Chapter 2

Computer Graphics Hardware

Exercises

2-1. Operating characteristics for display technologies are discussed in Sections 2-1 through 2-3 and in the references cited at the end of the chapter.

2-2. Applications appropriate for the various display technologies are discussed in Sections 2-1 through 2-3 and in the listed references.

2-3. A system manual can be consulted to obtain screen dimensions and the number of pixel positions that can be displayed in the x and y directions. If x and y screen dimensions are not listed, they can be measured. The ratio of pixel positions to screen dimensions gives the resolutions for the horizontal and vertical directions. Aspect ratio is the ratio of the y and x resolutions.

Alternatively, resolution can be determined by displaying equal-pixel, straight-line segments in the x and y directions and measuring the length of each line.

For example, if 100-pixel lines in the x and y directions measure 4 cm and 5 cm, respectively, then

$$\text{x resolution} = \frac{100}{4} \text{ pixels per cm}$$

$$\text{y resolution} = \frac{100}{5} \text{ pixels per cm}$$

and

$$\text{aspect ratio} = \frac{\text{y resolution}}{\text{x resolution}} = \frac{4}{5}$$

To adjust dimensions of objects to maintain relative proportions, we can make the adjustments either to the vertical or to the horizontal dimensions. That is, vertical dimensions can be scaled by a factor of 4/5, or horizontal dimensions can be scaled by a factor of 5/4.

2-4. Frame-buffer size for each of the systems using 16 bits of color information is:

800 x 600 x 16 bits / 8 bits per byte = 960 KB

1280 x 960 x 16 bits / 8 bits per byte = 2.4576 MB

1680 x 1050 x 16 bits / 8 bits per byte = 3.528 MB

Buffer sizes for the same systems using 32 bits of color are:

800 x 600 x 32 bits / 8 bits per byte = 1.92 MB

1280 x 960 x 32 bits / 8 bits per byte = 4.9152 MB

1680 x 1050 x 32 bits / 8 bits per byte = 7.056 MB

2-5. Storage needed for the frame buffer is

$$800 \times 1000 \times 6 \text{ bits} \div 8 \text{ bits per byte} \approx 486 \text{ KB}$$

2-6. The times to load the two frame buffers are:

800 x 600 x 16 bits / 10^5 bits per sec = 76.8 sec

1680 x 1050 x 32 bits / 10^5 bits per sec = 564.48 sec = 9.408 min

2-7. Total bits in the printer frame buffer is

$$8.5 \times 11 \times 300^2 \approx 8.4 \times 10^6 \text{ bits}$$

Therefore, loading time is

$$\frac{8.4 \times 10^6 \text{ bits}}{32 \times 10^6 \text{ bps}} \approx 0.263 \text{ sec}$$

2-8. For the 800 by 600 system, the access rate is:

800 x 600 x 60 = 2.88 x 10^7 pixels per sec

and the access time is approximately 34.72 nanoseconds per pixel.

Similarly, for the 1680 by 1050 system, the access rate is:

1680 x 1050 x 60 = 1.0584 x 10^8 pixels per sec

and the access time is approximately 9.45 nanoseconds per pixel.

2-9. The diameter of screen pixels is

$$\frac{12}{1280} = \frac{9.6}{1024} = 9.375 \times 10^{-3} \text{ inches}$$

2-10. The scan rate for each pixel row is

30 frames/sec × 1050 lines/frame = 31,500 lines/sec

And so, the scan time is approximately 31.75 microseconds per scan line. (Scan time per frame is 1/30 sec, or approximately 33.3 milliseconds.)

2-11. Refresh time per frame is 1/*r* seconds, and the total retrace time during refresh of each frame is:

$$t_{retrace} = t_{vert} + m \cdot t_{horiz}$$

The fraction of the time spent in retrace is $r \cdot t_{retrace}$.

2-12. The fraction of the total refresh time per frame spent in retrace is:

$$65 \times (400 \times 10^{-6} + 1050 \times 4 \times 10^{-6}) \approx 0.299$$

2-13. The total number of available colors is $2^{24} = 16{,}777{,}216$. Using a different color for each screen pixel, we could display $1024^2 = 1{,}048{,}576$ colors at any one time.

2-14. Three-dimensional monitors and stereographic systems are discussed in Sections 2-1 and in the references.

2-15. Input and output devices used with virtual-reality systems are discussed in Sections 2-4 and 2-5.

2-16. Design applications for VR include interactively constructing systems and interactively studying system operating characteristics. Some VR design applications are given in Sections 1-2, 1-3, 2-1, 2-4, and in the references at the end of Chapters 1 and 2.

2-17. Some applications for large-screen displays are presented in Section 2-3.

2-18. Graphics software packages are discussed in Section 2-8. Basically, packages for graphics programming contain functions for specifying individual geometric components (primitives, such as lines and circles), attributes of individual primitives, and parameters for various graphics operations such as viewing and geometric transformations. A package for a specific application, such as architectural design, allows a user to create scenes in terms of architectural features, such as doors, windows, hallways, stairs, and rooms. Then a building can be rotated or viewed from a given direction, such as from the front, from above, or from the left side.

Themed Exercises

2-1. Students should have come up with a few proposals for projects that can be built on throughout the course. They may choose to develop only one, but having multiple options will allow for more flexibility later on. The most straightforward solution is a video game of some type, which leaves many design choices at different levels of creativity and ability. Other possibilities are interactive visualizations of certain types of dynamical systems or interactive presentations of two- and three-dimensional data.

2-2. The specifications of a system's graphics hardware and display device can sometimes be found via the operating system by examining the properties of the devices. If the make and model number of the devices can be found, then the specifications can most likely be looked up on the manufacturer's Web site.