CS3240

THE UNIVERSITY OF WARWICK

Third Year Examinations: Summer 2016

Computer Graphics

Time allowed: 3 hours.

Answer **FOUR** questions.

Read carefully the instructions on the answer book and make sure that the particulars required are entered on each answer book.

Use of approved calculators is permitted in this examination.

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1. (a) Distinguish between real-time and off-line computer graphics. How does computer graphics exploit human visual capabilities to achieve visual realism? [4]

   (b) What are the principal elements of a graphics system and what are the roles of an application model and a graphics kernel? [4]

   (c) What is meant by rasterization? Explain why standard frame-buffers store colour, transparency and depth information. [7]

   (d) i. Specify the 3D rotation matrix that rotates points about the z-axis by θ degrees.

   ii. Specify the rotation matrix that takes the negative z-axis onto the positive z-axis.

   iii. Give the set of rotations required to rotate a point about an arbitrary axis $(a, b, c)^T$ which passes through the origin.

   iv. What further homogeneous transformations would be required if the arbitrary axis in (iii) passed through a point (e, f, g) instead of the origin?

   Give a set of OpenGL transformation statements which implements a rotation of θ degrees, about axis $(a, b, c)^T$ which passes through point (e, f, g).

   [10]

Continued

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2. (a) Write down the parametric equation of a line between points (x_0, y_0) and (x_1, y_1). [4]

   (b) What inequalities need to be satisfied for this line to be clipped against a box with opposite corners at $(x_{min}, y_{min}), (x_{max}, y_{max})$? [4]

   (c) Using your answer to (b), explain the Liang-Barsky Clipping method for a line which crosses one or more clipping boundaries. [11]

   (d) In what ways is the Liang-Barsky method more efficient than the Sutherland-Cohen method? [6]

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3. (a) Distinguish between diffuse and specular reflectors. What is meant by global illumination? State briefly how it can be approximated. [6]

   (b) Describe and illustrate the Phong lighting model for a single point light source. Explain carefully the purpose of the parameters of the model. [6]

   (c) With appropriate diagrams and equations, explain how interpolated shading is achieved. What is meant by per-pixel shading and why is it expensive to calculate? Give and expression for the per-pixel shading value at the origin, $(0, 0)$, for a triangle:

   $$\{(-1, -1), (1, -1), (0, 1)\},$$

   if the vertices have the illumination and normal attributes,

   $$\{I_0, \mathbf{n}_0\}, \{I_1, \mathbf{n}_1\}, \{I_2, \mathbf{n}_2\}.$$

   [6]

   (d) Explain how texture mapping works in terms of the necessary coordinate transformations required. [7]

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4. A piece-wise polynomial, Bezier approximation curve of order $n = 2$ needs to be designed to fit a set of points $\{\mathbf{p}_k\}$.

   (a) What set of blending functions need to be specified and, hence, what is the parametric form of the curve $Q(u)$? [4]

   (b) Using your previous answer, or otherwise, derive a *matrix* form of $Q(u)$. [6]

   (c) Write down the first derivative of the curve, $Q^{'}(u)$, and state the boundary condition which will ensure C_1 continuity for successive piecewise approximations. [4]

   (d) Given $\Delta Q(u) = Q(u + \delta) - Q(u)$ and $\Delta^2 Q(u) = \Delta Q(u + \delta) - \Delta Q(u)$, what are the constant terms,

   $$\{\Delta^2 Q(0), \Delta Q(0), Q(0)\}$$

   needed to accelerate the drawing of $Q(u)$? [8]

   (e) How many multiplies and adds would be needed to trace part of a quadratic Bezier patch over one $u + \delta u$ or $v + \delta$ step? [3]

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5. (a) What are the main components of a GPU-based framebuffer graphics system? [4]

   (b) Detail the 3D Viewing Pipeline, carefully explaining where texture-mapping, blending and atmospheric effects, like fog, can be combined with vertex operations. [4]

   (c) Derive Bresenham's decision parameter P_{k+1} for the $k + 1$ step of a line, given that $P_k = 2\Delta y\, x_k - 2\Delta x\, y_k + K$, where (x_k, y_k) is the currently set pixel, the slope is $\frac{\Delta y}{\Delta x}$ and K is a constant term. What are the two values that P_{k+1} can take? [8]

   (d) Outline how the Mid-point method works in efficiently scan converting implicit curves. Derive the starting decision parameter value, P_0, for a drawing a circle centred at the origin, with radius r. [9]

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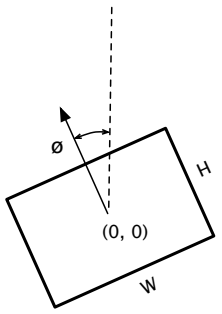
6. (a) What is meant by orthographic and perspective projection? What is the screen y coordinate of (p_x, p_y, p_z) if the centre of projection is at $(0, 0, 0)$ and the view-plane is at a distance d from the viewer? [6]

   (b) A viewing system is defined with the eye at $(0, 0, 1)$, an up-vector $(0, -1, 0)^T$ and a view plane given by

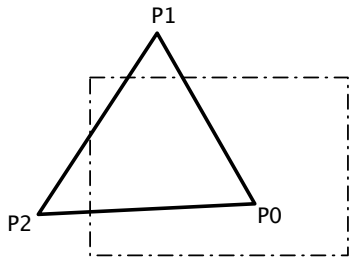
$$\begin{pmatrix} 0 & 0 & -1 \end{pmatrix} \begin{pmatrix} x \\ y \\ z \end{pmatrix} = 0.$$

   i. What are the view coordinates (v_x, v_y) of world coordinates (w_x, w_y, w_z)? [4]

   ii. What are the screen coordinates of the same points on a viewport of size $H \times W$ which is centred on the view axis and has an up-vector which is at ϕ degrees to the vertical axis? [4]



   (c) Describe carefully the Sutherland-Hodgman polygon clipping algorithm. Illustrate your answer with the following example. Show when it can fail to work correctly.



   [6]

   (d) What are winding numbers and how do they work? [5]

End