# Bio 595

# Computers in Biomedical Research

# Class notes set 9

# Fall 2003

# Image Processing

**What is it?**

**An image from a video camera or other optical detector can be digitized, converted to numeric form, and stored in a computer.**

**A picture is stored as integers representing quantized intensities of picture elements (pixels) in a rectangular sampling grid.**

# Image processing system pieces

- an image detector, usually video-based
- the computer
- a digitizer, usually plug-in boards
- an analog or digital image storage device (recorder)
- a mass storage device connected to the computer (hard disk or removable media like a Jaz disk)
- a monitor (parameters affecting system performance include image resolution, screen size)
- an array processor board (optional)
- a high resolution graphics display controller
- a hard copy device like a color inkjet or laser printer
- image processing software.

# Video Detectors

- scanners (e.g. densitometer or drum scanner)
- phototubes, photomultipliers
- linear and area photodiode arrays
- video tubes (including the vidicon)
- image dissector
- newvicon
- SIT, ISIT silicon-intensified target (high sensitivity)
- High sensitivity cameras cooled to minimize the camera's "dark current". Modern cameras usually are solid state array detectors such as CCD, CPD, CID, and MOS types.
- Slow scan cameras use worm gear-driven linear CCD arrays.

# Video detector Performance factors

resolution
dynamic range
contrast
dark current
noise
sensitivity
lag
persistence
spectral response
blooming
distortion
scan rate

# Television scanning standards

US standard: 30 frames/second, 2 fields/frame, odd and even fields interlaced. (cf European standard, 25 frames/second)

There are 525 lines in a single frame video image (cf European standard, 625 lines)

Each video ‘raster’ line takes 63.5 μsec to be drawn left to right on the screen

# Television

Electronic controls on the video cameras used in the laboratory usually include

A manual pedestal (DC offset adjust)

Gamma (or gain control) which permit expansion of low contrast regions of interest within the full black-white dynamic range.

Many video camera circuits have auto gain, auto-pedestal (or "auto-black") settings, but those designed for research use offer a manual override.

# Computers

**Widely used for image processing:**

- **Pentium PCs**
- **Macintosh PPCs**
- **UNIX workstations (Sun Sparc or SGI Indigos)**

# Image Processing Hardware

**Includes such elements as**

- **a dedicated  ALU (arithmetic and logic unit)**
- **video buffers**
- **LUT memory (where information about color or gray scale conversion is stored)**
- **array processor (memory and logic circuitry for fast manipulation of the digital image).**

# Digitizer

**Usually a flash video (high speed) A-D converter, typical 8 bit (256 intensity levels represented) monochrome or color input (3 x 8 bit) board.**

**Digitizer converts each video line into 640 sequential 8-bit intensity values; a typical image is 480 x 640 pixel x 8 bit.**

# Video Recorder

VCR formats include 1/2" (VHS, beta-cam), 3/4" (U-Matic); 1/2”, 1" (C) reel-to-reel videotape.

Special capabilities of VCR include still frame, slow motion, time lapse, high speed operation.

Performance factors include bandwidth, resolution, picture definition. Other video recording technologies include magnetic disk (e.g. RAID disk arrays) and laser disks.

Newest technology: solid state (TiVo-like)

# Attributes of an Image

Contrast (range of amplitudes of gray levels within the image)

Intensity resolution of the gray scale - how many different integer values are used to encode the brightness of spots (pixels) in the image?

Might be 64, 256 or 1,024.

Spatial resolution - how many integers span the x vs. y dimensions of the image?

Image magnification - ratio of the size of the displayed or printed output image compared to actual specimen size.

# Sequence of Instrument Components

**Image degradation can occur in each of these: (in order)**

- **specimen itself**
- **microscope and camera optical elements like lenses and mirrors**
- **optical detector**
- **digitizer**
- **computer**
- **display device**
- **film or printer used to reveal image output**

# Image Processing Software

**Written in Fortran or Pascal, now usually C++**
**Image processing software operations can include:**

- **gray scale expansion (contrast manipulation, enhancement)**
- **sharpening of edges (to delineate boundaries, objects)**
- **reduction of video noise by image “summation”, the averaging of successive images**
- **removal of fixed pattern noise by subtracting images (subject minus background)**
- **spatial filtering**
- **obtaining quantitative information from analysis of pictorial details ("feature extraction")**

# The Histogram

Histogram of gray level intensities measured from individual pixels contains useful information

if some possible gray levels are not be represented in the histogram, the resultant image can be a low contrast image, with much detail obscured by its dull grayness.

Histogram's gray values can be reassigned by software (done in contrast enhancement) - called an I/O transfer curve manipulation operation (ITF stands for image transfer function)

Gray level histogram is used in thresholding, clipping, normalization, boundary threshold selection, area and optical density computations

# Pseudocolor Contrast Enhancement

Encode parts of brightness spectrum using color - check each pixel of the image, re-map output in that assigned color

Use separate LUTs (look-up tables) for red, blue, and green output to color the display

# More Software Options

- erosion of boundaries (reducing object boundaries to single pixel line thickness)
- dilation (thickening) of boundaries
- counting number of objects
- sizing of objects
- rubber-sheeting
- auto-focusing a microscope
- auto logging of measured objects

# Image Processing Operations

- **Point, local, and global functions.**
- **Example of a point operator: contrast enhancement, using the value conversion y=mx+b, to shift image gain (m) and offset or brightness (b).**
- **Example of a local operator is smoothing (low pass filtering) to produce a background image for subtraction from the original image in order to remove variations in illumination across the image).**
- **Example of a global operator: image subtraction: subtract picture 1 from picture 2. Another example: logical OR of picture 1 with picture 2**

# Some terms...

**Digitize**

**Convert the input analog video signal into an x by y (such as 480 by 640) array of discrete pixels (picture elements). A real-time or flash digitizer converts the entire video image in one frame period, 1/30th of a sec.**

# Archive

**Store or retrieve images to or from a removable hard, floppy or optical disk storage device connected to the computer.**

# Pan, Scroll & Roam

**Move the displayed region of interest from one area of the stored image to another.**

**Panning: movement along the X axis of the image**

**Scrolling: movement along the Y axis**

**Roaming: movement along both axes simultaneously, as on a diagonal.**

# Zoom

**Increase the image magnification so that 1/4th, 1/16th or 1/64th of the original digitized image will fill the entire screen display.**

**With more advanced programming, other zoom ratios can be achieved.**

# Area Of Interest (AOI)

**Specify the x,y coordinates of a rectangle or parallelogram on the screen to identify the image portion on which we wish to perform subsequent image processing operations.**

# Histogram

- Calculate (and display) the histogram of a specified AOI; plot the frequency of occurrence of each possible pixel brightness in the AOI as a function of pixel brightness.
- For color images, this can be done separately for each of the three primary (red, green, blue) colors.
- The intensity histogram characterizes the contrast information in the picture.

# Pseudocolor (false color)

**Selected colors are assigned to gray value amplitudes in order to distinguish regions of the original (monochrome) image with equal or similar image brightness, or to enhance slight differences in these brightness.**

# Enhance Contrast

- Adjust the image contrast by rearranging the distribution of pixel intensities to achieve a desired result.
- Histogram of pixel intensities can be shifted by adding a constant (positive or negative) value to every pixel to make the resultant image brighter or darker without changing its dynamic range.
- Or, the histogram can be stretched by multiplying each pixel by a constant (and adding a second constant)
- If the (first) constant is greater than one, the resultant image will exhibit sharper contrast than the original image.

# Histogram Equalization

**Changes the dynamic range of pixel intensities so that the entire range of pixel intensity levels (in a monochrome image) is utilized.**

**Process usually yields an image which does not appear under- or overexposed.**

# Warp

- Transforms the geometry or spatial mapping of the original image
- A linear warp is equivalent to a rotation of the original image by some angle; a quadratic warping, or "rubber-sheeting", stretches and distorts the original image so that landmarks in the image are forced to the best fit of specified coordinates in the new image.
- This technique is useful in superimposing two images from different sources, or in correcting a view distorted by the perspective from which the camera recorded the image.

# Thresholding

**Replace each pixel with a background pixel brightness (or color) if the magnitude is below a selected threshold value, and leave pixels above this brightness unchanged.**

**In binary thresholding, pixels above background are also set to a fixed pixel brightness; thus, all pixels are replaced by one of two values which can be represented by 0s and 1s (black and white).**

# Spatial Filter

**Pass selected frequency components of an image and remove other components.**

**A high-pass filter leaves contrast details which change rapidly in the image while removing slow variations in image brightness.**

**A low-pass filter removes high frequency information (such as random noise or speckle) while leaving slowly changing variations in intensity of regions of the image.**

# Spatial Filter

**These filters utilize convolutions, which process a small rectangle of pixels at a time, using a "kernel" or filter mask, typically of 3x3 or 5x5 pixels.**

**A variety of filter routines are available (e.g., Laplacian, horizontal or vertical edge detection, or with a user-specified mask).**

# Non-Convolution Filters

**Dilation filter - lighter elements in the image are thickened, and the image is brightened.**

**Erosion filter - lighter elements in the image are thinned, and the image is dimmed.**

**Median filter - smoothes out an image and removes noise.**

**Sobel filter - a second order edge detector, yielding very high contrast edge definition.**

# Multiple Image Processing

Combine one image with another specified image file on a pixel-by-pixel basis.

Operations can include subtraction (one image subtracted from another, leaving a difference image), addition, averaging, and various logic operations (AND, OR, XOR, NAND, NOR).

In image averaging, successive incoming images (say, 480x640 pixel x 8 bit) are successively summed in an image buffer of a greater number of bit planes (e.g. 12 or 16 bits deep).

# Image Restoration

Reconstruct or restore a degraded image.

One common method is by removal of periodic (or near periodic) noise from the fourier transform of the image (where the image is transformed from the spatial to the frequency domain).

The transformed processed image must then be retransformed to the spatial domain.

# Image Analysis

**The measurement of properties of objects detected in an image.**

**Might involve accumulation of statistics regarding objects in the image, such as object area, perimeter, curvature, shape factor, area of holes, average radius, total particle count, object brightness, object density, etc.**

# Image Editing

**Painting or retouching an image with a software brush (in color, grayscale or pattern), airbrush, erase, cut, paste, insert text, or draw graphics shapes such as circle, rectangle or polygon.**