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MANIPAL INSTITUTE OF TECHNOLOGY

(A Constituent Institute of MU – Deemed University)

Manipal – 576 104

VI SEMESTER B.E. DEGREE END SEMESTER EXAMINATIONS – MAY 2008

SUBJECT: MEDICAL IMAGE PROCESSING (BME-310)

(REVISED CREDIT SYSTEM)

Wednesday, May 28, 2008: 9.00 a.m.– 12.00 noon

TIME: 3 HOURS **MAX. MARKS: 100**

Instructions to Candidates:

1. **Answer <u>any FIVE</u> full questions.**
2. **Please answer to the point.**
3. **Draw labeled diagram wherever necessary**

1. (a) Show that $e^{j(\omega_1 m+\omega_2 n)}$ is an *eigen-function* of a 2D (discrete) linear shift-invariant system. 6

(b) The mask associated with a 2D digital filter is sketched in Fig. 1.

(i) Sketch the output $y(m,n)$ of the filter if the input input $x(m,n) = \delta(m,n)$. 2

(ii) Sketch the output image, if the input is: $x(m,n) = \delta(m+1,n+1) + \delta(m-1,n-1)$. 4
NOTE: Sketch your results *on a* 7×7 *support* (centered at the origin).

(iii) Is the filter causal? Is it a zero-phase filter? Justify your answers. 4

(c) When would you resort to 2D linear filtering through FFT, instead of 2D convolution? Indicate the circumstances clearly. 4

2. (a) Find the output of the 3×3 *median filter* on the image in Fig. 2. 6

(b) Identify *two* advantages and *two* disadvantages of the filter in Q. 2 (a), *as evident from this example only* (*i.e.*, not general advantages and disadvantages). 4

(c) Find the output of another median filter defined over the "star"-shaped neighborhood as sketched:
NOTE: the input to this median filter is the image in Fig. 2. 6

$$\begin{bmatrix} & x & \\ x & x & x \\ & x & \end{bmatrix}$$

(d) Write down your observations. 4

3. (a) Explain concisely, the role of rods and cones in handling visual perception over a wide range of intensities. Is the human visual system a linear device? Why, or why not? 6

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(b) (i) Find the result of applying the gray-level transformation T, sketched in Fig. 2 (a), on the image given in Fig. 3(b). 8

(ii) If the *just-noticeable difference* for a given observer is 3 units, what can you say about the effect of the transformation? 2

(c) What are the four important properties of the discrete cosine transform (DCT) that makes it effective in image compression algorithms? 4

4. (a) (i) Find the low-pass filter-mask and also the high-pass filter-mask associated with the high-frequency-boost filter-mask h_{HFB}: 6

$$h_{\text{HFB}} = \begin{bmatrix} -\frac{1}{8} & -\frac{1}{8} & -\frac{1}{8} \\ -\frac{1}{8} & 2 & -\frac{1}{8} \\ -\frac{1}{8} & -\frac{1}{8} & -\frac{1}{8} \end{bmatrix}$$

(ii) Based on the sum of the values of the filter-coefficients, what can you say about the nature of the three filter-masks? 3

(b) How would you compute and plot the magnitude of the 2D frequency-response of the filter, over a grid of size 512×512 using MATLAB? Note that the result must be properly centered. Indicate the important steps clearly (you *need not* write a program). 6

(c) Explain briefly, the role of *coincidence detection* in PET. 3

(d) What is beam-hardening? *Why* does it affect the quality of image reconstructed from X-ray projections? 2

5. (a) Consider the transmission of an infinitesimally thin monochromatic X-ray beam of intensity I_i through a cross-section of the human body along a line parameterized by t and θ (see Fig. 4). If I_0 is the intensity measured by a detector at the exit-point, deduce the relationship between the I_i, I_0 and the 2D distribution of attenuation $\mu(x,y)$. 6

(b) Consider an image consisting of *a point* of intensity (gray-level) 1, at (2,1) in the coordinate system as shown in Fig. 5.

(i) *Sketch* the projections of the image at 0^0, 45^0, 90^0 and 135^0 respectively. 8

(ii) Using the projections found in step (i), *sketch* the image obtained by *backprojection only* (i.e., *no filtering is involved*). The region-of-interest (ROI) is the same as that of the original image. 6

NOTE: You *must clearly indicate* the *values of all the* (i) *coordinates involved,* (ii) *and* (ii) *intensities* (*gray-levels*) involved in the projections & in *the backprojected image*.

NOTE: All the description in this question is in continuous coordinates.

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6. (a) (i) What are the effects (on the protons, and hence on the magnetic field associated with them) of an *RF excitation at Larmor frequency*, applied to a subject under the influence of a uniform magnetic field? Indicate the reasons behind the effects. 4

(ii) When would the RF excitation be called a "90^{o} excitation"? 2

(b) Consider tissues *A* and *B* under the influence of a *uniform* magnetic field: the value of T_1 associated with *A* is *lower* than that with *B*. If two 90^{0} RF pulses are *applied in quick succession* (i.e., *within 500 ms*), what would be the relative (i) strength and (ii) frequency, of the signal due to tissue *A* – picked up by a coil in the vicinity, *measured at the end of the second RF pulse*? Justify your answer. 6

(c) Write down the expressions for the two gradients to be applied simultaneously along orthogonal directions, to slice through the 2D Fourier transform of the image data at an angle of 45^{0}. 4

(d) What are frequency- and phase-encoding gradients? 4

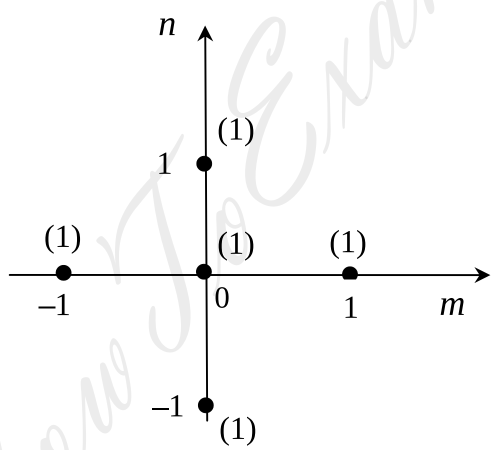

Figure 1 **[Question # 1 (a)]**

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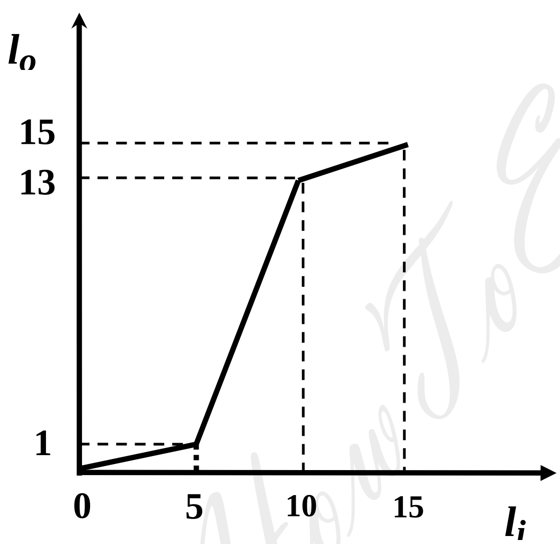
4	5	6	7	8	6	8
4	15	6	7	8	6	8
4	5	6	7	8	10	8
4	5	6	7	10	6	8
4	5	6	10	8	6	8
4	5	10	7	8	6	8
4	10	6	7	8	6	8

Figure 2 [Question # 2]



(a) The transformation, *T*

5	7	7	9	9	9
5	7	7	9	9	9
5	7	7	14	9	9
5	7	7	9	9	9
5	7	7	9	9	9
5	7	7	9	9	9

(b) Input image

Figure 3 [Question 3 (b)]

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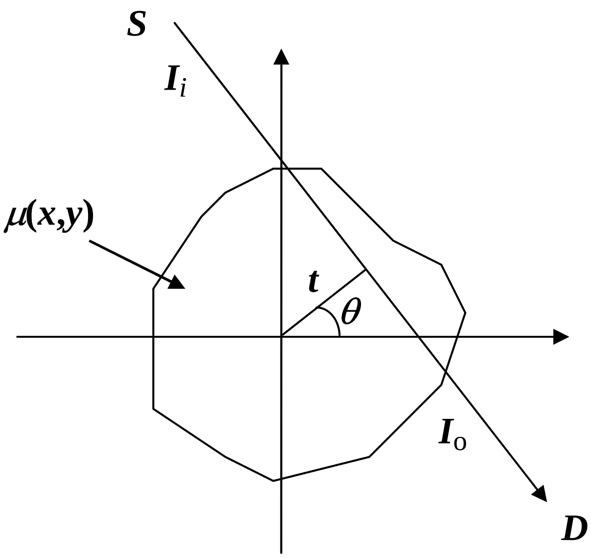

Figure 4 **[Question # 5 (a)]**

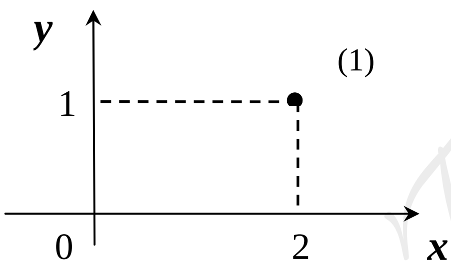

Figure 5 **[Question # 5 (b)]**

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