Department of Electrical Engineering
Indian Institute of Technology Kharagpur

Medical Image Analysis (EE61008)

Mid-Semester Examination **Spring, 2015-16**

Credits: 4 Full Marks: 70 Duration of Examination: 2 hours
Date: Friday, 19 February 2016, 9-11 AM

Instructions:

1. All questions are compulsory. Marks are indicated in parentheses. Clearly state all assumptions in your answer.
2. Please write your name, roll number, subject name and code, date and time of examination on the answer script before attempting any solution.
3. Use of only electronic calculators is permitted.
4. No extra resources viz. graph papers, log-tables, trigonometric tables would be required.

Question 1:

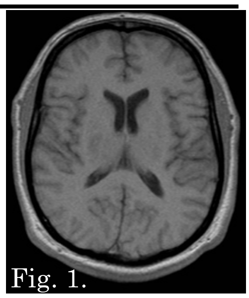

Fig. 1.

Identify the following in Fig. 1

(a) Organ? (1 mark)
(b) Plane of imaging? (Transverse, Sagittal, Coronal) (1 mark)
(c) Modality? (1 mark)
(d) Structure / anatomical location of interest? (1 mark)

Question 2:

The following matrix in I is a snippet of an RGB image from a digital histology sample and the seeds for the two classes are marked in the matrix M as 1 and 2 and the unmarked pixels are in 0. Compute the following for estimating the response of the random walker analogue of an electrical network, assuming 8-connected relationship between the pixels, and the edge conductance between the i^{th} and j^{th} pixel in I defined as $w_{i,j} = e^{-\beta\|\mathbf{c}_i - \mathbf{c}_j\|}$ where $\mathbf{c}_i$ is the (r,g,b) colour triplet vector representing the i^{th} pixel and $\|.\|$ is the Euclidean distance measure. Also consider that $\beta = 100$.

$$I = \begin{bmatrix} (100,0,0) & (0,1,0) & (0,100,0) \\ (0,0,100) & (1,1,1) & (100,0,0) \\ (100,0,0) & (1,0,0) & (0,100,0) \end{bmatrix} \qquad M = \begin{bmatrix} 0 & 1 & 0 \\ 0 & 0 & 0 \\ 0 & 2 & 0 \end{bmatrix}$$

a. Draw the graph representation of the random walks solver? (2 marks)
b. Mark the edge conductivity (weights) on the graph? (4 marks)
c. What is the probability for each class associated with the underlined pixel in I as estimated by solving the electrical network equivalent of the random walks? (10 marks)

Question 3:

The following matrix consists of the readings of a CT scanner in Hounsfield unit (HU) as recorded in the matrix H and the ground truth for 2 classes as marked in the matrix G. Using the following standard range of HU readings, can you predict the class labels for the two tissue types, i.e. 1 – fat where HU is in range (-200 to -50) and 2 – brain tissue HU in range (30 to 40) and answer the following questions:

$$H = \begin{bmatrix} -120 & 32 & 33 & 34 & 40 \\ -115 & -123 & 31 & 37 & 37 \\ -132 & -100 & -100 & 36 & 39 \\ -198 & -143 & 32 & 39 & 38 \end{bmatrix} \qquad G = \begin{bmatrix} 1 & 1 & 2 & 2 & 2 \\ 1 & 1 & 2 & 2 & 2 \\ 1 & 1 & 2 & 2 & 2 \\ 1 & 1 & 2 & 2 & 2 \end{bmatrix}$$

Compute the (a) TP, (b) TN, (c) FP, (d) FN, (e) accuracy, (f) sensitivity, (g) specificity, (h) precision, (i) F1 score and (j) Kappa score. (20 marks)

Question 4:

a. Construct a binary decision tree using the information provided in H and G. Provide all necessary details of the steps involved in the process. (10 marks)

b. Comment on the node purity of the leaf nodes in terms of the posterior probability of each class in the leaf nodes of the decision tree. (5 marks)

Question 5:

A standard 7 T MRI machine has an effective imaging volume dimension of 60 cm x 60 cm along the transverse section and a length of 200 cm. The slice encode gradient is of 40 mT/m and the frequency encode gradient is of 40 μT/m. Compute the following:

a. Range of magnetic field strength to be experienced within the effective imaging volume? (2 marks)

b. Range of Larmor frequencies to be experienced within the effective imaging volume by a hydrogen atom with a gyromagnetic ratio of $\gamma = 42.58$ MHz/T ? (2 marks)

c. Consider that the voxel resolution of the MRI imaging device is 10 mm x 10 mm x 10mm. What is the minimum frequency hop between two neighboring voxels in the volume? (5 marks)

Question 6:

Consider a vector $\mathbf{x}$ to be the input to a perceptron model such that it produces a vector $\hat{\mathbf{y}}$ as the output. They are related as $\hat{\mathbf{y}} = f_{\mathrm{NL}}(\mathbf{w}.[\mathbf{x};1])$, and the non-linear activation function is $f_{\mathrm{NL}}(z) = \frac{1}{1+e^{-z}}$, and $\mathbf{w}$ is termed as the connection weights relating the input to the output. Say that during training of the network using the gradient descent rule, for a set of given inputs $\{\mathbf{x}_i, \mathbf{y}_i\}$ the error between the observed as the predicted is written as the cost function of the learning rule as

$$J(\mathbf{w}) = \frac{1}{N}\sum_{i=1}^{N} \|\hat{\mathbf{y}}_i - \mathbf{y}_i\|$$

then derive the analytical form of the following?

$$\frac{\partial J(\mathbf{w})}{\partial \mathbf{w}}$$

(6 marks)