EGT2
ENGINEERING TRIPOS PART IIA

Monday 30 April 2018 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) Describe how variations in the speed of ultrasound in tissue can distort the B-scan images acquired by medical ultrasound machines. Illustrate your answer by explaining how the thickness of layers of fat and liver may be represented incorrectly when scanned from certain directions. Explain which of the two tissues (fat and liver) may appear too thick and which may appear too thin, and why. [15%]

(b) A medical ultrasound scanner with a 10 MHz linear array probe is used to scan a test object in a water bath at 10 °C. The test object consists of three parallel, thin nylon wires, P, Q and R, as shown in Fig. 1. Figure 1 is not drawn to scale. Two scans are acquired. In both scans, the direction of the wires is aligned with the elevational direction of the ultrasound probe, so the wires appear as dots in the B-scans. All measurements are taken from the centres of these dots. In scan A, the probe transducer surface is parallel to the line between wire P and wire Q. In scan B, the probe transducer surface is perpendicular to the line between wire P and wire Q. The speed of sound in water at 10 °C is 1447 m/s. The ultrasound machine is calibrated for the speed of sound in average soft tissue, 1540 m/s.

(i) In scan A, the distance between wire P and wire Q is 3.30 cm, based on the calibration of the ultrasound machine. The distance between wire P and wire Q appears to be different in scan B. Estimate the apparent distance between wire P and wire Q in scan B, based on the calibration of the ultrasound machine. [20%]

(ii) What is the true distance between wire P and wire Q? [10%]

(iii) In scan A, the distance between wire P and wire R is 3.57 cm, based on the calibration of the ultrasound machine. In scan B, the distance between wire P and wire R is 3.45 cm, based on the calibration of the ultrasound machine. What is the true distance between wire P and wire R? [40%]

(iv) What is the difference between the areas of the triangle formed by the three wires when measured in scan A and in scan B, based on the calibration of the ultrasound machine? Justify your answer. [15%]

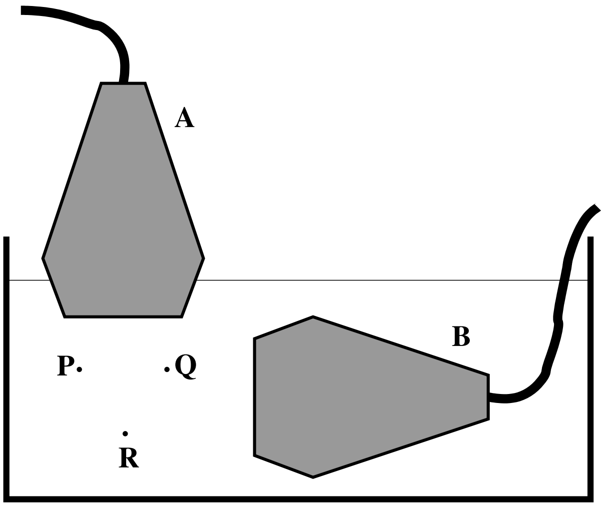

Fig. 1

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2 (a) Describe the process of photoelectric absorption of X-ray photons. [20%]

(b) Define the Radon transform of a two-dimensional function $f(x,y)$ in terms of line integrals at perpendicular angle ϕ and distance s from the origin. [20%]

(c) Sketch the sinogram of the function

$$f(x,y) = \delta(x-2)\delta(y-2) + \delta(x)\delta(y-1)$$

over the range of perpendicular angles $0 \leq \phi \leq \pi$, where $\delta()$ is the Dirac delta function. Note that $\delta(x-p)\delta(y-q)$ is a two-dimensional delta function at the point (p,q). [30%]

(d) Find the two-dimensional Radon transform of the function $f(x,y)$ in (c), in terms of the perpendicular angle ϕ and the distance s from the origin. [30%]

3 (a) Sampled rectilinear scalar data can be visualised by fitting piecewise cubic parametric splines and then resampling the splines at arbitrary locations, as required. What properties of the fitted splines are beneficial and easy to achieve? [20%]

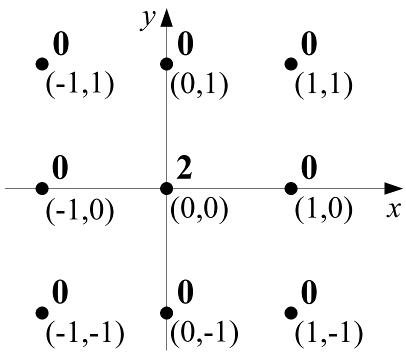


Fig. 2

(b) Figure 2 shows some uniformly sampled scalar data, at locations (x, y), whose values (in bold) are zero except at the origin. An interpolant is used to visualise the data between these samples. In each of the following cases sketch, and give the equation for, the iso-contour at a threshold of 1 in the region $x \geq 0$, $y \geq 0$, when:

(i) the data is interpolated using the nearest neighbour method; [10%]

(ii) the data is interpolated using bilinear interpolation. [20%]

(c) A Delaunay triangulation is calculated for the points in Fig. 2, in the region $x \geq 0$, $y \geq 0$, and the data is then bilinearly interpolated within each triangle.

(i) Explain why there are two solutions for the Delaunay triangulation in this region, and sketch these solutions. [10%]

(ii) For each of the solutions in (i), sketch the iso-contour at a threshold of 1 within this region. There is no need to provide any equations. [20%]

(d) The data can alternatively be interpolated using radial basis functions with basis $e^{-\alpha r^2}$. Explain how the value of α affects the resulting interpolant and suggest, with reasons, a value of α appropriate for this data. [20%]

4 Figure 3(a) shows a square painting as it appears in a rendering. Perspective effects result in its far edge appearing shorter than its near edge. The painting is modelled as two triangles. Points A and B are two of the triangles' vertices.

(a) Explain how intensity and depth (z_s) values within the interior of each triangle are derived from vertex attributes. Consider both Gouraud and Phong shading. [30%]

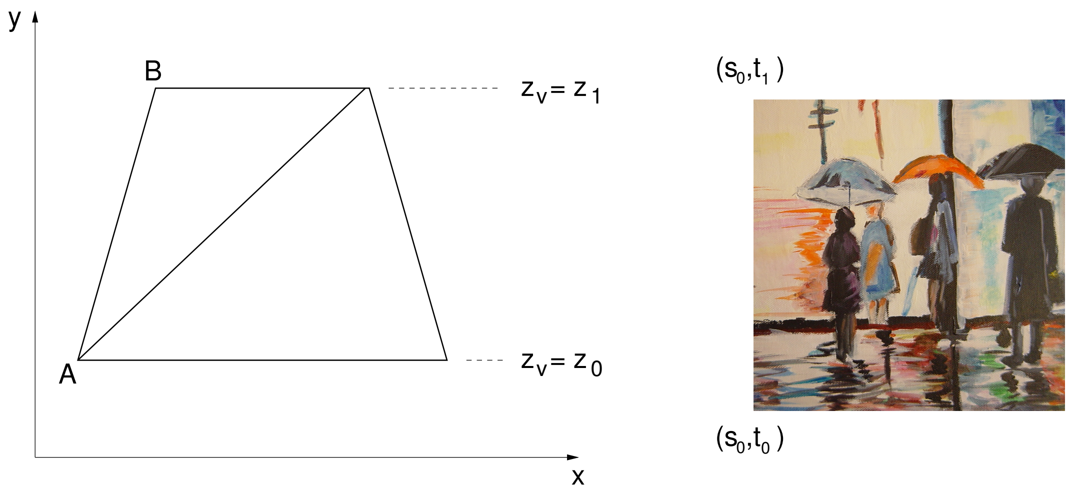
(b) Figure 3(b) shows a 2D texture map that is to be applied to the painting. The programmer associates vertex A with the texture map point (s_0, t_0) and vertex B with (s_0, t_1). Texture coordinates along the edge AB are calculated according to

$$t_\alpha = \frac{(1-\alpha)(t_0/z_0) + \alpha(t_1/z_1)}{(1-\alpha)(1/z_0) + \alpha(1/z_1)}$$

where α is the fraction of the distance along the rendered edge from A to B, and z_0 and z_1 are the z_v values at A and B respectively.

(i) Sketch graphs showing how t_α varies with α for: the special case where $z_1 = z_0$; the typical case where $|z_1| > |z_0|$; and the extreme case where $|z_1| \gg |z_0|$. Also, sketch versions of Fig. 3(a) for the special and extreme cases. [30%]

(ii) With reference to the extreme case, discuss the potential for rendering artefacts at the front and back of the painting, and suggest how they might be suppressed. [40%]



(a) (b)

Fig. 3

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