Computer graphics and design

Introduction : Computer graphics is concerned with producing images and animations (or sequences of images) using a computer. This includes the hardware and software systems used to make these images. The task of producing photo-realistic images is an extremely complex one, but this is a field that is in great demand because of the nearly limitless variety of applications. The field of computer graphics has grown enormously over the past 10–20 years, and many software systems have been developed for generating computer graphics of various sorts. This can includesystems for producing 3-dimensional models of the scene to be drawn, the rendering software for drawing the images, and the associated user- interface software and hardware.

Definition of 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. “Perhaps the best way to define computer graphics is to find out what it is not. It is not a machine.

It is not a computer, nor a group of computer programs. It is not the know-how of a graphic designer, a programmer, awriter, a motion picture specialist, or a reproduction specialist.

Computer graphics is all these –a consciously managed and documentedtechnology directed toward communicating information accurately and descriptively.

History

The Age of Sutherland

In the early 1960's IBM, Sperry-Rand, Burroughs and a few other computer companies existed. The computers of the day had a few kilobytes of memory, no operating systems to speak of and no graphical display monitors. The peripherals were Hollerith punch cards, line printers, and roll-paper plotters. The only programming languages supported were assembler, FORTRAN, and Algol. Function graphs and “Snoopy'' calendars were about the only graphics done.

In 1963 Ivan Sutherland presented his paper Sketchpad at the Summer Joint Computer Conference. Sketchpad allowed interactive design on a vector graphics display monitor with a light pen input device. Most people mark this event as the origins of computer graphics.

Hardware and Technology

Doug Englebart invented the mouse at Xerox PARC. The Evans & Sutherland Corporation and General Electric started building flight simulators with real-time raster graphics. The floppy disk was invented at IBM and the microprocessor was invented at Intel. The concept of a research network, the ARPANET, was developed.

Software and Algorithms

Rendering (shading) were discovered by Gouraud and Phong at the University of Utah. Phong also introduced a reflection model that included specular highlights. Keyframe based animation for 3-D graphics was demonstrated. Xerox PARC developed a ``paint'' program. Ed Catmull introduced parametric patch rendering, the z-buffer algorithm, and texture mapping. BASIC, C, and Unix were developed at Dartmouth and Bell Labs.

Hardware and Technology

An Evans & Sutherland Picture System was the high-end graphics computer. It was a vector display with hardware support for clipping and perspective. Xerox PARC introduced the Altos personal computer, and an 8 bit computer was invented at Intel.

Application of Computer Graphics

Medical Imaging

There are few endeavors more noble than the preservation of life. Today, it can honestly be said that computer graphics plays an significant role in saving lives. The range of application spans fromtools for teaching and diagnosis, all the way to treatment. Computer graphics is tool in medical applications rather than an a mere artifact. Nocheating or tricks allowed.

Scientific Visualization

Computer graphics makes vast quantities of data accessible. Numerical simulations frequently produce millions of data values. Similarly, satellite-based sensors amass data at rates beyond our abilities to interpret them by any other means than visually. Mathematicians use computer graphics to explore abstract and high-dimensional functions and spaces. Physicists can use computer graphics to transcend the limits of scale. With it they can explore both microscopic and macroscopic world

Computer Aided Design

Computer graphics has had a dramatic impact on the design process. Today, most mechanical and electronic designs are executed entirely on computer. Increasingly, architectural and product designs are also migrating to the computer. Automated tools are also available that verify tolerances and design constraints directly from CAD designs. CAD designs also play a key role in a wide range of processes from the designof tooling fixtures to manufacturing.

Graphical User Interfaces (GUIs)

Computer graphics is an integral part of everyday computing. Nowhere is this fact more evident than the modern computer interface design. Graphical elements such as windows, cursors, menus, and icons are so common place it is difficult to imagine computing without them. Once graphics programming was considered a speciality. Today, nearly all professional programmers must have an understanding of graphics in order to accept input and present output to users.

Games

Games are an important driving force in computer graphics. In this class we are going to talk about games. We'll discuss on how they work. We'll also question how they get so much done with so little to work with.

Entertainment

If you can imagine it, it can be done with computer graphics. Obviously, Hollywood has caught on to this. Each summer, we are amazed by state- of-the-art special effects. Computer graphics is now as much a part ofthe entertainment industry as stunt men and makeup. The entertainment industry plays many other important roles in the field of computer graphics.

What is Interactive Computer Graphics?

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

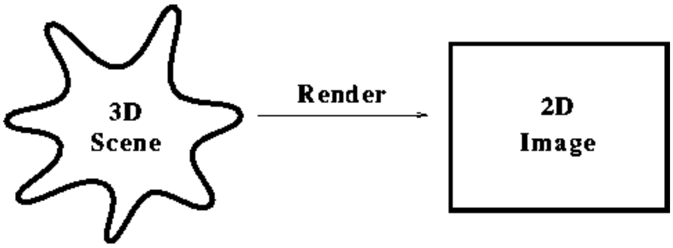
Basic components of an interactive graphics system input (e.g., mouse, tablet and stylus, force feedback device, scanner, live video streams…), processing (and storage), display/output (e.g., screen, paper-based printer, video recorder, non-linear editor.

What do we need in computer graphics?

In computer graphics we work with points and vectors defined in terms of some coordinate frame (a positioned coordinate system). We also need to change coordinate representation of points and vectors, hence to transform between different coordinate frames. Hence a mathematical background of geometry and algebra is very essential and also a knowledge of basic programming in C language.

The Graphics Rendering Pipeline

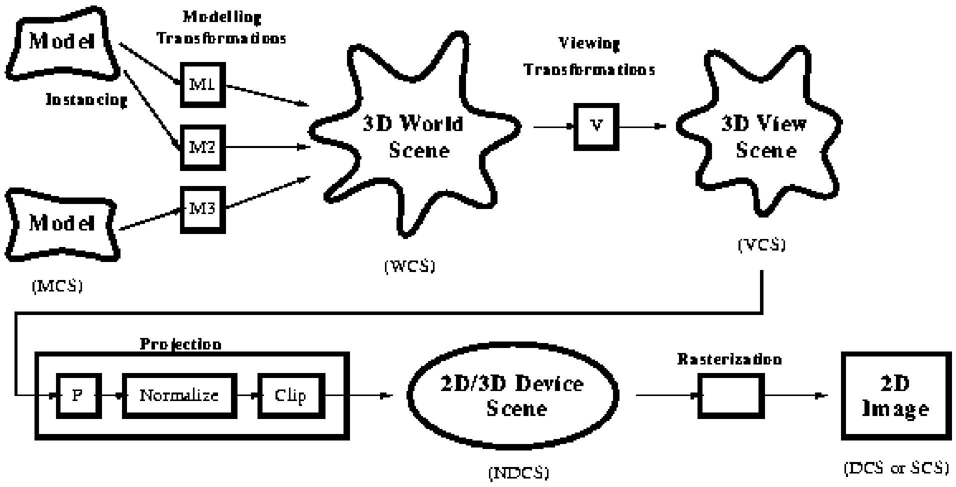
Rendering is the conversion of a scene into an image:
The scene composed of models in three space.



Models, composed of primitives, supported by the rendering system. Models entered by hand or created by a program.

For our purposes today, models already generated. The image drawn on monitor, printed on laser printer, or written to a raster in memory or a file. These different possibilities require us to consider device independence.

Classically, “model” to “scene”' to “image” conversion broken into finer steps, called the graphics pipeline. Commonly implemented in graphics hardware to get interactive speeds. At a high level, the graphics pipelineusually looks like



Each stage refines the scene, converting primitives in modelling space to primitives in device space, where they are converted to pixels (rasterized).

A number of coordinate systems are used:

MCS: Modeling Coordinate System.WCS: World Coordinate System.
VCS: Viewer Coordinate System.
NDCS: Normalized Device Coordinate System.
DCS or SCS : Device Coordinate System or equivalently the ScreenCoordinate System.

Keeping these straight is the key to understanding a rendering system. Transformation between two coordinate systems represented with matrix. Derived information may be added (lighting and shading) and primitives may be removed (hidden surface removal) or modified (clipping).

Hardware

"Vector graphics" Early graphic devices were line-oriented. Forexample, a "pen plotter" from H-P. Primitive operation is line drawing. "Raster graphics" Today's standard. A raster is a 2-dimensional grid of pixels (picture elements). Each pixel may be addressed and illuminated

independently. So the primitive operation is to draw a point; that is, assign a color to a pixel. Everything else is built upon that. There are a variety of raster devices, both hardcopy and display.

Hardcopy:
Laserprinter Ink-jet printer
Film recorder
Electrostatic printerPen plotter

Display Hardware

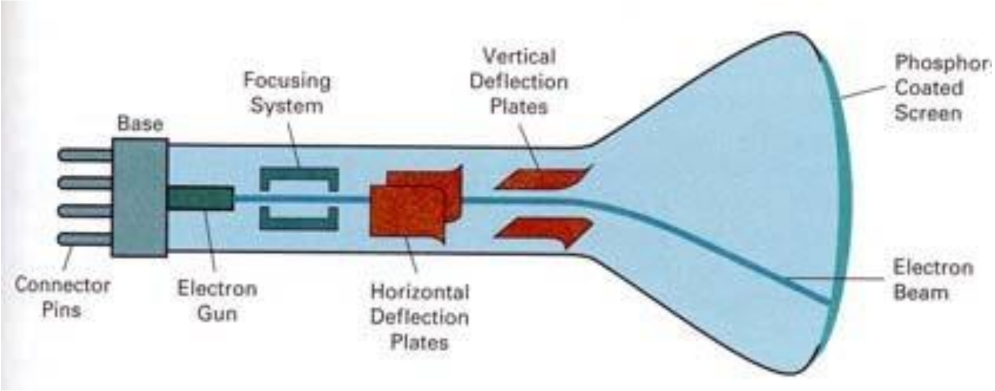
An important component is the "refresh buffer" or "frame buffer" which is a random-access memory containing one or more values per pixel, used to drive the display. The video controller translates the contents of the frame buffer into signals used by the CRT to illuminate the screen. Itworks as follows:

The display screen is coated with “phospors” which emit light when excited by an electron beam. (There are three types of phospor, emitting red, green, and blue light.) They are arranged in rows, with three phospor dots (R, G, and B) for each pixel.

The energy exciting the phosphors dissipates quickly, so the entire screen must be refreshed 60 times per second.

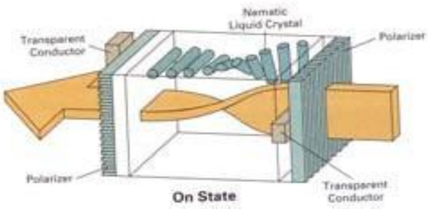
An electron gun scans the screen, line by line, mapping out a scan pattern. On each scan of the screen, each pixel is passed over once. Using the contents of the frame buffer, the controller controls the intensity of the beam hitting each pixel, producing a certain color.

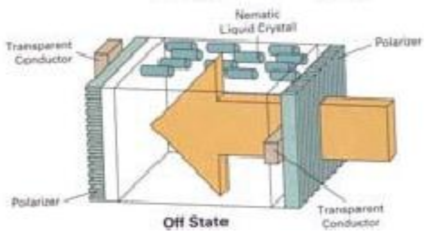
Cathode Ray Tube (CRT)



Electron gun sends beam aimed (deflected) at a particular point on the screen, Traces out a path on the screen, hitting each pixel once per cycle. “scan lines” · Phosphors emit light (phosphoresence); output decays rapidly (exponentially - 10 to 60 microseconds) · As a result of this decay, the entire screen must be redrawn (refreshed) at least 60 times per second. This is called the refresh rate . If the refresh rate is too slow, we will see a noticeable flicker on the screen. CFF (Critical Fusion Frequency) is the minimum refresh rate needed to avoid flicker. This depends to some degree on the human observer. Also depends on the persistence of the phosphors; that is, how long it takes for their output to decay. · The horizontal scan rate is defined as the number of scan lines traced out per second. · The most common form of CRT is theshadow-mask CRT. Each pixel consists of a group of three phosphor dots (one each for red, green, and blue), arranged in a triangular form called a triad. The shadow mask is a layer with one hole per pixel. To excite one pixel, the electron gun (actually three guns, one for each of red, green, and blue) fires its electron stream through the hole in the mask to hit that pixel. · The dot pitch is the distance between the centers of two triads. It is used to measure the resolution of the screen.

Liquid Crystal Display (LCD)





A liquid crystal display consists of 6 layers, arranged in the following order (back-to-front):

A reflective layer which acts as a mirror
A horizontal polarizer, which acts as a filter, allowing only thehorizontal component of light to pass through

A layer of horizontal grid wires used to address individual pixels

The liquid crystal layer

A layer of vertical grid wires used to address individual pixels
A vertical polarizer, which acts as a filter,allowing only the verticalcomponent of light to pass through

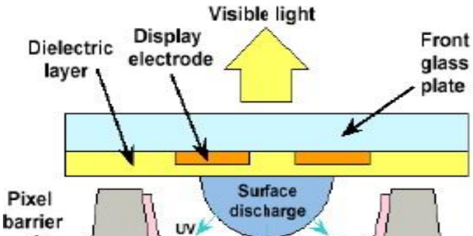
How it works:

The liquid crystal rotates the polarity of incoming light by 90 degrees. Ambient light is captured, vertically polarized, rotated to horizontalpolarity by the liquid crystal layer, passes through the horizontal filter, isreflected by the reflective layer, and passes back through all the layers,giving an appearance of lightness. However, if the liquid crystal molecules are charged, they become aligned and no longer change the polarity of light passing through them. If this occurs, no light can pass through the horizontal filter, so the screen appears dark.

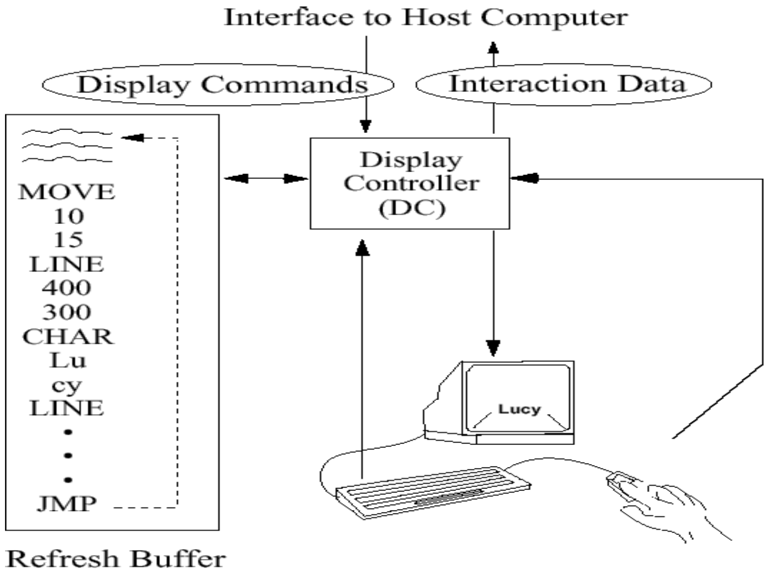
The principle of the display is to apply this charge selectively to points in the liquid crystal layer, thus lighting or not lighting points on the screen. Crystals can be dyed to provide color. An LCD may be backlit, so as not to be dependent on ambient light.

TFT (thin film transistor) is most popular LCD technology today. Plasma Display Panels

Promising for large format displaysBasically fluorescent tubes High-voltage discharge excites gas mixture (He, Xe)Upon relaxation UV light is emitted UV light excites phosphorsLarge viewing angle



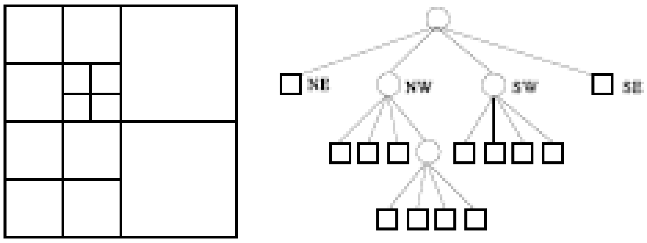
Vector Architecture



Raster Architecture

Quadtrees

A *quadtree* is a rooted tree so that every internal node has four children. Every node in the tree corresponds to a square. If a node v has children, their corresponding squares are the four quadrants, as shown



Quadtrees can store many kinds of data. We will describe the variantthat stores a set of points and suggest a recursive definition. A simple recursive splitting of squares is continued until there is only one point in a square. Let P be a set of points. The definition of a quadtree for a setof points in a square $Q = [x1_Q : x2_Q]$ £ $[y1_Q : y2_Q]$ is as follows:

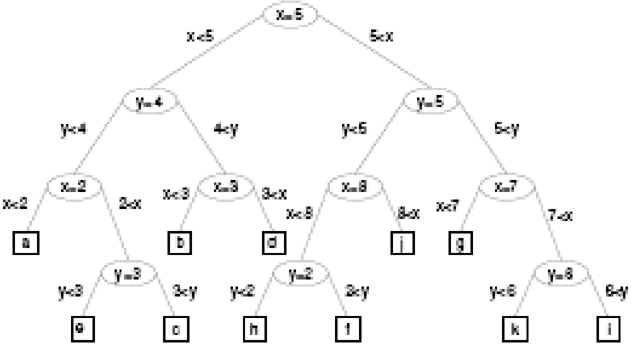
- If $jPj \cdot 1$ then the quadtree is a single leaf where Q and P are stored.
- Otherwise let Q_{NE}, Q_{NW}, Q_{SW} and Q_{SE} denote the four quadrants. Let x_{mid} $:= (x1_Q + x2_Q)/2$

and y_{mid} := $(y1_Q + y2_Q)/2$, and define P_{NE} := {p Î P : $p_x > x_{mid}$ ^ $py > ymid$}P_{NW} := {p Î P : p_x · x_{mid} ^ $py >$ $ymid$}P_{SW} := {p Î P : p_x · x_{mid} ^ py · $ymid$} P_{SE} := {p Î P : $p_x > x_{mid}$ ^ py · $ymid$}

The quadtree consists of a root node v, Q is stored at v. In the following, let $Q(v)$ denote the square stored at v. Furthermore v has four children: The X-child is the root of the quadtree of the set P_X, where X is an element of the set *{NE, NW, SW, SE}*.

K-d-Trees

The *k*-*d*-tree is a natural generalization of the one dimensional searchtree.
Let *D* be a set of *n* points For convenience let *k* = 2 and let usassume that all *X*-
and
Y-coordinates are different.



First we search for split values of the x coordinaters on the x coordinaters. Then we split d by the split line x=s into subsets.

For both sets we proceed with the Y-coordinate and split-lines Y = t_1 and Y = t_2. We repeat the process recursively with the constructedsubsets. Thus, we obtain a binary tree, namely the 2-tree of the point set D, as shown in the Figure above. Each internal node of the tree corresponds to a split-line.

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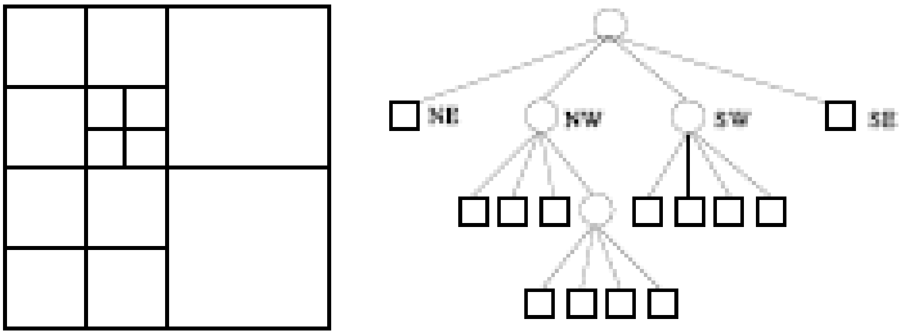

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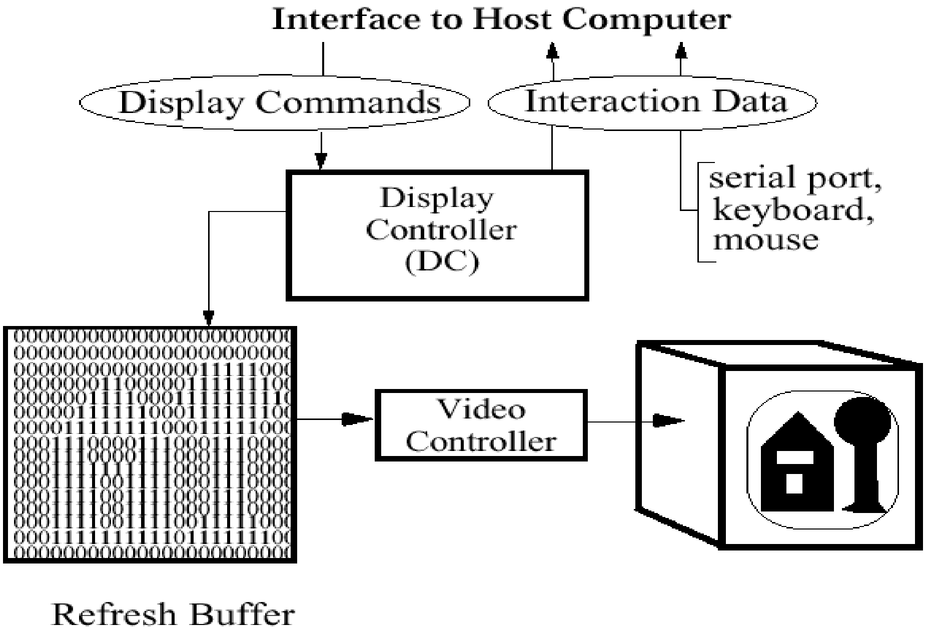
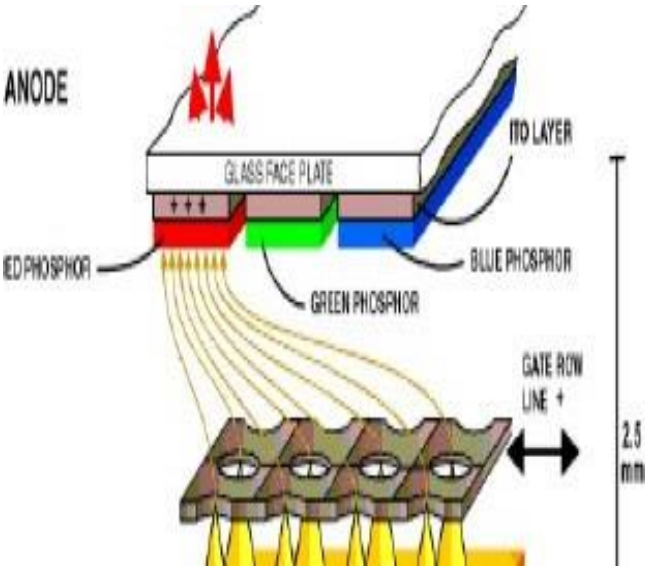


Raster display stores bitmap/pixmap in refresh buffer, also known as bitmap, frame buffer; be in separate hardware (VRAM) or in CPU's main memory (DRAM) Video controller draws all scan-lines at Consistent >60 Hz; separates update rate of the frame buffer and refreshrate of the CRT

Field Emission Devices (FEDs)



Works like a CRT with multiple electron guns at each pixel uses modest voltages applied to sharp points to producestrong E fields
Reliable electrodes proven difficult to produceLimited in size
Thin, and requires a vacuum

Interfacing between the CPU and the Display

A typical video interface card contains a display processor, a frame buffer, and a video controller. The frame buffer is a random access memory containing some memory (at least one bit) for each pixel,indicating how the pixel is supposed to be illuminated. The depth of the frame buffer measures the number of bits per pixel. A video controller then reads from the frame buffer and sends control signals to the monitor, driving the scan and refresh process. The display processor processes software instructions to load the frame buffer with data.

(Note: In early PCs, there was no display processor. The frame buffer was part of the physical address space addressable by the CPU. The CPU was responsible for all display functions.)
Some Typical Examples of Frame Buffer Structures:

- For a simple monochrome monitor, just use one bit per pixel.
- A gray-scale monitor displays only one color, but allows for a rangeof intensity levels at each pixel. A typical example would be to use 6-8 bits per pixel, giving 64-256 intensity levels. For a color monitor, we need a range of intensity levels for each of red, green, and blue. There are two ways to arrange this.

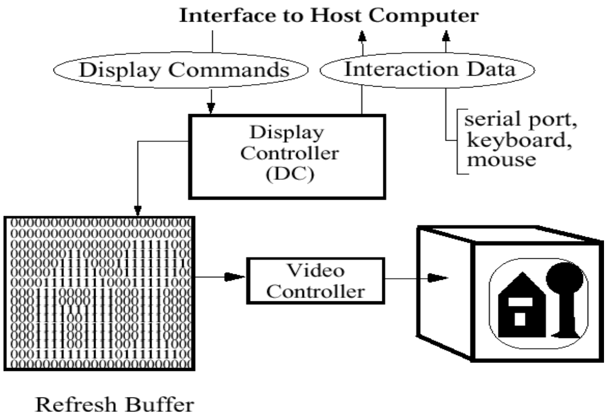
1) A color monitor may use a color lookup table (LUT). For example,we could have a LUT with 256 entries. Each entry contains a color represented by red, green, and blue values. We then could use a frame buffer with depth of 8. For each pixel, the frame buffer contains an index into the LUT, thus choosing one of the 256 possible colors. This approach saves memory, but limits the number of colors visible at any one time.

2) A frame buffer with a depth of 24 has 8 bits for each color, thus 256 intensity levels for each color. 224 colors may be displayed. Any pixel can have any color at any time. For a 1024x1024 monitor we would need 3 megabytes of memory for this type of frame buffer. The display processor can handle some medium-level functions like scan conversion (drawing lines, filling polygons),

not just turnpixels on and off. Other functions: bit block transfer, display list storage.Use of the display processor reduces CPU involvement and bus traffic resulting in a faster processor. Graphics processors have been increasing in power faster than CPUs, a new generation every 6-9 months. example: 10 3E. NVIDIA GeForce FX

3) 125 million transistors (GeForce4: 63 million)
4) 128MB RAM
5) 128-bit floating point pipeline

One of the advantages of a hardware-independent API like OpenGL is that it can be used with a wide range of CPU-display combinations, from software-only to hardware-only. It also means that a fast video card may run slowly if it does not have a good implementation ofOpenGL.



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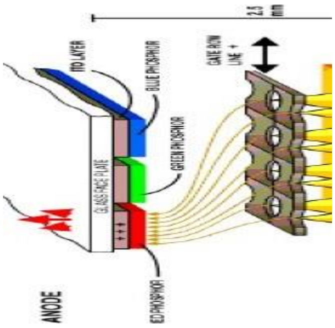

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