UNIVERSITY OF VICTORIA
FINAL EXAMINATIONS APRIL 2017
CSC 305: INTRODUCTION TO COMPUTER GRAPHICS

Instructor: B WYVILL Duration: 120 minutes

TO BE ANSWERED IN EXAM BOOKLETS

STUDENTS MUST COUNT THE NUMBER OF PAGES IN THIS EXAMINATION PAPER BEFORE BEGINNING TO WRITE, AND REPORT ANY DISCREPANCY IMMEDIATELY TO THE INVIGILATOR.

THIS QUESTION PAPER HAS 4 PAGES INCLUDING THIS PAGE.

Instructions

- Please fill in your **name** and **ID number** on the exam booklet.
- All answers are to be provided in the exam booklet.
- Attempt all questions.
- **Show all your work, for every question.**
- This is a closed-book exam but a single sided sheet of notes is permitted.
- Scientific Calculators may be used, but smart phones and similar gadgets are not permitted.
- State any assumptions you make.
- Ensure all cell phones are turned off.
- You are required to remain for the first 30 minutes.
- Students

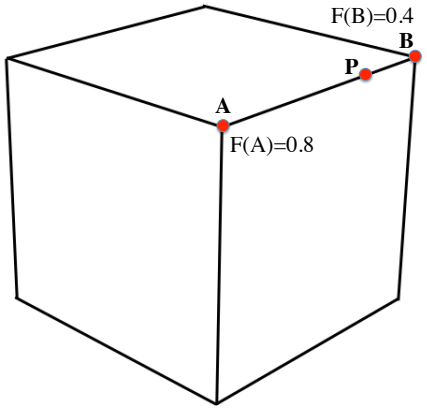

Figure 1: Question One

Question 1 ..... *(6 points)*

Implicit modelling

(a) In the polgonization algorithm described in class (due to Wyvill, Wyvill and McPheeters) parts of an iso-surface are found in each cubic voxel. If linear interpolation is used find the intersection of the surface and edge AB in figure 1, find the position of P, on the 0.5 contour, in terms of A and B (i.e. distance from A and B.) How can you obtain a better estimate? [3]

(b) Implicit skeletal point primitives V and W each have a radius of influence of $R = 1.0$. The primitives are placed with their centres 0.6 units apart. The filter fall off function used is: $f(E) = 1-(r/R)$ where r is the distance from the primitive to the point E, whose field value is to be calculated. How should the scalar values generated by each primitive be combined if the intersection of the two surfaces is desired? By taking a series of points along the line joining the two primitives (at least 6 points), make a table showing the distance to each primitive and the corresponding field values. Also show the combined total field. Sketch the corresponding 0.5 iso-surface. [3]

Question 2 ..... *(6 points)*

A-buffer and Modelling

(a) Describe the anti-aliasing method used in the A-buffer algorithm. How is the partial coverage of a pixel by a polygon fragment calculated? What other advantages does A-buffer have over Z-buffer? [2]

(b) If the top vertex of a triangle intersects the centre of the top edge of a pixel and each triangle edge goes through the lower vertices of the pixel (see Figure 2), calculate the coverage of the pixel using the method of A-buffer. (Hint break the pixel into 8x4 sub-pixels.) [2]

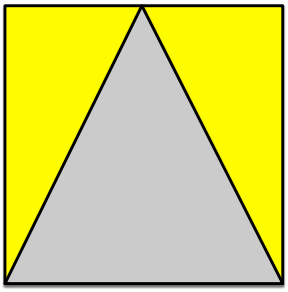

Figure 2: Question two

(c) Joe Hackquick wants to build a fractal landscape using a polygon mesh. Describe an algorithm that would help him generate the mesh. How could he control the roughness of the mountains? [2]

Question 3 ..... *(6 points)*

Ray-tracing

(a) Joe Hackquick has a job counting the number of rays used in a ray tracer. He has 100 spheres and has estimated that nine out of ten rays do not hit any sphere. The ray tracer will trace the first and second reflection rays. There are three light sources in the scene. The image size is 1024×768 and there are 9 jittered rays per pixel. How many rays does Joe count? State any assumptions you make. [2]

(b) To speed up his ray tracer, Joe Hackquick cannot decide between a hierarchy of bounding spheres and uniform space subdivision. Describe the benefits and problems with these methods. [2]

(c) Joe has to ray trace a non-axis aligned ellipsoid. His boss tells him he can do this by ray tracing a sphere and use instancing, but Joe finds that the normal calculation is incorrect. What is he likely doing wrong? What is the correct method of finding the normal in the world space? [2]

Question 4 ..... *(6 points)*

Splines

(a) A $2D$ Bezier curve consists of two segments contained in the following two control polygons: [3]

$$A(-2,0) \;\; B(-2,-2) \;\; C(0,-2) \;\; D(0,0)$$

and

$$D(0,0) \;\; E(0,2) \;\; F(2,2) \;\; G(2,0)$$

Given the Bezier basis functions:

$$Q(t) = (1-t)^3 P_1 + 3t(1-t)^2 P_2 + 3t^2(1-t)P_3 + t^3 P_4$$

Show that the continuity of the segments is (or is not) G^0, G^1 and G^2.

(b) Joe Hackquick is trying to build a generalized cylinder around a cubic curve. He is using the method of *rotation minimizing frames*. The first frame is given by the following vectors: [3]

$$\boldsymbol{B_0} = [0, 0, 1], \quad \boldsymbol{T_0} = [3, 4, 0], \quad \boldsymbol{N_0} = [-0.8, 0.6, 0]$$

At the next point along the curve where a frame is required, the new tangent is calculated as $\boldsymbol{T_1} = [2, 3, \sqrt{12}]$ How does Joe define the new frame? Calculate the rotation axis and angle to rotate the old frame. To save time you can give the angle in terms of the sine and cosine.

Question 5 ..... *(7 points)*

General Computer Graphics

(a) What are the ambiguous cases in the polygonization algorithm identified in the paper by Wyvill, Wyvill and McPheeters, but missed in the Marching Cubes paper? [1]

(b) Why is the polygonization algorithm described in the paper by Wyvill, Wyvill and McPheeters, more economic on memory usage than the method described in the Marching Cubes paper? [1]

(c) Given a point P and a scalar field whose value at P is returned by a black-box function $f(P)$, how can the gradient be estimated? How is the normal calculated knowing the gradient? [1]

(d) Define parametric and modelling space. [1]

(e) In a ray tracer using uniform space subdivision, a bug occurs so that objects are often clipped along vertical planes. What is a likely cause of the bug? [1]

(f) What is meant by a *ray signature*? Why does the method of bounding spheres not require this? [1]

(g) Bonus. Joe Hackquick thinks he knows the answer to Life the Universe and Everything. He writes the answer in binary. What does he write? [1]

END