Coming up today

- Keyframe animation
- Procedural animation for basic character animation
  - Procedural animation with keyframe animation
  - Inverse kinematics
- Procedural animation as a broader field
  - Artificial life animation
  - Physics based modelling and animation
Basic keyframe animation

- Animator draws or models the starting and ending points of a transition, called keyframes, and sets their position in time.
- The remaining frames in between 2 keyframes are interpolated from them.
- The animator is in control of everything at every point in time.
Basic keyframe animation problems

- Transitions in interactive setting
  - Blend walking and running animation?
  - Create a walk ↔ run transition animation?
    - 15 animations - 105 blends required

- Unrealistic movement
  - No proper feedback from the environment
  - Not acceptable anymore
Procedural Animation

- a type of computer animation, used to automatically generate animation in real-time to allow for a more diverse series of actions than could otherwise be created using predefined animations
- Animator not in control of everything anymore
- a) Integrated with keyframe animation
  - Roughly follows keyframes
  - Change dynamically
    - e.g. getting hit while running, going up the stairs
- b) Fully procedural animation
  - Initial parameters and some sort of input parameters are provided to control the animation
    - Initial position; forces, torques in time
Keyframe + procedural animation

- Dynamic combining of multiple animations
  - Lower body running
  - Upper body swinging a sword
  - Body recoiling to a blow

- What you can achieve with just 14 keyframes and procedural animation:
To actually feel connected to the world...

- animated objects must physically be connected to it
  - Feet position should depend on the surface
  - Running into a wall
  - Climbing an object
- To do this, a technique called inverse kinematics is used
- First, we must understand what are rigging and kinematic chains
Rigging

- Digital skeleton
  - Parts that do not move relative to themselves
  - Joints connecting the parts
- Has an hierarchy called kinematic chain
  - E.g. abdomen → torso → left shoulder → left upper arm → left lower arm → palm → thumb
Inverse kinematics

- The mathematical process of recovering the movements of an object in the world from some other data
- When a finger is repositioned, what should rest of the body do?
  - Jacobian transpose method
  - Pseudoinverse method
  - Damped least squares method
  - Singular value decomposition method

- [https://www.youtube.com/watch?v=NxoIoW0mRtg](https://www.youtube.com/watch?v=NxoIoW0mRtg)
Fields of procedural animation

● Artificial life
  ○ Behavioral animation
  ○ Artificial evolution
  ○ Branching object generation
  ○ Facial features

● Physics-based modeling and animation
  ○ Particle systems
  ○ Rigid body dynamics
  ○ Fluid dynamics
  ○ Fur & hair dynamics
  ○ Flexible dynamics
    ■ Cloth
    ■ Ragdolling
Artificial life

- *Deals with things that are virtually alive*
- Behavioral animation
  - Simulates interactions of artificial lives
  - Flocking, predator-prey, virtual human behaviors
  - [https://www.youtube.com/watch?v=M028vafB0I8](https://www.youtube.com/watch?v=M028vafB0I8)
- Artificial evolution
  - Evolution of artificial life forms
  - Artificial life forms reproduce and mutate over time
- Branching object generation
  - Generating plants, trees etc and simulating their behaviour
  - L-systems, BOGAS
- Facial features
  - Mostly replaced with mo-cap and post-editing
Physics based modeling and animation

- *Deals with things that are not alive*
- Particle systems
  - Simulate behaviors of fuzzy objects, such as clouds, smoke, fire and water
- [https://www.youtube.com/watch?v=MPV3B4kTFL](https://www.youtube.com/watch?v=MPV3B4kTFL)
Physics based modeling and animation

- **Rigid body dynamics**
  - Simulates dynamic interaction among rigid objects
  - Takes into account various physical characteristics
    - Elasticity, friction, mass
  - [https://www.youtube.com/watch?v=VSQhvu8fZ0U](https://www.youtube.com/watch?v=VSQhvu8fZ0U)

- **Fluid dynamics**
  - Simulates flows, waves and turbulence of water and other liquids
  - [https://www.youtube.com/watch?v=U3acQ5dDKEs](https://www.youtube.com/watch?v=U3acQ5dDKEs)
Fur & hair dynamics

- It's hard to get it right: [https://www.youtube.com/watch?v=FexDVPd08qY](https://www.youtube.com/watch?v=FexDVPd08qY)
- For real time: AMD's TressFX and NVIDIA's HairWorks
  [https://www.youtube.com/watch?time_continue=83&v=qXRJZ1z3Fsg](https://www.youtube.com/watch?time_continue=83&v=qXRJZ1z3Fsg)
HairWorks

- [https://www.youtube.com/watch?v=VFWr44ZIEZc](https://www.youtube.com/watch?v=VFWr44ZIEZc)
Flexible dynamics: cloth

- Simulates behaviors of flexible objects, e.g. clothes
- Geometric method
  - Only good for static frames
    1. Cloth divided into vertices
    2. Vertices positions are calculated
    3. Vertices are connected with curves
- Physical method
  - Cloth is treated as a vertex grid connected by springs
  - Each vertex has a point mass
  - Mechanical equilibrium is applied
- Particle/energy method
  - Advancement of physical method
  - All vertices interact with each other directly
  - Energy interactions determine the shape

https://www.youtube.com/watch?v=KBfxnayllOY
Flexible dynamics: ragdolling

- Commonly used in place of static animations for falling/death etc
- Verlet integration
  - Bones have simple constraints to bones further away
- Inverse kinematics
  - Animation is played, at end IK applied to force a valid position
- Blended ragdolling
  - Animation blended with physics
- Fully procedural
  - Multi-layered physical models
  - Unique every time
- [https://www.youtube.com/watch?v=6rtOWhF6iw8](https://www.youtube.com/watch?v=6rtOWhF6iw8)
Some more videos

- Animating a very realistic horse
  https://www.youtube.com/watch?v=YncZtLaZ6kQ
- Fully procedurally animated and evolving bipedal creatures (no keyframes):
  https://www.youtube.com/watch?v=pgaEE27nsQw
- CGI animation breakdown
  https://www.youtube.com/watch?v=on21u4BsuK0
Thanks for listening!

https://www.youtube.com/watch?v=bYl7N4U-JMI