FIGURE 2.1-1

Computer imaging system hardware.

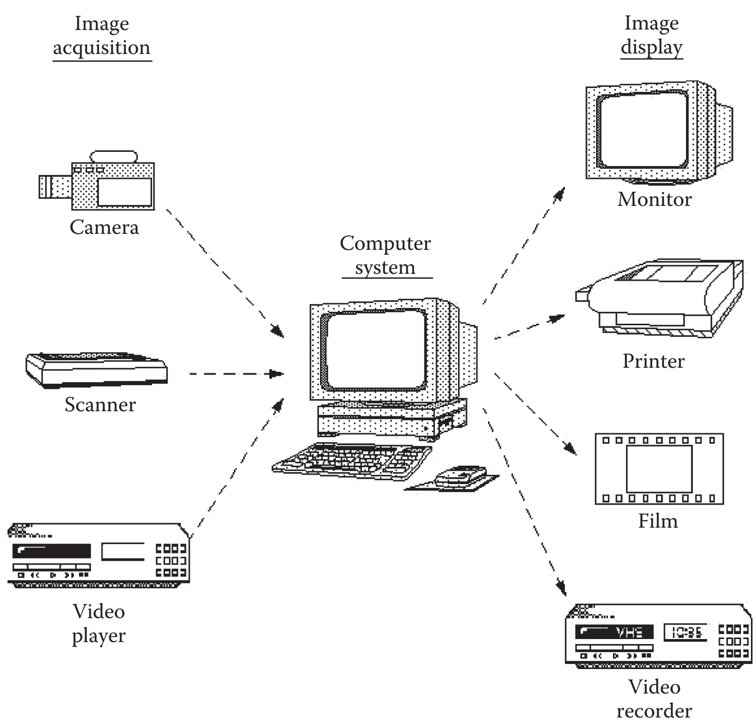


FIGURE 2.1-2

The video signal.

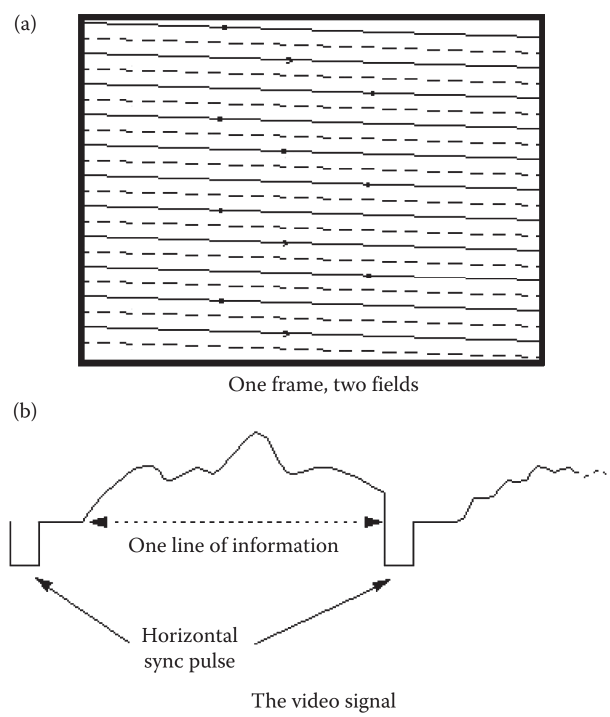


FIGURE 2.1-3

Digitizing (sampling) an analog video signal.

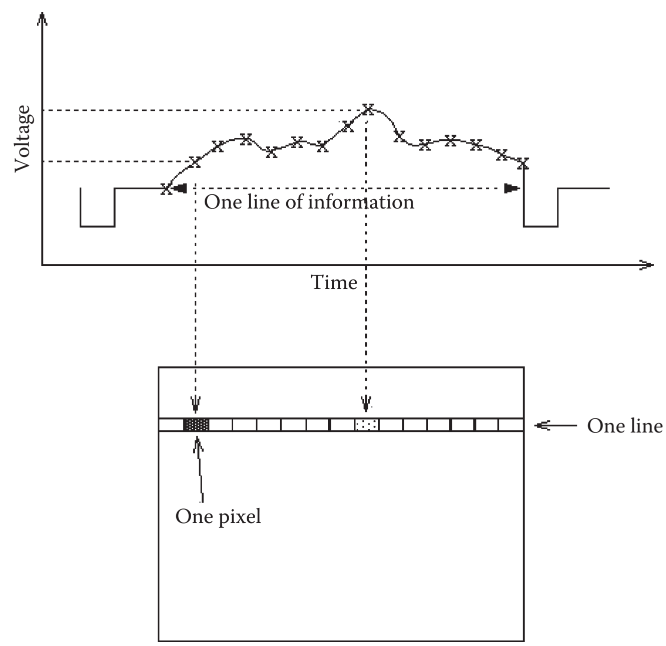


FIGURE 2.1-4

Aspect ratio. The *aspect ratio* is the ratio of the image or display width (columns) to the image or display height (rows or lines). (a) The aspect ratio is 4:3 for standard definition television (SDTV), and (b) 16:9 for high definition television (HDTV).

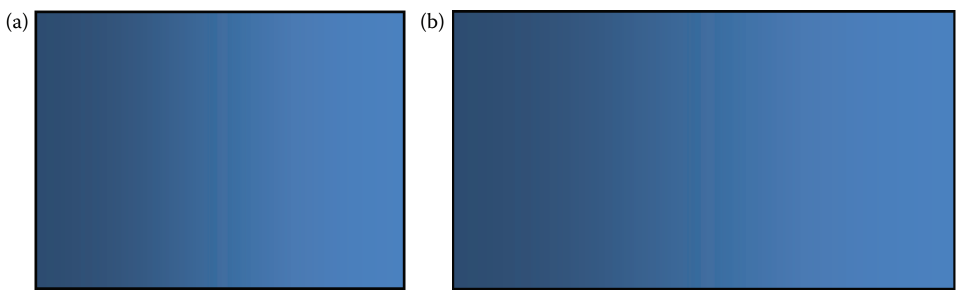


FIGURE 2.1-5

The hierarchical image pyramid.

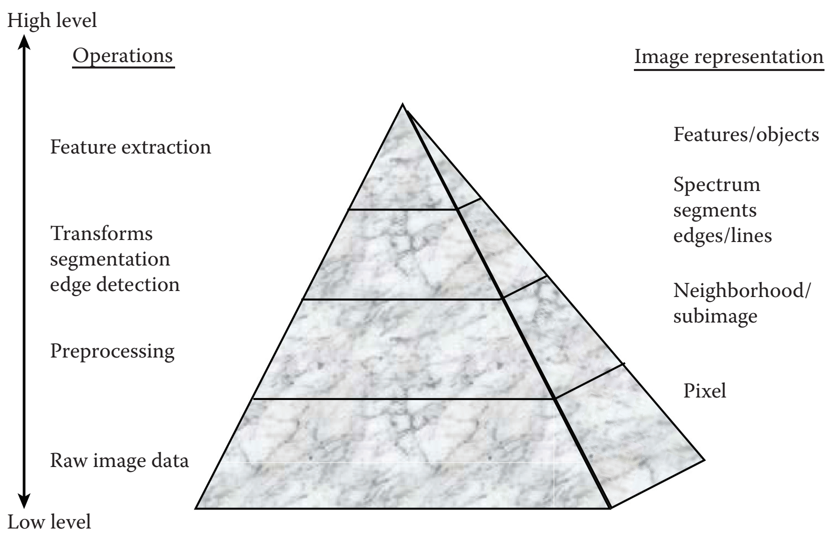


FIGURE 2.2-1

The electromagnetic spectrum.

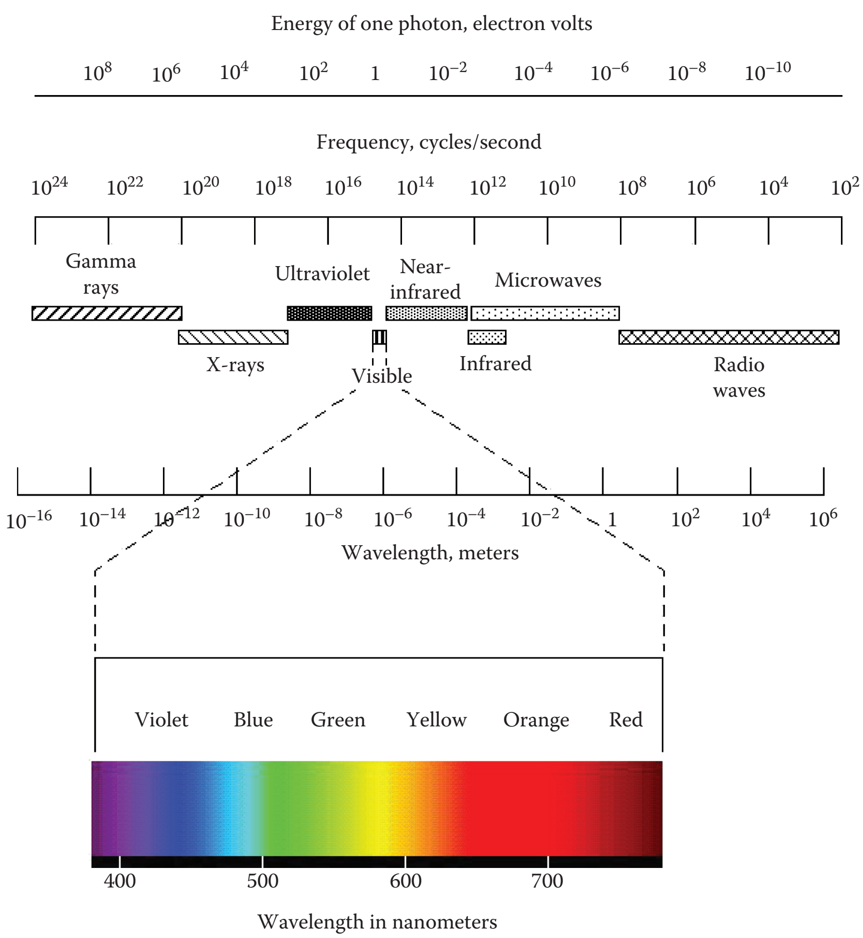


FIGURE 2.2-2

Model for visible light imaging. The light source emits light that is reflected from the object and focused by the lens onto the image sensor.

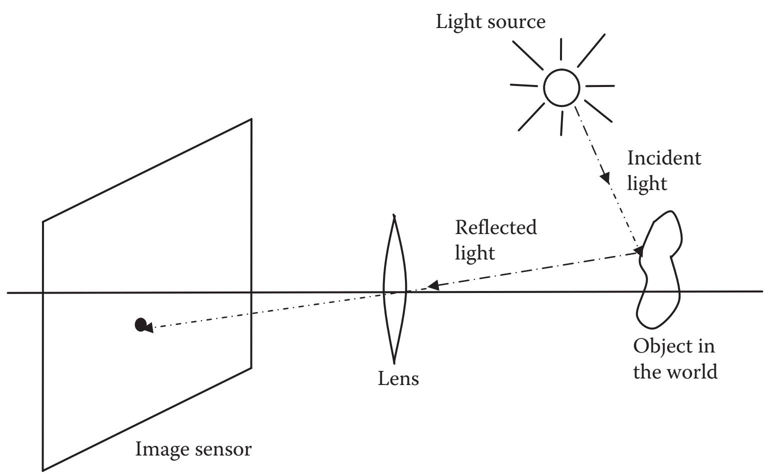


FIGURE 2.2-3

The reflectance function. Here we see that the way in which an object reflects the incident light, the reflectance function, has a major effect on how it appears in the resulting image. The reflectance function is an intrinsic property of the object and relates to both color and texture. (a) Monochrome image showing brightness only, the color determines how much light is reflected and the surface texture determines the angle at which the light is reflected, and (b) color image, the color determines those wavelengths that are absorbed and those that are reflected.

(a)

(b)

FIGURE 2.2-4

Irradiance and radiance. Irradiance is the measured light falling on the image plane. It is measured in power per unit area. Radiance is the power reflected or emitted per unit area into a directional cone having a unit of solid angle. Note that all the reflected light is not captured by the lens.

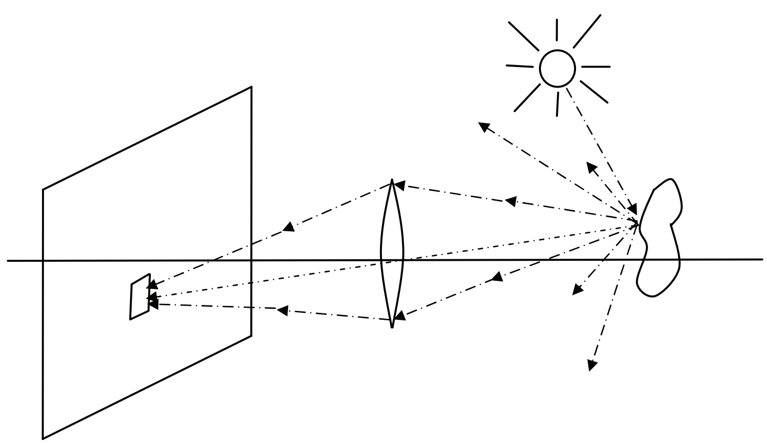


FIGURE 2.2-5

Relationship between points in the world and points in the image. A lens will focus an image of an object only at a specific distance given by the lens equation.

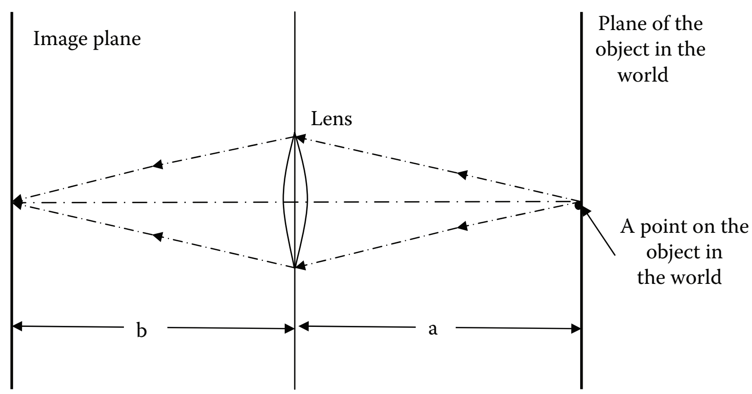


FIGURE 2.2-6

The blur circle from a poorly focused lens. As the object is moved closer to the lens, it gets blurry. Application of the lens equation shows the object is actually focused behind the image plane. The blur equation defines the amount of blur. Specifically, it gives the diameter of a blur circle, corresponding to a point in the original in focus image.

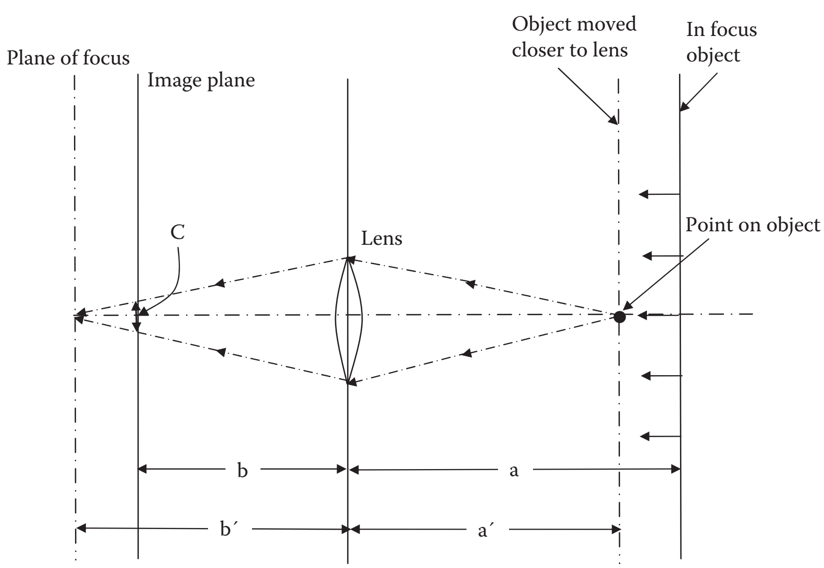


FIGURE 2.2-7

Field of view (FOV). The FOV for an imaging system depends on both focal length of the lens, f, and the size of image sensor, d.

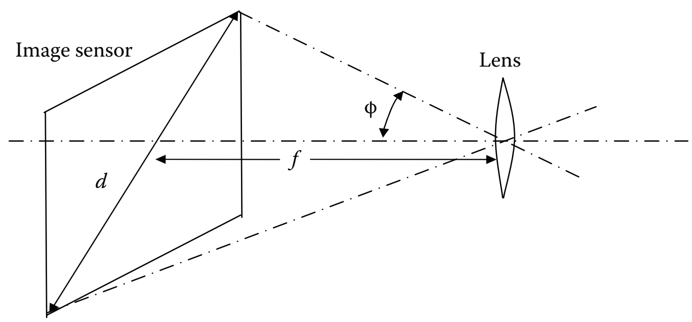


FIGURE 2.2-8

The vignetting effect. A compound lens causes less light on the edges of the image to get through to the image sensor. This has the effect of decreasing brightness as we move away from the center of the image.

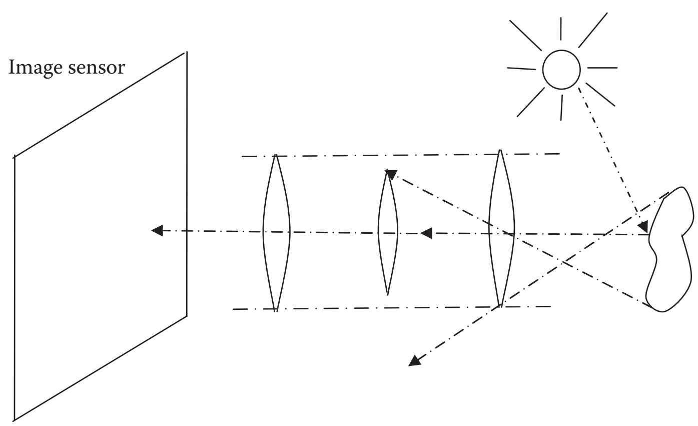


FIGURE 2.2-9

Generic imaging sensors (a) single imaging sensor, (b) linear or line sensor, and (c) two-dimensional or array sensor.

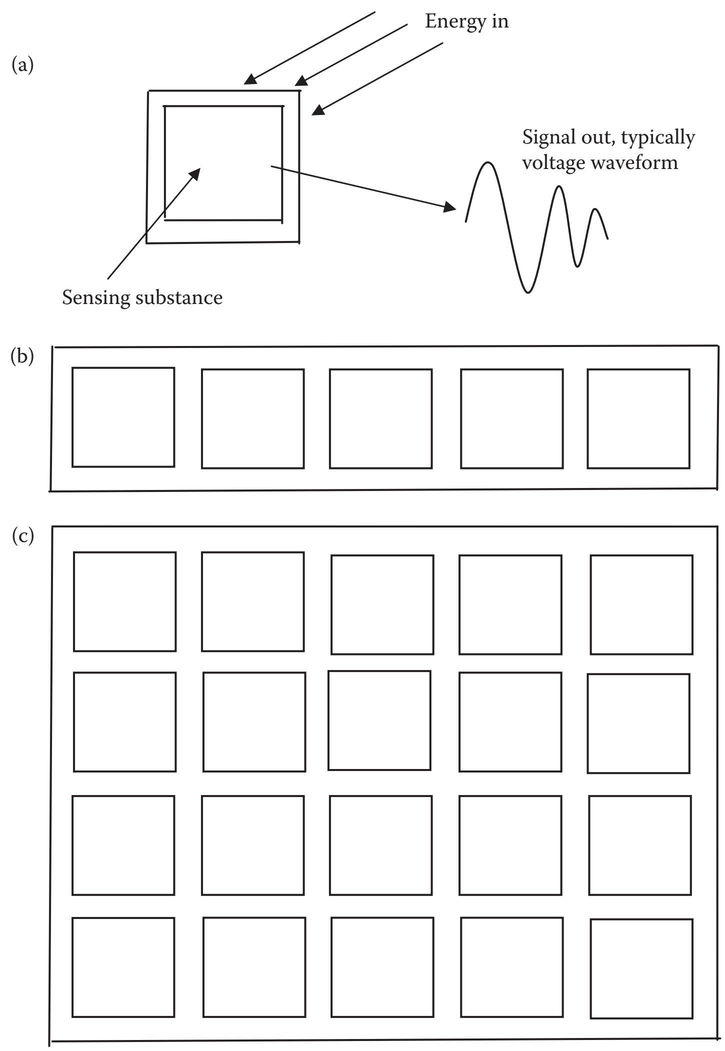


FIGURE 2.2-10

X-ray and UV images. (a) X-ray of a chest with an implanted electronic device to assist the heart (Image courtesy of George Dean.), (b) dental x-ray, (c) and (d) fluorescence microscopy images of cells, generated by emitting visible light when illuminated by ultraviolet (UV) light (Cell images courtesy of Sara Sawyer, SIUE.), (e) one “slice” of a computerized tomography (CT) image of a patient’s abdomen, multiple 2-D image “slices” are taken at various angles and are then assembled to create a 3-D image (Image courtesy of George Dean.).

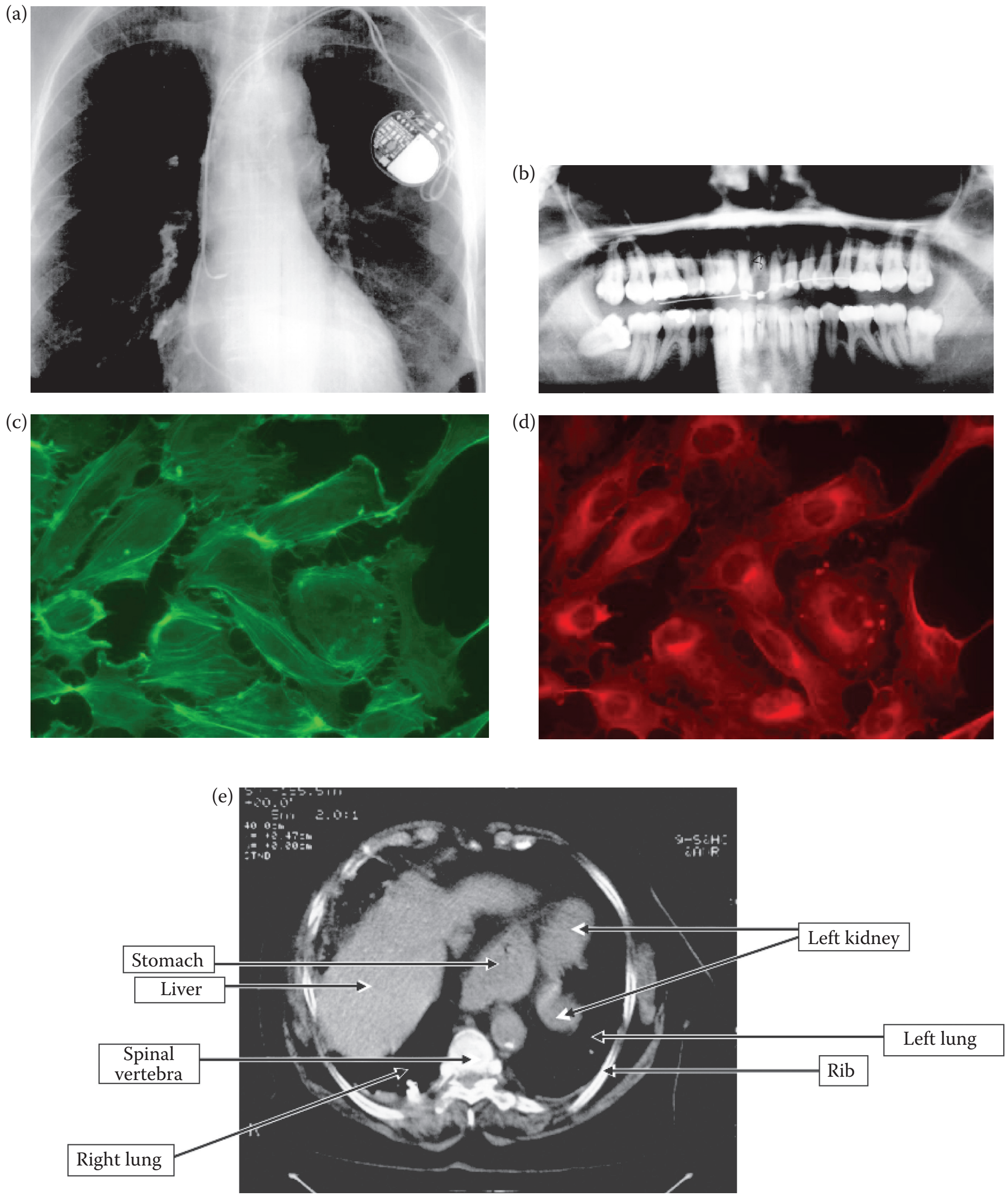


FIGURE 2.2-11

Infrared images. (a) Infrared satellite image showing water vapor, (b) infrared satellite imagery in the near infrared band (Images courtesy of National Oceanic and Atmospheric Administration, NOAA.), (c) and (d) thermographic images being used in research to determine their efficacy in diagnosing brain diseases in canines (Images courtesy of Long Island Veterinary Specialists.).

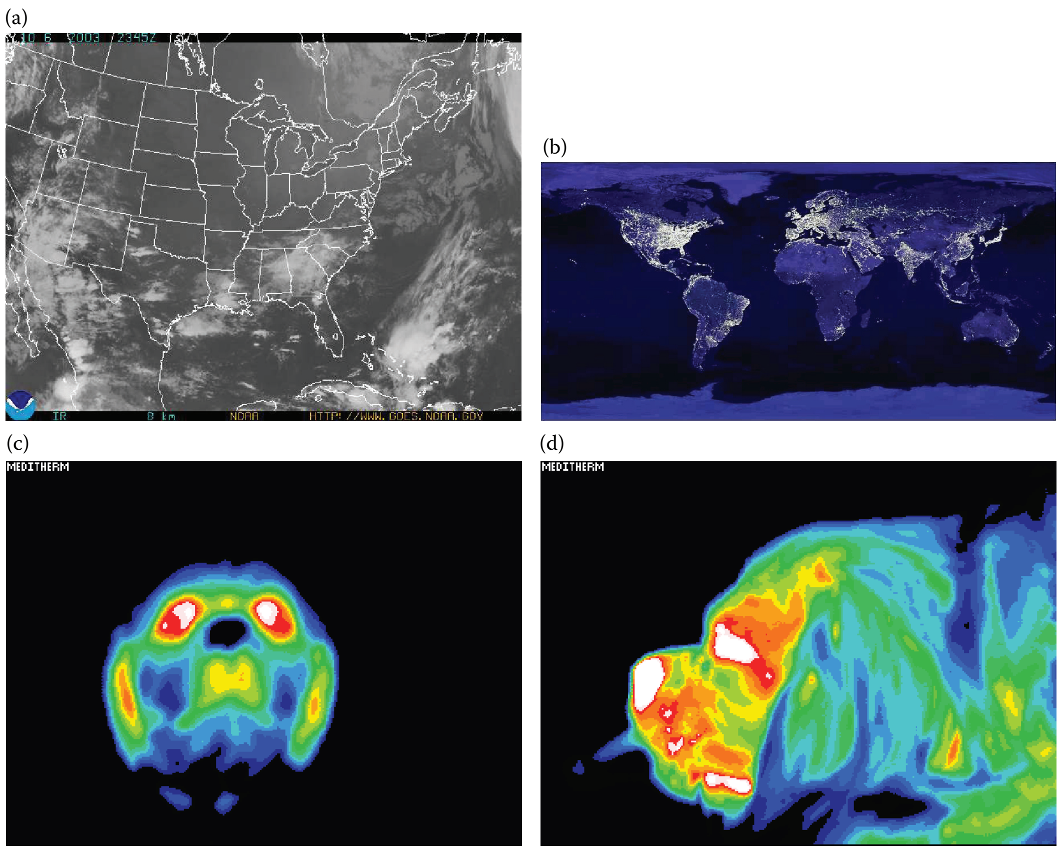
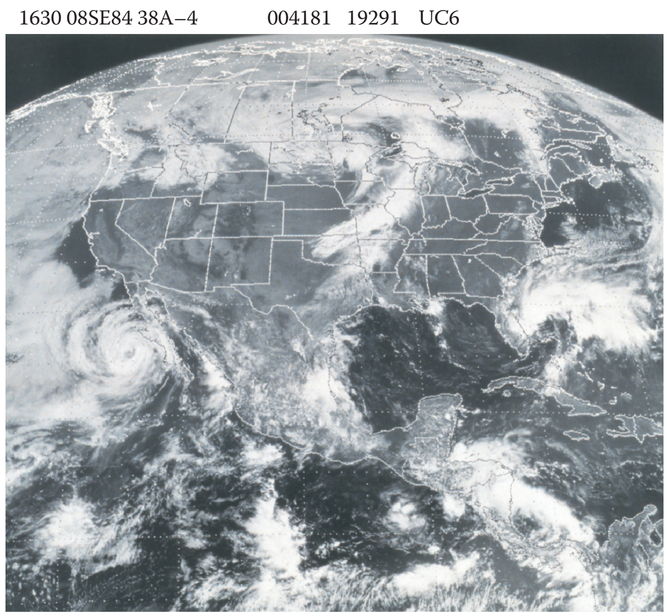


FIGURE 2.2-12

Multispectral and radio wave images. (a) Multispectral Geostationary Operational Environmental Satellite (GOES) image of North America, showing a large tropical storm off Baja, California, a frontal system over the Midwest, and tropical storm Diana off the east coast of Florida (Courtesy of NOAA.), (b) magnetic resonance image (MRI) of a patient's shoulder, MRI images are created using radio waves, this is a single 2-D "slice," multiple images are taken at different angles and assembled to create a 3-D image (Image courtesy of George Dean.).

(a)



(b)

FIGURE 2.2-13

(a) Standard ultrasound image of a baby showing the head, arm, and body, (b) standard ultrasound image showing face and eyes, (c) newer 3-D ultrasound image showing baby face and arm, and (d) 3-D ultrasound of baby yawning (Images Courtesy of Kayla and Aaron Szczeblewski.).

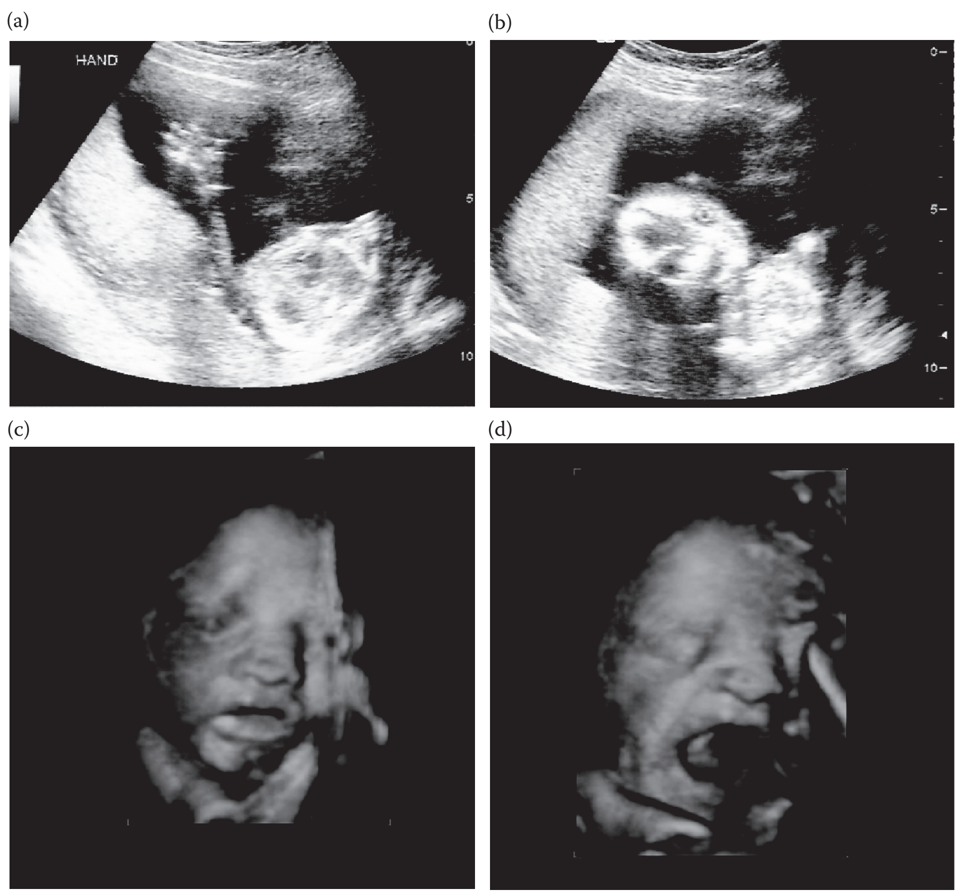


FIGURE 2.2-14

(a) Scanning electron microscope (SEM), (b) SEM image of a mosquito, (c) logic gate in a microchip, (d) strawberry, (e) brittlestar, (f) hollyhock pollen. (Photos courtesy of Sue Eder, Southern Illinois University Edwardsville.)

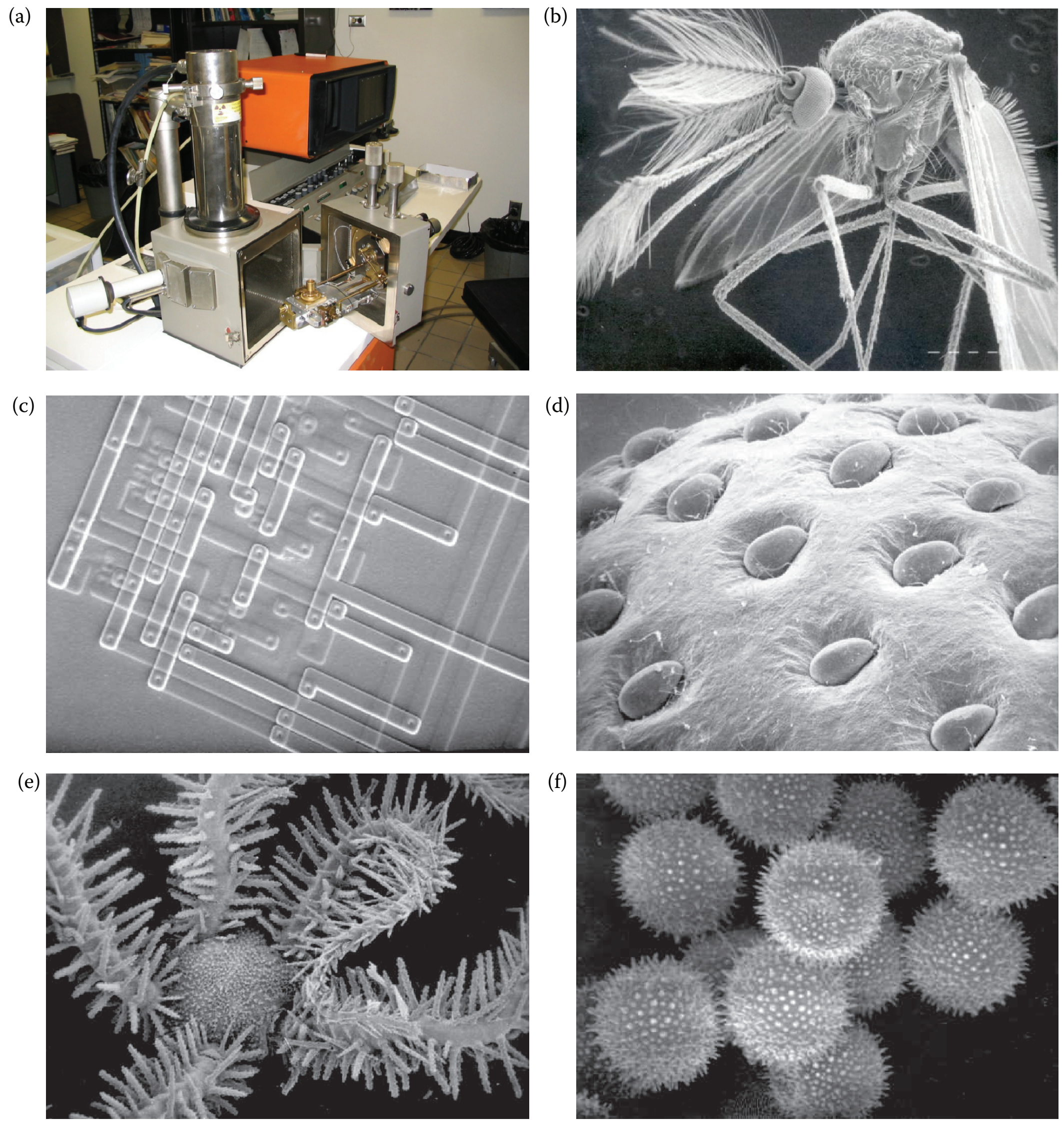


FIGURE 2.2-15ab

Computer-generated images. (a) Graphics image of an insect that employs a particle system to simulate a plume of fire, the right image shows the individual particles are texture-mapped squares, (b) graphics image of a simple 3-D hand where each section of the hand is a sphere, the right image shows the hand after rotating the joints to produce a specific gesture.

(a) (b)

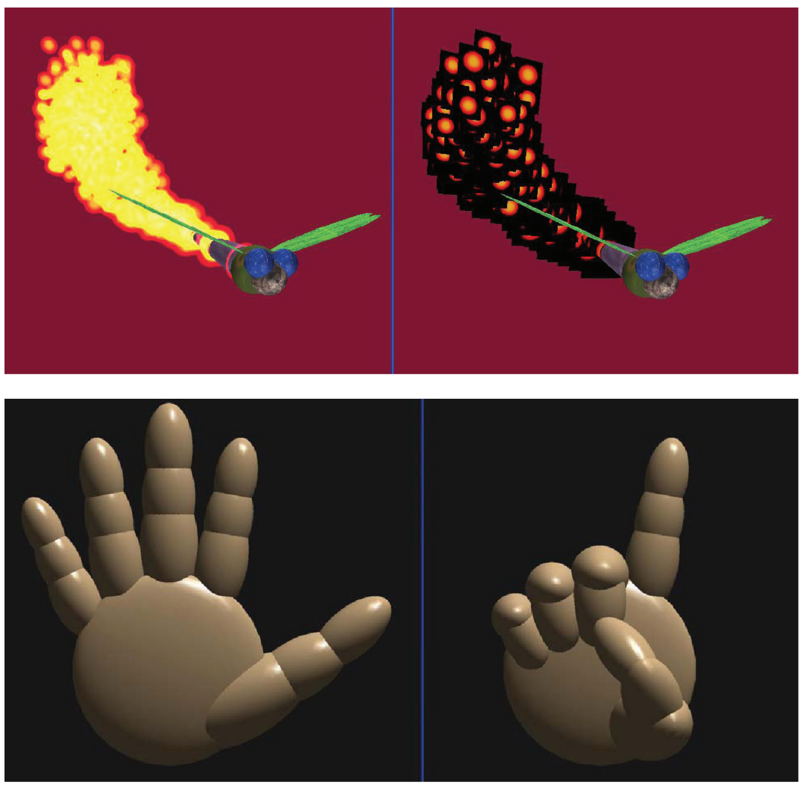


FIGURE 2.2-15c-f

Computer-generated images. (c) an image of a butterfly processed by edge detection (see Chapter 4), (d) Fourier transform spectrum image of an ellipse (see Chapter 5), (e) x-ray image of a hand processed by frequency domain pseudocolor (see Chapter 8), (f) error image from an image compressed with block truncation coding (see Chapter 10). (Graphics images courtesy of William White, Southern Illinois University Edwardsville; original butterfly photo courtesy of Mark Zuke.)

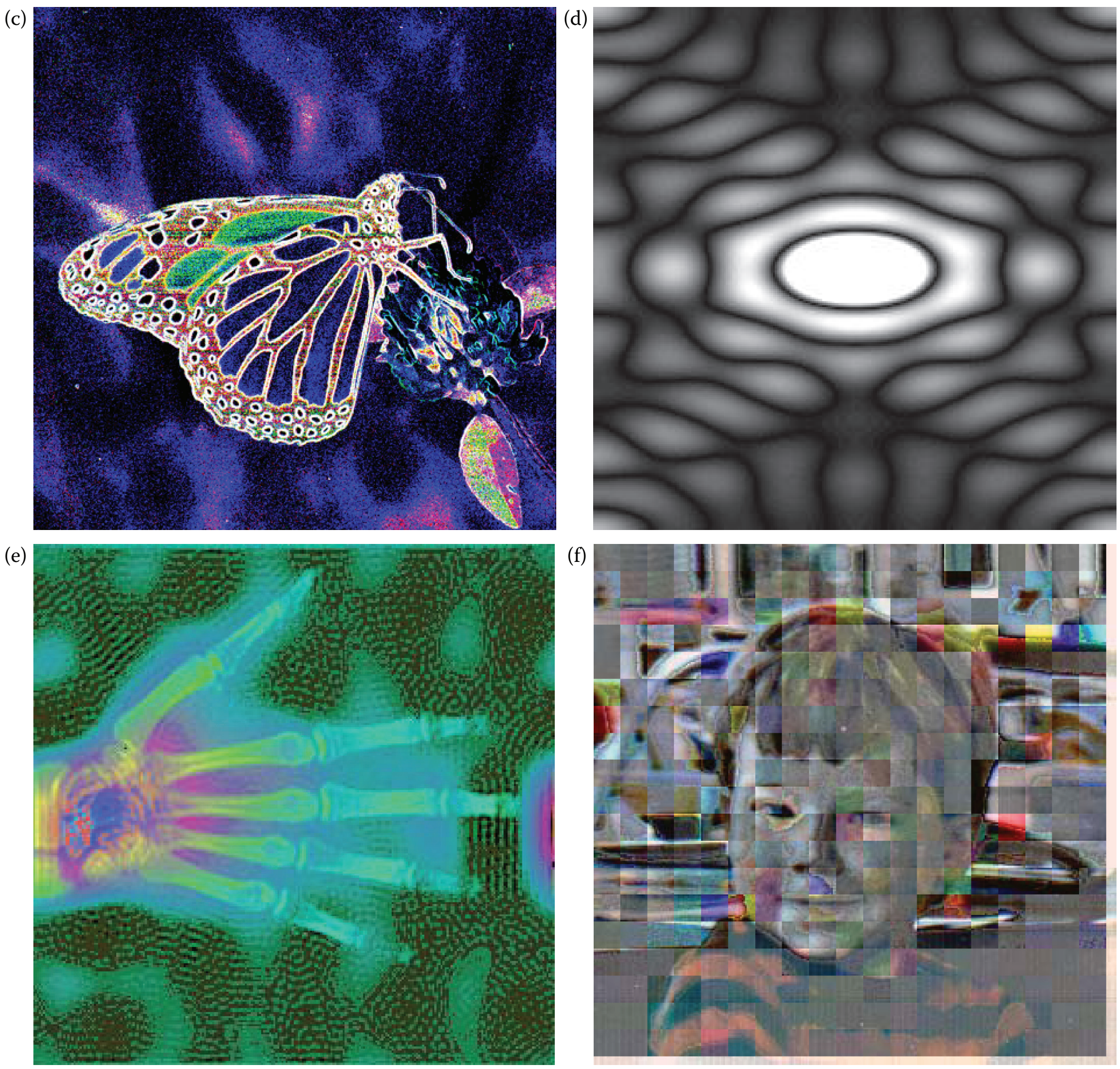
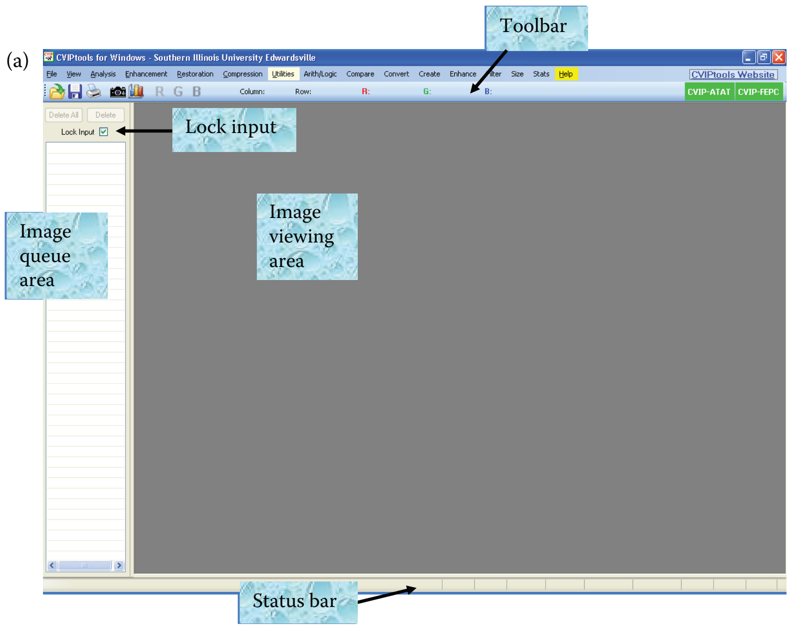


FIGURE 2.3-1

CVIPtools main window. (a) The main CVIPtools window when the program is first invoked, (b) main window with images in the queue, and the *View* option *CVIP Function Information* at the bottom.

(a)



(b)

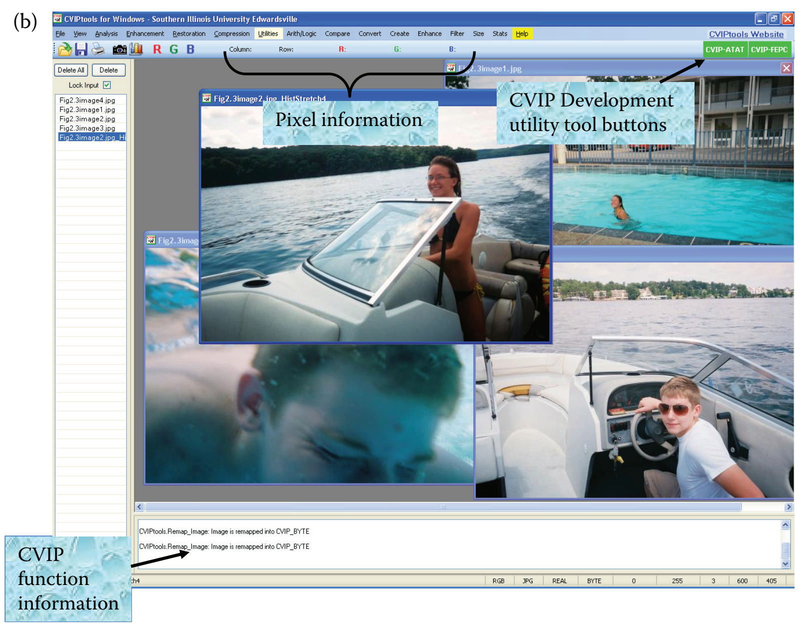


FIGURE 2.3-2

CVIPtools analysis window. (a) The drop-down menu for the analysis window, and (b) the analysis window with the Edge/Line Detection tab selected.

(a)

(b)

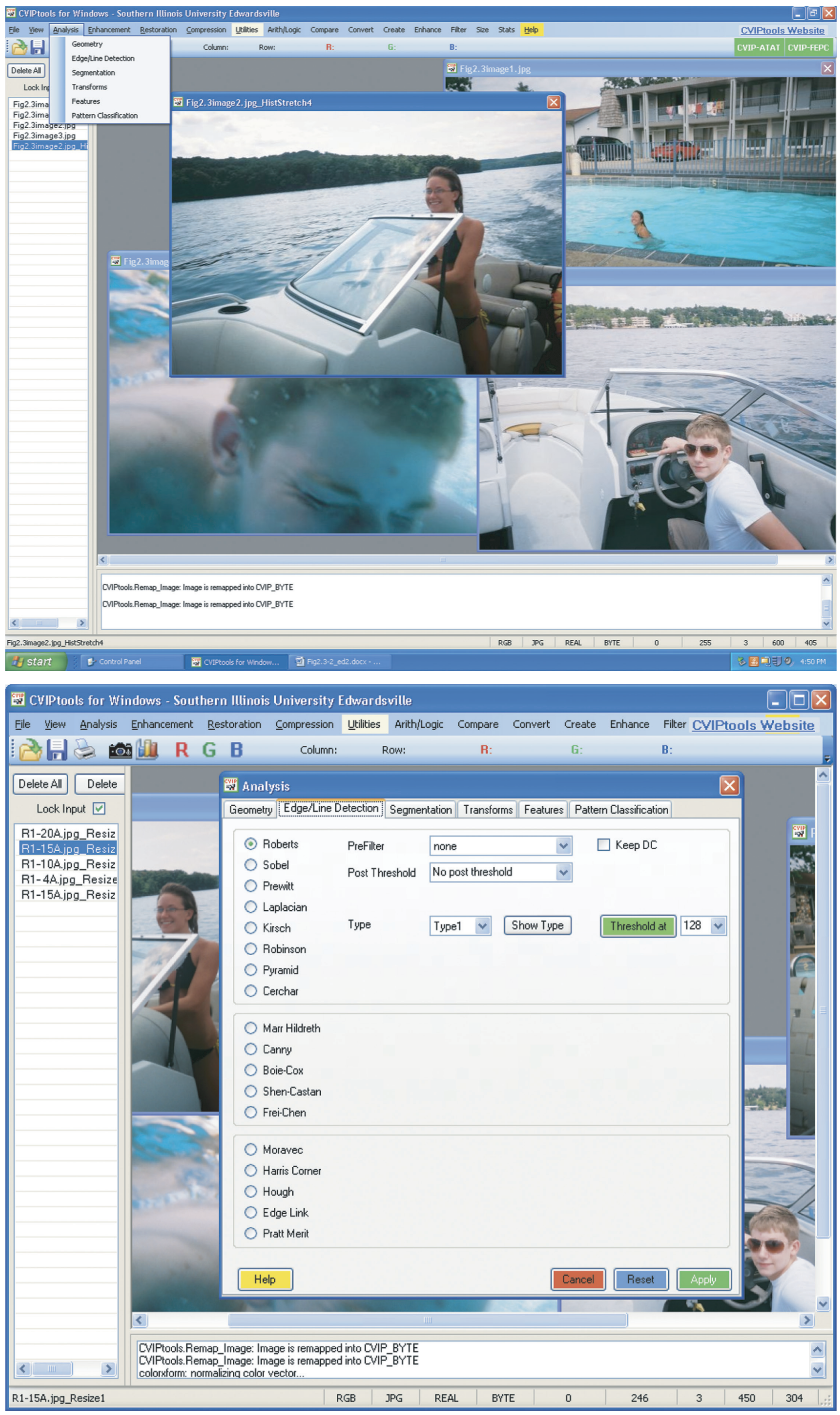


FIGURE 2.3-3

CVIPtools enhancement window. The enhancement window with the pseudocolor tab selected.

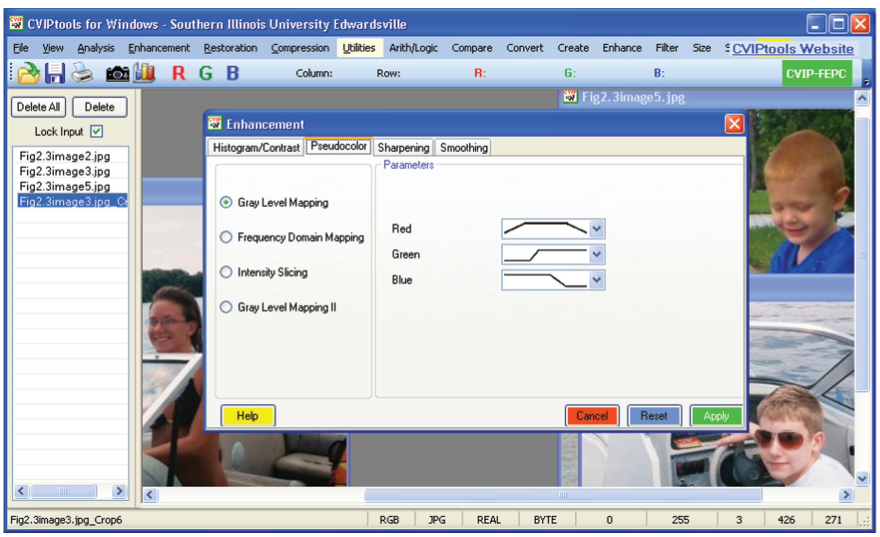


FIGURE 2.3-4

CVIPtools restoration window. The restoration window with the frequency filters tab selected.

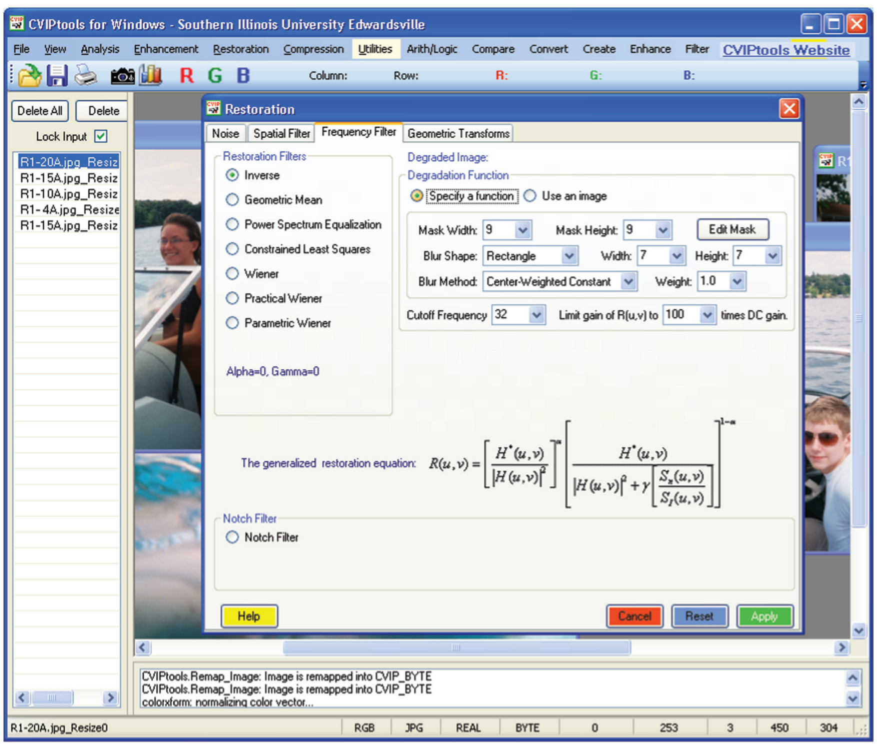


FIGURE 2.3-5

CVIPtools compression window. The compression window with the lossy tab selected.

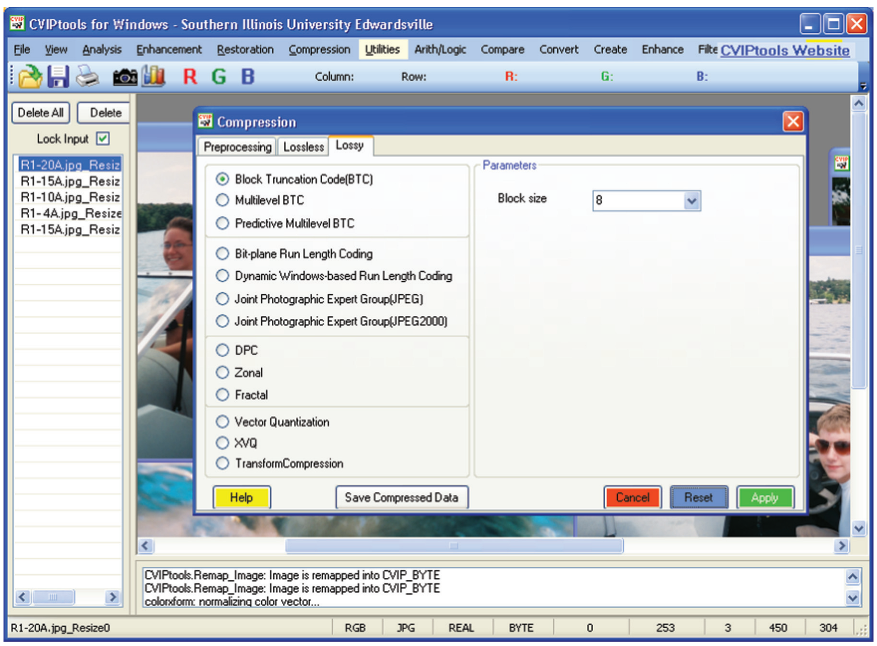
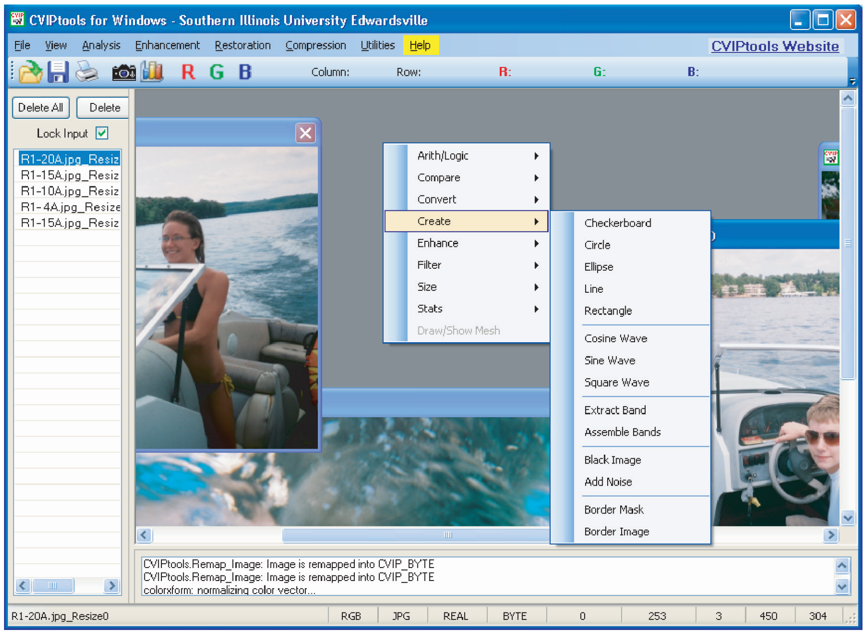


FIGURE 2.3-6ab

CVIPtools utilities. The utility functions can be accessed with two methods. (a) The two-level menu for *Utilities* will pop-up with a right mouse click in the image viewing area, or (b) click on *Utilities* at the top of the main window and the primary menu for *Utilities* will appear across the top, and will toggle each time the *Utilities* button is selected.

(a)



(b)

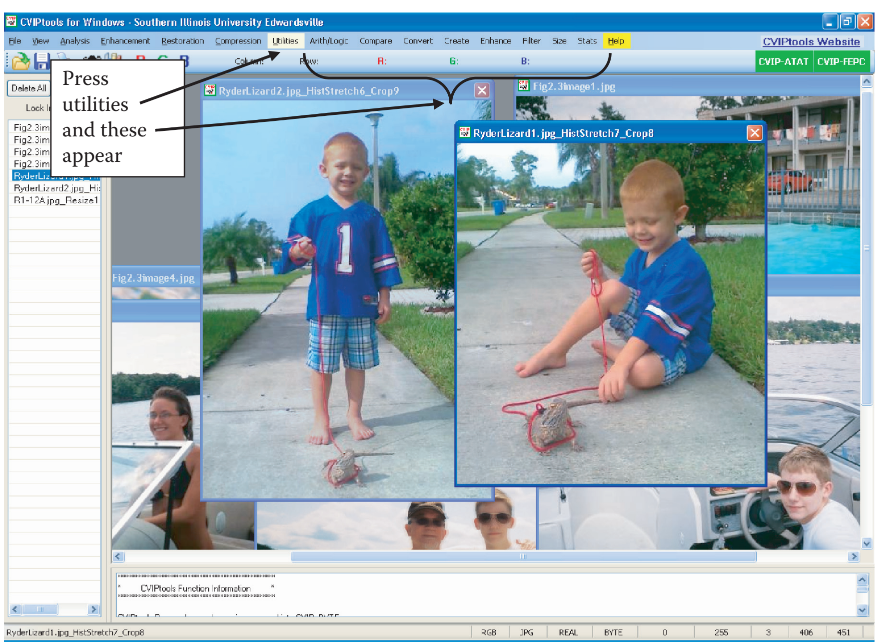


FIGURE 2.3-6c

CVIPtools utilities. (c) an example Utilities window selection.

(c)

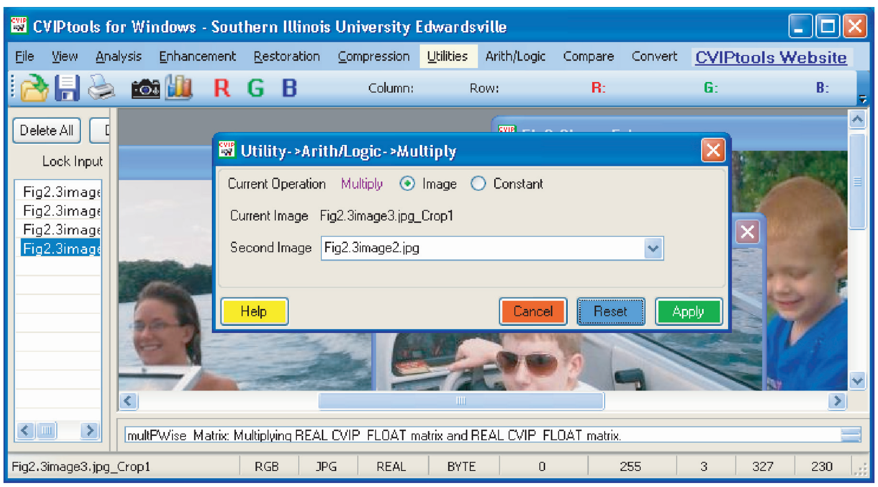
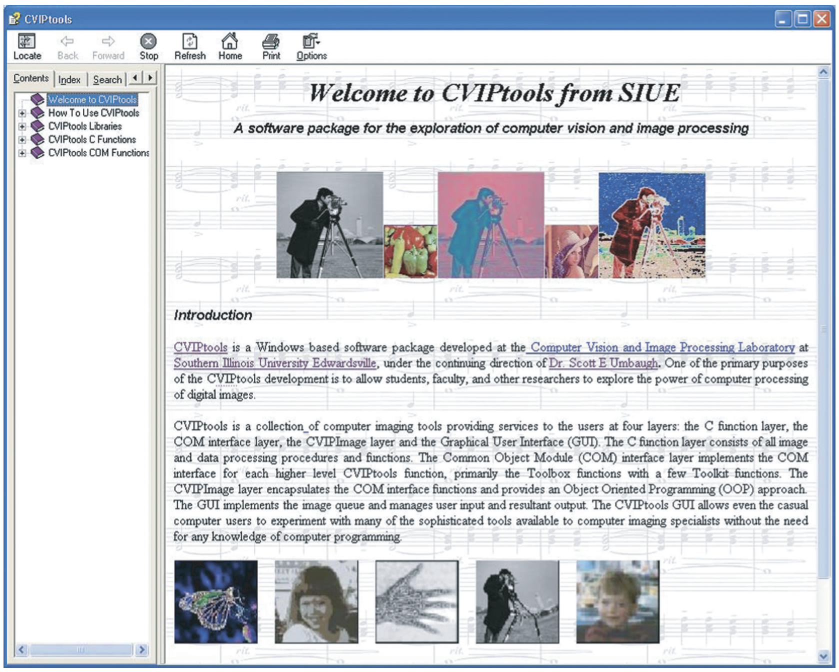


FIGURE 2.3-7ab

The CVIPtools help window. The help window contains information about using CVIPtools and contains documentation for the libraries and C functions, and includes CVIPtools related Internet links. It has an index of all the documents it contains and allows for keyword searches to assist the user in finding what they need. (a) The help window as it appears when first selected, (b) help window showing an example of a page under *How to Use CVIPtools.*

(a)



(b)

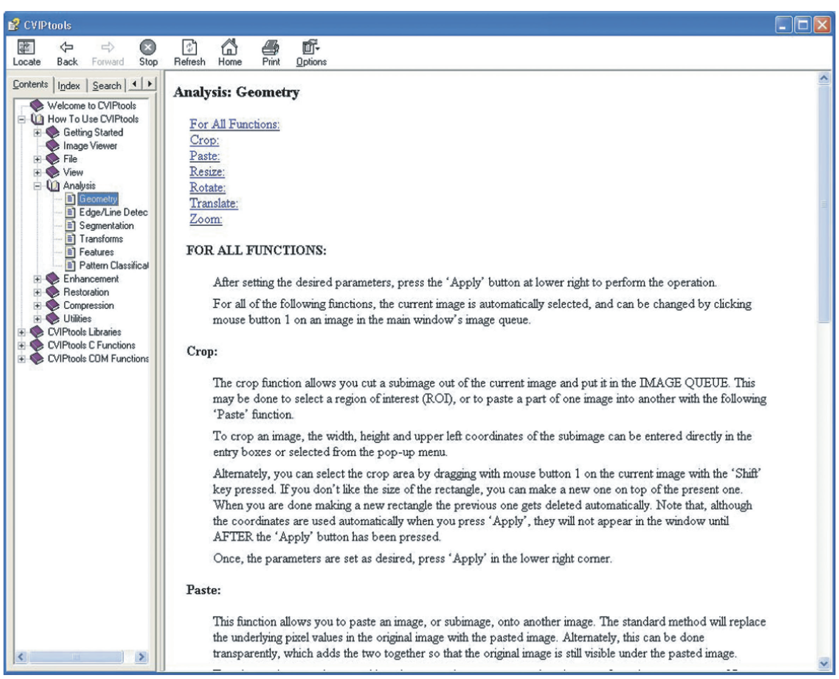
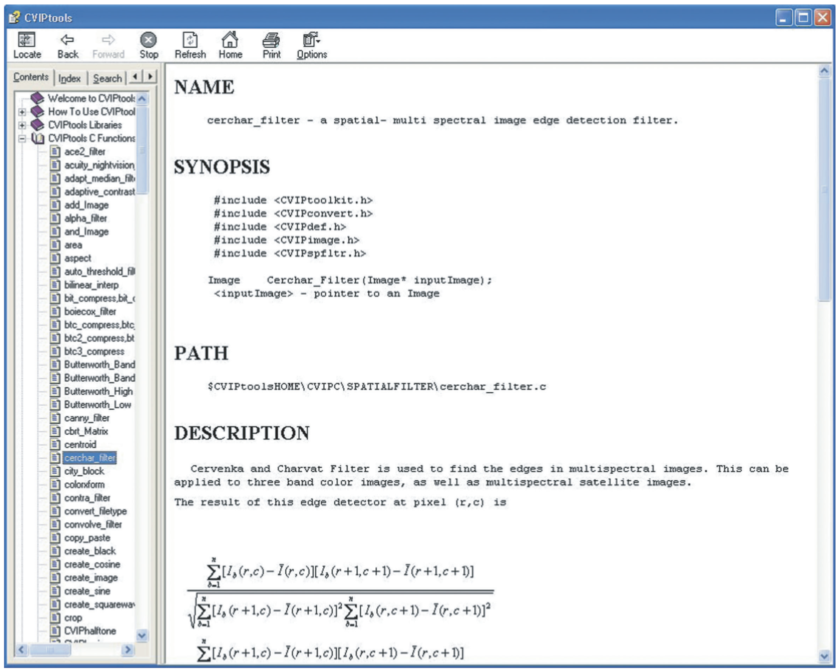


FIGURE 2.3-7cd

The CVIPtools help window. (c) help window showing an example of C function documentation, (d) If the user scrolls down a C function Help page, an example of usage in a CVIPlab program is included.

(c)



(d)

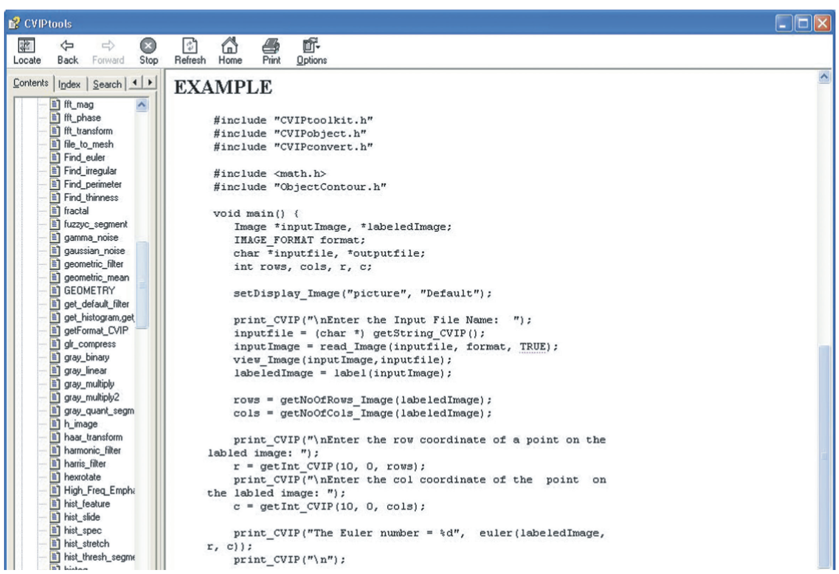


FIGURE 2.3-8a

CVIPtools development utility main windows. (a) Computer Vision and Image Processing Algorithm Test and Analysis Tool, *CVIP-ATAT*, showing the main window after a project is opened.

(a)

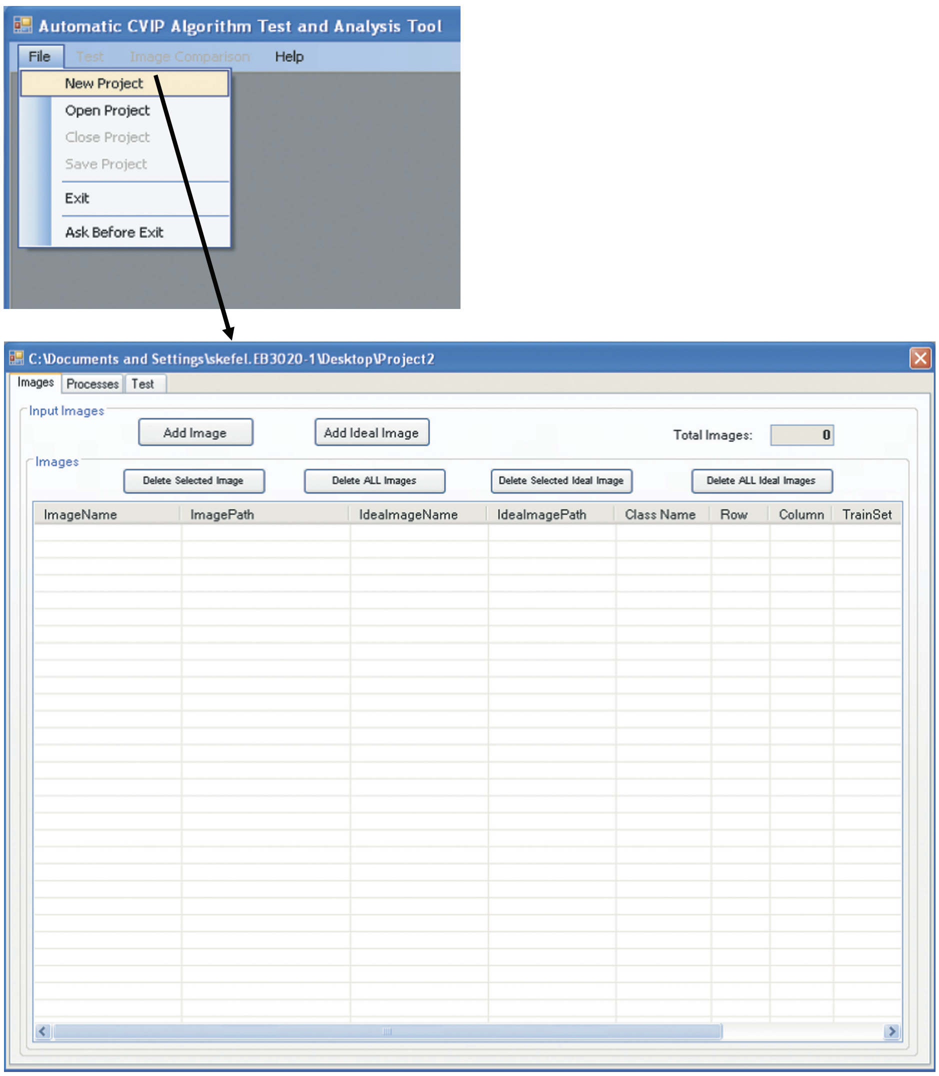


FIGURE 2.3-8b

CVIPtools development utility main windows. (b) Computer Vision and Image Processing Feature Extraction and Pattern Classification Tool, *CVIP-FEPC*, showing the main window with images loaded.

(b)

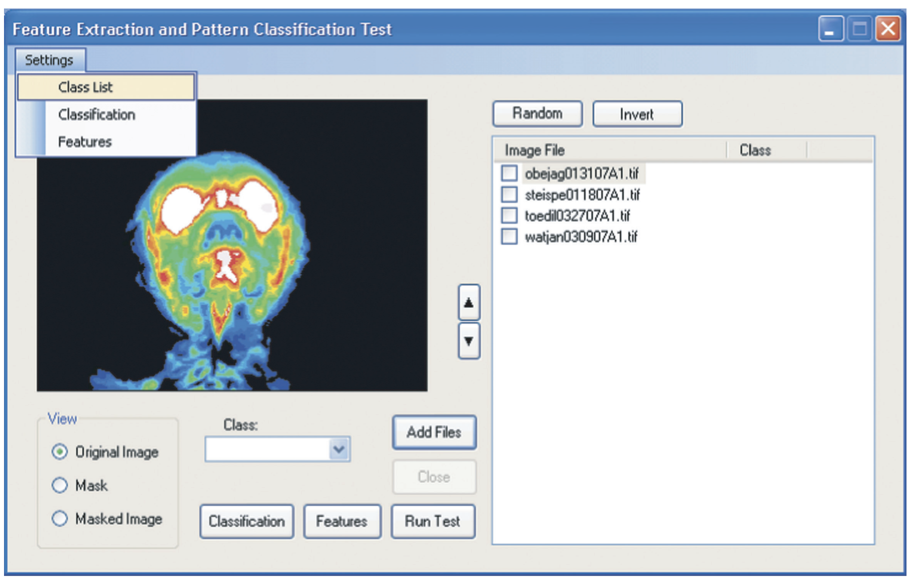
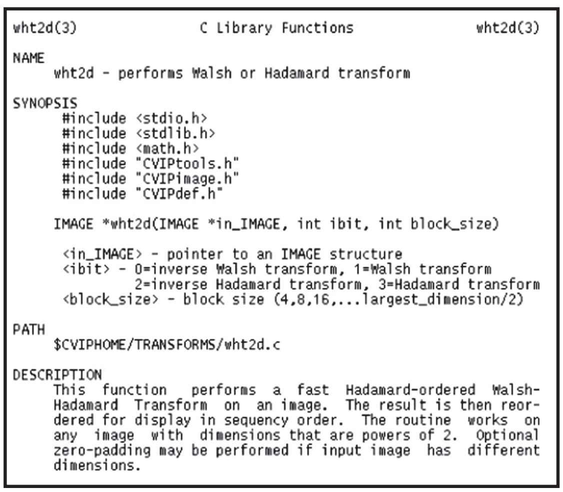


FIGURE 2.4-1

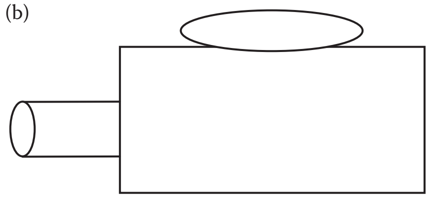
Binary images. (a) Binary text, (b) object outline, and (c) edge detection and threshold operation.

(a)



```
wht2d(3)                C Library Functions                wht2d(3)

NAME
     wht2d - performs Walsh or Hadamard transform

SYNOPSIS
      #include <stdio.h>
      #include <stdlib.h>
      #include <math.h>
      #include "CVIPtools.h"
      #include "CVIPimage.h"
      #include "CVIPdef.h"

     IMAGE *wht2d(IMAGE *in_IMAGE, int ibit, int block_size)

      <in_IMAGE> - pointer to an IMAGE structure
      <ibit> - 0=inverse Walsh transform, 1=Walsh transform
               2=inverse Hadamard transform, 3=Hadamard transform
      <block_size> - block size (4,8,16,...largest_dimension/2)

PATH
     $CVIPHOME/TRANSFORMS/wht2d.c

DESCRIPTION
     This  function   performs  a  fast  Hadamard-ordered  Walsh-
     Hadamard  Transform  on  an image.  The result is then reor-
     dered for display in sequency order.  The routine  works  on
     any  image  with  dimensions that are powers of 2.  Optional
     zero-padding may be performed if input image  has  different
     dimensions.
```

(b)



(c)

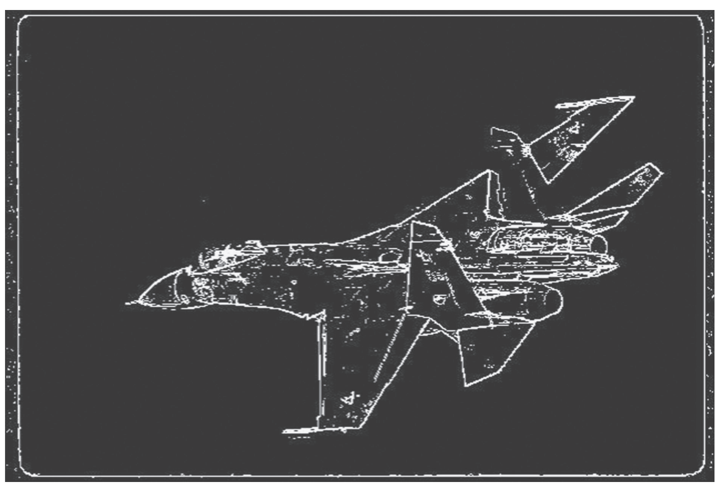


FIGURE 2.4-2

Gray-scale or gray-level images; also referred to as monochrome images. (a) and (b) These images are typically 8-bits per pixel for a total of 256 brightness values (0–255). In some applications requiring higher brightness resolution, such as medical imaging or astronomy, 12- or 16-bit per pixel representations are used.

(a) (b)

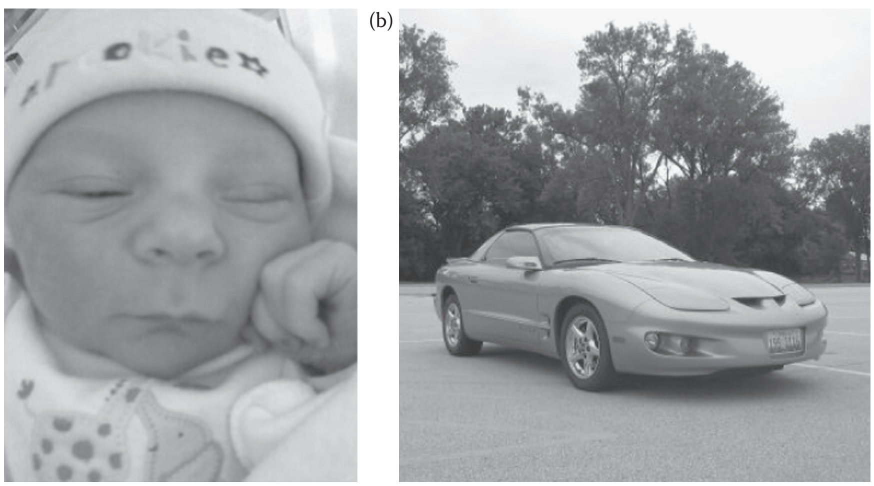


FIGURE 2.4-3a

Color image representation. (a) A typical color image can be thought of as three separate images: $I_R(r,c)$, $I_G(r,c)$, and $I_B(r,c)$, one for each of the red, green, and blue color bands.

(a)

FIGURE 2.4-3bc

Color image representation. (b) The three color bands combined into a single color image. (c) A color pixel vector consists of the red, green, and blue pixel values (R,G,B) at one given row/column pixel coordinate (*r*,*c*). (Original image courtesy of Scott R. Smith.)

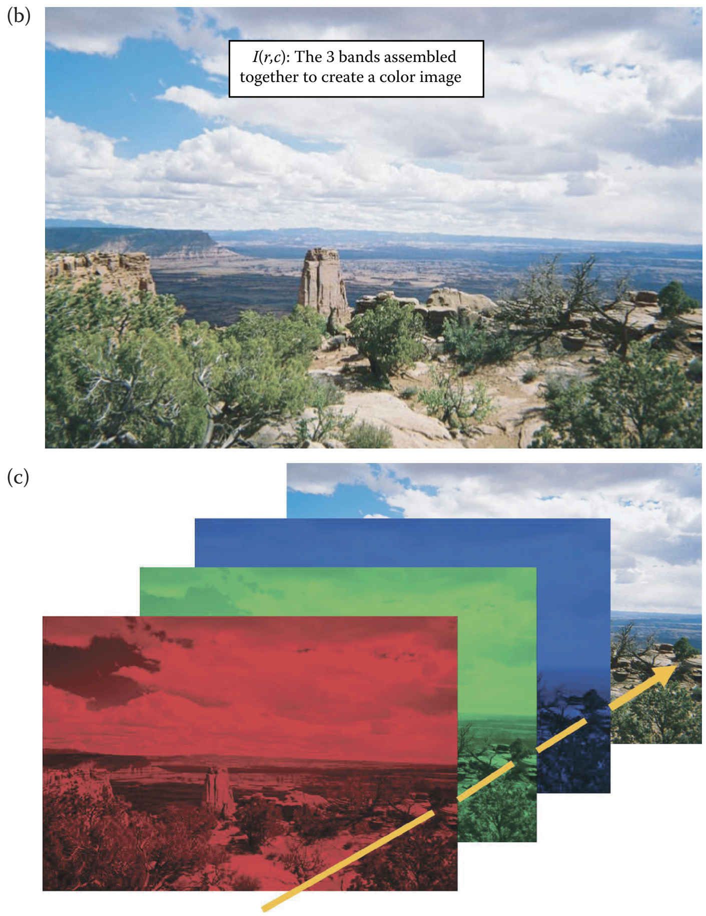


FIGURE 2.4-4

HSL color space. (a) Schematic representation of the HSL color space, and (b) color representation of the HSL color space.

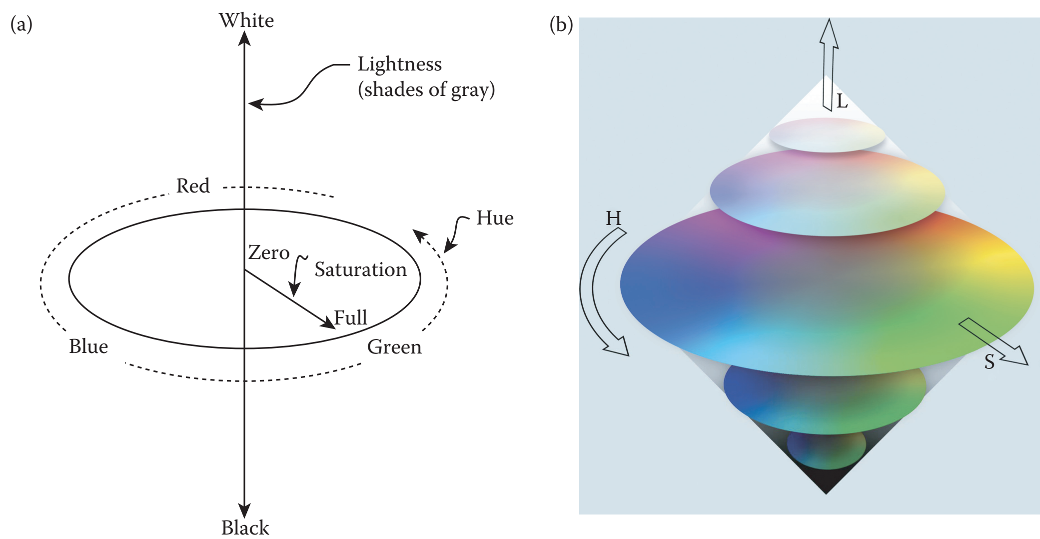


FIGURE 2.4-5

RGB to HSL mapping.

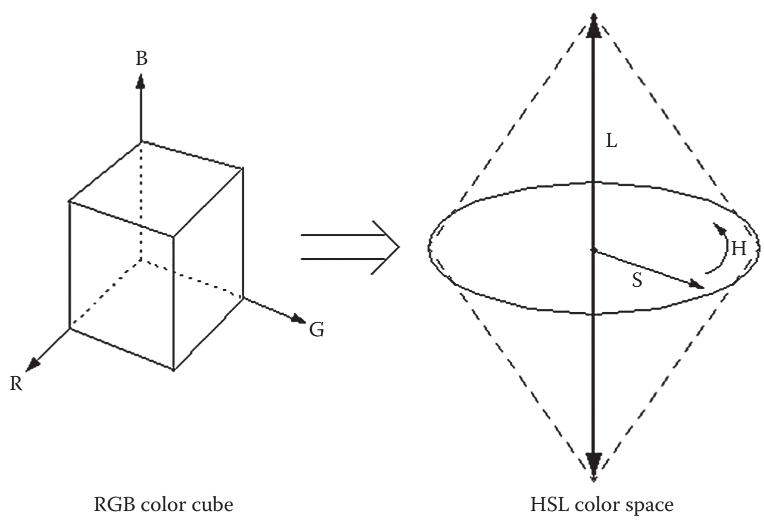


FIGURE 2.4-6

Spherical coordinate transform (SCT). (a) The SCT separates the red, green, and blue information into a 2-D color space defined by angles A and B, and a 1-D brightness space defined by L, and (b) a color pixel vector (R,G,B).

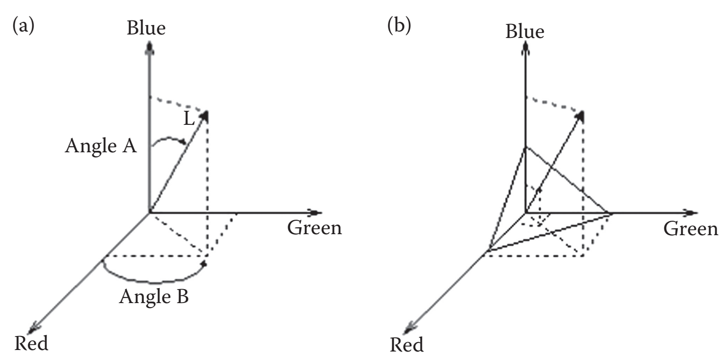


FIGURE 2.4-7

Cylindrical coordinates transform.

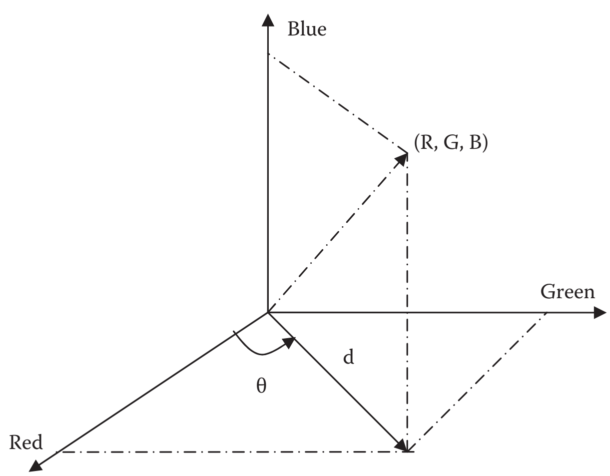


FIGURE 2.4-8

Color perception. Color A may be green and color B may be orange. Colors C and D may be slightly different shades of green, but ΔCD = ΔAB. In this case, we have two pair of colors with the same "color difference," but the perceptual difference is much greater for one pair than the other.

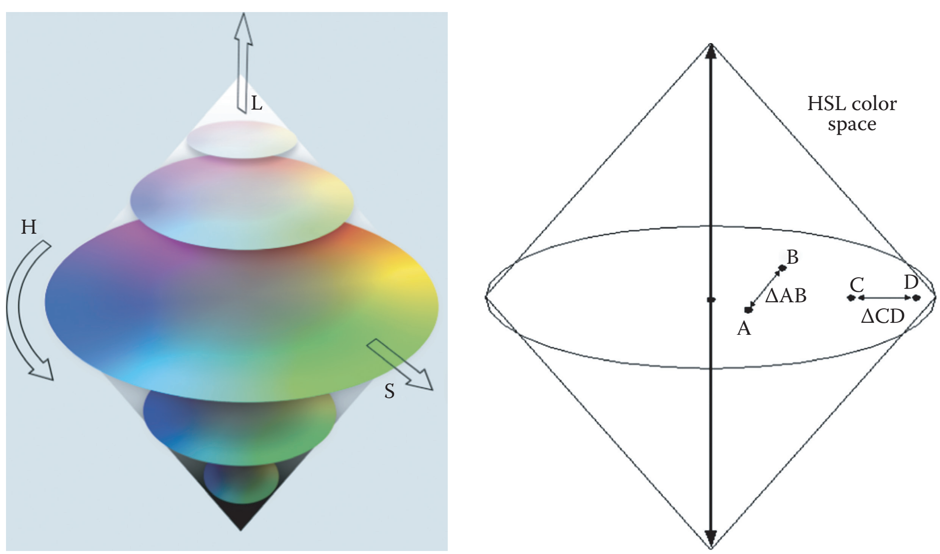


FIGURE 2.4-9

Look-up table (LUT)

8-Bit index	Red	Green	Blue
0	R_0	G_0	B_0
1	R_1	G_1	B_1
2	R_2	G_2	B_2
⋮	⋮	⋮	⋮
254	R_{254}	G_{254}	B_{254}
255	R_{255}	G_{255}	B_{255}

One byte is stored for each pixel in I(r, c). when displayed this 8-bit value is used as an index into the LUT, and the corresponding RGB values are displayed for that pixel.

FIGURE 2.4-10

Remapping for display. Original data ranges outside the bounds of a standard image. It is remapped to the 8-bit range from 0 to 255.