What is animation?
- Make objects change over time according to scripted actions

What is simulation?
- Predict how objects change over time according to physical laws

Thomas Funkhouser
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COS 426, Fall 2000

University of Illinois
Pixar
Outline

- Principles of animation
- Keyframe animation
- Articulated figures

Principles of Traditional Animation

- Squash and stretch
- Slow In and out
- Anticipation
- Exaggeration
- Follow through and overlapping action
- Timing
- Staging
- Straight ahead action and pose-to-pose action
- Arcs
- Secondary action
- Appeal
**Principles of Traditional Animation**

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Disney

Principles of Traditional Animation

- Slow In and Out

Watt Figure 13.5
Principles of Traditional Animation

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Disney

Principles of Traditional Animation

- Anticipation (and squash & stretch)

Lasseter ‘87
Principles of Traditional Animation

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Disney

Computer Animation

- Animation pipeline
  - 3D modeling
  - Motion specification
  - Motion simulation
  - Shading, lighting, & rendering
  - Postprocessing

Pixar
Keyframe Animation

- Define character poses at specific time steps called “keyframes”

Keyframe Animation

- Interpolate variables describing keyframes to determine poses for character in between
Keyframe Animation

- Inbetweening:
  - Linear interpolation - usually not enough continuity

![Linear interpolation graph](image1)

H&B Figure 16.16

Keyframe Animation

- Inbetweening:
  - Spline interpolation - maybe good enough

![Spline interpolation graph](image2)

H&B Figure 16.11
Keyframe Animation

• Inbetweening:
  ◦ Cubic spline interpolation - maybe good enough
    » May not follow physical laws

Lasseter '87
Keyframe Animation

- Inbetweening:
  - Inverse kinematics or dynamics

Outline

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Articulated Figures

- Character poses described by set of rigid bodies connected by “joints”

Scene Graph

Articulated Figures

- Well-suited for humanoid characters

Scene Graph
Articulated Figures

- Joints provide handles for moving articulated figure

Articulated Figures

- Inbetweening
  - Compute joint angles between keyframes
Example: Walk Cycle

- Articulated figure:

![Articulated figure diagram]

- Hip joint orientation:

![Hip joint orientation diagram]
Example: Walk Cycle

- Knee joint orientation:

  ![Knee joint orientation](image1)

Example: Walk Cycle

- Ankle joint orientation:

  ![Ankle joint orientation](image2)
Example: Run Cycle

Example: Ice Skating

(Mao Chen, Zaijin Guan, Zhiyan Liu, Xiaohu Qie, CS426, Fall98, Princeton University)
Example: Horse

Challenges of Animation

- Temporal aliasing
  - Motion blur
Temporal Aliasing

- Artifacts due to limited temporal resolution
  - Strobing
  - Flickering
Temporal Aliasing

- Artifacts due to limited temporal resolution
  - Strobing
  - Flickering
Motion Blur

- Composite weighted images of adjacent frames
  - Remove parts of signal under-sampled in time

Summary

- Animation requires ...
  - Modeling
  - Scripting
  - Inbetweening
  - Lighting, shading
  - Rendering
  - Image processing