Lecture 17 of 41

Animation 1 of 3: Basics, Keyframing
Sample Exam Review

William H. Hsu

Department of Computing and Information Sciences, KSU

KSOL course pages: http://bit.ly/hGvXlH / http://bit.ly/eVizrE
Public mirror web site: http://www.kddresearch.org/Courses/CIS636
Instructor home page: http://www.cis.ksu.edu/~bhsu

Readings:

Today: §5.1 – 5.2, Eberly *2*^{e} – see http://bit.ly/ieUq45
Next class: no new reading – review Chapters 1 – 4, 20
Optional review session during next class period; evening exam time TBD
Lecture 18 reading (two class days from today): §4.4 – 4.7, Eberly *2*^{e}

Lecture Outline

- Reading for Last Class: §2.6, 20.1, Eberly *2*^{e}; OpenGL primer material
- Reading for Today: §5.1 – 5.2, Eberly *2*^{e}
- Reading for Next Lecture (Two Classes from Now): §4.4 – 4.7, Eberly *2*^{e}
- Last Time: Shading and Transparency in OpenGL
  - Transparency revisited
  - OpenGL how-to: http://bit.ly/hRaQgk
    - Alpha blending (15.020, 15.040)
    - Screen-door transparency (15.030)
  - Painter's algorithm & depth buffering (z-buffering)
- Today: Introduction to Animation
  - What is it and how does it work?
  - Brief history
  - Principles of traditional animation
  - Keyframe animation
  - Articulated figures: inbetweening

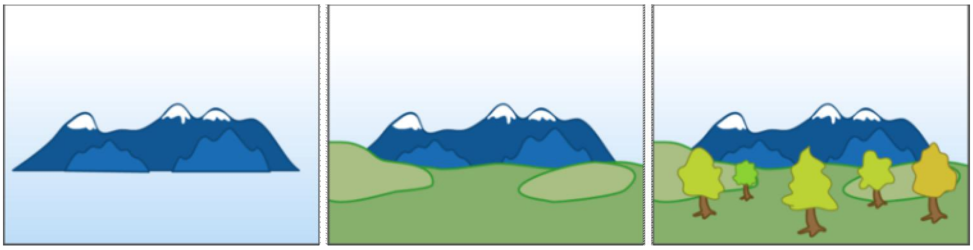
Where We Are

Lecture	Topic	Primary Source(s)
0	Course Overview	Chapter 1, Eberly 2^e
1	**CG Basics: Transformation Matrices; Lab 0**	**Sections (§) 2.1, 2.2**
2	Viewing 1: Overview, Projections	§ 2.2.3 – 2.2.4, 2.8
3	Viewing 2: Viewing Transformation	§ 2.3 esp. 2.3.4; FVFH slides
4	**Lab 1a: Flash & OpenGL Basics**	**Ch. 2, 16^1, Angel *Primer***
5	Viewing 3: Graphics Pipeline	§ 2.3 esp. 2.3.7; 2.6, 2.7
6	Scan Conversion 1: Lines, Midpoint Algorithm	§ 2.5.1, 3.1; FVFH slides
7	**Viewing 4: Clipping & Culling; Lab 1b**	**§ 2.3.5, 2.4, 3.1.3**
8	Scan Conversion 2: Polygons, Clipping Intro	§ 2.4, 2.5 esp. 2.5.4, 3.1.6
9	Surface Detail 1: Illumination & Shading	§ 2.5, 2.6.1 – 2.6.2, 4.3.2, 20.2
10	**Lab 2a: Direct3D / DirectX Intro**	**§ 2.7, Direct3D handout**
11	Surface Detail 2: Textures; OpenGL Shading	§ 2.6.3, 20.3 – 20.4, *Primer*
12	Surface Detail 3: Mappings; OpenGL Textures	§ 20.5 – 20.13
13	**Surface Detail 4: Pixel/Vertex Shad.; Lab 2b**	**§ 3.1**
14	Surface Detail 5: Direct3D Shading; OGLSL	§ 3.2 – 3.4, Direct3D handout
15	Demos 1: CGA, Fun; Scene Graphs: State	§ 4.1 – 4.3, **CGA handout**
16	**Lab 3a: Shading & Transparency**	**§ 2.6, 20.1, *Primer***
17	**Animation 1: Basics, Keyframes; HW/Exam**	**§ 5.1 – 5.2**
	Exam 1 review; Hour Exam 1 (evening)	**Chapters 1 – 4, 20**
18	**Scene Graphs: Rendering; Lab 3b: Shader**	**§ 4.4 – 4.7**
19	**Demos 2: SFX; Skinning, Morphing**	**§ 5.3 – 5.5, CGA handout**
20	Demos 3: Surfaces; B-reps/Volume Graphics	§ 10.4, 12.7, **Mesh handout**

Lightly-shaded entries denote the due date of a written problem set; heavily-shaded entries, that of a machine problem (programming assignment); blue-shaded entries, that of a paper review; and the green-shaded entry, that of the term project.

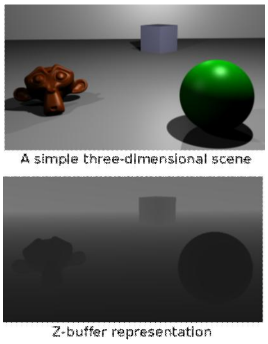
Green, **blue** and **red** letters denote **exam review**, **exam**, and **exam solution review** dates.

Review:
Painter's Algorithm *vs.* z-Buffering



© 2004 – 2009 Wikipedia, *Painter's Algorithm*
http://bit.ly/eeebCN

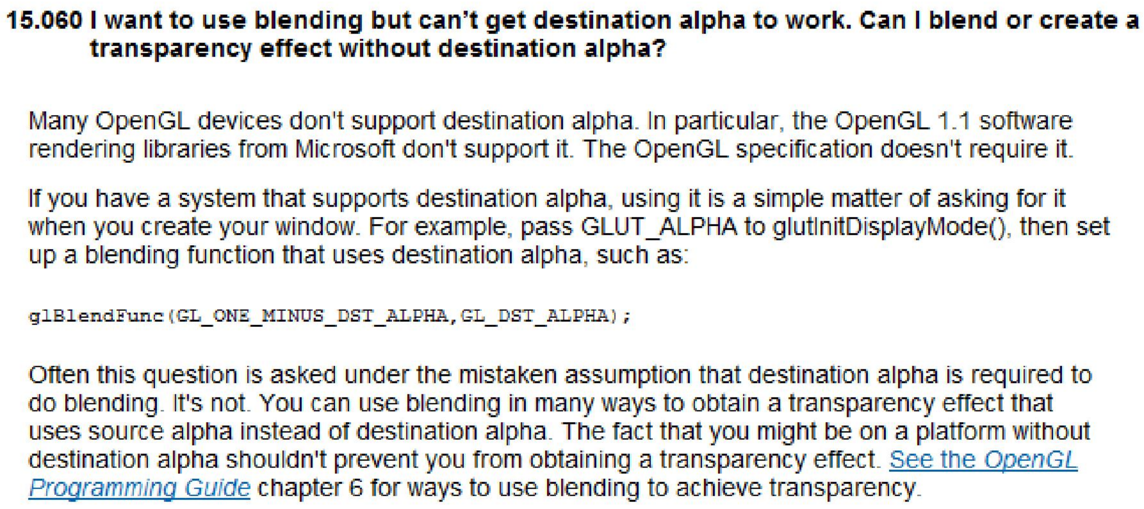
© 2009 Wikipedia, *Z-buffering*
http://bit.ly/gGRFMA



A simple three-dimensional scene

Z-buffer representation

Transparency in OpenGL:
Final Note



15.060 I want to use blending but can't get destination alpha to work. Can I blend or create a transparency effect without destination alpha?

Many OpenGL devices don't support destination alpha. In particular, the OpenGL 1.1 software rendering libraries from Microsoft don't support it. The OpenGL specification doesn't require it.

If you have a system that supports destination alpha, using it is a simple matter of asking for it when you create your window. For example, pass GLUT_ALPHA to glutInitDisplayMode(), then set up a blending function that uses destination alpha, such as:

```
glBlendFunc(GL_ONE_MINUS_DST_ALPHA,GL_DST_ALPHA);
```

Often this question is asked under the mistaken assumption that destination alpha is required to do blending. It's not. You can use blending in many ways to obtain a transparency effect that uses source alpha instead of destination alpha. The fact that you might be on a platform without destination alpha shouldn't prevent you from obtaining a transparency effect. See the OpenGL Programming Guide chapter 6 for ways to use blending to achieve transparency.

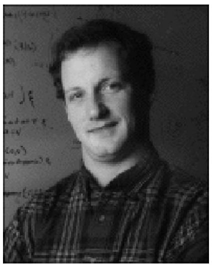
© 1997 – 2011 Khronos Group
http://bit.ly/hRaQgk

Acknowledgements: Computer Animation Intro

Jason Lawrence
Assistant Professor
Department of Computer Science
University of Virginia
http://www.cs.virginia.edu/~jdl/

Computer Science at the University of Virginia

Acknowledgment: slides by Misha Kazhdan, Allison Klein, Tom Funkhouser, Adam Finkelstein and David Dobkin
http://bit.ly/eB1Oj4



Thomas A. Funkhouser
Professor
Department of Computer Science
Computer Graphics Group
Princeton University
http://www.cs.princeton.edu/~funk/

PRINCETON UNIVERSITY

Overview

- Some early animation history
  - http://web.inter.nl.net/users/anima/index.htm
  - http://www.public.iastate.edu/~rllew/chrnearl.html
- Computer animation

CS 4810: Introduction to Computer Graphics – http://bit.ly/hPlXdi

Thaumatrope

- Why does animation work?
- Persistence of vision
- 1824 John Ayerton invents the *thaumatrope*
- Or, 1828 Paul Roget invents the *thaumatrope*

Thaumatrope

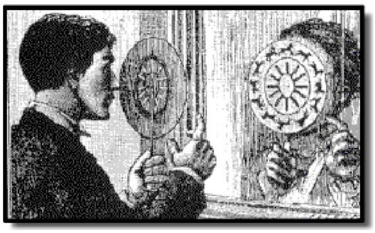
What makes this bottle like the Goddess Flora

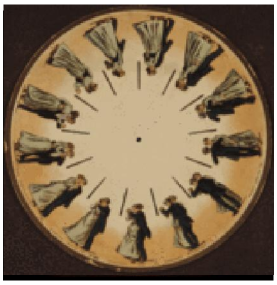
Thaumatrope of flowers & vase (1825)
© 2008 Wikipedia, *Thaumatrope*
http://bit.ly/fFI6xH

Adapted from slides © 2010 J. Lawrence, University of Virginia
CS 4810: Introduction to Computer Graphics – http://bit.ly/hPIXdi

Phenakistoscope

- Invented independently by 2 people in 1832
- Disc mounted on spindle
- Viewed through slots with images facing mirror
- Turning disc animates images



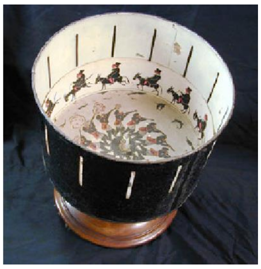


Phenakistoscope of couple (1893)
© 2007 Wikipedia, *Phenakistoscope*
http://bit.ly/eAnURG

Adapted from slides © 2010 J. Lawrence, University of Virginia
CS 4810: Introduction to Computer Graphics – http://bit.ly/hPlXdi

Zoetrope (1834)

- Images arranged on paper band inside a drum
- Slits cut in the upper half of the drum
- Opposite side viewed as drum rapidly spun
- Praxinoscope is a variation on this



Tarzan © 2000 Disney
http://youtu.be/zc3MnoSS5Hw

Adapted from slides © 2010 J. Lawrence, University of Virginia
CS 4810: Introduction to Computer Graphics – http://bit.ly/hPIXdi

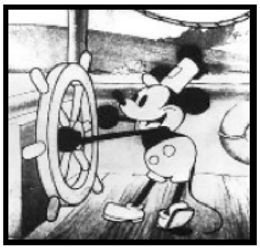
Animation History

- Animation and technology have always gone together!
- Animation popular even before movies
- Movies were big step forward!
- “Humorous Phases of Funny Faces” (1906)

CS 4810: Introduction to Computer Graphics – http://bit.ly/hPlXdi

Key Developments [1]: Storytelling & Cel Animation

- Plot
- Creation of animation studios
- Getting rid of "rubber-hose" bodies
- Inking on cels



"Steamboat Willie"
Walt Disney (1928)

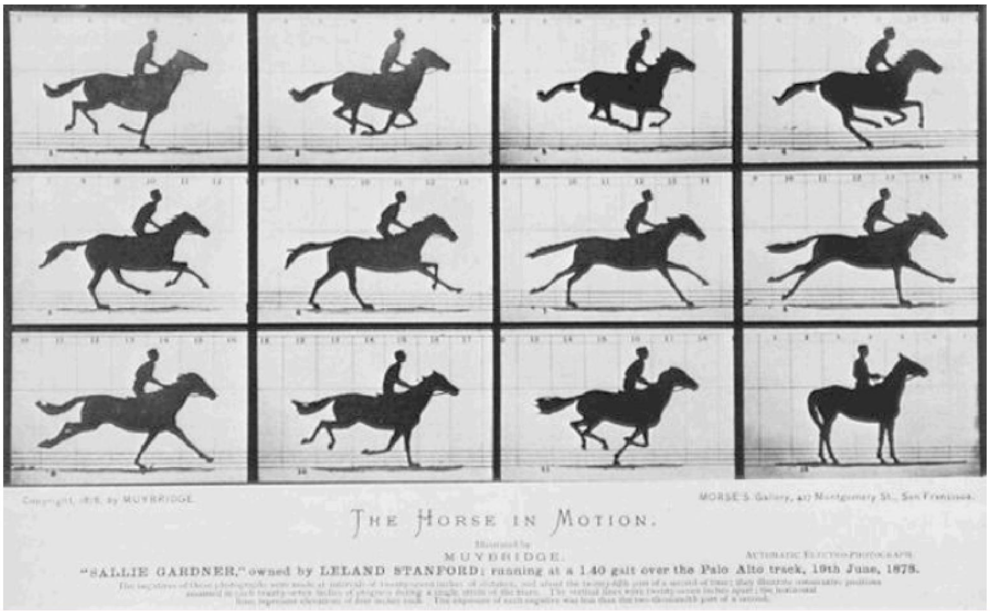
"Felix the Cat"
Pat Sullivan (1919)

"Gertie the Dinosaur"
Windsor McCay (1914)

CS 4810: Introduction to Computer Graphics – http://bit.ly/hPIXdi

Key Developments [2]: Rotoscoping (1921)

- Max Fleischer invents rotoscoping (1921)


Copyright, 1878, by MUYBRIDGE
MORSE'S Gallery, 417 Montgomery St., San Francisco.
THE HORSE IN MOTION.
Illustrated by
MUYBRIDGE.
AUTOMATIC ELECTRO-PHOTOGRAPH
"SALLIE GARDNER," owned by LELAND STANFORD; running at a 1.40 gait over the Palo Alto track, 19th June, 1878.

© 2010 J. Lawrence, University of Virginia
CS 4810: Introduction to Computer Graphics – http://bit.ly/hPIXdi

Key Developments [4]
Fleischer’s Rotoscope

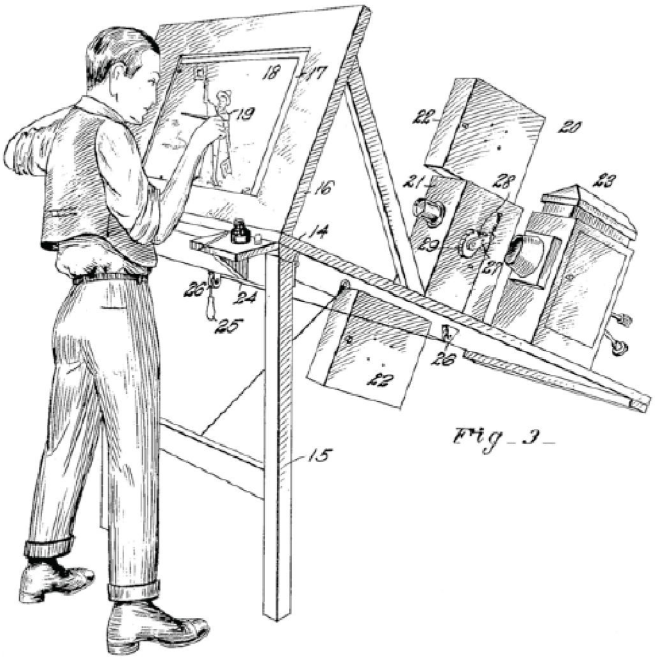
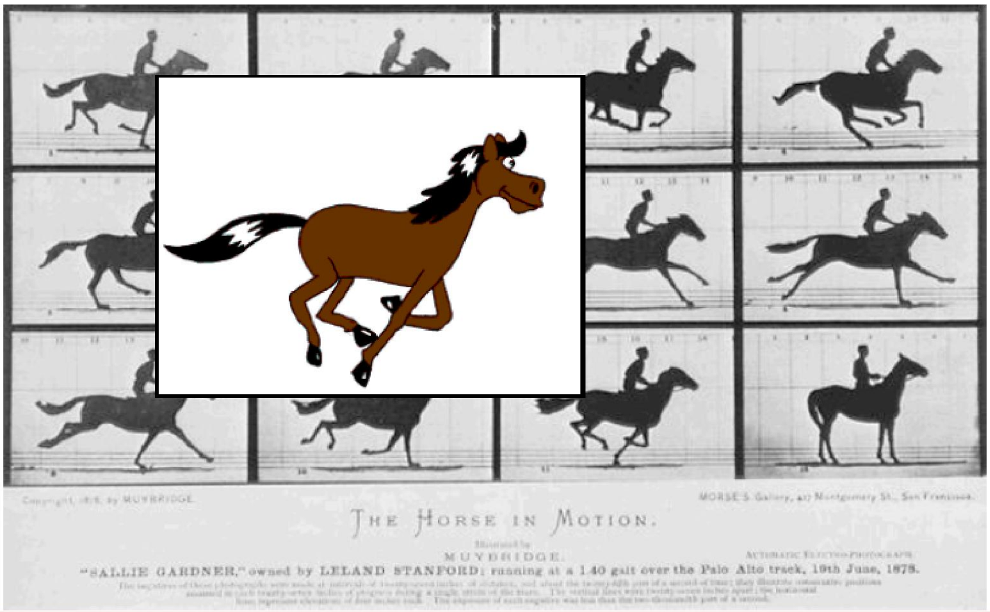


Fig_3_

CS 4810: Introduction to Computer Graphics – http://bit.ly/hPIXdi

Key Developments [5]: Using Rotoscoping

- Max Fleischer invents rotoscoping (1921)

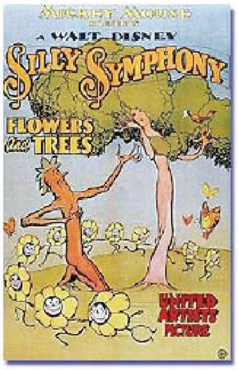

Copyright, 1878, by MUYBRIDGE
MORSE'S Gallery, 417 Montgomery St., San Francisco.
THE HORSE IN MOTION.
MUYBRIDGE.
"SALLIE GARDNER," owned by LELAND STANFORD; running at a 1.40 gait over the Palo Alto track, 19th June, 1878.

Adapted from slides © 2010 J. Lawrence, University of Virginia
CS 4810: Introduction to Computer Graphics – http://bit.ly/hPIXdi

Key Developments [6]: Color

- “Flowers and Trees” (1932) uses color!
- “Snow White” (aka “Disney’s Folly”) released 1937

“Flowers and Trees”
Walt Disney



“Snow White”
Walt Disney

© 2010 J. Lawrence, University of Virginia
CS 4810: Introduction to Computer Graphics – http://bit.ly/hPIXdi

Overview

- Some early animation history
  - http://web.inter.nl.net/users/anima/index.htm
  - http://www.public.iastate.edu/~rllew/chrnearl.html
- Computer animation

© 2010 J. Lawrence, University of Virginia
CS 4810: Introduction to Computer Graphics – http://bit.ly/hPIXdi

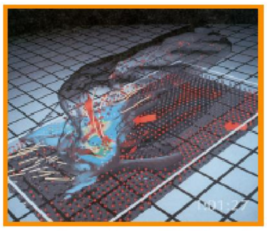
Animation, Simulation, & Visualization

- What is animation?
  - Make objects change over time according to scripted actions

Pixar

- What is simulation?
  - Predict how objects change over time according to physical laws

Wilhelmson *et al.* (2004)
http://youtu.be/EgumU0Ns1YI
http://avl.ncsa.illinois.edu
http://bit.ly/eA8PXN

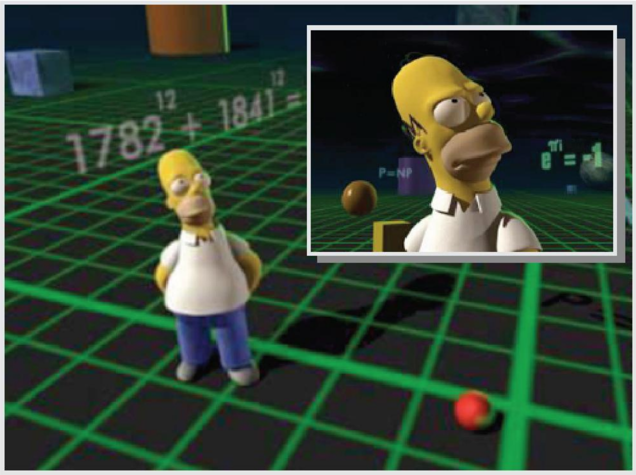


University of Illinois

Adapted from slides © 2010 J. Lawrence, University of Virginia
CS 4810: Introduction to Computer Graphics – http://bit.ly/hPIXdi

2-D & 3-D Animation

Homer 2-D

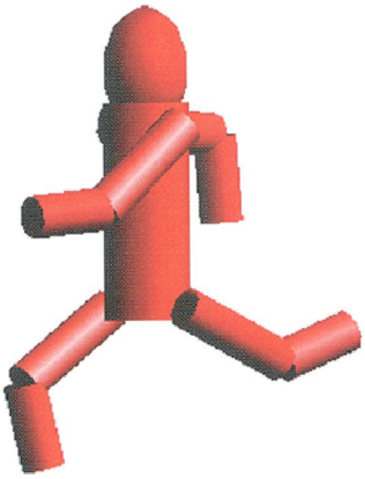


Homer 3-D
http://youtu.be/TKQ8Ilr6PgU (Making Of)

CS 4810: Introduction to Computer Graphics – http://bit.ly/hPIXdi

Outline

- Principles of animation
- Keyframe animation
- Articulated figures

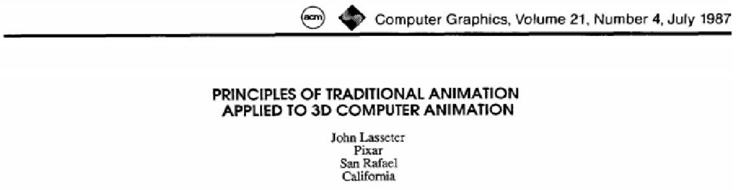


Angel Plate 1

CS 4810: Introduction to Computer Graphics – http://bit.ly/hPIXdi

Traditional Animation [1]: Lasseter’s List of Principles (1987)

- Squash and Stretch
- Timing
- Anticipation
- Staging
- Follow Through and Overlapping Action
- Straight Ahead Action and Pose-to-Pose Action
- Slow In and Out
- Arcs
- Exaggeration
- Secondary action
- Appeal



Computer Graphics, Volume 21, Number 4, July 1987

PRINCIPLES OF TRADITIONAL ANIMATION
APPLIED TO 3D COMPUTER ANIMATION

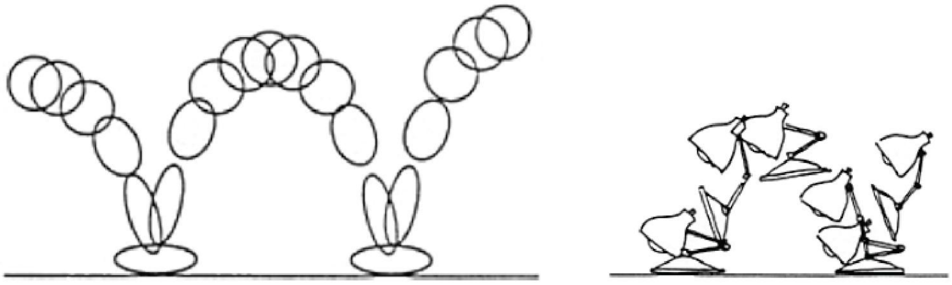
John Lasseter
Pixar
San Rafael
California

Lasseter, J. (1987). Principles of traditional animation applied to 3D computer animation. *Computer Graphics*, 21(4), pp. 35-44.
SIGGRAPH: http://bit.ly/1DsO44
ACM Portal: http://bit.ly/eyx2PN

© 2010 J. Lawrence, University of Virginia
CS 4810: Introduction to Computer Graphics – http://bit.ly/hPIXdi

Traditional Animation [2]: Squash & Stretch

- Defining the rigidity and mass of an object by distorting its shape during an action.



© 2010 J. Lawrence, University of Virginia
CS 4810: Introduction to Computer Graphics – http://bit.ly/hPIXdi

Traditional Animation [3]: Timing

- Spacing actions to define the weight and size of objects and the personality of characters.
  - Heavier objects accelerate slower
  - Lethargic characters move slower
  - Etc.

© 2010 J. Lawrence, University of Virginia
CS 4810: Introduction to Computer Graphics – http://bit.ly/hPIXdi

Traditional Animation [4]: Anticipation

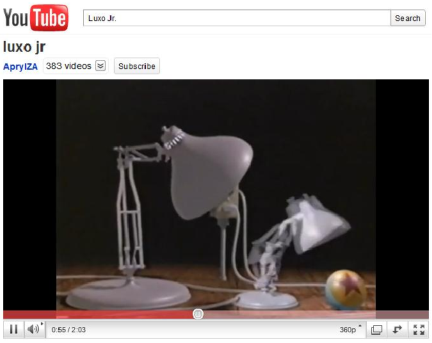
- The preparation for an action.
  - Muscle contraction prior to extension
  - Bending over to lift a heavy object
  - Luxo's dad responds to Luxo Jr. off screen before Luxo Jr. appears.

Luxo Jr. © 1986 Pixar
http://www.pixar.com/shorts/ljr/
http://youtu.be/qGxoui3lFS0

CS 4810: Introduction to Computer Graphics – http://bit.ly/hPlXdi

Traditional Animation [5]: Staging

- Presenting an idea so that it is unmistakably clear.
  - Keeping the viewer's attention focused on a specific part of the scene.
  - Luxo Jr. moves faster than his dad, and so we focus on him.



Luxo Jr. © 1986 Pixar
http://www.pixar.com/shorts/ljr/
http://youtu.be/qGxoui3IFS0

© 2010 J. Lawrence, University of Virginia
CS 4810: Introduction to Computer Graphics – http://bit.ly/hPIXdi

Traditional Animation [6]: Follow Through & Overlapping Action

- The termination of an action and establishing its relationship to the next action.
  - Loose clothing will "drag" and continue moving after the character has stopped moving.
  - The way in which an object slows down indicates its weight/mood.

© 2010 J. Lawrence, University of Virginia
CS 4810: Introduction to Computer Graphics – http://bit.ly/hPIXdi

Traditional Animation [7]: Straight-Ahead vs. Pose-to-Pose Action

- The two contrasting approaches to the creation of movement.
  - Straight Ahead Action:
    - » Action is drawn from the first frame through to the last one.
    - » Wild, scrambling actions where spontaneity is important.
  - Pose-to-Pose Action:
    - » Poses are pre-conceived and animator fills in the in-betweens.
    - » Good acting, where the poses and timing are all important.

© 2010 J. Lawrence, University of Virginia
CS 4810: Introduction to Computer Graphics – http://bit.ly/hPIXdi

Traditional Animation [8]: Slow In-And-Out

- The spacing of in-between frames to achieve subtlety of timing and movements.

CS 4810: Introduction to Computer Graphics – http://bit.ly/hPIXdi

Traditional Animation [9]: Arcs

- The visual path of action for natural movement.
  - Make animation much smoother and less stiff than a straight line for the path of action

© 2010 J. Lawrence, University of Virginia
CS 4810: Introduction to Computer Graphics – http://bit.ly/hPIXdi

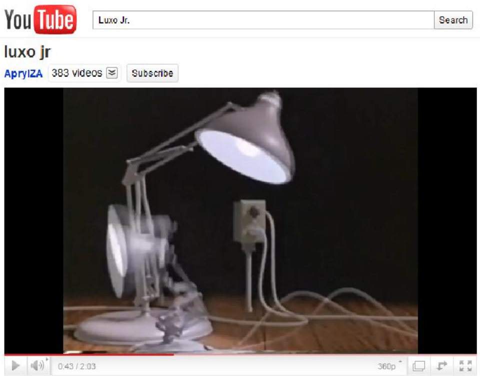
Traditional Animation [10]: Exaggeration

- Accentuating the essence of an idea via the design and the action.

© 2010 J. Lawrence, University of Virginia
CS 4810: Introduction to Computer Graphics – http://bit.ly/hPIXdi

Traditional Animation [11]: Secondary Action

- The Action of an object resulting from another action.
  - The rippling of Luxo Jr.'s cord as he bounces around the scene.



Luxo Jr. © 1986 Pixar
http://www.pixar.com/shorts/ljr/
http://youtu.be/qGxoui3lFS0

© 2010 J. Lawrence, University of Virginia
CS 4810: Introduction to Computer Graphics – http://bit.ly/hPIXdi

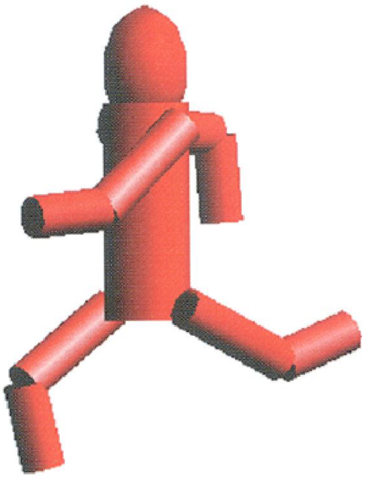
Traditional Animation [12]: Appeal

- Creating a design or an action that the audience enjoys watching.
  - Charm
  - Pleasing design
  - Simplicity
  - Communication
  - Magnetism
  - Etc.

© 2010 J. Lawrence, University of Virginia
CS 4810: Introduction to Computer Graphics – http://bit.ly/hPIXdi

Outline

- Principles of animation
- Keyframe animation
- Articulated figures

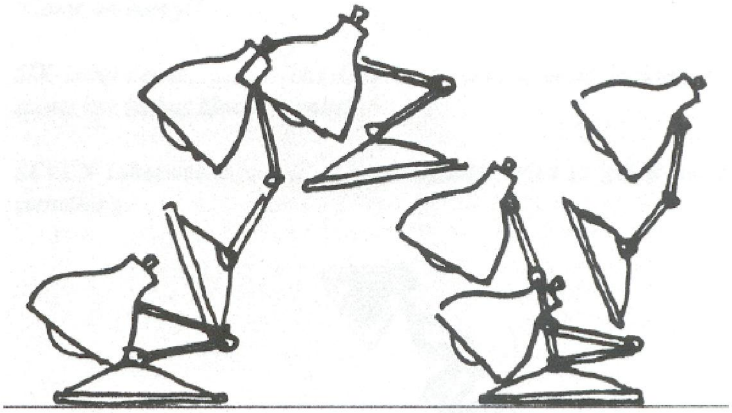


Angel Plate 1

© 2010 J. Lawrence, University of Virginia
CS 4810: Introduction to Computer Graphics – http://bit.ly/hPIXdi

Keyframe Animation [1]: Keyframes

- Define character poses at specific time steps called "keyframes"

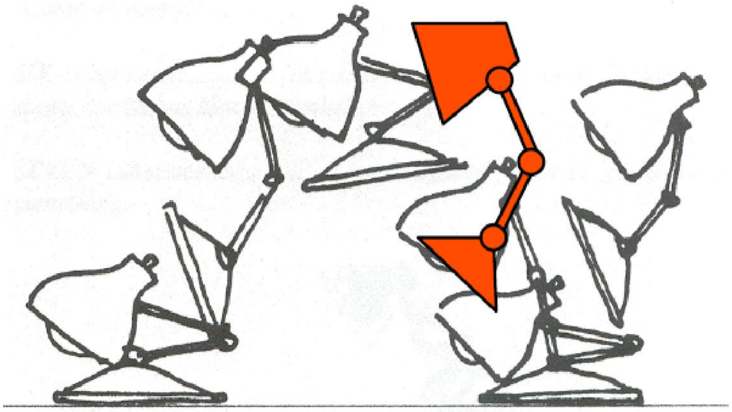


Lasseter `87

© 2010 J. Lawrence, University of Virginia
CS 4810: Introduction to Computer Graphics – http://bit.ly/hPIXdi

Keyframe Animation [2]: Interpolation (*aka* Inbetweening)

- Interpolate variables describing keyframes to determine poses for character “in-between”

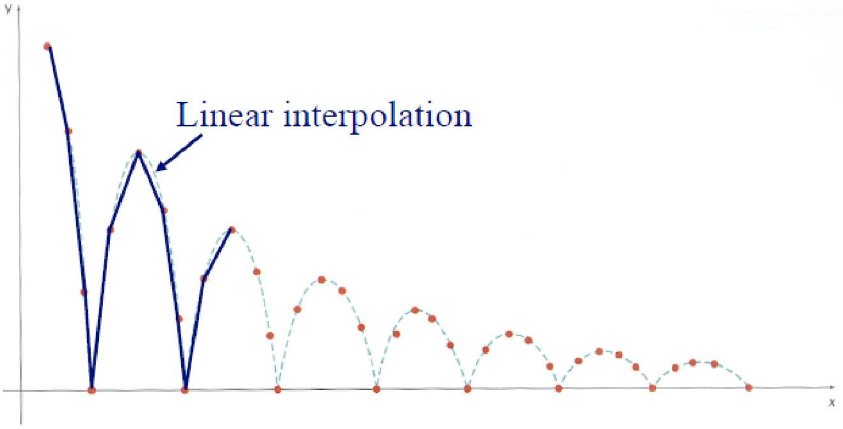


Lasseter `87

CS 4810: Introduction to Computer Graphics – http://bit.ly/hPIXdi

Keyframe Animation [3]: Linear Interpolation aka Lerping

- Inbetweening:
  - Linear interpolation - usually not enough continuity

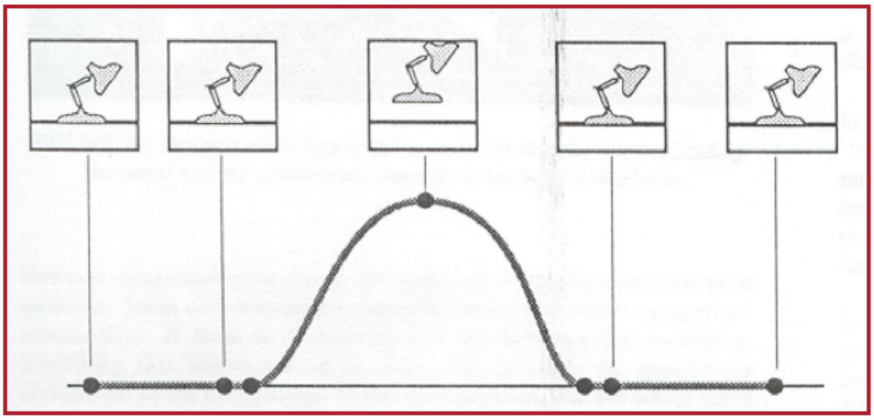


H&B Figure 16.16

CS 4810: Introduction to Computer Graphics – http://bit.ly/hPIXdi

Keyframe Animation [4]: Cubic Curve (Spline) Interpolation

- Inbetweening:
  - Cubic spline interpolation - maybe good enough
    - May not follow physical laws

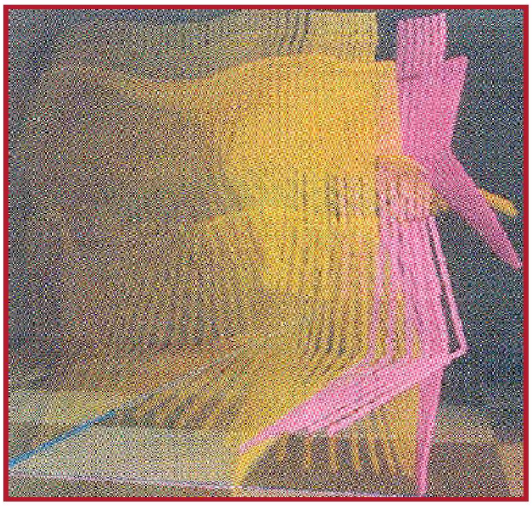


Lasseter `87

© 2010 J. Lawrence, University of Virginia
CS 4810: Introduction to Computer Graphics – http://bit.ly/hPIXdi

Keyframe Animation [5]: Dynamics & Kinematics

- Inbetweening:
  - Kinematics or dynamics

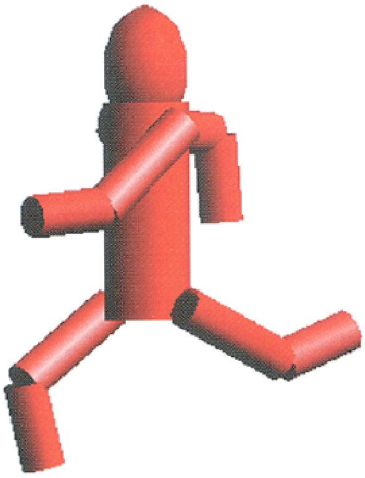


Rose et al. `96

© 2010 J. Lawrence, University of Virginia
CS 4810: Introduction to Computer Graphics – http://bit.ly/hPIXdi

Outline

- Principles of animation
- Keyframe animation
- Articulated figures

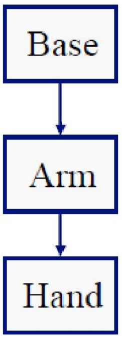


Angel Plate 1

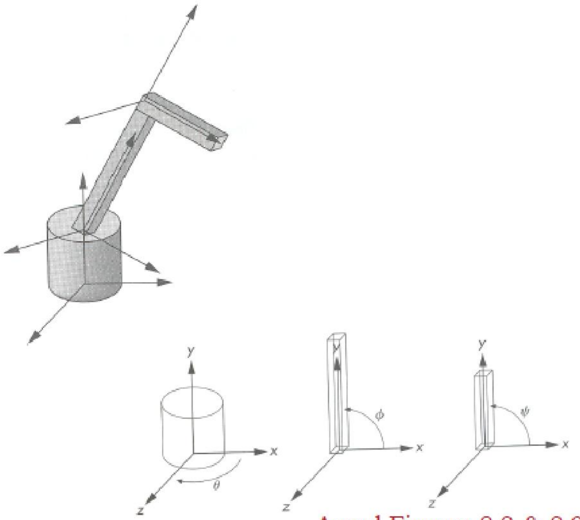
© 2010 J. Lawrence, University of Virginia
CS 4810: Introduction to Computer Graphics – http://bit.ly/hPIXdi

Articulated Figures [1]: Definition

- Character poses described by set of rigid bodies connected by “joints”



Scene Graph

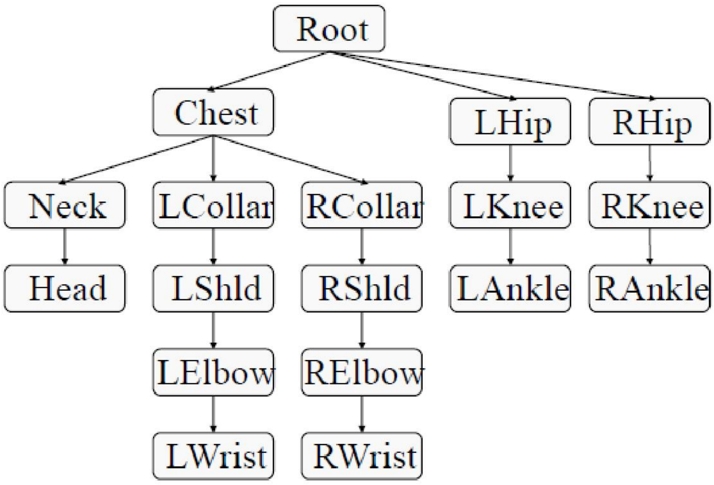


Angel Figures 8.8 & 8.9

CS 4810: Introduction to Computer Graphics – http://bit.ly/hPIXdi

Articulated Figures [2]: Character Modeling

- Well-suited for humanoid characters



Root

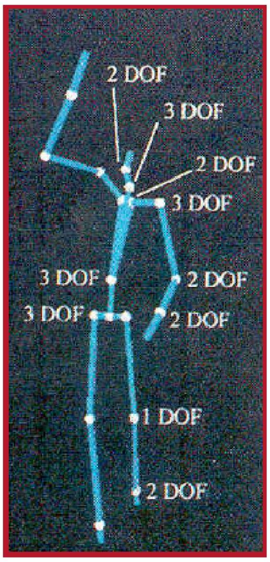
Chest LHip RHip

Neck LCollar RCollar LKnee RKnee

Head LShld RShld LAnkle RAnkle

LElbow RElbow

LWrist RWrist

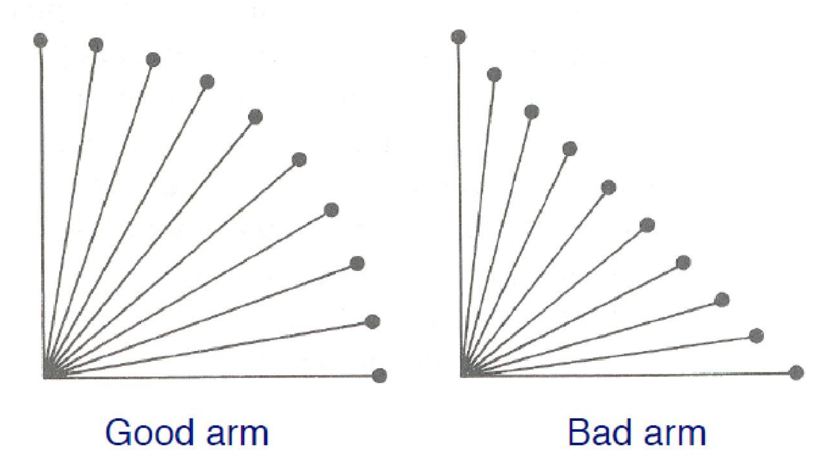


Rose et al. `96

CS 4810: Introduction to Computer Graphics – http://bit.ly/hPIXdi

Articulated Figures [3]: Angular Interpolation

- Inbetweening
  - Interpolate angles, not positions, between keyframes

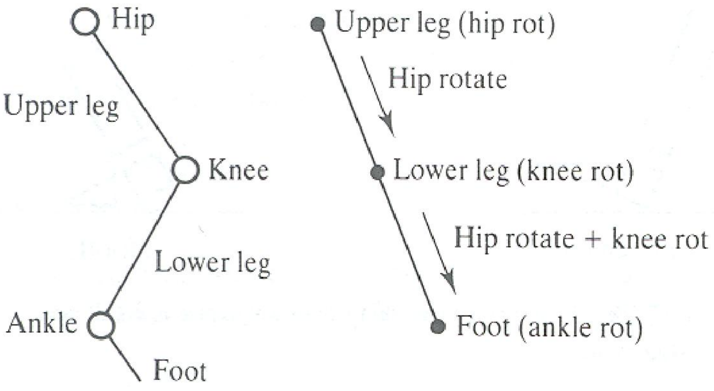


Watt & Watt

© 2010 J. Lawrence, University of Virginia
CS 4810: Introduction to Computer Graphics – http://bit.ly/hPIXdi

Articulated Figures [4]: Bones & Joints

- Articulated figure:

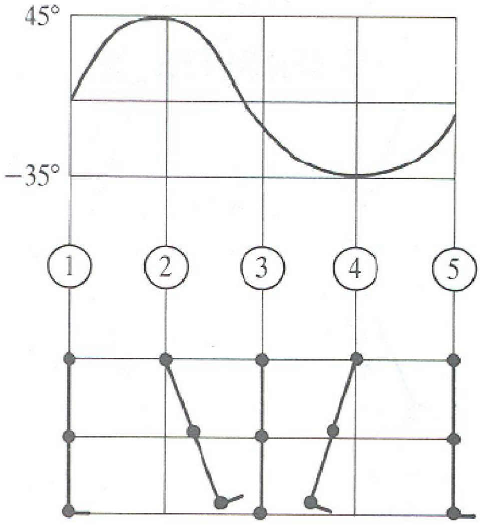


Watt & Watt

© 2010 J. Lawrence, University of Virginia
CS 4810: Introduction to Computer Graphics – http://bit.ly/hPlXdi

Articulated Figures [5]: Example – Walk Cycle 1

- Hip joint orientation:

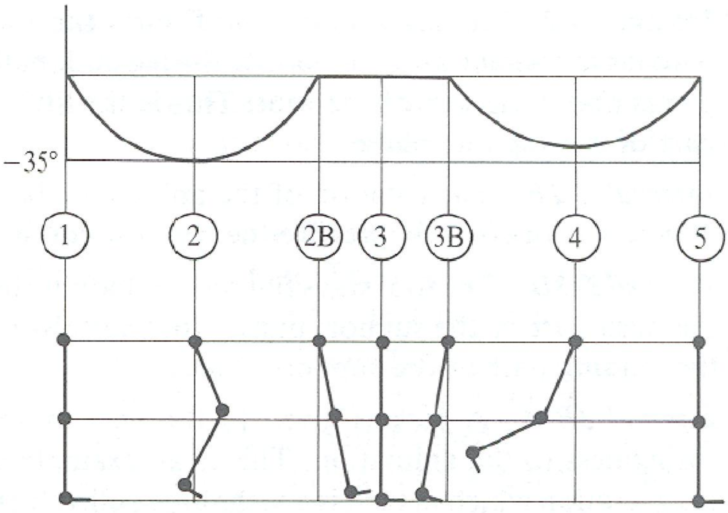


Watt & Watt

CS 4810: Introduction to Computer Graphics – http://bit.ly/hPIXdi

Articulated Figures [6]: Example – Walk Cycle 2

- Knee joint orientation:

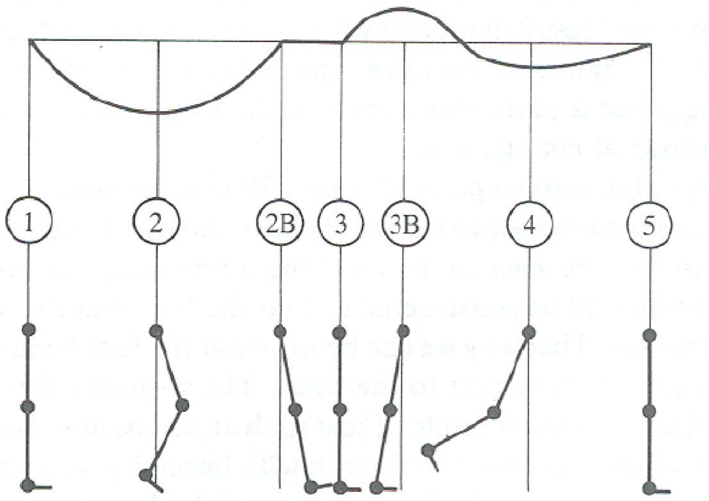


Watt & Watt

© 2010 J. Lawrence, University of Virginia
CS 4810: Introduction to Computer Graphics – http://bit.ly/hPIXdi

Articulated Figures [7]: Example – Walk Cycle 3

- Ankle joint orientation:



Watt & Watt

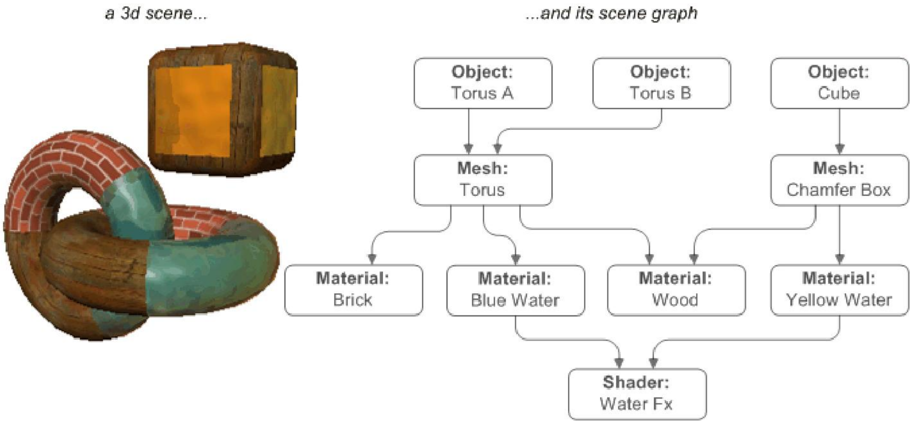
CS 4810: Introduction to Computer Graphics – http://bit.ly/hPIXdi

Articulated Figures [7]: Example – Walk Cycle 4

© 2002 D. M. Murillo
http://bit.ly/eZ9MA8

© 2010 J. Lawrence, University of Virginia
CS 4810: Introduction to Computer Graphics – http://bit.ly/hPlXdi

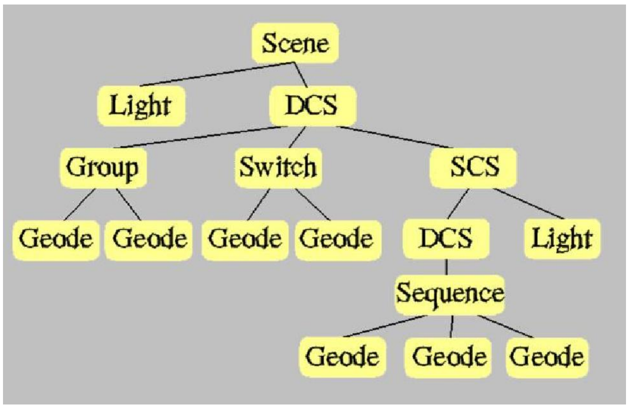
Looking Ahead: Scene Graph Traversal



http://bit.ly/eM1gz8

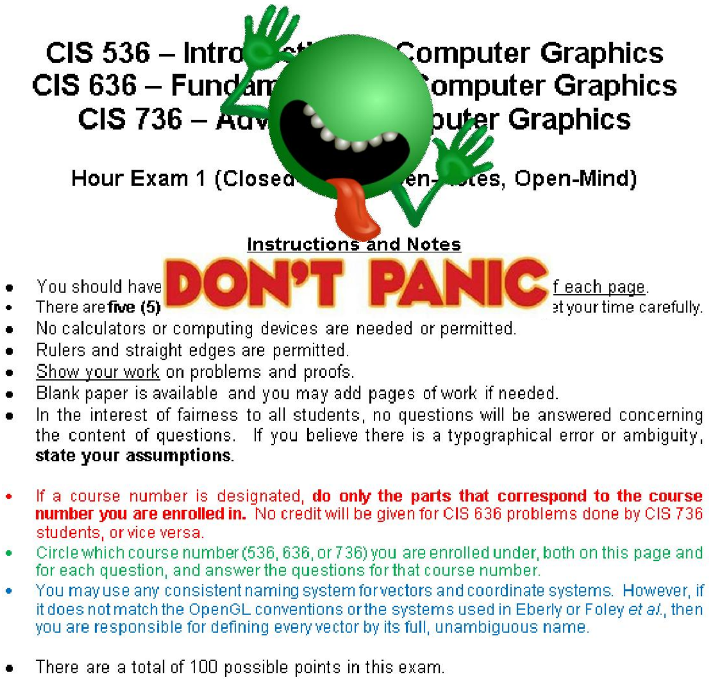
Looking Ahead: Scene Graph Rendering

IRIS Performer



Performer © 1997 D. Pape
http://www.evl.uic.edu/pape/talks/VSI97/pf/

Problem Set 3:
Hour Exam 1Review



CIS 536 – Intro Computer Graphics
CIS 636 – Fundam omputer Graphics
CIS 736 – Adv puter Graphics

Hour Exam 1 (Closed en- tes, Open-Mind)

Instructions and Notes

- You should have f each page.
- There are **five (5)** et your time carefully.
- No calculators or computing devices are needed or permitted.
- Rulers and straight edges are permitted.
- Show your work on problems and proofs.
- Blank paper is available and you may add pages of work if needed.
- In the interest of fairness to all students, no questions will be answered concerning the content of questions. If you believe there is a typographical error or ambiguity, **state your assumptions**.

- If a course number is designated, **do only the parts that correspond to the course number you are enrolled in.** No credit will be given for CIS 636 problems done by CIS 736 students, or vice versa.
- Circle which course number (536, 636, or 736) you are enrolled under, both on this page and for each question, and answer the questions for that course number.
- You may use any consistent naming system for vectors and coordinate systems. However, if it does not match the OpenGL conventions or the systems used in Eberly or Foley *et al.*, then you are responsible for defining every vector by its full, unambiguous name.

- There are a total of 100 possible points in this exam.

Summary

- Reading for Last Class: §2.6, 20.1, Eberly *2*^{e}; OpenGL primer material
- Reading for Today: §5.1 – 5.2, Eberly *2*^{e}
- Reading for Next Lecture (Two Classes from Now): §4.4 – 4.7, Eberly *2*^{e}
- Last Time: Shading and Transparency in OpenGL
  - Alpha blending
  - Painter’s algorithm – less efficient, can handle non-opaque objects
  - Depth buffering (*z*-buffering) – in hardware, fast, opaque only
- Today: Introduction to Animation
  - What is it and how does it work?
  - Brief history
  - Principles of traditional animation
  - Keyframe animation
  - Articulated figures: inbetweening

Terminology

- Shading and Transparency in OpenGL: Alpha, Painter's, *z*-buffering
- Animation – Bringing Still Objects "to Life" (Change Over Time)
- Early Animation
  - Thaumatrope (*c.* 1824) – early Victorian toy prefiguring flipbooks
  - Flipbook – simple paper-based animation technique
- Action in Traditional Animation
  - Before: squash & stretch, timing, anticipation, staging
  - During: exaggeration, secondary
  - After: follow-through & overlapping action
  - Design: straight-ahead *vs.* pose-to-pose
- Keyframe Animation
  - Inbetweening – interpolation technique
    - Lerping – linear interpolation
    - Splines & other cubic curves
  - Articulated figures: angular interpolation