

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

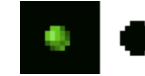
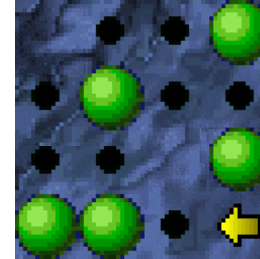
- The goal is to insert several copies of the small sprite into the larger image



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

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 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

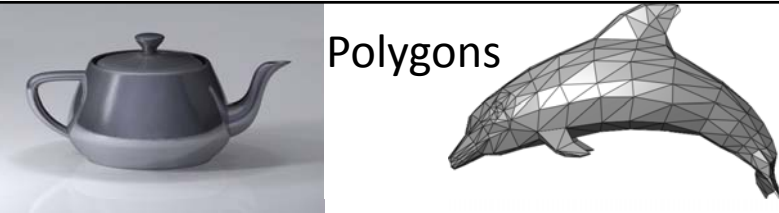
GPU I/O

- 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



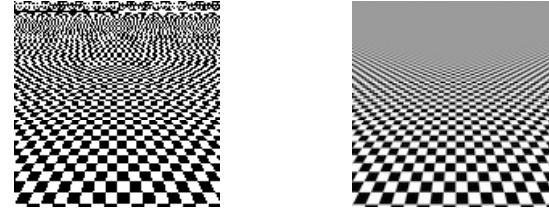


Polygons

- 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

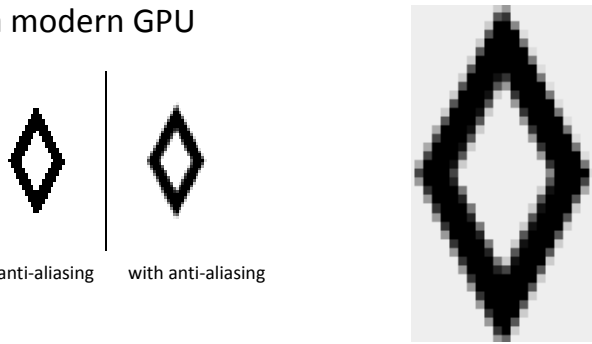
- Anti-aliasing improves how an image is viewed by smoothing the image when details are below the image resolution



Without Anti-aliasing With Anti-aliasing

Anti-aliasing by the GPU

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



without anti-aliasing with anti-aliasing

Edge pixels are gray

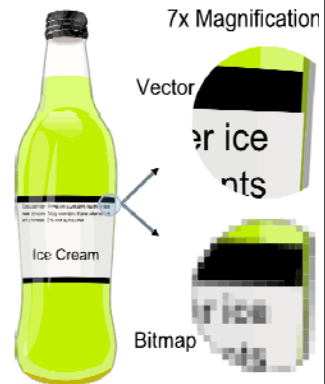
GPU

- 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