UNIVERSITY OF CALGARY
DEPARTMENT OF ELECTRICAL AND COMPUTER ENGINEERING
SCHULICH SCHOOL OF ENGINEERING
ENEL697 DIGITAL IMAGE PROCESSING
TEST NO. 1
WINTER 2011 SESSION
2 March 2011

Instructions:

1. This is a closed-book, closed-notes test.
2. Calculators and other electronic devices are not permitted.
3. Answer all five questions.
4. Total marks = 20.
5. Time permitted = 90 minutes.

Question 1: Give an equation to define the normalized correlation coefficient between two digital images, $f(m, n)$ and $g(m, n)$.

Let $f(m, n)$ represent a template of a pattern to be detected. With another equation, explain how a delay or shift could be included in the correlation coefficient to detect the presence of copies of the template in the image $g(m, n)$.

(4 marks)

Question 2: Starting with the basic definition of the first-order differences in the horizontal and vertical directions (partial derivatives), derive the expressions for the second-order differences in the two directions. Show and explain how the expressions you derive may be combined and modified to obtain the 3×3 mask or operator to compute the Laplacian.

(4 marks)

Question 3: Given the point spread function (PSF), $h(m, n)$, of a linear shift-invariant (LSI) system, explain how the modulation transfer function (MTF) of the system may be obtained. Give detailed mathematical expressions for the procedure.

Write mathematical expressions that define the relationships between an input to the system and the corresponding output in both the spatial and frequency domains.

(3 marks)

Question 4: You are given the following digital image:

$$f(m,n) = \begin{bmatrix} 1 & 2 & 1 & 2 & 6 \\ 3 & 5 & 4 & 3 & 4 \\ 5 & 4 & 7 & 2 & 5 \\ 3 & 2 & 1 & 3 & 1 \\ 2 & 5 & 3 & 4 & 6 \end{bmatrix}. \tag{1}$$

For the pixel with the value of 7 in the input image, give the output for the following operations using a 3×3 neighborhood:

1. mean
2. median
3. min
4. max
5. α-trimmed mean filter with $\alpha = 1/3$.

Show all steps in your calculations of the results.

(4 marks)

Question 5: Write the complete expression for the periodic convolution of an image, $f(m,n)$, with the PSF, $h(m,n)$, of an LSI system. Let both functions be of size $M \times N$.

Explain the construction of the matrix $\mathbf{f}$ to represent the image $f(m,n)$ and the block-circulant matrix $\mathbf{h}$ as well as the related circulant submatrix h_m to represent the PSF, so that the convolution relationship may be expressed as a product of the two matrices.

Give the matrix opration for convolution and indicate the sizes of all of the matrices involved in the relationship.

(5 marks)

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