1. a How does the Comb function represent the sampling of a continuous function to give discrete digital samples? What is the Fourier transform of a Comb function and indicate clearly using a diagram what is the sampling frequency? What is the Fourier transform of a Rect function?

[5 Marks]

b How does aliasing occur? You want to collect an Electrocardiogram in time without aliasing where the beat to beat time is 0.5s and the width of the R wave is 0.01s. At what frequency should you sample in time?

[5 Marks]

c What matrix size should be used for digital subtraction angiogram, where the image size was a circle of 10 cm diameter and the resolution in space is 0.2mm in both x and y?

[5 Marks]

d Describe in reasonable detail why and how you would then perform masked subtraction in digital subtraction angiography. What is meant by warped subtraction in this context, and how could it be implemented?

[10 Marks]

[Turn Over]

2. a What is meant by a fuzzy region of interest (ROI)? Outline briefly an application of fuzzy ROIs with respect to medical images?

[5 Marks]

b Describe two alternative data structures that could be used to store a (binary) region of interest, indicating how much memory they might require. Show how they might behave with respect i) translation, ii) rotation, or iii) changing the size of an ROI without changing its shape.

[6 Marks]

c You would like to find the absolute size of an organ from a series of medical image slices which contain it. Describe an algorithm, for example by thresholding, which you might use to determine this volume and indicate and assess the size of various sources of error in this volume estimation.

[6 Marks]

d If an edge is defined as being the set of places with a high value of the slope (gradient) of the image, show how you would find and connect such edges in a 2D image, and what additional constraints you might apply. How could you handle regions where no sharp gradient on the edge of an object exists?

[8 Marks]

[Continued]

3. a Define the quadratic error (L2 norm) used to compare 2 sets of values, for example 2 images. Indicate a situation when the minimum quadratic error might not be appropriate for showing a good correspondence between 2 images.

[4 Marks]

b Describe in reasonable detail an iterative algorithm for performing tomographic reconstruction of for example x-ray CT data, describing in particular the forward operation and the rules for stopping the iterative procedure.

[6 Marks]

c Describe the backprojection operator, as used in such a tomographic reconstruction operation, and estimate the computation time (as the number of computer instructions) that would be required to implement this operator. Distinguish between projection driven and pixel driven versions of backprojection.

[6 Marks]

d Compare the total computation time that might be required to implement such an iterative reconstruction algorithm, with respect to that required by filtered backprojection.

[4Marks]

e What filter is used in filtered backprojection, and why? How is it modified to reduce the noise in the final reconstruction, and how can this be optimised?

[5 Marks]

[Turn Over]

4. a What is the Discrete Fourier transform, and how is it used in magnetic resonance imaging (MRI) to relate position to frequency when reading out one signal (excitation) from such an imaging system?

[5 Marks]

b Describe how you would use either ultrasound or magnetic resonance or x-ray angiography to determine how fast blood is flowing in a vessel. How would you detect if a restriction (stenosis) existed in such a blood vessel? How could you then attempt to estimate the size and severity of the stenosis?

[6 Marks]

c Describe either i) phase encoding in MRI or ii) the use of phased arrays to obtain 3D images in ultrasound.

[8 Marks]

d In the method described in section c, what is approximately the minimum time required to acquire an image, and what limits this minimum time?

[6 Marks]

[Continued]

5. a What is a Co-occurrence matrix?

[4 Marks]

b How could the Co-occurrence matrix be used to estimate the texture of an image? Give an example of why one might be interested in texture in a medical image.

[6 Marks]

c How can the Co-occurrence matrix be used as part of the process of registering the spatial coordinates of 2 medical image datasets?

[8 Marks]

d Describe how and why image registration can be used in computer assisted surgery, for example, tracking the deformation of the brain during surgery. In particular distinguish between rigid and non-rigid registration methods.

[7Marks]

[Turn Over]

6. a Outline the user requirements of a Picture Archiving and Communication System (PACS). Do these include image processing, and if so for what purposes? What is the place of an Electronic Patient Record with respect to a PACS environment?

[6 Marks]

b Estimate the speed required for a PACS network, for a system where 5Gbytes of image data are acquired daily, all of which are reported during a 2 hour period, and where each report also includes looking at previously acquired patient data.

[5 Marks]

c Give a description of an object orientated model of a report. How would you link together images, graphics, text and voice comments? Describe the differences between creating such a report and viewing it as a referring clinician afterwards.

[8 Marks]

d Discuss the needs of archiving in PACS. In particular comment on the following issues: i) lossless v. lossy data compression, ii) response time requirements as a function of the age of data, iii) the use of distributed databases, iv) garbage collection and robustness v) security of access.

[6 Marks]

[End of Paper]

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Answer any THREE questions.

Marks for each part of each question are indicated in square brackets.

Calculators may be used.

(Algorithms may be written in any suitable language.)