Midterm Review
Human Visual System: Fundamentals

- Human Eye
  - Receptors, Cones and Rods
  - Visually acuity
  - Non-uniform sampling
  - Brightness adaptation

- Image Model
  - \( f(x,y) = i(x,y)r(x,y) \)

- Basic Transforms
  - Translation, Scale, Rotation, Homogenous Coordinates
  - Projection
Writing DIP software

- Minimum info needed for an image data structure
- Indexing images as 1D arrays
- Handling underflow/overflow
- Rescaling intensity levels
- Image boundaries
Example Questions

• Assume we have represented a grayscale (depth=1) image as a 1D array. If the image is (400x300) [width x height], what is the offset in this 1D array for the pixel f(30,42)?

  imaData[ offset ]

• Write the pseudo-code for re-scaling an image.

• If I am reflecting the boundaries of an image, what image coordinate will the following pixel represent, f(-10,20)?
Operations and Labeling

- Arithmetic and Logic Operators
  - addition, subtraction, AND, OR, NOT

- Pixel Relationships
  - N_4, N_8, N_D
  - Connectivity
    - 4-connectivity, 8-connectivity, M-connectivity
  - Distances
    - Euclidean, D_4 distance (city block), D_8 distance (chessboard), M-connectivity Distance
Geometric Transforms

- 2D Transformations
  - Affine
    - Properties
      - maps lines to lines
      - Preserves lines, equispaced points, incident
      - Usefulness
        » Maps triangle to triangle between source and destination spaces
  - Projective
    - Properties
      - Preserves incident, maps lines-to-lines
        » Maps general quadrilaterals between source and destination spaces
Geometric Transforms

- Image Transformation
  - Forward Mapping
  - Reverse Mapping
- Sampling and Reconstruction
  - Aliasing
  - Fourier Transform
    - Be able to perform a Fourier transform such as the one we did in class (1-D continuous case)
    - Formula for Magnitude and Phase-shift
    - Fourier Pairs
Geometric Transforms

• Convolution identity between $F(u)$ and $f(x)$
  • Convolution example

• Convolution, Sampling and Filtering
  - Nyquist Rate
  - Reconstruction
    • Multiplying with a filter in frequency domain = convolution with the filters Fourier transform in the spatial domain
Intensity Transformations

- Point-processing
  - $s = T(r)$
  - Image Histogram

- Simple Transformations
  - Contrast Stretching/Compression
  - Windowing
  - Properties of $T(r)$
  - Gray-level Slicing

- Histograms
  - What they tell you about an image
    - Low contrast, High contrast, Bright Image
Intensity Transformations

• Histogram Equalization
  - Formula for Discrete Case
    • Properties
    • Histogram Specification

• Local Histogram Equalization

• Processing based on averaging
Example Questions

- Explain how image averaging works. What is the main idea behind this procedure?

- Describe how local histogram equalization is performed.

- What is the formula to compute the transformation $T(r)$ in order to perform histogram equalization?
Spatial Domain Filtering

- Neighbor operators with “masks”
  - Convolution in the spatial domain
- Smoothing Filter (Low Pass)
  - Blurring
  - Requirements for mask
  - Non-linear smoothing filters
    - Kth nearest neighbor
    - Max Homogeneity Smoothing
    - Median Filter
  - Iterative application of filters and convergence
Spatial Domain Filtering

- Sharpening filters (Hi-pass)
  - Mask formation
  - Hipass = Original - Lowpass
  - High-boost filter

- Derivative filters
  - Filter Criteria (coefficients must sum to 0)
  - Also sharpens
  - First Order
    - Gradient
    - Gradient Magnitude
  - Sobel and Prewitt operators
Example Questions

- Apply the following filter to the marked pixel,

\[
\begin{array}{cccc}
2 & 2 & 4 & 4 \\
2 & 2 & 0 & 0 \\
1 & 2 & 3 & 4 \\
2 & 7 & 2 & 6 \\
\end{array}
\]

\[
\begin{array}{ccc}
1 & 1 & 1 \\
1 & 1 & 1 \\
1 & 1 & 1 \\
\end{array}
\]

\[
\frac{1}{9} \times
\]

What is the resulting new value?
Example Questions

- What is the criteria for a sharpening filter?
- What is the criteria for a derivative filter?
- Draw the 3x3 Sobel and Prewitt Operators.
- Give the formula to compute the gradient magnitude?
Frequency Domain Filtering

- Discrete Fourier Transform
  - Definition
  - Properties
  - Image Power Calculation

- Ideal Filters
  - High-pass
  - Low-pass

- Butterworth Filter (Low-pass)
  - Definition
  - Variation to control the filter at a certain $D_0$
Frequency Domain Filtering

- **Butterworth Filter (High-pass)**
  - Definition
  - Variation to control the filter at a certain $D_0$

- **High-Boost filter**

- **Homomorphic Filter**
  - $f(x,y) = i(x,y)r(x,y)$
  - Filter pipe-line
Example Questions

• What is the formula for a low-pass 2D Butterworth filter?
  - Modify this filter such that \( H(u,v) = 1/\sqrt{2} \) at the cut-off frequency \( D_0(u,v) \).

• Describe the procedure for performing the Homomorphic frequency domain filter.

• What is the formula to compute the Image Power?

• What does \( F(0,0) \) tell you about the image?
FFT

- What is FFT
- Butterfly Graph
- Separability of 2D FFT
Example Questions

• Construct a 4-point FFT
Extra Credit

- These four images shown are blurred using square averaging masks of size $n = 1$ (original image), 15, 25, and 45 respectively. The vertical bar on the lower part of (b) and (d) are blurred, but a clear separation exists between them. However they have merged in image (c), in spite of the fact that the mask that produced this image is significantly smaller than the masked that produced image (d), explain this