (1937)
First Digital-Computer-Generated Animation

Ivan Sutherland, “Sketchpad” (1963) – Light pen, vector display
Early Computer Animation

Ed Catmull & Frederick Parke, “Computer Animated Faces” (1972)
Digital Dinosaurs!

Jurassic Park (1993)
First CG Feature Film

First Fully Clothed CG Character

Animated Short Film, Pixar, "Geri's Game" (1997)
Clothing was dynamically simulated
Computer Animation - Present Day

Sony Pictures Animation, “Cloudy With a Chance of Meatballs” (2009)
Animation Principles
(slides courtesy Mark Pauly)
Animation Principles

From


In turn from

• “The Illusion of Life”
  Frank Thomas and Ollie Johnston

Same for 2D and 3D

http://www.siggraph.org/education/materials/HyperGraph/animation/character_animation/principles/prin_trad_anim.htm
Squash and Stretch

Refers to defining the rigidity and mass of an object by distorting its shape during an action.

Shape of object changes during movement, but not its volume.
Timing

Rate of acceleration conveys weight

Speed and acceleration of character’s movements convey emotion

Timing for Animation, Whitaker & Halas
Anticipation

Prepare for each movement
For physical realism
To direct audience’s attention

Timing for Animation, Whitaker & Halas
Follow Through

Overlapping motion
Motion doesn’t stop suddenly
Pieces continue at different rates
One motion starts while previous is finishing, keeps animation smooth

Timing for Animation, Whitaker & Halas
Staging

Picture is 2D
Make situation clear
Audience looking in right place
Action clear in silhouette

Disney Animation: The Illusion of Life
Ease-In and Ease-Out

Movement doesn’t start & stop abruptly.
Also contributes to weight and emotion
Arcs

Move in curves, not in straight lines

This is how living creatures move

Disney Animation: The Illusion of Life
Exaggeration

Helps make actions clear
Helps emphasize story points and emotion
Must balance with non-exaggerated parts

Timing for Animation, Whitaker & Halas
Secondary Action

Motion that results from some other action

Needed for interest and realism

Shouldn’t distract from primary motion
Appeal

Attractive to the eye, strong design

Avoid symmetries

Disney Animation: The Illusion of Life
Personality

Action of character is result of its thoughts
Know purpose & mood before animating each action
No two characters move the same way
Further Reading

- The Illusion of Life: Disney Animation by Frank Thomas and Ollie Johnston
- Timing for Animation by Harold Whitaker and John Halas
- Cartoon Animation by Preston Blair
12 Animation Principles

1. Squash and stretch
2. Anticipation
3. Staging
4. Straight ahead and pose-to-pose
5. Follow through and overlapping
6. Slow in and slow out
7. Arcs
8. Secondary action
9. Timing
10. Exaggeration
11. Solid drawings
12. Appeal
12 Animation Principles

Applications:

• Movies
• Games
• User interfaces
• ...

CS184/284A, Lecture 22
Ren Ng, Spring 2016
Computer Animation
Keyframe Animation

Animator (e.g. lead animator) creates keyframes
Assistant (person or computer) creates in-between frames ("tweening")

Keyframes

"Tweens"
Keyframe Interpolation

Think of each frame as a vector of parameter values

Hearn, Baker and Carithers, Figure 16.11
Keyframe Interpolation of Each Parameter

Linear interpolation usually not good enough

Recall splines for smooth / controllable interpolation
Forward Kinematics
(Slides with James O’Brien)
Forward Kinematics

Articulated skeleton

- Topology (what’s connected to what)
- Geometric relations from joints
- Tree structure (in absence of loops)

Joint types

- Pin (1D rotation)
- Ball (2D rotation)
- Prismatic joint (translation)
Forward Kinematics

Example: simple two segment arm in 2D
Forward Kinematics

Animator provides angles, and computer determines position \( p \) of end-effector

![Diagram of a two-segment arm with equations for \( p_z \) and \( p_x \)]

\[
\begin{align*}
    p_z &= l_1 \cos(\theta_1) + l_2 \cos(\theta_1 + \theta_2) \\
    p_x &= l_1 \sin(\theta_1) + l_2 \sin(\theta_1 + \theta_2)
\end{align*}
\]

Warning: Z-up Coordinate System
Forward Kinematics

Animation is described as angle parameter values as a function of time

\[ p_z = l_1 \cos(\theta_1) + l_2 \cos(\theta_1 + \theta_2) \]

\[ p_x = l_1 \sin(\theta_1) + l_2 \sin(\theta_1 + \theta_2) \]
Example: Walk Cycle

Articulated figure:

- Hip
  - Upper leg
    - Knee
      - Lower leg
        - Ankle
          - Foot

- Upper leg (hip rot)
  - Hip rotate
    - Lower leg (knee rot)
      - Hip rotate + knee rot
        - Foot (ankle rot)

Watt & Watt

Slide credit: Tom Funkhouser
Example: Walk Cycle

Hip joint angle

Slide credit: Tom Funkhouser
Example: Walk Cycle

Knee joint angle

Slide credit: Tom Funkhouser
Example: Walk Cycle

Ankle joint angle
Example Walk Cycle
Inverse Kinematics
Inverse Kinematics

Egon Pasztor
Inverse Kinematics

Animator provides position of end-effector, and computer must determine joint angles that satisfy constraints
Inverse Kinematics

Direct inverse kinematics: for two-segment arm, can solve for parameters analytically

\[
\begin{align*}
\theta_2 &= \cos^{-1} \left( \frac{p_z^2 + p_x^2 - l_1^2 - l_2^2}{2l_1 l_2} \right) \\
\theta_1 &= \frac{-p_z l_2 \sin(\theta_2) + p_x (l_1 + l_2 \cos(\theta_2))}{p_x l_2 \sin(\theta_2) + p_z (l_1 + l_2 \cos(\theta_2))}
\end{align*}
\]
Inverse Kinematics

Why is the problem hard?

- Multiple solutions separated in configuration space
Inverse Kinematics

Why is the problem hard?

- Multiple solutions connected in configuration space
Inverse Kinematics

Why is the problem hard?

• Solutions may not always exist
Inverse Kinematics

Numerical solution to general N-link IK problem

• Choose an initial configuration

• Define an error metric (e.g. square of distance between goal and current position)

• Compute gradient of error as function of configuration

• Apply gradient descent (or Newton’s method, or other optimization procedure)
Style-Based IK

Grochow et al., Style Based Inverse Kinematics
Kinematics Pros and Cons

Strengths

• Direct control is convenient
• Implementation is straightforward

Weaknesses

• Animation may be inconsistent with physics
• Time consuming for artists
Rigging
Rigging

Rigging is a set of higher level controls on a character that allow more rapid & intuitive modification of pose, deformations, expression, etc.

Important

• Like strings on a puppet
• Captures all meaningful character changes
• Varies from character to character

Expensive to create

• Manual effort
• Requires both artistic and technical training
Types of Rigging

- Procedural Rigging
- Skeletal Rigging
- Anatomical Rigging

Skeleton
Skinning on top


Posing

Use the rigging controls to put the character into a given pose.
Rigging Example

Courtesy Matthew Lailler via Keenan Crane
Blend Shapes

Instead of skeleton, interpolate directly between surfaces

E.g., model a collection of facial expressions:

Simplest scheme: take linear combination of vertex positions

Spline used to control choice of weights over time
Blend Shapes

Courtesy Félix Ferrand
Motion Capture
Motion Capture

Data-driven approach to creating animation sequences

- Record real-world performances (e.g. person executing an activity)
- Extract pose as a function of time from the data collected

Motion capture room for ShaqFu
Motion Capture Pros and Cons

Strengths

• Can capture large amounts of real data quickly
• Realism can be high

Weaknesses

• Complex and costly set-ups
• Captured animation may not meet artistic needs, requiring alterations
Motion Capture Equipment

**Optical**
(More on following slides)

**Magnetic**
Sense magnetic fields to infer position / orientation.
Tethered.

**Mechanical**
Measure joint angles directly.
Restricts motion.
Optical Motion Capture

- Markers on subject
- Positions by triangulation from multiple cameras
- 8+ cameras, 240 Hz, occlusions are difficult

Retroreflective markers attached to subject

IR illumination and cameras

Slide credit: Steve Marschner
Optical Motion Capture

Source: http://fightland.vice.com/blog/ronda-rousey-20-the-queen-of-all-media

Ronda Roussey in Electronic Arts’ motion capture studio
Motion Data

Subset of motion curves from captured walking motion.

From Witkin and Popovic, 1995
Challenges of Facial Animation

Uncanny valley

• In robotics and graphics

• As artificial character appearance approaches human realism, our emotional response goes negative, until it achieves a sufficiently convincing level of realism in expression
Challenges of Facial Motion Capture

Final Fantasy Spirits Within
Facial Motion Capture

Discovery, “Avatar: Motion Capture Mirrors Emotions”, https://youtu.be/1wK1lxr-UmM
Things to Remember

Principles of animation
Computer character animation
Rigging, posing, keyframes, interpolation
Forward and inverse kinematics
Motion capture: data driven animation
Acknowledgments

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