

EGT2
ENGINEERING TRIPOS PART IIA

Tuesday 30 April 2019 2 to 3.40

Module 3G4

MEDICAL IMAGING & 3D COMPUTER GRAPHICS

*Answer not more than **three** questions.*

All questions carry the same number of marks.

*The **approximate** percentage of marks allocated to each part of a question is indicated in the right margin.*

*Write your candidate number **not** your name on the cover sheet.*

STATIONERY REQUIREMENTS

Single-sided script paper

SPECIAL REQUIREMENTS TO BE SUPPLIED FOR THIS EXAM

CUED approved calculator allowed

Engineering Data Book

10 minutes reading time is allowed for this paper at the start of the exam.

You may not start to read the questions printed on the subsequent pages of this question paper until instructed to do so.

- 1 (a) In medical ultrasonic imaging, describe how the attenuation in soft tissue of the ultrasound beam varies with its frequency. What are the advantages and disadvantages of using a high frequency beam? [30%]
- (b) In X-ray computed tomography imaging, describe how the attenuation in soft tissue of the radiation varies with its frequency. [10%]
- (c) Describe how it is possible to correct for attenuation effects in positron emission tomography (PET). Explain why it is not possible to use the same method to correct for attenuation in single photon emission computed tomography (SPECT). [30%]
- (d) Draw a labelled diagram of a scintillation crystal photomultiplier-coupled detector. Explain how it works and why it is suitable for use in nuclear medicine scanners. [30%]
- 2 (a) Describe the strengths and weaknesses of medical magnetic resonance imaging (MRI). What physical properties of the material are imaged by MRI? [20%]
- (b) Describe the role and functionality of the following components of an MRI imaging system: main fixed magnetic field; radio frequency transmitter; gradient fields. [30%]
- (c) For each type of MRI image listed below, which of fat, liver, kidney, water, cerebral white matter or cerebral grey matter would appear brightest? Justify your answer by explaining how the brightness relates to the relevant relaxation coefficient (T1 or T2).
- (i) A T1-weighted MRI image. [15%]
- (ii) A T2-weighted MRI image. [15%]
- (d) Describe the process of free induction decay in an MRI scanner. Why is this process not useful for imaging on its own? [20%]

- 3 (a) Describe how shape-based interpolation can be used to estimate the surface of an object from a few cross-sections. [20%]

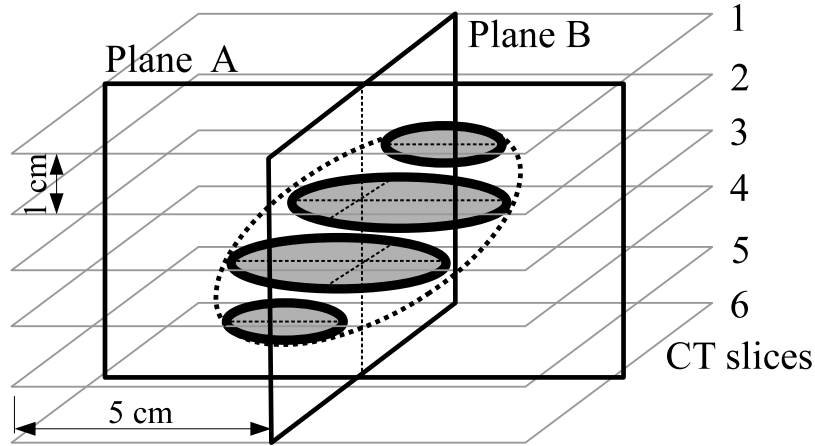


Fig. 1

(b) Figure 1 is a representation of a CT scan of an ellipsoidal tumour. There are six CT slices, of which slices 2 to 5 intersect the tumour, with cross-sections shown in bold. In order to treat the tumour with radiotherapy, the surface (called the ‘tumour volume’) is to be reconstructed using shape-based interpolation. A ‘planning volume’, which extends the tumour volume by at least 1 cm in all directions, is also required. This is to be created using the same shape-based interpolation process, but with an iso-surface at a different value. Discuss the effect of each of the following on the accuracy of these volumes (you can assume a small pixel size):

- (i) the spacing of the CT slices with respect to the tumour size; [10%]
- (ii) the orientation of the tumour with respect to the CT slices. [10%]

(c) Sketch the intersections of the tumour and planning volumes on the planes A and B in Fig. 1. Use one sketch for each plane, ensuring you note the locations of the CT slices, the approximate location of the actual tumour, and any problems with either volume. [20%]

(d) With the same tumour volume as in (b), the planning volume is now created by performing a 3D distance transform of the tumour volume, and then selecting an appropriate iso-surface of this new, 3D distance transform.

- (i) Repeat the sketches in (c) for this new procedure, highlighting any differences from the previous sketches. [20%]
- (ii) Which errors in (b) are corrected with the new procedure, and which remain? [20%]

4 (a) In a computer graphics viewing system, the mapping from view coordinates to homogeneous 3D screen coordinates can be written as

$$\begin{bmatrix} X \\ Y \\ Z \\ w \end{bmatrix} = \begin{bmatrix} wx_s \\ wy_s \\ wz_s \\ w \end{bmatrix} = \begin{bmatrix} d/x_{\max} & 0 & 0 & 0 \\ 0 & d/y_{\max} & 0 & 0 \\ 0 & 0 & -f/(f-n) & -fn/(f-n) \\ 0 & 0 & -1 & 0 \end{bmatrix} \begin{bmatrix} x_v \\ y_v \\ z_v \\ 1 \end{bmatrix}$$

(i) Sketch the shape of the view volume in both coordinate systems. Annotate your sketch to show d , y_{\max} , n and f . [20%]

(ii) Sketch a typical relationship between z_v (on the x -axis) and z_s (on the y -axis). [10%]

(iii) Why is this particular nonlinear relationship necessary for correct functioning of the surface rendering pipeline? [10%]

(b) Consider an edge of a polygon lying between vertices A and B. The view coordinates of A and B are $(4, 0, -15)$ and $(20, 0, -15)$ respectively: all lengths are in cm. The viewing parameters are $d = 1$ cm, $n = 5$ cm, $f = 25$ cm and $x_{\max} = 1$ cm.

(i) Show that the edge intersects the boundary of the view volume. Working entirely in view coordinates, find the view coordinates of the new vertex introduced by the Sutherland-Hodgman clipper. [20%]

(ii) Find the homogeneous 3D screen coordinates of A and B, and mark their locations on a sketch in the $X-w$ plane. With the aid of your sketch, and working entirely in homogeneous 3D screen coordinates, find the homogeneous 3D screen coordinates of the new vertex introduced by the Sutherland-Hodgman clipper. [30%]

(iii) Verify that the view and homogeneous 3D screen coordinates you found in (i) and (ii) correspond to the same point. [10%]

END OF PAPER

Part IIA 2019

Module 3G4: Medical Imaging & 3D Computer Graphics

Numerical Answers

4. (b) (i) $(15, 0, -15)$ (ii) $(15, 0, 12.5, 15)$