Animation
Itinerary

- Review—Basic Animation
- Keyed Animation
- Motion Capture
- Physically-Based Animation
- Behavioral Animation
What is Animation?

“Making things move”
What is Animation?

Consider a model with $n$ parameters
- Polygon positions, control points, joint angles...
- $n$ parameters define an $n$-dimensional state space

An animation is a path through the state space

Animation is the task of specifying a state space trajectory
Modeling vs. Animation

- **Modeling:** What are the parameters?
- **Animation:** How do the parameters change?
- Two inter-dependent processes, one cannot be done without the other in mind
- Sometimes hard to distinguish one from the other
Animation Methods

- Frame-by-frame
  - Traditional cel animation, ignored here
- Keyframing, or keyed animation
  - Specify only important values, interpolate
- Performance-based
  - Motion capture, real-world data recorded
Animation Methods

- **Procedural**
- **Physically-based**
  - Dynamics
  - Gravity, rigid bodies, spring-mass systems
- **Behavioral**
  - "Decision-based"
  - Includes grouping/flocking
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Keyframing

Given two hand-drawn keyframes, how should we interpolate between them?
Keyframing

- Computer animation defines “keyframes” on several different parameters.
- A sequence of “keyframes” is a sequence of points in multi-dimensional state space.
- These may be interpolated between relatively easily.
Keys vs. Keyframes

In computer animation, there’s no need for keys to fall on certain frames or occur at the same time for all values (all we care about is obtaining a path through state space for each parameter)

Each parameter may have values specified at places known to be important for that parameter, and paths for all parameters are determined independently
Which parameters are keyed?

- **For a rigid object:**
  - Position, orientation
- **For a deformable object:**
  - Position, orientation, squish/stretch
- **For a character:**
  - …
Which parameters are keyed?

- For a character:
  - Position/orientation
  - Joint angles
  - Squish/stretch (think cartoons)
  - Facial expressions
  - Breathing?
  - Hair?
  - Clothes?
  - …
How are keys specified?

- Manually by the animator
- By a script
- Motion capture
How are keys interpolated?

- Splines! (surprise)
- Typical approach:
  - C1 continuity by default
  - Animators given ability to manipulate tangents at arbitrary points, breaking C1 continuity if desired
- Why is the above necessary?
  - Consider the motion of the foot of a running character
Issues with keyed motion

- Which parameters should be keyed?
- When should keys occur?
- How should keys be specified?
- Bad things that can happen:
  - Invalid motion ("clipping")
  - Unnatural motion
    - Impossible bends or twists of joints
    - "The long way around" (think *The Exorcist*)
Keys are not good for everything!

- For motion which is governed by simple physics, simulate the physics!
- Anything which can be effectively generated by an algorithm probably should be (though the results of a non-realtime algorithm might be stored to keys)
- Keys are static—animation with any interactivity requires clever use of them
Keys and Interactivity?

Though keys themselves are static, they may still be used in interactive applications.

Examples:

- Often keys don’t need to change—animating a character’s walk cycle while changing its heading slightly looks acceptable.
- If a character changes from one action to another, interpolate from the current parameters to the first keys of the new trajectory.
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What is Motion Capture?

Motion capture is the process of tracking real-life motion in 3D and recording it for use in any number of applications.

In the context of computer animation, motion capture is a method of recording real-world data and mapping it onto a character we wish to move.
Why?

- Keys are generated by instruments measuring a performer—they do not need to be set manually.
- The details of human motion such as style, mood, and shifts of weight are reproduced with little effort.
Mocap Technologies

Optical passive

- Multiple high-res, high-speed cameras
- Light bounced from camera off of reflective markers
- High quality data
- Markers placeable anywhere
- Lots of work to extract joint angles
- Occlusion
- Which marker is which? (correspondence problem)
- 120-240 Hz @ 1 Megapixel
Mocap Technologies

Optical active

- Markers themselves emit signals
- Easy to determine which is which, no correspondence problem
Mocap Technologies

- Electromagnetic
  - Sensors give both position and orientation
  - No occlusion or correspondence problem
  - Little post-processing
  - Limited accuracy
Mocap Technologies

**Exoskeleton**
- Really Fast (~500Hz)
- No occlusion or correspondence problem
- Little error
- Movement restricted
- Fixed sensors
Motion Capture

Why not?

- Data captured is static key values, sometimes difficult to map to different situations
- Equipment can be expensive
Motion Capture

Why not?

- Difficult for non-human characters
  - Can you move like a gerbil?
  - Can you capture a gerbil’s motion?
- Actors needed
  - Which is more economical:
    - Paying an animator to place keys
    - Hiring a Martial Arts Expert
When to use Motion Capture?

Complicated character motion
- Where “uncomplicated” ends and “complicated” begins is up to question
- A walk cycle is often more easily done by hand
- A Flying Rabid Monkey Kick might be worth the overhead of mocap

Can an actor can better express character personality than the animator?
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Physically-based Animation

- HUGE field
  - Rigid body dynamics
  - Deformable objects
  - Mass-spring systems
  - Collision detection (and response)
  - Hair
  - Cloth
  - Fluids

This section is a brief review—see Chris’ lecture!
Physically-Based Animation

- Simulate the *physics* of the desired situation
- Common approach: Start with small, simple phenomena and use these as building blocks for more complex situations
- Typically involves many interacting forces, producing differential equations which must be solved or approximated
Example: Mass-spring system

- A single spring obeys Hooke’s Law (remember?)
  - $F = k(x - x_0)$
- Add a damping force:
  - $F = -kv$
Example: Mass-spring system

- A two-dimensional grid might be used to simulate cloth
- Adding constraints ("tacks") and a force of gravity produces a physical situation with which we’re familiar
Example: Mass-spring system

- A three-dimensional mass-spring structure can be used to simulate “jello”
- Unfortunately this is about the only type of motion that can be produced with this structure, and the urgent need to simulate gelatin doesn’t often arise
Issues with Physically-Based Animation

**Stability**
- Approximations of large systems of equations can easily cause a collapse or explosion due to compounded numerical error

**Efficiency**
- Accuracy can be very costly, and building a system that is both stable and efficient is a nontrivial task.
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Behavioral Animation

- Includes grouping/flocking behavior
- Each character determines its own actions by making decisions given its surroundings
- A simple set of rules can lead to seemingly complex behavior
Behavioral Animation

Example: Boids, originally made in 1986


Each boid has three basic rules:

- Separation
  - Avoid crowding neighbors too closely
- Alignment
  - Steer to same heading as neighbors
- Cohesion
  - Navigate towards average position of neighbors
Behavioral Animation

- Most familiar use is probably crowd generation for movies
- Most-hyped case of this is the “MASSIVE” system used in the Lord of the Rings movies
Behavioral Animation

First, generic animation for each behavior is created (walk cycles, falling over, standing up, jumping up and down, etc).

After this relatively small number of clips is created, the animator may then specify motion on a very high level.
Behavioral Animation

Sequence of character decisions:

Animation:
- Plays walk cycle
- Transitions (interpolates) to jump sequence
- Plays jump sequence
- Transitions to run cycle
- Plays run cycle
- (while moving character appropriately)
Summary

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