Introduction

**(Thanks to Professions Andries
van Dam and John Hughes)**

What is Computer Graphics?

- Computer graphics generally means creation, storage and manipulation of models and images
- Such models come from diverse and expanding set of fields including physical, mathematical, artistic, biological, and even conceptual (abstract) structures

Frame from animation by William Latham, shown at SIGGRAPH 1992. Latham uses rules that govern patterns of natural forms to create his artwork.

Modeling vs. Rendering

- Modeling
  - Create models
  - Apply materials to models
  - Place models around scene
  - Place lights in scene
  - Place the camera
- Rendering
  - Take "picture" with camera
- Both can be done by modern commercial software:
  - Autodesk Maya™ ,3D Studio Max™, Blender™, etc.

Point Light

Spot Light

Directional Light

Ambient Light
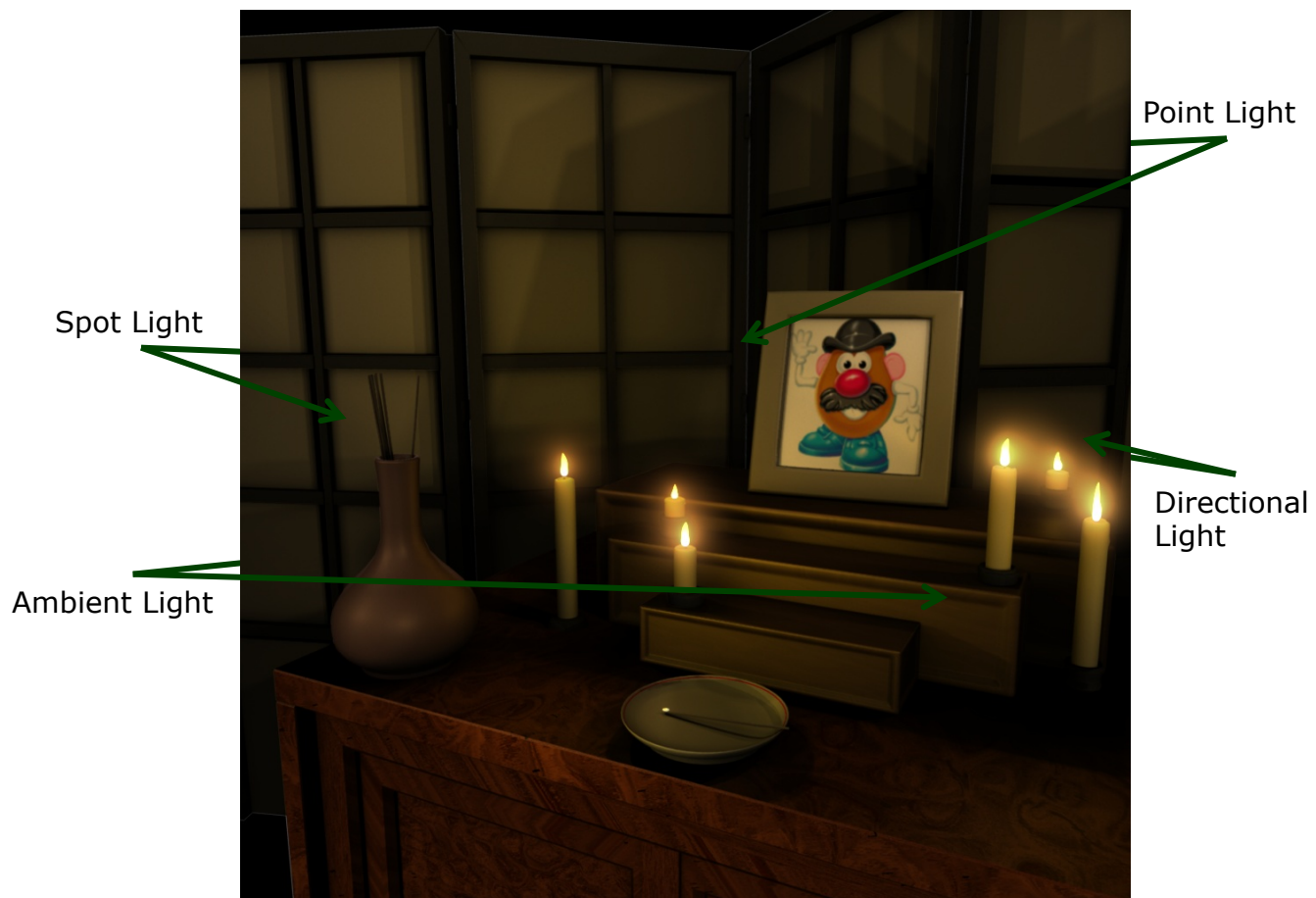
CS128 lighting assignment by Patrick Doran, Spring 2009

Solved problem: Rendering

Avatar 2009

What is Interactive Computer Graphics? (1/2)

- User controls contents, structure, and appearance of objects and their displayed images via rapid visual feedback

- Basic components of an interactive graphics system
  - input (e.g., mouse, tablet and stylus, multi-touch…)
  - processing (and storage)
  - display/output (e.g., screen, paper-based printer, video recorder…)

- First truly interactive graphics system, Sketchpad, pioneered at MIT by Ivan Sutherland for his 1963 Ph.D. thesis

- Used TX-2 transistorized "mainframe" at Lincoln Lab

Note CRT monitor, light pen and function-key panel

What is Interactive Computer Graphics? (2/2)

- Almost all key elements of interactive graphics system are expressed in first paragraph of Sutherland's 1963 Ph.D. thesis, *Sketchpad, A Man-Machine Graphical Communication System:*

  The Sketchpad system uses drawing as a novel communication medium for a computer. The system contains input, output, and computation programs which enable it to interpret information drawn directly on a computer display. Sketchpad has shown the most usefulness as an aid to the understanding of processes, such as the motion of linkages, which can be described with pictures. Sketchpad also makes it easy to draw highly repetitive or highly accurate drawings and to change drawings previously drawn with it…

- Today, still use non-interactive *batch mode* for final production-quality video and film (special effects), where one frame of a 24 fps movie may take 8-24 hours to render on fastest PC!
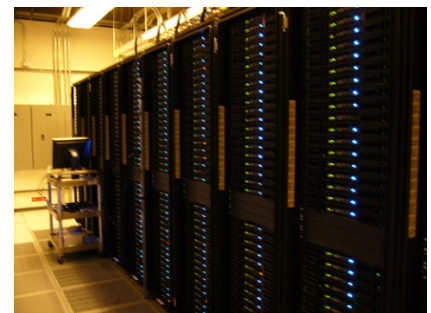
Render farm

Hardware

- ## Hardware revolution
  - Moore's Law: every 12-18 months, computer power improves by factor of 2 in price / performance as feature size shrinks
  - Significant advances in commodity graphics chips every 6 months, outrunning CPU chip advance
    - CPU: Intel Itanium 2 dual core has 1.7 billion transistors total
    - GPU: Radeon HD 5850 dual core has 1.8 billion per core
  - Newest processors are 64-bit, dual/quad/8 core
    - Intel Core 2 Quad™, AMD Athlon64 X2™, Mac Pro™ Quad/8-Core
  - Graphic subsystems
    - Offloads graphics processing from CPU to chip designed for doing graphics operations fast
    - nVidia GeForce™, ATI Radeon™
    - GPUs, being so fast are used for special purpose computation, also being ganged together to make supercomputers
  - GPU has led to development of other dedicated subsystems
    - Physics: nVidia PhysX PPU (Physics Processing Unit)
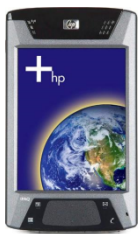   - Artificial Intelligence: AIseek Intia Processor

Project Natal

Input devices

nVidia GeForce™ chip

Enabling Modern Computer Graphics

- Many form factors
    - Cell Phones/PDAs (e.g., iPhones), Laptop/Desktops,
    - 3D immersive virtual reality systems such as Brown's Cave™ (180 George Street)
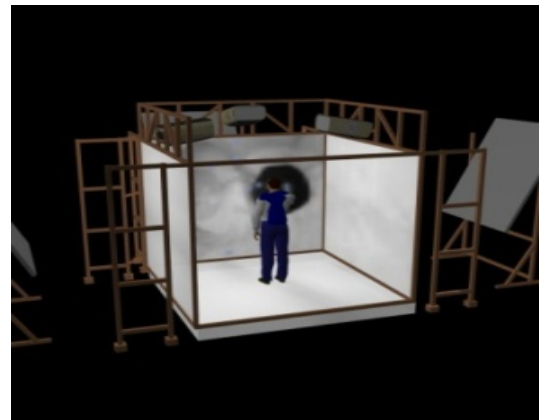
HP I-Paq™   Blackberry Storm™   Apple iPhone™

Brown's Cave™

- Software Improvements
    - Algorithms and data structures
        - Modeling of materials
        - Rendering of natural phenomena
        - Acceleration data structures for ray tracing
    - Parallelization
        - Most operations are embarrassingly parallel: changing value of one pixel is often independent of other pixels
    - Distributed and Cloud computing
        - Send operations into 'cloud', get back results, don't care how
        - Rendering even available as internet service!

Environmental (R)evolution (1/3)

## Character Displays (1960s – now)

- **Display:** text plus alphamosaic pseudo-graphics
- **Object and command specification:** command-line typing
- **Control over appearance:** coding for text formatting (.p = paragraph, .i 5 = indent 5)
- **Application control:** single task

Environmental (R)evolution (2/3)

2D bitmap raster displays for PCs and workstations (1972 at Xerox PARC - now)

- **Display:** windows, icons, legible text, "flat earth" graphics

  Note: late 60's saw first use of raster graphics, especially for flight simulators

- **Object and command specification:** minimal typing via WIMP (Windows, Icons, Menus, Pointer) GUI: point-and-click selection of menu items and objects, widgets and direct manipulation (e.g., drag and drop), "messy desktop" metaphor

- **Control over appearance:** WYSIWYG (which is really WYSIAYG, What You See Is **All** You Get)

- **Application control:** multi-tasking, networked *client-server* computation and window management (even "X terminals")
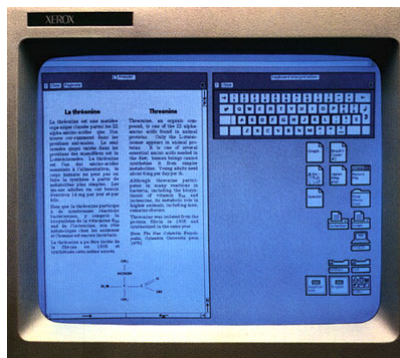
Environmental (R)evolution (3/3)

## 3D graphics workstations (1984 at SGI – now)

- **Display:** real-time, pseudo-realistic images of 3D scenes
- **Object and command specification:** 2D, 3D and nD input devices (controlling 3+ degrees of freedom) and force feedback haptic devices for point-and-click, widgets, and direct manipulation
- **Control over appearance:** WYSIWYG (still WYSIAYG)
- **Application control:** multi-tasking, networked (client/server) computation and window management
- High-end PCs with hot graphics cards (nVidia GeForce™, ATI Radeon™) have supplanted graphics workstations
- Such PCs are clustered together over high speed buses or LANs to provide "scalable graphics" to drive tiled PowerWalls, Caves, etc.

Silicon Graphics® Octane2™

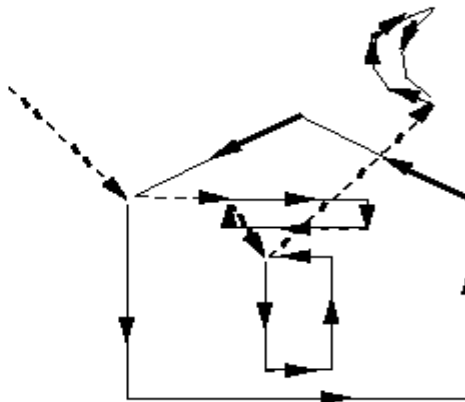# Graphics Display Hardware

- Vector (calligraphic, stroke, random-scan)
  - Driven by display commands (move (x, y), char("A") , line(x, y)…)
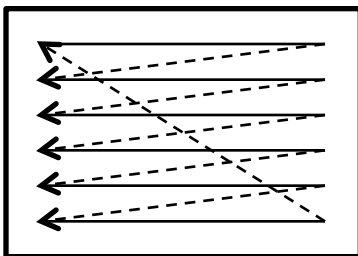 - Survives as "scalable vector graphics"
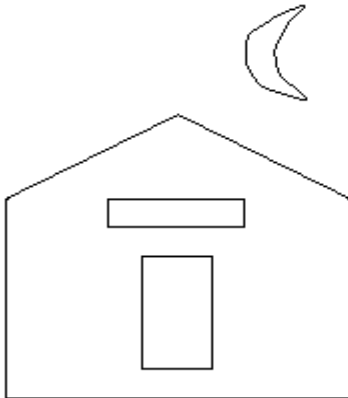
Ideal Drawing

Vector Drawing

- Raster (TV, bitmap, pixmap) used in displays and laser printers
  - Driven by array of pixels (no semantics, lowest form of representation)
  - Note "jaggies" (aliasing errors) due to sampling continuous primitives

Raster

outline primitives

filled primitives

Conceptual Framework for Interactive Graphics

- Graphics library/package is intermediary between application and display hardware (Graphics System)
- Application program maps application objects to views (images) of those objects by calling on graphics library. Application model may contain lots of non-graphical data (e.g., non-geometric object properties)
- User interaction results in modification of model and/or image
- Unlike with FX, images are often means to an end: synthesis, design, manufacturing, visualization,…
- This hardware and software framework is more than 4 decades old but is still useful, indeed dominant

Software ← → **Hardware**

Application Model/data base → Application program → Graphics Library → Graphics System/ GPU
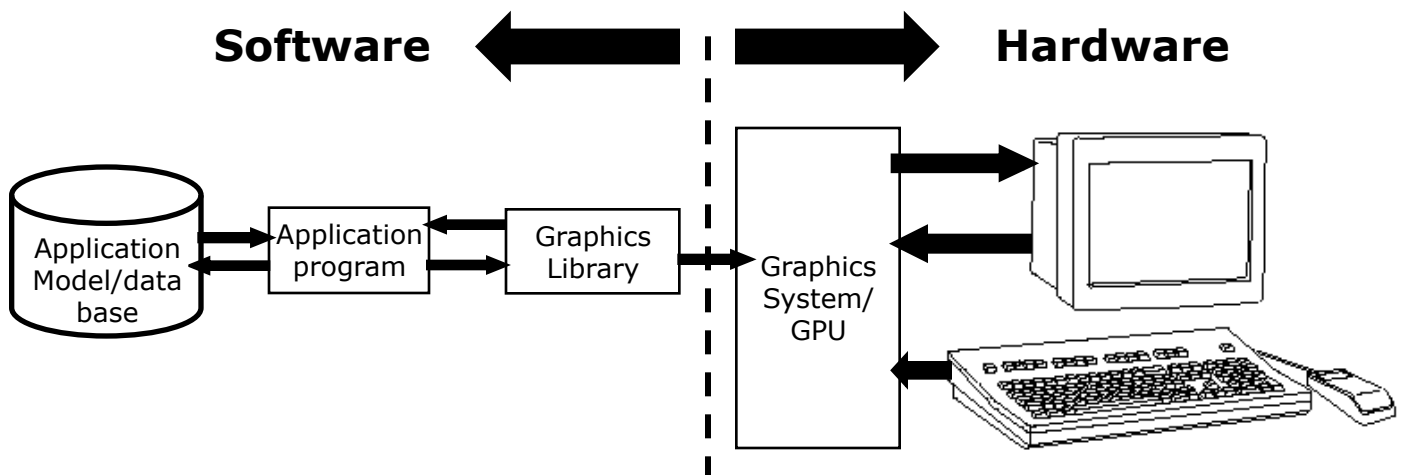
Graphics Library

- Examples: OpenGL™, DirectX™, Windows Presentation Foundation™ (WPF), RenderMan™
- Primitives (chars, lines, polygons, meshes,…)
- Attributes
    - color
    - line style
    - material properties for 3D
- Lights
- Transformations
- Immediate mode vs. retained mode
    - immediate mode: no stored representation, package holds only attribute state, and application must completely draw each frame
    - retained mode: library compiles and displays from **scenegraph** that it maintains, a complex DAG. It is a display-centered extract of the Application Model
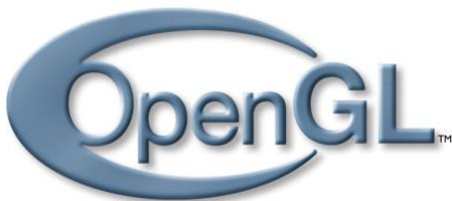
Today's trend: Simulation and Modeling

ACM SIGGRAPH 2007

Adaptively Sampled Particle Fluids

Bart Adams
Stanford University / KU Leuven

Mark Pauly
ETH Zürich

Richard Keiser
LiberoVision Inc. / ETH Zürich

Leonidas J. Guibas
Stanford University

Video courtesy of ETH

**http://data.agg.ethz.ch/publications/
2007/adams_2007_ASP.avi**

Interactive Programming