with fractional parts such as 4-1/2 or 3/4, another technique, called **floating-point notation** (see Section 1.7), is used.

Representing Images

One means of representing an image is to interpret the image as a collection of dots, each of which is called a **pixel,** short for "picture element." The appearance of each pixel is then encoded and the entire image is represented as a collection of these encoded pixels. Such a collection is called a **bit map.** This approach is popular because many display devices, such as printers and display screens, operate on the pixel concept. In turn, images in bit map form are easily formatted for display.

The method of encoding the pixels in a bit map varies among applications. In the case of a simple black-and-white image, each pixel can be represented by a single bit whose value depends on whether the corresponding pixel is black or white. This is the approach used by most facsimile machines. For more elaborate black-and-white photographs, each pixel can be represented by a collection of bits (usually eight), which allows a variety of shades of grayness to be represented. In the case of color images, each pixel is encoded by more complex system. Two approaches are common. In one, which we will call RGB encoding, each pixel is represented as three color components—a red component, a green component, and a blue component—corresponding to the three primary colors of light. One byte is normally used to represent the intensity of each color component. In turn, three bytes of storage are required to represent a single pixel in the original image.

An alternative to simple RGB encoding is to use a "brightness" component and two color components. In this case the "brightness" component, which is called the pixel's luminance, is essentially the sum of the red, green, and blue components. (Actually, it is considered to be the amount of white light in the pixel, but these details need not concern us here.) The other two components, called the blue chrominance and the red chrominance, are determined by computing the difference between the pixel's luminance and the amount of blue or red light, respectively, in the pixel. Together these three components contain the information required to reproduce the pixel.

The popularity of encoding images using luminance and chrominance components originated in the field of color television broadcast because this approach provided a means of encoding color images that was also compatible with older black-and-white television receivers. Indeed, a gray-scale version of an image can be produced by using only the luminance components of the encoded color image.

ISO—The International Organization for Standardization

The International Organization for Standardization (more commonly called ISO) was established in 1947 as a worldwide federation of standardization bodies, one from each country. Today, it is headquartered in Geneva, Switzerland, and has more than 100 member bodies as well as numerous correspondent members. (A correspondent member is usually a standardization body from a country that does not have a nationally recognized standardization body. Such members cannot participate directly in the development of standards but are kept informed of ISO activities.) ISO maintains a website at http://www.iso.org.

A disadvantage of representing images as bit maps is that an image cannot be rescaled easily to any arbitrary size. Essentially, the only way to enlarge the image is to make the pixels bigger, which leads to a grainy appearance. (This is the technique called "digital zoom" used in digital cameras as opposed to "optical zoom" that is obtained by adjusting the camera lens.)

An alternate way of representing images that avoids this scaling problem is to describe the image as a collection of geometric structures, such as lines and curves, that can be encoded using techniques of analytic geometry. Such a description allows the device that ultimately displays the image to decide how the geometric structures should be displayed rather than insisting that the device reproduce a particular pixel pattern. This is the approach used to produce the scalable fonts that are available via today's word processing systems. For example, TrueType (developed by Microsoft and Apple) is a system for geometrically describing text symbols. Likewise, PostScript (developed by Adobe Systems) provides a means of describing characters as well as more general pictorial data. This geometric means of representing images is also popular in **computer-aided design (CAD)** systems in which drawings of three-dimensional objects are displayed and manipulated on computer display screens.

The distinction between representing an image in the form of geometric structures as opposed to bit maps is evident to users of many drawing software systems (such as Microsoft's Paint utility) that allow the user to draw pictures consisting of pre-established shapes such as rectangles, ovals, and elementary curves. The user simply selects the desired geometric shape from a menu and then directs the drawing of that shape via a mouse. During the drawing process, the software maintains a geometric description of the shape being drawn. As directions are given by the mouse, the internal geometric representation is modified, reconverted to bit map form, and displayed. This allows for easy scaling and shaping of the image. Once the drawing process is complete, however, the underlying geometric description is discarded and only the bit map is preserved, meaning that additional alterations require a tedious pixel-by-pixel modification process. On the other hand, some drawing systems preserve the description as geometric shapes that can be modified later. With these systems, the shapes can be easily resized, maintaining a crisp display at any dimension.

Representing Sound

The most generic method of encoding audio information for computer storage and manipulation is to sample the amplitude of the sound wave at regular intervals and record the series of values obtained. For instance, the series 0, 1.5, 2.0, 1.5, 2.0, 3.0, 4.0, 3.0, 0 would represent a sound wave that rises in amplitude, falls briefly, rises to a higher level, and then drops back to 0 (Figure 1.12). This technique, using a sample rate of 8000 samples per second, has been used for years in long-distance voice telephone communication. The voice at one end of the communication is encoded as numeric values representing the amplitude of the voice every eight-thousandth of a second. These numeric values are then transmitted over the communication line to the receiving end, where they are used to reproduce the sound of the voice.

Although 8000 samples per second may seem to be a rapid rate, it is not sufficient for high-fidelity music recordings. To obtain the quality sound reproduction obtained by today's musical CDs, a sample rate of 44,100 samples per second