The 3D rendering pipeline (our version for this class)

3D models in model coordinates → 3D models in world coordinates → 2D Polygons in camera coordinates → Pixels in image coordinates

- Scene graph
- Camera
- Rasterization

- Animation, Interaction
- Lights
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
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


Maya
Chapter 8 - Animation

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• Animation principles
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)

![Image of Flash motion tweens with ease in parameter settings]
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

http://www.3dluvr.com/clisk3d/anim3.htm
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

mass m, gravitation g,
fall: $v = g \times t,$
$y = y_0 - \frac{1}{2} g \times t^2,$
jump: $v_2 = -c \times v_1$
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)

• 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://billysalisbury.com/tutorials_principles.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..

http://www.ultimatedisney.com/images/w-z/wdac-v6-03.jpg
Pixar: For the Birds (2008)