Mechanical Engineering

Computer Graphics and Image Processing

1. Consider a curve defined by polynomial parametric segments Pj(s) for i = 1, 2, m that interpolates a set of points $\{A_i\}$ $0 \leq I \leq m$ in three dimensions.
    a. What is meant by C_k continuity at the junction of two segments? [3 marks]
    b. What is the least order of the polynomials that must be used to achieve Ck continuity at the junctions? [2 marks]
    c. Derive the Over Hauser formulation for a set of weighting functions w_2(s), w_1(s), w0(s) and wi(s) so that the cubic curve segment joining Ai-1 and Ai can be expressed as Pi(s) = w_2(s)Ai_2 + w_1(s)Ai_1 + w0(s)Ai + w1(s)Ai+1 for 1 < i < m. [10 marks]
    d. Extend this formulation to give a set of parametric patches Pi,j(s,t) for 1 < i < m and 1 < j < n interpolating a surface through an array of points {Ai,j}0<i<m,0<j<ra. [5 marks]
2. A program is required to draw an arc from (0,1) to (1,0) of the circle centered at the origin with unit radius.
    a. One approach would be to draw a segment of the cubic Over Hauser curve defined by (-1,0) (0,1), (1,0) and (0, -1).
        i. Explain how a segment of an Over Hauser curve in general can be represented as an Hermite cubic and so as a Bezier cubic. [4 marks]
        ii. Derive the formula for the resulting Bezier curve, P(t). [3 marks]
        iii. Calculate the coordinates of P (1). How large is the error? [Hint: y/2 « 1.414.] [3 marks]
    b. Calculate revised control points for the Bezier curve so that it models the circular arc more accurately. [4 marks]
    c. Describe in outline an alternative way of efficiently drawing the arc by calculating the pixels that lie on it directly. [6 marks]
3. Describe in detail the Cohen-Sutherland algorithm to clip a straight-line segment against a rectangle. [8 marks]
4. Extend the algorithm from part (a) to clip a line against a three-dimensional viewing frustrum. [6 marks]
5. Describe how to clip a Bezier curve against a screen rectangle. [6 marks]

6. Consider display technologies for hand-held devices.
   a. Explain the principles of operation of each of the following.

   Note: You may illustrate your answers with a diagram.

      i. Liquid crystal displays. [5 marks]

      ii. Electrophoretic (electronic paper) displays. [5 marks]

   b. Compare and contrast their characteristics. [6 marks]

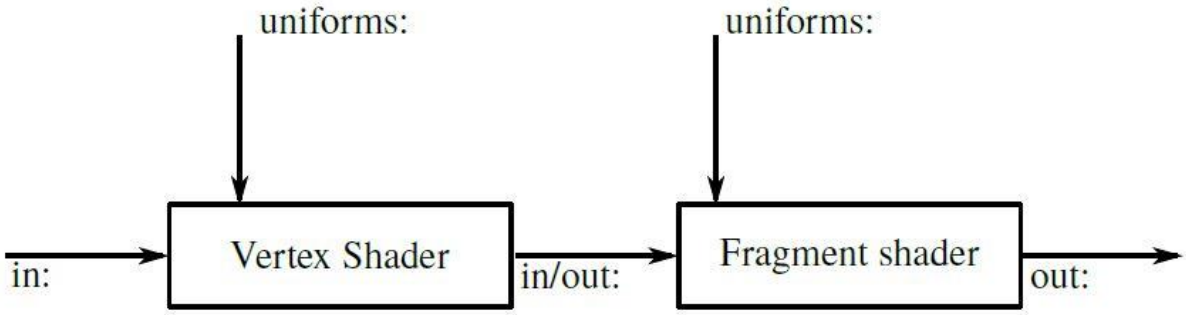
   c. Explain how liquid crystal and electrophoretic displays can show images. [4 marks]

7. Consider rendering a triangular mesh using OpenGL. A uniform material is used for the entire mesh and the reflection model of the material consists of ambient, diffuse and specular components. There are two-point light sources in the scene. Given these assumptions, answer the following questions:

   i. Gourand and Phong shading are two different methods of interpolating colors between vertices. Explain how each method interpolates colors. [5 marks]

   ii. Discuss the trade-offs in terms of quality and computational costs for Phong and Gourand shading. Assume that the number of rendered pixels is much larger than the number of vertices. What kind of artefacts can one of the methods produce and what is the reason for those artefacts? [7 marks]

   iii. For each of Gourand and Phong shading, explain how you would implement each shading method using vertex and fragment shaders in OpenGL. Complete the diagram shown below by listing all inputs, outputs and uniforms for each shader. Then, explain what is computed in each shader in the case of both shading methods. There is no need to write equations or code, but you may include them if it helps your explanation.



[8 marks]

8. Consider the calculation of light emanating from a point on a surface.
    a. What is meant by the following terms? Explain how their contribution to the overall amount of reflected light is calculated.
        i. Ambient illumination. [2 marks]
        ii. Diffuse reflection. [4 marks]
        iii. Specular reflection. [4 marks]
    b. Suppose that the surface is represented as a polyhedral mesh with triangular faces. Explain how illumination is calculated across a face using each of the following.
        i. Gouraud shading. [3 marks]
        ii. Phong shading. [3 marks]
    c. Explain where the calculations for Gouraud and Phong shading should be performed when using OpenGL. [4 marks]