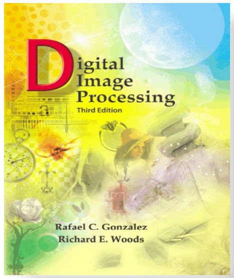


Review for Exam I, EE552 2/2009

•Elements of Visual Perception

- •Image Formation in the Eye (and relation to a photographic camera).
- •Brightness Adaption and Discrimination.

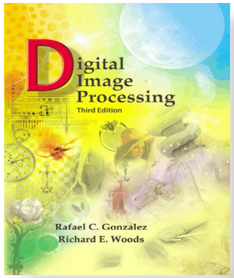
•Light and the Electromagnetic Spectrum

- •Gamma rays, <u>visible spectrum (Violet – Infrared)</u>, Radio waves.
- •Visible spectrum spans the range from ~0.4 μm (violet) to about ~0.7 μm (red).
- •Light that does not have color is called *monochromatic light* (i.e. each band of an RGB image).
- •Attribute of monochromatic light is *intensity*.

Chromatic color spans the range ~0.4 μm through ~0.7 μm.

•Image Sensing and Acquisition

- •Depending on the source, illumination is reflected from, or transmitted through objects.
- •Principal sensor arrangements used to transform energy into digital images: single sensor, line sensor, array sensor.
- •Image acquisition using array sensors.
- •A simple image formation model: $f(x,y) = i(x,y)r(x,y)$. The reflectance value is bounded by 0 (total absorption) and1 (total reflectance).



Review for Exam I, EE552 2/2009

- Image Sampling and Quantization
    - To create a digital image we need to convert the continuous sensed data into digital form using two processes: *sampling and quantization*.
    - Digitizing the coordinates is sampling, digitizing the amplitude is called quantization.
    - Representing Digital Images. A real plane spanned by the coordinates of an image is called the *spatial domain*.
    - The number of intensity levels in an image is $L=2^k$.
    - The number of bits required to store a digitized image is $b=M\times N\times k$
    - Image interpolation: *nearest neighbors, bilinear* ($v(x,y)=ax+by+cxy+d$), *bicubic interpolation* ($v(x,y)=\sum_{i=0}^{3}\sum_{j=0}^{3}a_{ij}x^i y^j$).
- Basic Relationships Between Pixels
    - A pixel has 4-neighbors, diagonal neighbors, and 8-neighbors.
    - Two pixels can be 4-adjacent, 8-adjacent, and m-adjacent.
    - Distance measures: Euclidean ($D(p,q)=[(x-s)^2+(y-t)^2]^{1/2}$), city-block distance ($D(p,q)=|x-s|+|y-t|$), chessboard distance ($D(p,q)=\max(|x-s|+|y-t|)$).

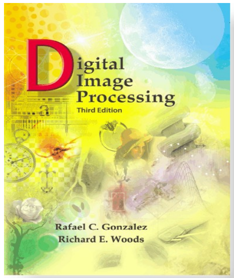
Review for Exam I, EE552 2/2009

•Mathematical Tools Used in DIP

- •Array versus matrix operations.
- •Linear versus nonlinear operations.
- •Arithmetic operations: summation, subtraction, multiplication, division <u>between corresponding pixels</u>.
- •Applications of arithmetic operations:
  - ➢Reduction/removal of noise in a corrupted noise (noise uncorrelated and zero mean).
  - ➢Shading correction (multiplication by the inverse of the shading function $h(x,y)$).
  - ➢Masking, also called *region of interest* (ROI) operations.
  - ➢ Scaling of images (linear).
- •Basic set and logical operations: A is a subset of B ($A \subseteq B$), intersection ($A \cap B$), union ($A \cup B$).
- •Spatial operations: single-pixel operations (transformation functions), neighborhood operations (involves a neighborhood of m×n pixels), geometric spatial transformations (scaling, rotation, translation, shear (vertical) and shear (horizontal)).

Review for Exam I, EE552 2/2009

- Vector and Matrix Operations
  - Vector and matrix operations are routinely used in multispectral image processing.
  - Euclidean distance between a pixel vector z and an arbitrary point a in n-dimensional space is
    $D(z,a) = [(z-a)^T(z-a)]^{1/2}$
  - Image transforms. Image processing tasks are best formulated by transforming the input image, carrying a specified task, and then applying the inverse transform.
  - Forward and inverse transforms can be *separable* ($r(x,y,u,v) = r1(x,u)r2(y,v)$) and *symmetric* ($r(x,y,u,v) = r1(x,u)r1(y,v)$).



Review for Exam I, EE552 2/2009

- Intensity Transformation and Spatial Filtering
  - Basic spatial domain process is $g(x,y) = T[f(x,y)]$.
  - Intensity (gray-level or *mapping*) transformation function $s = T(r)$.
  - Image negatives are obtained using the negative transformation $s = L - 1 - r$.
  - *Log* transformations have the form $s = c\log(1 + r)$.
  - Power-Law (*Gamma*) transformations $s = cr^{\gamma}$.
  - *Contrast stretching* is used to expand the range of intensity levels in an image.
  - *Intensity-level slicing* is used to highlight a specific range of intensities in an image.

- Histogram Processing
  - Transformation (intensity mapping) of the form $s = T(r) \quad 0 \le r \le L - 1$.
  - A transformation function of particular importance in DIP is $s_k = T(r_k) = (L-1)\sum_{j=0}^{k} p_r(r_j)$ which performs a *histogram equalization* or histogram linearization transformation.
  - *Histogram matching* is used to generate a processed image that has a specified histogram $s_k = T(r_k) = (L-1)\sum_{j=0}^{k} p_r(r_j)$ and $G(z_q) = s_k = (L-1)\sum_{i=0}^{q} p_z(z_i)$ *and* $z_q = G^{-1}(s_k)$.
  - Global histogram processing can be adapted to *local enhancement* (local histogram processing).
  - Local mean and variance can be used to change an image based on local characteristics in a neighborhood $S_{x,y}$, i.e. change the intensity of a pixel if the local mean is larger/smaller than global mean.

Review for Exam I, EE552 2/2009

•Fundamentals of Spatial Filtering

- •A spatial filter consists of (1) a neighborhood, and (2) a predefined operation.
- •Spatial correlation and convolution. Correlation is the process of moving a filter mask over the image and computing the sum of products. Convolution consists in a similar process but the filter is first rotated 180˚.
- •Vector representation of linear filtering; $R = w^T z$, where w are the coefficients of the filter and z are the corresponding image intensities.

•Smoothing Spatial Filters

- •Output of a *smoothing*, linear spatial filter is simply the average of the pixels in a neighborhood.
- •It is computationally more efficient to have coefficients valued 1, and then at the end of the process divide by a constant.
- •*Order-statistic* (nonlinear) filters are based on ordering (ranking) the pixels in a neighborhood like the *median filter*.
- •Median filters are effective in the presence of impulse noise.

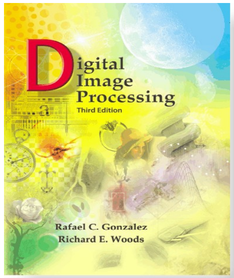
Review for Exam I, EE552 2/2009

- Sharpening Spatial Filters
  - Sharpening can be accomplished by spatial differentiation.
  - The *Laplacian* is a sharpening filter that uses *second-order derivatives* $\nabla^2 f = \frac{\partial^2 f}{\partial x^2} + \frac{\partial^2 f}{\partial y^2}$.
  - Image sharpening using the Laplan $g(x,y) = f(x,y) + c[\nabla^2 f(x,y)]$.
  - Sharpening using first-order derivatives – the gradient.

$$\nabla f \equiv \begin{bmatrix} gx \\ gy \end{bmatrix} = \begin{bmatrix} \frac{\partial f}{\partial x} \\ \frac{\partial f}{\partial y} \end{bmatrix}$$

  - *Roberts* cross gradient operators: $M(x,y) \approx |z9 - z5| + |z8 - z6|$.
  - *Sobel* operators: $M(x,y) \approx |(z7 + 2z8 + z9|-(z1 + 2z2 + z3)|$

$$|(z3 + 2z6 + z9|-(z1 + 2z4 + z7)|$$



Review for Exam I, EE552 2/2009

•Filtering in the Frequency Domain

•The Fourier transform of a "box" function is a sinc function.

•Convolution in the time domain represents a multiplication in the frequency domain:

$f(t) * h(t) \Leftrightarrow H(\mu)F(\mu)$.

•Sampling and the Fourier Transform of Sampled Functions

•The *Sampling Theorem* which states that that a band-limited function can be recovered completely from its samples if they are acquired at a rate exceeding twice the highest frequency in the function $1/\Delta T > 2\mu_{max}$.

• *Aliasing* or frequency aliasing is a process in which high frequency components of a function "masquerade" as lower frequencies.

•The DFT of One Variable

•The DFT of a sampled signal is *continuous and infinitely periodic* with period $1/\Delta T$.

• The discrete Fourier transform pair allows transformation to and from the frequency domain.

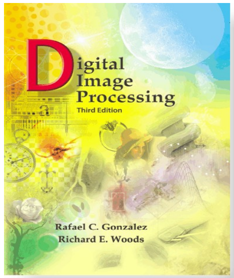
•Extension of the DFT to two variables. The Fourier transform of a 2-D "box" produces a 2-D sinc function.

•*Aliasing in images* can be avoided if images are smoothed first (antialiasing) and then resampled.

Review for Exam I, EE552 2/2009

- The 2-D DFT and its inverse.
- Properties of the 2-D DFT: relationship between spatial and frequency intervals, translation and rotation, periodicity, symmetry properties.
- Table 4.1 (allowed to bring a copy of it to the exam).
- The 2-D DFT is complex in general and can be expressed as $F(u,v) = |F(u,v)|e^{j\phi(u,v)}$
- The zero-frequency term ($F(0,0)$) is proportional to the average value of $f(x,y)$; $F(0,0) = MN\bar{f}(x,y)$.

- The Basics of Filtering in the Frequency Domain
  - Filtering in the frequency domain consists on modifying the Fourier transform of an image. The filtering equation is $g(x,y) = \Im^{-1}\{H(u,v)F(u,v)\}$.
  - Summary steps for filtering in the frequency domain (Method in section 4.7.3).
  - Correspondence between filtering in the spatial and frequency domains. A Gaussian lowpass in the frequency domain corresponds to a smoothing filter in the spatial domain, a Gaussian highpass in the frequency domain corresponds to a sharpening filter in the spatial domain.



Review for Exam I, EE552 2/2009

- Image Smoothing Using Frequency Domain Filters
  - Lowpass filters: ideal (ILPF), Butterworth (BLPF), and Gaussian (GLPF).
  - Applications of lowpass filtering: machine perception, cosmetic processing, remote sensing.

- Image Sharpening Using Frequency Domain Filters
  - Highpass filters: ideal (IHPF), Butterworth (BHPF), and Gaussian (GHPF).
  - Applications of lowpass filtering: machine perception, cosmetic processing, remote sensing.
  - Laplacian in the frequency domain.
  - Homomorphic filtering can be used to filter an image which is product of two terms, i.e. illumination and reflectance.
  - Notch filters

- The Fast Fourier Transform (FFT)
  - Can reduce the number of computations of the DFT from $(MN)^2$ multiplications and additions to $MN \log_2 MN$ multiplications and additions.
  - It uses the *successive-doubling method* to partition the 1-D transform into half and then into even and odd sequences.