Lecture Notes: Computer Graphics and Multimedia

Video Display Hardware

Computers are almost always equipped with some form of video adapter. This may be a card that is plugged into the computer's motherboard, or it may be physically built in to the motherboard. Either way it will expose a socket that can be attached to a video monitor with the appropriate cable (usually attached to the monitor).

The video adapter's job is to store an in-memory representation of the currently displayed image on the video monitor. The adapter converts this representation to a signal understood by the monitor.

This in-memory representation of the display consists of a 2-dimensional matrix of dots, called pixels (for Picture Elements). The dimensions of this matrix can vary depending upon the characteristics of the video adapter and the monitor; the larger the matrix, the more detail can be displayed onscreen at any time.

The dimensions of this matrix is called the display resolution. Several resolutions are common: 640 pixels wide by 480 pixels high (once called VGA), 800 x 600, 1024 x 768, 1152 x 870, 1280 x 1024, 1600 x 1200.

There is one more "dimension" to this matrix: colour depth. Each pixel may be represented in memory as a number of bits. One bit can accommodate two colours: black and white. More colours require greater bit depths. Several colour depths are common: 1 (black and white), 4 (16 colours), 8 (256 colours), 16 (65,536 colours), 24 (~17 million colours, a.k.a. High Colour), and 32 (~4 billion colours, a.k.a. True Colour).

The amount of memory (in bits) required to store this matrix is the product of the height in pixels, the width in pixels, and the colour depth in bits. For example, an 800 x 600 black and white image will require 800 x 600 x 1 = 480,000 bits, or about 60,000 Bytes. That same image represented in True Colour will require 800 x 600 x 32 = 15,360,000 bits, or about 1,920,000 Bytes (almost 2 MegaBytes).

Video adapters are equipped with their own RAM chips to store these matrices. Adapters with more memory can represent higher resolutions and/or numbers of colours, than can comparable adapters with less memory.

Of course, just because an adapter supports higher resolutions, the video monitor may not (this is particularly true of thin-screen monitors). Higher resolutions and colour depth require more data to be transmitted from the adapter to the monitor. The adapter must also send this data to the monitor between 60 and 120 times per second (60-120Hz) to match the monitor's scan rate (how fast the electron beam zigzags its way down the phosphor screen). A higher frequency usually means less flicker (and less eyestrain) but not all monitors can support these high frequencies for all resolutions and colour depths (setting the adapter to too high a frequency can damage the monitor!). Thin-screen monitors, like the kind you find in laptop computers, function very differently than CRT (Cathode Ray Tube) monitors, and so frequency isn't as much of a concern for them.

Image Formats

The accompanying handout (Computer Image Formats) describes a few common bitmap and vector image formats.

A bitmap image--sometimes called a raster image--is made up of nothing but pixels. It is the format most commonly used for photographs or hand drawings. Bitmap images typically require lots of storage space (height x width x colour depth). Bitmap images also do not expand well: each pixel is stretched into larger and larger blocks, giving the overall image a "chunky" look (this is called aliasing).

Bitmap image formats often include compression. The details of this compression are complex, but the simple idea is just to record any repeating pattern once, along with the number of times it repeats. For example, a line of 57 blue pixels could be compressed by just storing the number 57 and 1 blue pixel.

Some compression techniques are lossless: the uncompressed image is identical to the original image down to the very last bit. Lossy compression can often produce more compact images, but at the expense of some visual detail. This is usually manifested as discoloured patches on the image.

Unlike Bitmap images, vector images are composed of simple instructions using drawing primitives: lines, arcs, polygons, text, etc. All that need be stored is the type of primitive, and a few extra characteristics: width, starting point, ending point, colour, texture, etc.

Vector image formats are therefore much more compact than bitmap formats, although they can't be used to express complex images such as photographs. However, vector images scale in size very well because they are not
converted to pixels until immediately before they are drawn onscreen (which is always done using pixels).

Here is how the two format types compare:

<table>
<thead>
<tr>
<th></th>
<th>Bitmap</th>
<th>Vector</th>
</tr>
</thead>
<tbody>
<tr>
<td>Scales</td>
<td>Appears &quot;chunky&quot; when enlarged.</td>
<td>Smooth.</td>
</tr>
<tr>
<td>(reaction to</td>
<td>Large, often requiring compression.</td>
<td>Small.</td>
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<td>changes in size)</td>
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<td>Suited for:</td>
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**Image Formats for the Web**
Currently, the most common image formats used for the web are JPEG and GIF. PNG is the anticipated successor to both formats, but it's still not as popular as the others.

JPEG is best suited for photographs or drawings containing many colours.

GIF is best suited for icons or simple pictures that contain no more than 256 colours.

GIF images can also include a transparent colour, that lets whatever colour is behind the GIF show through.

Because JPEG uses a lossy compression algorithm (the amount of compression can be varied), some images may display patchy colours (JPEG artifacts). However, the payoff is that the images can usually be compressed much more than the comparable GIF.

**Digital Audio**
CD-quality audio is digitized by sampling the analog audio wave 44.1 thousand times per second and each sample is assigned an amplitude encoded into a 16-bit number. Stereo audio requires double the storage, so 1 second of CD-quality stereo audio takes: 44,100 * 16 * 2 = 172KB. That comes out to about 10MB per minute, meaning that most songs require between 20MB (The Ramones) and 170MB (Iron Butterfly).

Various compression techniques have arisen that are able to significantly reduce the size of audio files without seriously reducing the quality. One of the most popular at the moment is the MP3 format (MPEG III) that can achieve a variable compression ratio of between 5 and 20 (the most common ratio is 7, so a 4 minute song would require only 5.7MB rather than the 40MB needed by an uncompressed format.

Music compression is more complicated than the algorithms used in images. Typically, the compression algorithm removes parts of the audio signal that aren't audible to the human ear, or that don't drastically change the shape (timbre) of the sound. In this way, audio compression is a lossy type of compression since the original can't be perfectly reconstituted from the compressed form.

**Digital Video**
Digital video is essentially a sequence of bitmap images, displayed at a certain frequency. Most film is shot at 24 frames per second, so that's a common frequency.

Obviously, digital video requires a huge number of bits. For example, a 640 by 480 video display (the approximate resolution of a television) using 32-bit True Colour at 30 frames per second (TV's frequency) would require: 640 x 480 x 32 x 30 = 35MB. A 30-minute television program at that rate would consume about 62GB of storage.

By the way, that figure does not include the audio portion of the program.

Clearly, 35MB per second is far greater than the bandwidth of just about any consumer network technology in existence. Therefore, like images and audio, digital video is highly compressed using advanced lossy-type algorithms.

One of the things that can be done with video is to only store the parts of a single frame that are different from the previous frame. This so-called psychovisual compression closely matches the way humans watch motion pictures: most of our focus is on things that move. The other parts of the display can be much more compressed, but the loss of quality is not noticed as much.