The 3D rendering pipeline (our version for this class)
Chapter 8 - Animation

• Animation before the time of 3DCG

• Animation techniques
  – keyframing
  – bone animation & motion capture
  – simulation

• Animation principles
Animation == bring to life

• Generally any kind of **moving** graphics
  – flipbooks
  – cartoon films
  – computer animation

• Sequence of single images
  – Movie: 24, TV: 30, Comp.: up to >100/sec.

• Impression of movement >6 fps (???)

• 3D animation most often at video frame rates
Creating a Classic Cartoon Animation

- Idea > treatment > story board, sound
- Draw keyframes (expensive)
  - important or tricky phases of motion
- Interpolate between keyframes (cheap)
  - easy and straightforward phases
- Color and film the single frames

http://webshiva.com/Spring_2005_History_Apimation/lectures/images/us ns 2.jpg

http://www.cdd4ever.com/Backlot03/CDDMSheets/DarlaMS01.gif
Creating 3D Computer Animation

• Idea > treatment > story board
• Describe keyframes explicitly
  – complete description of the 3D world state
• Interpolate between keyframes
  – calculate state of the world for each frame
• Render and display/store single frames

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Keyframing

- Define certain parameters of the scene for certain frames
  - not all in every keyframe
  - also known from other authoring systems (e.g. Flash, MS Expression Blend)
  - also applied in purely textual programming and scripting languages (e.g. XAML, JavaFX)

Keyframing the Position
Linear Interpolation

\[
x = x_0 + \frac{t - t_0}{t_1 - t_0} (x_1 - x_0), \quad y = y_0 + \frac{t - t_0}{t_1 - t_0} (y_1 - y_0)
\]
Spline Interpolation (Non-Linearity in Space/Value)

- still only define key frames as control points of the spline
- interpolate in a smooth curve
- risk of overshooting when controlling the splines
Non-Linearity in Time

• In reality, physics does not allow properties of objects to change in an instant
  – Example: Object taking up speed

• “Ease in” and “ease out”
  – Starting and ending phase of movement
  – Smooth transition
  – Example: Speed changes from zero to given velocity

• Other non-linear behavior over time:
  – E.g. constant acceleration greater than 0 (or varying acceleration)
Keyframing the Orientation

- Choose rotation axis
- Interpolate angle about this axis
- Or: shortest path on the unit sphere
Keyframing the Size
Keyframing Mesh Deformation

- Grab a control point
- Keyframe its position
- Deform the polygon mesh accordingly
Keyframing the Color

- Can be done in RGB or HSV color space
- What’s between yellow and blue then??
- RGB: ________    HSV: __________
Keyframing the Virtual Camera

- Position
- Orientation
- Field of view
- Depth of field
Keyframing the Light Setup

- directional light
- positional light
- ambient light
- spotlight
- area light

- position
- direction
- beam angle
Other Things to Keyframe

• levels of detail
• visibility
• transparency, shininess
• texture / bump maps
• shading parameters
• rendering method
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Bone animation

• Also: skeletal animation

• Define a skeleton for a polygon mesh
  – topology/structure of the model

• Move only the bones of this skeleton
  – by keyframing joint angles
  – by motion capture data
  – by inverse kinematics

• Polygon mesh follows and deforms
  – connection between bone and mesh is not rigid
  – mesh stays closed and smooth
Motion Capture

• Tracking position and/or orientation of
  – limbs of an actor
  – feature points of a face
  – optical markers on a suit

• Define a relation between tracked feature points and 3D scene points

• Move the mesh exactly along the tracked data

• Still gives the most realistic results
Real-Time Rendering and Motion Capturing

• “Avatar” (2009, James Cameron)
  – Large motion-capture stage
  – “full performance capture”
  – Skull caps for actors with facial expression capture cameras

• “Virtual Camera” Augmented Reality technology
  – Shows virtual counterparts of actors in real-time

• Huge amount of data assets

• Rendering machine:
  4,000 servers with 35,000 processors

Making of Avatar (Cut)
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Physics simulation

- Physics engine is often an integral part of 3D games
  - calculations can be done efficiently on GPUs, for example
  - can handle large numbers of objects

- Not all aspects of physics need to be simulated

- Two examples
  - Inverse kinematics
  - Particle systems

\[
\begin{align*}
\text{mass } m, \\
\text{gravitation } g, \\
\text{fall: } v &= g \cdot t, \\
&= \frac{1}{2} g \cdot t^2 \\
&= y_0 - \frac{1}{2} g \cdot t^2, \\
\text{jump: } v_2 &= -c \cdot v_1
\end{align*}
\]
Inverse Kinematics

• Kinematics describes, how an object moves
• *Forward* kinematics: how does the object move, given the joint angles
• *Inverse* kinematics: what are the joint angles, given the object motion

• Mainly a way to save work in keyframing
Particle Systems

- Used for various phenomena
  - dust, explosions
  - fire
  - grass, hair, fur

- Generates a large number of objects
- Moves them with simple physics
- Handle collisions etc..

- No detailed influence on single objects
- Parameters of creation and motion can be controlled
AI Example: Flocks, Herds, Schools

• A classic example of a simulation of a natural phenomenon (1987)
• http://www.red3d.com/cwr/boids/

• Each bird/fish has 3 simple control principles

  – Separation: steer to avoid crowding local flockmates

  – Alignment: steer towards the average heading of local flockmates

  – Cohesion: steer to move toward the average position of local flockmates
Stanley & Stella in Breaking the Ice (1987)
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Animation Principles

• Known by cell animators for a long time
• Will make your animations look appealing
• Often have to do with exaggeration
  – support our perception of a character/motion

• Examples here from tutorials at
  • http://www.comet-cartoons.com/toons/3ddocs/charanim/
  • http://www.siggraph.org/education/materials/HyperGraph/animation/character_animation/principles/prin_trad_anim.htm
  • http://billysalisbury.com/tutorials_principles.htm
Timing

• The exact same motion can express entirely different things at different speeds
• Generally: slow timing conveys calm, fast timing conveys hectic
• "The difference between the right timing and the almost right timing, is the difference between lightning and a lightning bug."
Ease In and Out (or Slow In and Out)

• All motions in nature start slowly and accelerate
• Due to physics (inertia of mass)
• Heavy objects generally accelerate slower
• Light objects accelerate faster
• Can be combined with object deformations
Arcs

- Many motions in nature happen in arcs.
- Linear motions only in machines
- Motion in arcs look more natural on characters
Anticipation

• Motions in nature never start abruptly.
• There is always a phase before the actual motion, when the character already knows he wants to move.
• Is used with much exaggeration in cartoons
Exaggeration

- Motions come across more pointedly when exaggerated
- Light exagg. = only emphasizing the motion
- Strong exagg. = cartoon-like appearance
Squash and Stretch

- Soft objects are squashed when they hit an obstacle and stretch when released.
- All objects are soft to *some* extent
- Again: exaggeration creates a cartoon-like appearance
Secondary Action

- Secondary story/character/movement in the background
- Should not outpower main action
- Creates a counterpoint to the main action
- Can be used for running gags, Eastereggs
- Can create ironic side notes
- Can emphasize atmosphere

Example:
- fingers on the table
- Figure in the background
Follow Through and Overlapping Action

• Same as anticipation, but at the end of an action
• Object goes past its resting point and then comes back to where it would normally be.
• Again: exaggeration creates a cartoon-like appearance
Straight Ahead and Pose-To-Pose Action

- Define pose frame by frame from start to end
- Not sure where it will end until done
- Useful for fine tuning motions

- Define start pose and end pose
- Interpolate poses inbetween
- Leads to well defined key frames
- Useful for tweaking the timing
Staging

- Make action and objects understandable
- Show actions one at a time
- Position objects to maximize silhouette
- Combine effects to convey a consistent message
Non-Symmetrical Posing and Performing

- Asymmetrical compositions are more interesting
- Nature is almost never *perfectly* symmetric
- Image diagonal can convey atmosphere
Snap

- Quick and abrupt motions
- Only a few frames long
- Convey something that happens abruptly
- Can be emphasized by sound
Weight

• Imitate physical behavior to convey the weight of objects
• Heavy objects accelerate slowly
• Light objects bounce higher
• Heavy objects push light ones aside
Line Crossing Error

• Camera must not cross the line of motion
• Otherwise will be perceived as 2 different motions
• Fix: cut a different scene in between

• not particular to 3D animation!
Appeal, Personality

- Appeal is anything the audience likes to see
- Can be quality of charm, design, simplicity, movements, communication
- Create believable personalities
  - Consistency in pose, facial expression, communication, behavior

- Image from „ferdinand the bull“
- Disney, 1938..
Pixar: For the Birds (2008)