Lecture 23: Thursday, 2 December 1999

Administrative:
  Class evaluations final 15 minutes
  Final project items:
    4-035 reserved for 6.837 (see my email)
    Written reports (ps, html, pdf) F 5pm
    Presentations in 3-133 (schedule posted)
      Friends, supporters &c. welcome
    Artifacts to TAs at end of session
    IAP/S2000 "6.837 night" in 26-100
Today, Final lecture:
  Future directions in graphics
    Other contexts
    Academia
    R & D
    Industry
  Class overview & summary

Gaming / Entertainment

Interaction techniques
    Disambiguating 2D/3D motions
    Rendering acceleration
    Incorporating Sound/Haptics
Networking / large #'s of characters
Autonomous characters ("AIs")
Geometric indexing & algorithms, e.g., for
    Efficient collision detection
    Efficient intervisibility/interaudibility

Rendering Algorithms

Realism vs. CPU, Storage Cost
Static/dynamic aspects:
  Observer
  Structural scene elements
  Detail scene elements
Realism:
  Procedural
  Physically-based
Use of parallelism, precomputation

Scientific Visualization & Analysis

Physical Phenomena
Visualizing Sensor Data
Simulation of Mechanical systems
    Linked rigid body kinematics
    Energy, momentum conservation
    Efficient collision detection
    Fluid flow, rendering – line w/ physics

Design/Evaluation Tools

Rapid specification and prototyping
  Input devices, 2D/3D disambiguation
Exploring design spaces
Evaluation of design alternatives
  Coupled simulations:
    Fire spread, egress routes, etc.
    Acoustic, illumination analysis
    Optimization loops, auto-design

Performance/Entertainment

Synthesis of live and CG characters
  Segmentation, masking, composition algorithms
Coupling visuals with audio streams
  Synchronization algorithms
  Generation of gestures, vocal tract & mouth
  CG Puppetry (e.g., Paris Media Lab)

Medical Applications

Image-guided surgery
Tele-robotic surgery
Education (visible male & female)

Modeling & Animation

Shape Definition
  Human-specified? Procedural? Sensed?
  Static or dynamic?
Texture Acquisition / Generation
Articulation & Kinematics
Lighting definition & preview
Key Framing Objects, Camera, etc.
Algorithmics:
  Computer Vision, Image Processing, Comp Geom,
Numerical Optimization, Artificial Intelligence...

Academia (Alphabetical Order)

Typical sequence:
  PhD (3-6 years)
  PostDoc (Common, 1-2 years)
  From there: industry, academic lab, academia
UC Berkeley
  Brian Barsky
    Splines, cornea modeling
  Paul Debevec, Jitendra Malik
    Semi-automated modeling from images
  David Forsythe
    Computer vision, global illumination
  Carlo Séquin
    Walkthroughs, fire-spreading simulation
    Geometric modeling and interaction
British Columbia (UBC)
  Dave Forsey
    Geometric modeling
  Alain Fournier
    Global illumination, real/synthetic imagery

Brown
  Andy van Dam
    Direct manipulation 3D UI's
  John Hughes
    Ceiling head-trackers, VR
    Gestural 3D user interfaces
Cal Tech
  Jim Arvo
    Global illumination (theory)
  Barr, Blinn, Kajiya
    Classical modeling, rendering
  Peter Schröder
    Global illumination, wavelets
Chapel Hill (UNC)
  Fred Brooks
    Virtual design & simulation systems
  Henry Fuchs
    Pixel-Planes, PixelFlow architectures
  Jack Snoeyink
    Computational geometry, GIS
  Dinesh Manocha
    Very large CAD, occlusion culling

Carnegie Mellon (CMU)
  Paul Heckbert
    Rendering, modeling, sampling
  Steve Seitz
    Image-based modeling & rendering
  David Baraff [to Pixar]
    Physically-based simulation (e.g., collisions)
  Andy Witkin [to Pixar]
    Procedural textures, image processing
Cornell
  Don Greenberg, Peter Shirley
    Architecture, Global Illumination
  Dan Huttenlocher
    Computational geometry, computer vision
UC Davis
  Ken Joy, complex CAD modeling/rendering
Georgia Tech
  Jessica Hodgins, human figures, p-based modeling
  Greg Turk, 3D scanning and editing
Harvard
  Steven Gortler, multiresolution methods, IBMR

MIT:
  Steve Benton
    Holography, static & dynamic
  Leonard McMillan
    Specialized rendering hardware
    Plenoptic (image-based) rendering
  Julie Dorsey
    Modeling and simulation; realism
  Olivier Faugeras, Berthold Horn
    Mathematical Vision
  Eric Grimson
    Image-guided surgery
  Ken Salisbury
    Haptic interfaces
  Seth Teller
    3D Capture; Comp. Geom.; Visib; Educational s/w
  Paul Viola
    Machine Vision, Formula understanding

Montreal
  Pierre Poulin
    Rendering, reflection models, particle systems
NYU
  Ken Perlin
    Rendering, multi-resolution desktop UIs
Princeton
  David Dobkin
    Comp geom, spatial data structures, discrepancy
  Bernard Chazelle
    Computational geometry, surface partitioning
  Adam Finkelstein
    Image indexing, animation, multi-res techniques
  Tom Funkhouser
    Interactivity, large many-user environments

Academia (cont.)

UC Santa Cruz
  Jane Wilhelms
    Volume rendering
Stanford
  Bill Dally
    Parallel, image-based rendering h/w
  Leo Guibas
    Comp geometry, global illumination
  Pat Hanrahan
    Volume rendering, global illumination, workbench
  Marc Levoy
    3D scanning, volume rendering
      Digital Michelangelo Project
Toronto
  Demetri Terzopoulos, solid modeling
UW (Seattle)
  Brian Curless: high-resolution 3D scanning
  David Salesin: Rendering, modeling

Industry

Development position (BSc, MSc, MEng, etc.)
R & D lab (usually requires advanced degree...)

R & D (mostly "R")

Lucent/Bell Labs
  Tom Duff: Rendering, digital imaging
  Ken Clarkson, Steve Fortune, Peter Shor
    Comp geom, randomized algs, quantum computing
Microsoft Research (Redmond)
  Michael Cohen, Jim Kajiya, Andy Glassner, Jim Blinn...
    Rendering, animation, agents
  Talisman architecture, Direct3D
MERL (Mitsubishi Electric Research Labs), Cambridge
  Perception, Haptics, Interaction, Vision
CRL (Compaq/DEC Research Labs), Cambridge
  Facial anim., smart-kiosks, vision-based interaction
IBM Watson, Yorktown, Almaden
  Gabriel Taubin, Holly Rushmeier...
    Solid modeling, surface design, visualization
  Satyan Coorg

    Occlusion culling, computer vision, optimization
Xerox PARC
  Data browsing, direct-manipulation UIs, CG & vis
DEC SRC
INRIA (France, many centers)

Industry R & D (some "R", lots of "D")

LEGO Futura (Boston)
  LEGO design, "smart" bricks
Viewpoint DataLabs (Oregon)
  Acquisition, motion capture (new VC rounds)
BDI (Boston Dynamics Inc.; Marc Raibert)
  Motion capture & merging, Haptics, VR
  Very good at autonomous motion & transitions
SRI, SDRC, Mitre, TASC, Aberdeen
  Military pursuits
  Photogrammetry, radar, range-finding...
Schlumberger
  3D modeling, site exploration

Government Labs

Lawrence Berkeley Labs
   Illumination engineering, goniometry
NIST
   Illumination standards, goniometry
NIMA/DMA
   Imagery & photogrammetry archives

Graphics Hardware

SGI GT, GTX, VGX, RE, REII, IR, 02, N64, Octane...
Cutting (bleeding) edge h/w development
   Near massively parallel, many $$ are OK
   Development: ASIC, off-shelf, μ-coding!
Workstation competition: IBM, Sun, HP, etc.
  6-18 month lag
Recently, low-end graphics, e..g, Indy, N64
PC-cards (NVidia, ATI, etc.) catching up at low end
Even Microsoft (Talisman, still a bad idea)

Graphics Libraries, UI Toolkits

OpenGL, Mesa, Inventor, Performer
   Template ports, etc.
Pixar RenderMan
IBM 3DIX, Brush
RenderWare, RenderMorphics
Direct3D
FLTK (cross-platform, very nice)

Graphics Application Development

Boeing
   Design/simulate jet with 10^{10} parts
AutoDesk
   AutoCAD modeler, on many/most designer desks
   Kinetix/3D Studio Max
InterGraph (CAD)
   Heavy use of scans, semi-automatic acquisition
Trumbull, Disney
   Interactive (sometimes autonomous) Vis Sim
   Autonomous ride development! (Raiders of Lost Ark)
NASA (including JPL)
   Large-scale scientific visualization

Creative Tool Users/Builders

Startup CAD/Visual Simulation hybrids
   LightScape (radiosity, illumination engineering)
   Virtus (rapid architectural prototyping, rendering)
   Other tools for fast house/room "sketching"
   Foto-Builder, Canoma: photogrammetric modelers

Interaction Devices

FakeSpace Boom (mechanical eye tracking)
Polhemus (6 DOF mouse; full-body motion capture)
SensAble devices Phantom (haptic device)
SpaceBall (6 DOF, torque + stick + push/pull)
Hi-Ball (6DOF LED-based head tracker from UNC)

Geometry Acquisition

CyberWare scanner (laser stripe with triangulation)
Video-brush, real time stereo acquisition, &c.
Satellite-imagery (side-looking + photogrammetry)
Range-scanners (AM; time-of-flight)
    Need UI, signal processing, geometry expertise

Cinematic "production" houses

Old days: animator, TD, s/w producer all one
Now: strong division
    Animators (artistic types)
        Be animators, express motion, emotion, etc.
    Engineers
        Craft tools that let animators be animators
PDI, Pixar
    "Puppeteering" view of world
    Animator is given lots of abstract strings
    Bottleneck: instrumenting models with "avars"
SoftImage/Alias
    Hierarchical modeling, DAG nodes
    Animator must specify causes, effects

Job directions

If you want to be an animator
    requires "classical" art skills
How (much) involved in production?
    Make pictures, or...
    Develop tools & infrastructure
        For example, at Pixar, many s/w
        engineers write per-surface "shaders"
What kind of coding?
    Infrastructure, steady tool development
    "Front lines", weird code for particular shot
        E.g,, stretching fabric on moving characters
        Often, front line stuff "migrates" to corpus

Examples

Pixar, modeling Mr. Potato Head
  There is no hierarchical (say, ascii) model
  All modeling is procedural, with "strings"
  MPH's mouth is a piece of code!
Toolmakers
  Fast
  Good high-level interface
  Not too many strings / DOFs!
  Support for subtle timing adjustments

Trends

Procedural modeling
  Stop-motion animation vs. bag of clay
Code, rather than object, toolkits
  Example: Prisms (SideEffects, Toronto)
  Pixar, RenderMan (C-like API + linear algebra)
  Also, Digital Domain
2D world
  Animo (2D system, bought by DreamWorks)
    Animator draws keyframes
    Animo: high-level control of spline shapes
  Near-intelligent systems for coloring, etc.
Image-Based Modeling and Rendering
  Generating novel views from real images

Tech Houses

Lyon-Lamb
WindLight
  Motion capture, R/T performance animation
Sony Picture, ImageWorks
Disney – hiring for coming films (CGI Dinosaurs)

Decisions

S/W only? Production (tool use) only? Both?
Huge CGI production for CDrom games (market?)
  Increasing use of fancy animation
  Focus mostly on user-level s/w
  Metropolis, Origin Systems
  Electronic Arts, Broderbund
Commercial spots
  PDI, Editel, PostPerformance, TapeHouse
Tight-focus effects, synthetic/real blends

Decisions

Effects? Live action? Synth/ Integration? Or...
  Lots of compositing issues
Animation (fully synthetic)
PDI does mixture, e.g., 3D Simpsons
R&H does mixture, Coca-Cola Polar Bear
ILM does mostly effects (Jurassic Park, Casper)

Small Studios

Buzz (Montreal)
Animatics (LA)
CORE Digital Pictures (Toronto)
  Outer Limits, TekWar
Foundation Imaging (LA)
  Babylon 5, SeaQuest
Area 51 (Burbank)
  Space Above and Beyond
Tippet Studios (Berkeley)
  Stop-motion, recently moving to CGI
  Verhoeven's "Starship Troopers"
  "... a fun place, full of motor heads and other oddities..."
  "An MIT graphics jock who has his/her head screwed on right
  and is interested in film could have a lot of fun there..."

6.837 Overview

Rendering Fundamentals (Classical Pipeline)
Modeling Fundamentals (Coord. systems, Objects)
Illumination Methods
  Local (diffuse, specular)
  Ray Tracing (Global, specular only, view-dep)
  Radiosity (Global, diffuse only, vie-indep.)
Hardware Acceleration (Graphics Arch.)
Advanced Topics
  Texture Mapping
  Conversational Interfaces
  Color Spaces & Perception
  Splines
  Animation
  Physically-Based Modeling
  Acceleration of Ray-Casting/Tracing
  Visibility Computations

This Class

At this point, we hope you:
  have mastered CG abstractions, some techniques
  are familiar with state of art & practice
  feel confident deploying CG for visualization
    and communication in your own discipline
  have had genuine, nearly unconstrained
    design and implementation experience
  can confidently initiate R & D in CG
    in industrial or academic setting

Thank you.