Display technology

Graphical displays are generally of two types: vector displays and raster displays.

Vector displays

Vector displays generally display lines, specified by their endpoints. Vector display systems operate by direct control of the electron beam of a cathode ray tube (CRT—discussed below).

Tektronics was a company that dominated the market for vector displays. Below are images from one of their terminals and a close-up of the display:

[From http://www.cca.org/vector/.]
Vector displays are becoming increasingly rare due to the advent of low-cost raster display technology. Vector displays must be periodically refreshed (at least the older models required this). The time required to refresh was proportional to the complexity of the scene, therefore complex scenes can be impractical for vector displays. However, vector displays have certain advantages, such as the absence of aliasing.

Aliasing is the jagged appearance of primitives as displayed on a raster device. This phenomenon is also known as “the jaggies”, or sometimes “the staircase effect”. This problem is resolved by various anti-aliasing techniques (to be discussed later in the term).

Below is an example of aliasing:
Raster displays

Raster displays typically have an array of addressable dots, which can be individually set to a particular color or intensity. Raster displays can be implemented by several technologies. Currently the most popular is the cathode ray tube, which can implement both raster and vector displays...

Cathode ray tube (CRT) technology

The standard computer monitor (or TV screen) is based on the cathode ray tube (CRT). Essentially, a beam of electrons is generated, and scanned across the inner surface of a glass tube. The inner surface of the tube is coated with a phosphor which emits light when electrons strike it. The intensity of the emitted light from a point on the phosphor depends on the number of electrons striking the phosphor.

The electron beam is scanned repeatedly over the phosphor surface, with the intensity of the beam modulated to produce the required dark and light spots. If the scanning rate is fast enough, the screen produces a steady image.

(Television images are redrawn 30 times per second; high quality monitors are refreshed 60 times per second, or more.)
Different phosphor materials emit different colors, so it is possible to construct a color display. Modern CRT devices use a triad of colored phosphors — red, green, and blue — to produce quite acceptable color output.

Usually, an electron gun is used for each of the primary colors, and a perforated grid called a shadow mask is used to isolate the electron beam to a single phosphor “dot”.

Electron "guns"
The quality of a color CRT display depends on the number of triads on the screen. There are a number of measures of this “quality” — the number of lines (rows of dots) and the “dot pitch” (distance between dots) being commonly quoted. Presently, good monitors can exceed 1200 lines, and can have more than 1600 triads per line. The dot pitch can be less than 0.25 mm. (Regular television has 480 lines x 640 triads per line, and is “interlaced” — every second line is redrawn each 1/60th of a second, for a full refresh rate of 1/30th of a second.)

A “standard” 17 inch monitor (16 inches viewable) can have specifications as follows:

- 0.25 mm dot pitch
- refresh rate 48–120 Hz
- 1024 x 768 resolution at 65 Hz
- 1600 x 1200 resolution at 65 Hz

A high end monitor (24 inch) can have a dot pitch of 0.22 mm, and a resolution of 2048 x 1536 at > 60Hz.
Liquid Crystal Display (LCD) technology

Liquid crystals are liquids with long organic molecules that can polarize light. When an electric field is applied, the molecular alignment (and consequently the direction of polarization) changes.

An LCD is a “sandwich” of different layers:

The reflective layer is simply a mirror. The two polarizing layers allows only light that is polarized in the appropriate direction to pass through. The two layers of grid wires allow a specific voltage to be applied to a particular part of the liquid crystal layer.

When no electric field is applied, the liquid crystals change the polarity of incident light by 90°. (The physics of this are beyond the scope of this course.) Therefore, light will get ap-
appropriately twisted to pass in through the vertical polarizer, through the liquid crystal layer, through the horizontal polarizer, reflect, and then back out again.

When an electric field **is** applied, the liquid crystals do not change the polarity of incident light. Hence, no light will be reflected out of the LCD at the point of applied voltage and a dark spot will appear in the display.
• Different “shades of grey” can be obtained by varying the voltage across the electrodes.

• Liquid crystals can be colored to produce a color display by adding color filters.

• LCD’s for computer displays are usually backlit.

• One problem with some LCD’s is that it takes about 1/4 of a second (250 ms.) to change state. This leaves “ghosts” on the display for a fraction of a second.

• This problem can be eliminated by adding a transistor amplifier to each pixel, so the voltage can be switched more rapidly (TFT — thin film transistors). TFT displays are more expensive to manufacture but have the following advantages:
  
  – Faster response time (25ms)
  – More shades of grey
  – Higher contrast ratio
  – Displays smaller and lighter

• Both types of LCD consume far less power than a CRT (about 75% less), and are therefore almost exclusively used in battery operated devices.
Plasma technology

Plasma displays provide an alternative to CRT’s and LCD’s. Plasma displays consist of a matrix of fluorescent bulbs.

As a voltage is applied to each bulb, the mixture of noble gases within the bulb becomes ionized and releases ultraviolet light. The UV photons strike a phosphor coating on the bulb that causes visible light to be released. Different coloured phosphors allow different colored pixels to be produced.

In comparison to CRT’s plasma displays are quite thin. Also, plasma displays provide a light source at each pixel and are therefore brighter and exhibit higher contrast than LCD displays. They also have larger viewing angles than LCDs — the image
looks good from a wide variety of angles. However, both LCD’s and CRT’s are actually able to achieve a higher resolution than plasma displays. LCD’s also consume less power and are thought to last longer. Plasma displays have historically had a “burn-in” problem, but this has been alleviated recently.

All the raster technologies have one thing in common — they have a finite number of regularly spaced points which can be set to some color.
Graphics cards

Graphics cards have taken on much of the responsibility for video output from the CPU. The most basic graphics card contains a frame buffer and circuitry to convert the color values into the voltages or currents used by the display.

Modern graphics cards have powerful graphics processors which handle many of the rendering functions and image transformations directly in their circuitry. (We will describe many of these functions later.)
A typical graphics card might look as follows:

Modern graphics cards contain much more memory than is required for the frame buffer.

Typically, some of this memory is used to store a description of the scene, (information about primitives, vertices, colors, etc.) which is interpreted by the graphics processor.

Other memory is used to store textures and other bitmaps.
The graphics processor

Modern graphics processors are very powerful computational devices, rivaling the power of the CPU. In fact, most have multiple, pipelined processors. (Many graphics functions can readily be parallelized.)

The following shows the architecture of the Raedon processor by one of Canada’s largest graphics companies, ATI: