15-462 Computer Graphics

Lecture 22

Animation

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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.

Motion Capture

- 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 @ 1Megapixel

Mocap Technologies

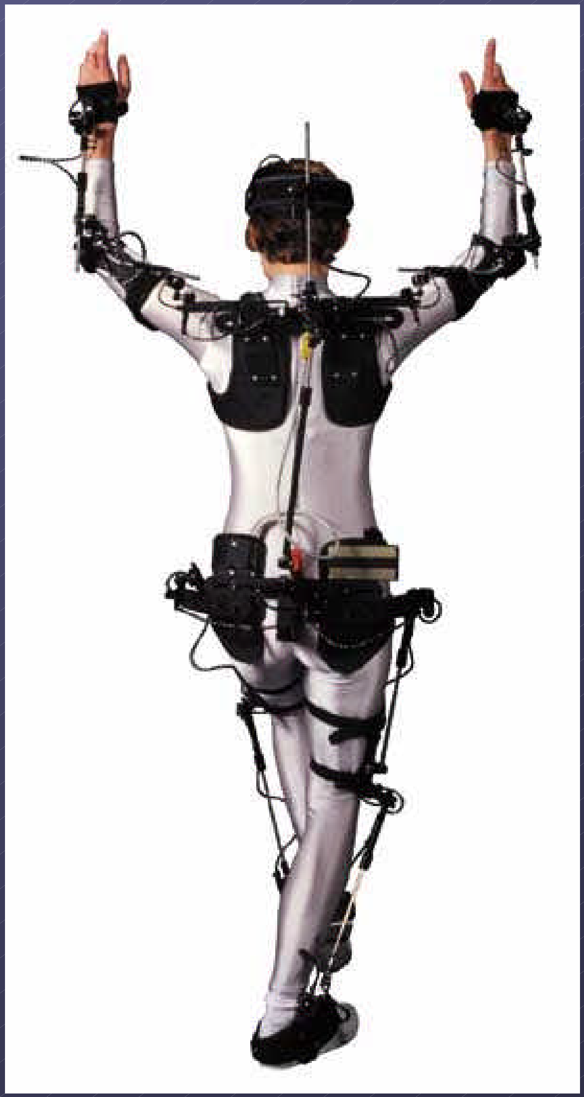
- Optical active
  - Markers themselves emit signals
  - Easy to determine which is which, no correspondence problem

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

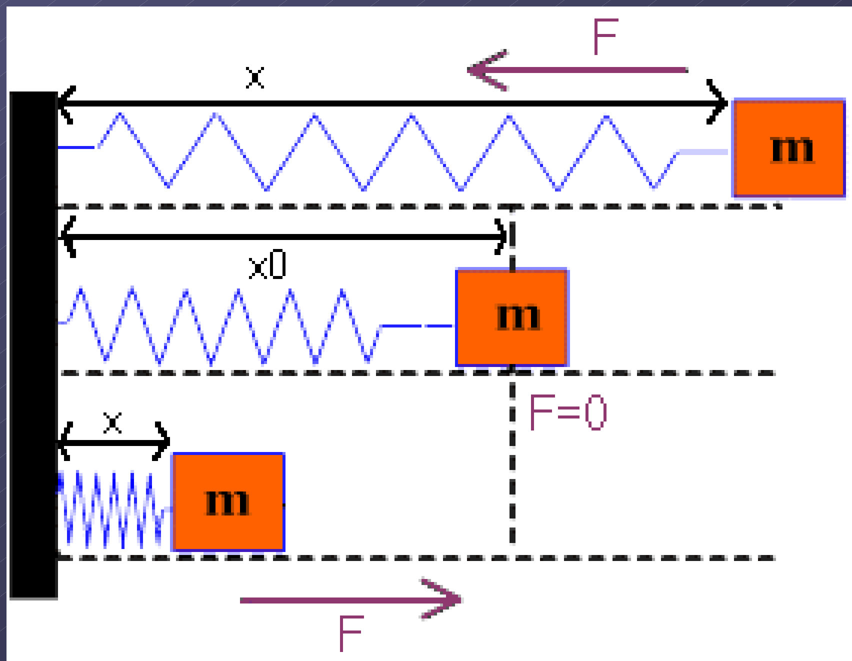
- HUGE field
  - Rigid body dynamics
  - Deformable objects
  - Mass-spring systems
  - Collision detection (and response)
  - Hair
  - Cloth
  - Fluids
- This section is a brief review—see Chris' lecture!

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

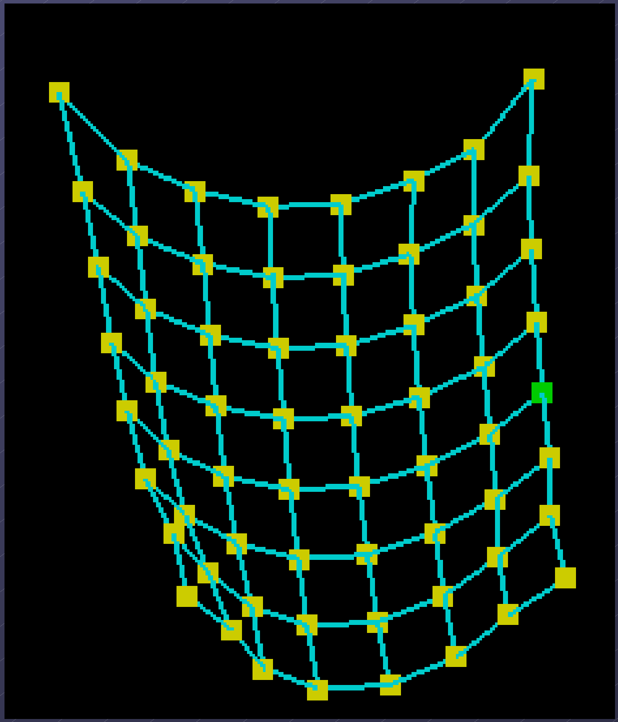
Example: Mass-spring system

- A single spring obey's Hooke's Law (remember?)
  - $F = k (x - x_0)$
- Add a damping force:
  - $F = -kv$



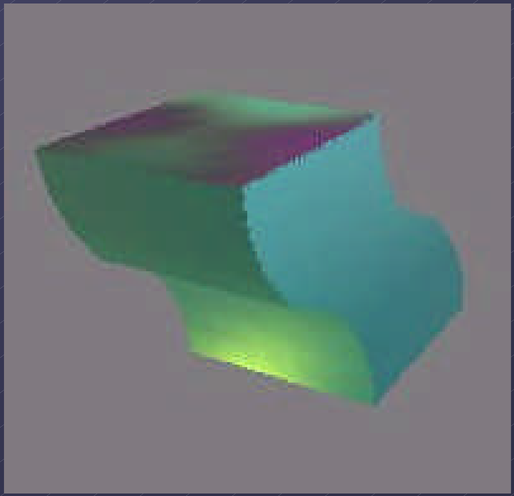
Example: Mass-spring system

- 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

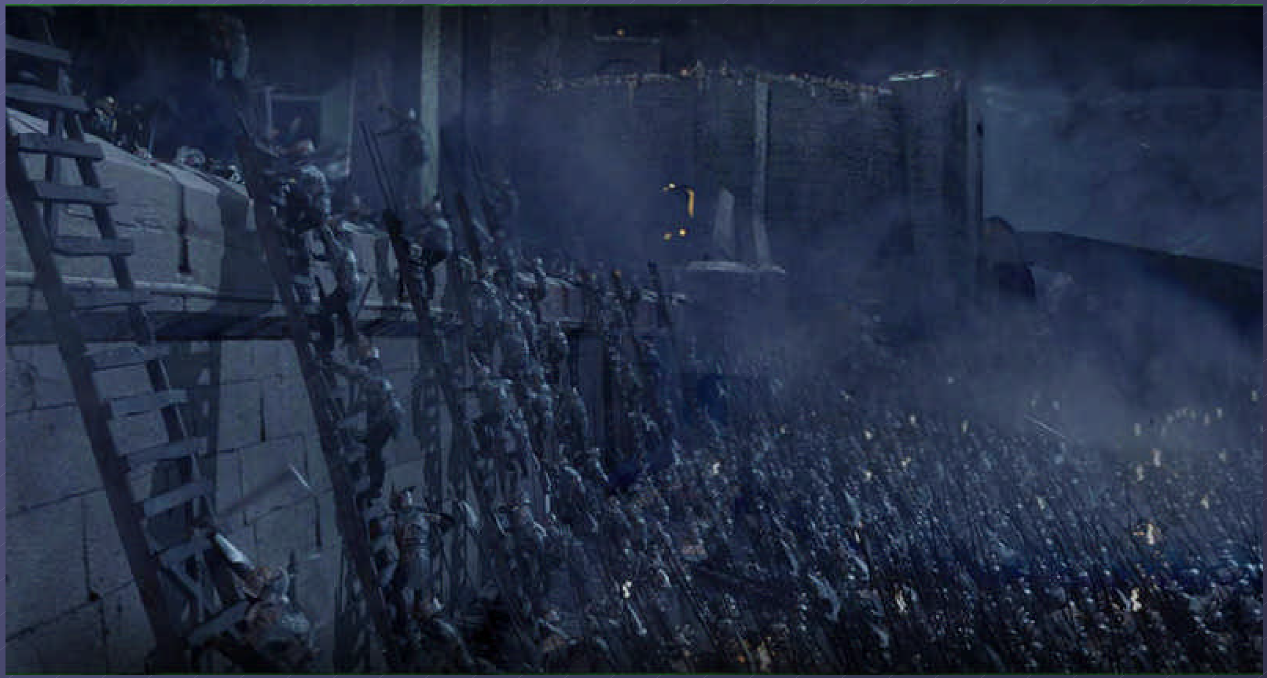
- Includes grouping/flocking behavior
- Each character determines its own actions by making decisions given its surroundings
- A simple set of rules can lead to seemingly complex behavior

Behavioral Animation

- Example: Boids, originally made in 1986
  - http://www.red3d.com/cwr/boids/
- 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:
  - “Walk. Jump. Run.”
- 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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