1. a i) How does the Comb function represent the sampling of a continuous function to give discrete digital samples? ii) Prove how interpolation with a Sinc function can be used to restore the original continuous signal from the sampled version.

[5 Marks]

b i) How could you preprocess the signal to avoid aliasing? ii) You want to collect an Electrocardiogram in time without aliasing. 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? iii) How might aliasing errors appear in the sampled data?

[5 Marks]

c i) What matrix size should be used for a digital subtraction angiogram, where the imaged region was a circle of 10 cm diameter and the resolution in space is 0.2mm in both x and y? ii) How many bits per pixel might be required? iii) How would you attempt to optimise the dynamic range of the data?

[5 Marks]

d i) Describe in reasonable detail why and how you would then perform masked subtraction in digital subtraction angiography. ii) What is meant by warped subtraction in this context, and how could it be implemented? iii) Over what region might you attempt to compute the warping function?

[10 Marks]

[Turn Over]

2. a i) What is meant by a fuzzy region of interest (ROI)? ii) How could this be used, when multiple classes of tissue exist, together with the partial volume effects? iii) How would you attempt then to convert the fuzzy ROI into a binary ROI?

[5 Marks]

b i) Describe three alternative data structures that could be used to store a (binary) region of interest, indicating how much memory they might require. ii) Show how they might behave with respect to 1) translation, 2) rotation or 3) changing the size of an ROI without changing its shape.

[6 Marks]

c i) 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 thresholding, which you might use to determine this volume ii) Indicate and assess the size of at least three sources of error in this volume estimation.

[6 Marks]

d i) 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. ii) What is a snake? iii) Define it in terms of its energy function. iv) Show how you could then handle regions where no sharp gradient on the edge of an object exists.

[8 Marks]

[Continued]

3. a i) Define the quadratic error (L2 norm) between 2 sets of values, for example 2 images. ii) Indicate a situation when the minimum quadratic error might not be appropriate for showing a good correspondence between 2 images. iii) What alternative norms (distance functions) can you suggest?

[4 Marks]

b i) Describe in reasonable detail an iterative algorithm such as the Maximum Likelihood Expectation Maximisation (MLEM) method for performing tomographic reconstruction of, for example, X-ray CT data. ii) Describe in particular the forward operator, the modification rule, and the rules for stopping the iterative procedure.

[6 Marks]

c i) Describe the forward projection algorithm, as used in such a tomographic reconstruction operation. ii) Estimate the computation time (as the number of computer instructions) that would be required to implement this operator. iii) How would you modify this operator when line integrals are a poor approximation to the true forward operation of acquiring data?

[6 Marks]

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

[4Marks]

e i) What filter is used in filtered backprojection, and why? ii) How is it modified to reduce the noise in the final reconstruction, and how can this be optimised? iii) How would you use information from the power spectrum of the data in this respect?

[5 Marks]

[Turn Over]

4. a i) What is the Discrete Fourier transform? ii) 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? iii) Describe how slice selection may then be performed.

[5 Marks]

b i) Describe how you would use either ultrasound or magnetic resonance or X-ray angiography to determine how fast blood is flowing in a vessel. ii) How would you detect whether a restriction (stenosis) existed in such a blood vessel? iii) How could you then attempt to estimate the size and severity of the stenosis? iv) How could you attempt to assess the shape of the lumen of the blood vessel, for example in angiography?

[6 Marks]

c Describe in reasonable detail 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, in terms of the resolution of the image acquired?

[6 Marks]

[Continued]

5. a Define a Co-occurrence matrix.

[4 Marks]

b i) How could the Co-occurrence matrix be used to estimate the texture of an image? ii) Indicate some parameters that you would measure on the Co-ocurrence matrix. iii) Give an example of why one might be interested in texture in a medical image.

[6 Marks]

c i) How can the Co-occurrence matrix be used as part of the process of registering the spatial coordinates of 2 medical image datasets? ii) Write down the form of the transform that is to be determined for rigid registration.

[8 Marks]

d i) 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. ii) What kinds of spatial constraints need to be applied in non-rigid registration?

[7Marks]

[Turn Over]

6. a i) Outline the user requirements of a Picture Archiving and Communication System (PACS). ii) Do these include image processing, and if so for what purposes? iii) What is the place of an Electronic Patient Record (EPR) with respect to a PACS system? iv) What kind of data would tend to be exchanged between an EPR and a PACS network?

[6 Marks]

b i) Estimate the speed required for a PACS network, if 5Gbytes of image data are acquired daily, all of which are reported during a 2 hour period, where each report also includes looking at previously acquired patient data. ii) How can the design of the network be modified to ensure greater throughput?

[5 Marks]

c i) Give a description of an object orientated model of a report. ii) How would you link together images, graphics, text and voice comments? iii) Describe the differences between creating such a report and viewing it as a referring clinician afterwards. iv) In particular, discuss how the choice of a windowing level for display would be different in the two cases.

[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 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 and total 25 per question.

Calculators may be used.

(Algorithms may be written in any suitable language.)