CENG 732
Computer Animation
Spring 2006-2007
http://www.ceng.metu.edu.tr/~tcan/ceng732/
metu.ceng.course.732

Course Description
• Main techniques covered in this course include:
  – Keyframing, story-boarding,
  – Kinematics, physically based dynamics modeling,
  – Motion capture,
  – Scene composition, lighting, and sound track generation
• Advanced topics such as dynamic simulation of flexible and rigid objects, facial animation, and behavioral/AI based animation are also studied.

Lecture Time/Place
• Mondays - 13:40 to 16:30 in A-101.

Course Objectives
• This course will teach the students about current techniques in computer animation. By the end of the course, the students should:
  – have learned the computational methods for modeling of motions in the physical and virtual world,
  – be able to storyboard, light, compose, and render an animated sequence,
  – and be able to read and critically evaluate the current literature in computer animation.

Prerequisites
• No formal prerequisites. However, CENG 477 Introduction to Computer Graphics is a prerequisite of the proposed course, which introduces the fundamental concepts of computer graphics which are essential in such an advanced computer animation course.

Textbook
• Online version:
  http://www.siggraph.org/education/materials/HyperGraph/animation/rick_parent/Outline.html
Reference Material

- Advanced Animation & Rendering Techniques by Watt and Watt.
- Computer Facial Animation by Parke and Waters.
- Principles of Three-Dimensional Computer Animation by Michael O'Rourke, Revised Edition.
- SIGGRAPH papers on Computer Animation.

Grading Policy

- Reading/written assignments (paper critics, short quizzes, or short presentations) : 20%
- Class project (teams of 2-3 students) : 50%
- Final exam : 30%

Instructor

- Tolga Can
- Office: B-109
- E-mail: tcan@ceng.metu.edu.tr
- Office Hours: Monday 10:30 - 12:00

Schedule

- Week 1: Introduction and overview of animation
- Week 2: Introduction to keyframing
- Week 3-4: Animating articulated structures, kinematics and inverse kinematics
- Week 5-6: Physically based modeling and simulation, particle system dynamics
- Week 7: Facial animation
- Week 8: Processing motion capture data, motion synthesis, motion recognition
- Week 9: Behavioral-AI based animation, crowd animation
- Week 10-12: Paper presentations
- Week 13-14: Project presentations

Computer Animation

- What is computer animation?
- What is animated?

Computer Animation

- What is computer animation?
  - Computer animation is the art of creating moving images via the use of computers
  - A technique in which the illusion of movement is created by displaying on a screen, or recording on a recording device a series of individual states of a dynamic scene

- What is animated?
  - Object position, orientation, shape
  - Light position, orientation, parameters
  - Object texture
  - Camera Parameters
Today

• Motion perception
• Technical evolution of animation
• Animation production
• Examples

Perception

• How do you perceive a rapid sequence of still images?
  – As a series of images or as a continuous single moving image?

Positive afterimage

• A single image presented to a viewer for a short time will leave an imprint of itself in the visual system for a short time after it is removed

Persistence of vision

• When a person is presented with a sequence of closely related still images at a fast enough rate, persistence of vision induces the sensation of continuous imagery.
• What if the rate is not fast enough?

Flicker

• The rate at which single images must be played back in order to maintain the persistence of vision is called the flicker rate.
• It depends on viewing distances, lighting conditions, etc.

What about the upper limits?

• What if an object moves too quickly with respect to the viewer?
  – Motion blur occurs (as in still cameras if the shutter speed is not fast enough)
• However, in computer graphics motion blur will not occur because each produced images is sampled at a precise instant in time. What will happen if an object is moving too fast (i.e., faster than the sampling rate?)
**Strobing**

- The images of a fast moving object can appear disjointed and the motion becomes jerky, if the sampling rate is not fast enough.
- In hand-drawn animation, fast moving objects are typically stretched in the direction of travel so that the object’s images overlap, reducing the strobing effect.

**Playback rate vs. Sampling rate**

- **Playback rate:** the number of images per second displayed in the viewing process
- The number of different images that occur per second.
- For example a hand drawn animation may be created at 6 frames per second; however it may be displayed on TV at 30 fps. (Each image displayed 5 times repeatedly.)

**History of Animation**

- 1891: Thomas Edison invented the motion picture projector
- 1896: Georges Melies made objects appear, disappear, change shape using camera tricks
- 1900: smoke is animated in a scene (J. Stuart Blackton)
- 1906: first animated cartoon (J. Stuart Blackton)
### History of Animation

- **Winsor McCay** is the first celebrated animator
  - *Little Nemo* (1911)
  - *Gertie the Dinosaur* (1914)
- **1914**: translucent cels (currently made from acetate) were patented (John Bray and Earl Hurd)
- Drawing of the background on long sheets of paper so that *panning* could be performed easily

### History of Animation

- **1915**: Max Fleischer patented *rotoscopy* (drawing images on cels by tracing over previously recorded live action)
- First popular animated character:
  - Felix the Cat (by Otto Messmer)

<table>
<thead>
<tr>
<th>Multiplane camera</th>
</tr>
</thead>
<tbody>
<tr>
<td><img src="image" alt="Multiplane Camera Diagram" /></td>
</tr>
<tr>
<td>Each plane can move independently in six directions</td>
</tr>
</tbody>
</table>

### Multiplane Camera

- Camera mounted above multiple planes (animation cels)
- Each plane can move in six directions
- The camera can move closer and farther away.

### Stop-motion Animation

- **With clay or puppets**
### Principles of Computer Animation
- Simulating Physics
- Designing Aesthetic Actions
- Effective Presentation of Actions
- Production Technique

### Simulating Physics
- Squash & Stretch
  - Object rigidity, mass should be consistent during squash & stretch.
- Timing
  - Weight, size, and personality of an object should determine how the actions are spaced through time
- Movement in arcs. Inertia, friction, and viscosity should be taken into account
  - Slow in & slow out, arcs
- Secondary actions should support main action
  - Example: If a character collides with boxes, the boxes should also move

### Designing Aesthetic Actions
- Exaggeration
  - To draw attention to an action
- Appeal
  - The action should be enjoyable to watch
- Follow through/overlapping action
  - Actions should flow into one another (instead of looking like disjoint movements)

### Effective Presentation of Actions
- Anticipation
  - An upcoming action should be set up so that audience knows it is coming
- Staging
  - The action environment has to be set up so that it is not missed by the audience
- Timing
  - Appropriate duration for the action should be given so that the intended effect reaches the audience

### Production Technique
- Straight ahead
  - Progressing from a starting point and developing the motion continually along the way
    - Example: physically based animation
- Pose to pose
  - Identifying key frames and then interpolating intermediate frames

### Animation Production
- Four-level hierarchy:
  - Production: The entire animation
  - Sequence: A major episode with an associated staging area
  - Shot: A continuous camera recording
  - Individual frames: A single recorded image
- A production usually consists of one to dozen sequences
**Animation Hierarchy**

<table>
<thead>
<tr>
<th>Production</th>
<th>Production</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Sequence 1</strong></td>
<td><strong>Sequence 2</strong></td>
</tr>
<tr>
<td>frame 1</td>
<td>frame 2</td>
</tr>
<tr>
<td>frame 3</td>
<td>frame 4</td>
</tr>
<tr>
<td>frame 5</td>
<td>frame 6</td>
</tr>
<tr>
<td>frame 7</td>
<td>frame 8</td>
</tr>
</tbody>
</table>

**Animation Production Steps**

- A *preliminary* story with a *script* is decided on
- A *storyboard* is developed
  - It lays out the action scenes by sketching representative frames
- A *model sheet* is developed that lists the characters in various poses
- The *exposure sheet* records information for each frame such as camera moves, sound track cues
- The *route sheet* records the statistics and responsibility of each scene

**Animatic**

- Also called a *story reel*. A prototype animation that helps to work on timing, revise storyboard, etc.

**Animation Production Steps**

- Once the storyboard has been decided on a *detailed story* is developed.
- *Key frames* are produced by master animators
- Associate and assistant animators produce the frames between the keys
  - This is called in-betweening
- Test shots, pencil test
  - Example

**Animation Production Steps**

- Inking
  - Transferring the penciled frames to cels
- Opaquing or painting
  - Application of color to the cels

**Sound**

- Music
- Special effects
- Voice
- In lip-synched animation, sound-track is created first and then animation is produced to fit the sound-track.
Computer vs. Conventional Animation

- Computer animation borrows a lot of ideas from conventional animation in terms of production approaches.
- However, there are differences:
  - The lighting, camera models, motion can be reused easily in computer animation
  - Multiple detailed models can be used in computer animation
- Test shot: short high quality rendering
- Pencil test: low quality models and approximate motions

Computer Animation Production Tasks

- The pipeline used by Pixar to produce Toy Story

Editing

- Non-linear editing
  - Sequence can be inserted at any order
- A linear electronic editing system

Digital On-line Nonlinear Editing

- An example time-line used for nonlinear digital editing

Digital Video

- With digital video all the non-linear editing tasks are easily done
- Other issues:
  - Compression?
  - Storage: An hour of uncompressed video is 76 Gb
  - Playback
History of Computer Animation

• Evans and Sutherland: '60s and '70s first interactive computer graphics programs
• University of Utah
  – 1972: Animated hand and face by Ed Catmull
  – 1973: Walking, talking human figure by Barry Wessler
  – 1974: Talking face by Fred Parke

History of Computer Animation

• At the end of 1970s, a project titled *The Works* was started to produce a wholly computer generated feature film (but never completed)
  – The used BBOP: a three-dimensional key-frame articulated figure animation system
• 1974: *Hunger*, the first computer animation nominated for an Academy Award
  – Object shape modification and line interpolation (2½ D)


History of Computer Animation

• 1971: Architectural walk-throughs of the Cornell University campus by Don Greenberg
• 1979: Ed Emshwiller demonstrated moving texture maps in Sunstone
• 1979: Voyager flyby animations by Jim Blinn

History of Computer Animation

• 1976: Graphical Symbiosis System (GRASS) was developed a derivative of which was used in the first Star Wars film.

History of Computer Animation

• The Middle Years (1980s):
  – Companies start to emerge
  – Hardware z-buffers were produced
  – Flight simulators developed
  – Animation of waves (Carla’s Island, 1981)
  – Flyby of fractal terrain (Vol Libre, 1980)
• The movie TRON (1982) is a landmark movie in its extensive use of computer-generated imagery

History of Computer Animation

• 3D animations emerge in 1980s and 1990s
• Award winning animations by Lucasfilm and Pixar
  – Luxo Jr. (1986)
  – Red’s Dream (1987)
  – *Tin Toy* (1988) – First computer animation to win an Oscar
  – Knick Knack (1989)
  – *Geri’s Game* (1999) – Won an Oscar
History of Computer Animation

• In 1984, 20 minutes of realistic computer animation was used in the movie *The Last Starfighter*. The action takes place in space as well as on planets.

• 1986: First time a synthetic character appeared in a live-action feature film (Young Sherlock Holmes)
• 1989: An alien creature that appears to be made from water is created for the movie *The Abyss*
• 1991: Terminator 2
• 1988: First digital blue screen matte extraction (Willow)
• 1994: A digital ping-pong ball is inserted into the movie in Forrest Gump

History of Computer Animation

• Use of particle systems
  – Lawnmower Man (1992)
  – Twister (1996)

• Toy Story
  – First full-length, fully computer generated 3D animated feature film
• High quality rendering
  – *Bunny* (Blue Sky Productions – 1999) uses ray tracing and radiosity
    • Winner of the 1998 Academy Award for Best Animated Short Film

Computer Animation

• Holy grail of computer animation
  – To produce a synthetic human character indistinguishable from a real person