

EGT2
ENGINEERING TRIPOS PART IIA

Friday 28 April 2017 2 to 3.30

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.

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 the purpose and operation of the following collimation devices and briefly comment on their strengths and weaknesses:

(i) the mechanical collimator in a gamma camera; [15%]

(ii) the electronic collimation system in a Positron Emission Tomography (PET) scanner; [15%]

(iii) the septa between the rings of a three-dimensional PET scanner; [15%]

(iv) the mechanical collimator in an X-ray Computed Tomography (CT) system. [15%]

(b) In the operation of a conventional medical Magnetic Resonance Imaging (MRI) scanner, how is the source of a particular magnetic resonance output signal localised in three-dimensional space? [20%]

(c) In the operation of a conventional medical ultrasound scanner, how is the location of a particular sound-scattering tissue structure determined? [20%]

2 (a) Why are surface normals important in computer-based rendering of surfaces, and how can these be generated from a surface mesh composed of triangles? [15%]

(b) Briefly describe *Marching Cubes*, comment on the properties of the surface generated by this process, and how these properties affect the subsequent generation of surface normals. [25%]

(c) A spherical 3D function $f(x,y,z)$ is sampled on an isotropic cubic grid:

$$f = (0.6)^2 - (x - x_0)^2 - (y - y_0)^2 - (z - z_0)^2$$

where (x_0, y_0, z_0) is the centre of the function. The grid extends to 20 samples in each dimension, so that:

$$x \in \{0, 1, \dots, 19\}, y \in \{0, 1, \dots, 19\}, z \in \{0, 1, \dots, 19\}$$

Marching cubes is then applied to the sampled data, with a threshold of 0.

(i) Sketch the resulting surface mesh for each of the following three cases, A, B and C, including the location of any samples inside the surface:

A. $x_0 = 10, y_0 = 10, z_0 = 10$;

B. $x_0 = 10.5, y_0 = 10, z_0 = 10$;

C. $x_0 = 10.5, y_0 = 10.5, z_0 = 10.5$. [20%]

(ii) For the same cases as in (i) above, calculate the maximum width of each surface, i.e. the distance between the vertices which are furthest apart. [25%]

(iii) What would the width in (ii) be if f was first sampled at a much higher resolution before using Marching Cubes? [5%]

(iv) Comment on the consequences of your previous answers for the use of Marching Cubes. [10%]

3 (a) Describe how a Catmull-Rom (C-R) parametric cubic spline is used to create a curve from a set of control points. How does this type of curve differ from a B-spline? [25%]

(b) Explain how a multi-segment C-R spline can be used to create a closed curve (i.e. a loop) from a set of control points. [5%]

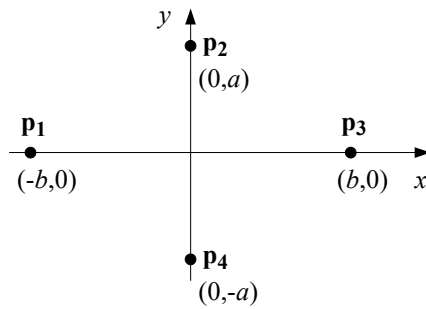


Fig. 1

(c) Figure 1 shows four points \mathbf{p}_1 to \mathbf{p}_4 with (x,y) coordinates which are functions of a and b . These are to be used as control points to form a closed loop using C-R splines. The C-R basis matrix \mathbf{M} is:

$$\mathbf{M} = \frac{1}{2} \begin{bmatrix} -1 & 3 & -3 & 1 \\ 2 & -5 & 4 & -1 \\ -1 & 0 & 1 & 0 \\ 0 & 2 & 0 & 0 \end{bmatrix}$$

- (i) Calculate the C-R spline curve segment, as a function of parameter t , between points \mathbf{p}_2 and \mathbf{p}_3 . What are the end-points at $t = 0$ and $t = 1$? [20%]
- (ii) Sketch the complete closed loop formed by the multi-segment C-R spline. [10%]
- (iii) Sketch the complete closed loop for the particular case when $a = 0, b > 0$. [10%]
- (iv) What are the parametric and geometric continuities (up to and including the second derivative) throughout the closed loop in (iii)? [30%]

4 (a) The monochromatic Phong reflection model is given by

$$I = I_a k_a + I_p k_d \mathbf{L} \cdot \mathbf{N} + I_p k_s (\mathbf{R} \cdot \mathbf{V})^n$$

Explain the meaning of the various terms.

[25%]

(b) Compare and contrast the process and results of Gouraud shading and Phong shading.

[20%]

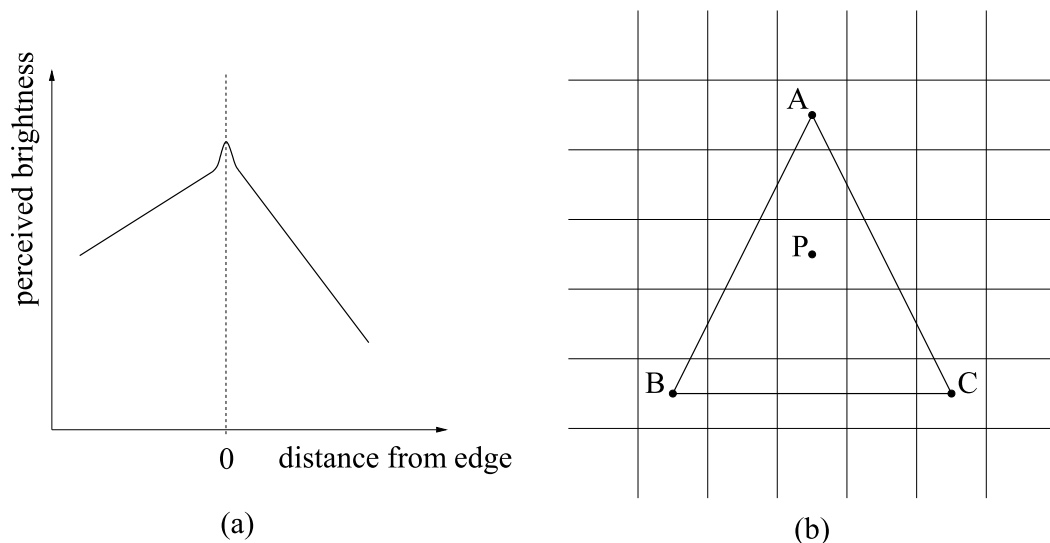


Fig. 2

(c) With Gouraud shading, the edges of the underlying polygons sometimes become obvious to the viewer, appearing distinctly brighter as in Fig. 2(a), especially in the vicinity of specular highlights. Discuss why this might be. Consider both the possibility of rendering artefacts and peculiarities of the human visual system.

[15%]

(d) A triangle, with vertices A, B and C, projects onto the image plane as shown in Fig. 2(b). The squares in Fig. 2(b) represent individual pixels. Assume a monochromatic Phong model with $I_p = k_d = 1$, $I_a = k_a = k_s = 0$ and $\mathbf{L} = [0 \ 0 \ 1]^T$. The vertex normals are $[0 \ 0.995 \ -0.1]^T$, $[0 \ 1 \ 0]^T$ and $[0 \ 0.995 \ 0.1]^T$ at A, B and C respectively.

- (i) Explain how it is possible that \mathbf{L} is the same at all three vertices. [5%]
- (ii) Assuming Phong shading, calculate the intensity at pixel P in Fig. 2(b). [25%]
- (iii) Would Gouraud shading result in a higher or lower intensity at pixel P? Justify your answer. [10%]

END OF PAPER

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Part IIA 2017

Module 3G4: Medical Imaging & 3D Computer Graphics

Numerical Answers

2. (c) (ii) 0.72, 1.11, 0 for A, B, C respectively

(iii) 1.2

3. (c) (i) $C(0) = \{0, a\}$, $C(1) = \{b, 0\}$

4. (d) (ii) 0