Multimedia
Graphic and Audio I/O

COMP375

• “A display connected to a digital computer gives us a chance to gain familiarity with concepts not realizable in the physical world. It is a looking glass into a mathematical wonderland.”

• “The ultimate display would, of course, be a room within which the computer can control the existence of matter. A chair displayed in such a room would be good enough to sit in. Handcuffs displayed in such a room would be confining, and a bullet displayed in such a room would be fatal.”

Ivan Sutherland
considered by many to be the creator of Computer Graphics

Graphics Throughput

• The monitor is the I/O device with the highest data throughput.
• Consider a 1200x1024 pixel display with 32 bit color that is refreshed 24 times a second. This requires 118 M bytes/sec or about 1 G bit/sec
• The challenge is to build a system that can handle that much data
• Far less data is actually transferred to the graphics controller

Graphics Processing Unit

• The Graphics Processing Unit (GPU) is a specialized processor that offloads 2D and 3D graphics rendering from the CPU
• Most computers have a GPU built into the mother board. Some computers have a separate video card for the GPU
History of Graphics Hardware

• The original IBM PC of 1982 could display only characters
• Boxes and primitive shapes could be created by displaying special characters such as ▼▼ ▲▲ — — —
• An area of memory contained the data that was displayed on the monitor. There were two bytes per character: data and attributes
• Programs could write directly to this display buffer

First Graphics Controller

• The IBM Professional Graphics Controller was one of the very first 2D/3D graphics accelerators available for the IBM PC in 1984.
• 10 years before hardware 3D acceleration became a standard
• Unable to succeed in the mass-market
  – High price ($4,500 in 1984 currency or $9,150 now)
  – Slow processor (Intel 8088 running at 8 MHz)
  – Lack of compatibility

CPU Control of Early Graphics

• The CPU had to do all of the processing for graphics in early computers
• The screen images were stored in RAM as framebuffers
• To move an object on the screen the CPU would have to move the bits representing the image
• Games would have to size the bit images to ensure the CPU could move them fast enough

Blitter

• The Commodore Amiga was the first mass-market computer to include a blitter in its video hardware
• Bit-Block Image Transfer (Bit BLIT) is a computer graphics operation in which several bitmaps are combined into one using logical operations such as AND, OR, XOR or NOT
• Useful for 2D graphics
Bit BLIT Example

• The goal is to insert several copies of the small sprite into the larger image

The sprite above is shown with a one bit mask

Bit BLIT Example

• The mask is ANDed with the image. This forms holes in the image.

The mask defines the area the sprite will occupy.

Bit BLIT Example

• The sprite is ORed with the image which copies the image into the holes

A bit mask with more than 1 bit would allow for partial transparency

Bit BLIT Example

• The mask is ANDed with the image. This forms holes in the image.

The mask defines the area the sprite will occupy.

OpenGL

• OpenGL software appeared in the early 1990s as a professional graphics API
• The influence of OpenGL eventually led to widespread hardware support
• OpenGL supports both 2D and 3D graphics
Linear Algebra

- Most 3D graphic functions can be defined as a matrix operation on an array containing the image.
- Translation, rotation, scaling and other actions can be implemented by matrix multiplication.

Modern Graphics Processing Unit

- A GPU is designed to perform high speed matrix manipulation.
- The GPU may connect to the CPU through a specialized bus such as PCI Express (PCIe) or Accelerated Graphics Port (AGP).
- NVIDIA and ATI control nearly 100% of the GPU market.
- The goal is to provide movie-like quality in a real-time game.

GPU I/O

- The input to a GPU is:
  - Data representing a model of the image to be displayed.
  - Commands specifying how the image should be displayed.
- The output of the GPU is sent to the monitor display:
  - Digital through a Digital Video Input (DVI).
  - Analog through VGA and other formats.

GPU Architecture

- To rapidly render an image, a GPU has many parallel processors.
- The Nvidia GF100 has 512 processor cores.
Polygons

- The graphic image is modeled as a collection of objects in 3D space
- The image displayed is determined by the point of view and lighting in the 3D space
- 3D graphic images can be composed of triangles or polygons
- Polygons can be smoothed and textured by the GPU

Anti-aliasing

- Anti-aliasing improves how an image is viewed by smoothing the image when details are below the image resolution

Anti-aliasing by the GPU

- Anti-aliasing is one of the features provided by a modern GPU

Edge pixels are gray

GPU

- A GPU can perform matrix manipulation faster than most CPUs.
- As the processing power of GPUs has increased, so has their demand for electrical power. High performance GPUs often consume more energy than current CPUs.
- Some researchers doing high performance matrix computation have built systems that use a GPU to do the computation.
Vector and Pixel Graphics

Images can be defined as pixels or vectors
• **Pixels** define how each dot should be colored
• **Vectors** define the objects in an image. A circle might be defined by its center and radius

Audio

• Computer audio usually has a digital-to-analog converter (DAC), which converts recorded or generated digital data into an analog format
• The output signal is connected to an amplifier, headphones, or external device
• Input can be converted from analog to digital