# Final Exam Schedule

- Final exam has been scheduled:
- 4:00 p.m. – 6:30 p.m., Tuesday, Dec. 6

- Requirement:
- Closed book and closed notes
- One page double-sided cheat sheet is allowed
- A calculator is allowed for +-*/

- It will cover all the topics discussed in class

# Review of Chapter 8, 9, and 10

- Chapter 8
  - Fundamentals of image compression
  - Image compression methods
- Chapter 9
  - Basic morphological operations
- Chapter 10
  - Edge-based image segmentation
  - Region-based image segmentation

# Fundamentals of Image Compression

- Compression ratio $C = \frac{b}{b'}$
- Data redundancy $R = 1 - \frac{1}{C}$
- Three types of data redundancy and their examples
  - Coding redundancy
  - Spatial/temporal redundancy
  - Irrelevant information

$$H = -\sum_{k=0}^{L-1} p_r(r_k)\log_2 p_r(r_k)$$

- Entropy and average number of bits $L_{\text{avg}} = \sum_{k=0}^{L-1} l(r_k) p_r(r_k)$
- Objective fidelity criteria

$$e_{\text{rms}} = \left[ \frac{1}{MN} \sum_{x=0}^{M-1} \sum_{y=0}^{N-1} \left[ \hat{f}(x,y) - f(x,y) \right]^2 \right]^{\frac{1}{2}}$$

$$SNR_{\text{ms}} = \frac{\sum_{x=0}^{M-1} \sum_{y=0}^{N-1} \hat{f}(x,y)^2}{\sum_{x=0}^{M-1} \sum_{y=0}^{N-1} \left[ \hat{f}(x,y) - f(x,y) \right]^2}$$

# Image Compression Methods

- Huffman coding
- Arithmetic coding
- Run-length coding

Requirement: encode/decode with these methods, working conditions for these methods; develop a compression method with a combination of these methods for a specific task

# Edge-based Image Segmentation

- Connectivity
- Edge detectors
  - First-order derivative: Roberts (2x2), Prewitt (3x3), Sobel (3x3)
  - Second-order derivative: Laplacian
  - Complex edge detectors: LoG, DoG, and canny

  Requirement: characteristics of these edge detector, perform simple edge detectors (1st and 2nd order) on an image
- Edge linking
  - Hough transform

  Requirement: find a basic shape (e.g. a line) using Hough transform

# Brief Review on Simple Edge Detectors

- First-order derivative
  - Roberts (2x2)
  - Prewitt (3x3)
  - Sobel (3x3, smooth + difference)
  - Thicker edge
  - One operator for one edge direction
- Second-order derivative
  - Laplacian (3x3)
  - Double edge
  - Zero-crossing
- Common issues:
  - Sensitive to image noise
  - Cannot deal with the scale change of the image

# Brief Review on Advanced Edge Detectors

- Laplacian of Gaussian (LoG) $\nabla^2 G(x, y)$
  - Gaussian smoothing + Laplacian
  - Localize the edge position based on zero-crossings
  - Spaghetti effect of zero-crossings
  - Multiple filtering processing for scale variations
- Difference of Gaussian (DoG)
  - Approximation of LoG
  - Two different sigmas handle the scale variations
- Canny edge detector
  - Gaussian smoothing + 1st order derivative
  - Nonmaxima suppression to get single edge
  - Double thresholding and connectivity analysis to detect and link edges
- Thresholding
  - Key factors affect thresholding
    - Separation between peaks
    - Noise level
    - Relative size of objects and background
    - Illumination and reflectance

# Region-based Image Segmentation

- Region growing
- Region-splitting and merging

Requirement: develop a region-based image segmentation method for a specific image

# Basics of Mathematical Morphology

- Set reflection and translation $\hat{B} = \{w \mid w = -b, b \in B\}$ $(B)_z = \{c \mid c = b + z, b \in B\}$
- Erosion and dilation
- Opening: $A \circ B = (A \ominus B) \oplus B$
  - Smooth the contour of an object: smoothing outer corners
  - Break narrow isthmuses
  - Eliminate thin protrusions
- Closing: $A \bullet B = (A \oplus B) \ominus B$
  - Fill narrow breaks and gaps
  - Eliminate long and thin gulfs
  - Eliminate small holes
- Hit-or-miss transform
- Other operations
  - Thinning and thickening
  - Hole filling
  - Connected component analysis
  - Convex hull
  - Skeleton

Requirement: the applications of these operations; perform erosion, dilation, opening, and closing operation on an image

# Properties of Erosion and Dilation

- **Dilation is commutative** $A \oplus B = B \oplus A$
- **Dilation is associative** $A \oplus B \oplus C = A \oplus \left(B \oplus C\right)$
- **Dilation** $A \oplus (B \cup C) = (A \oplus B) \cup (A \oplus C)$
- **Erosion** $(A \cap B) \ominus C = (A \ominus C) \cap (B \ominus C)$
- **Erosion and dilation are duals of each other**

$$A \oplus B = \left(A^c \ominus \hat{B}\right)^c$$

- $A \subseteq (C \ominus B)$ **if and only if** $(A \oplus B) \subseteq C$
- **If** $A \subseteq C,\ A \oplus B \subseteq C \oplus B$ **and** $A \ominus B \subseteq C \ominus B$

# Properties of Opening and Closing

- Opening: $(A \circ B) \circ B = A \circ B$

  $(A \circ B) \subseteq A$

  $if\ A \subseteq C, A \circ B \subseteq C \circ B$

- Closing $(A \bullet B) \bullet B = A \bullet B$

  $A \subseteq (A \bullet B)$

  $if\ A \subseteq C, A \bullet B \subseteq C \bullet B$

# Texture Representation

- Textures are made up of
  - stylized subelements
  - Spatially repeated in meaningful ways
- Representation:
  - How to design filters find the subelements
  - How to represent their statistics

# Texture Representations

- At a pixel
  - compute representations for a patch centered on the pixel
- For a region
  - compute representations for the whole region
  - summarizing the trends in pattern elements
    - either overall trend in filter responses
    - or histogram of vector quantized patches

# Good luck on your final exam!