UNIVERSITY OF VICTORIA
FINAL EXAMINATIONS APRIL 2016
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 9 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

This version of the exam has been modified to just be a set of questions that often come up. Answers are supplied. The marks attributed are no longer what was originally set as I have added extra questions.

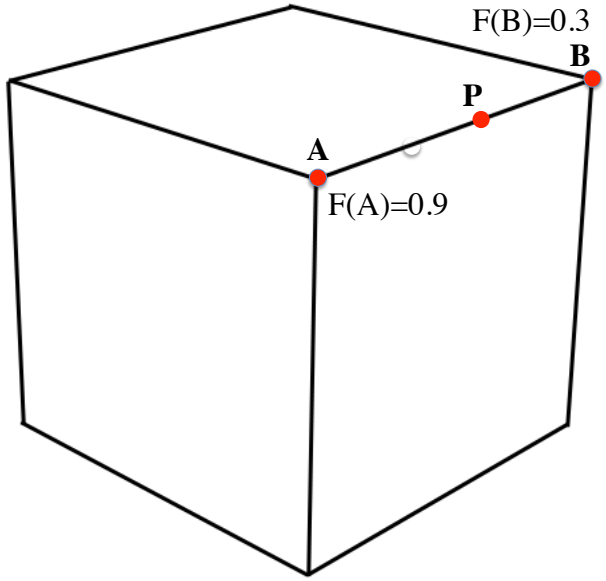

Figure 1: Question One

Question 1 ..... *(9 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. [3]

Answer:

$$\begin{aligned} f(P) &= 0.5 \;\; Iso - value \\ side &= 1 \\ \frac{f(P) - f(B)}{f(A) - f(B)} &= \frac{P - B}{side} \\ P &= B + \frac{f(P) - f(B)}{f(A) - f(B)} \end{aligned} \tag{1}$$

(b) Show how binary search can be used to give a better estimate Discuss the pros. and cons. of linear interpolation, [3]

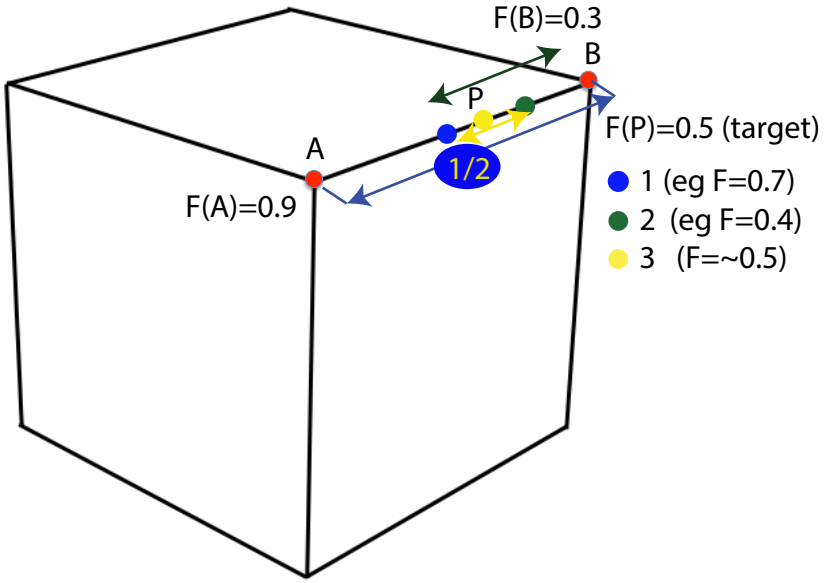

Figure 2: Question One binary search

Answer:

See Figure 2. Choose point half way along edge P_1 (blue), if $F(P_1) > iso$ subdivide towards lower value at B gives $P_2 = \frac{P_1 - B}{2}$ (green) point. Now $F(P_2) < iso$ so subdivide again $P = \frac{P_1 - P_2}{2}$ yellow point. I have stopped after three steps but you should take $F(P) - iso$ and compare against some small error, ϵ. Stop when the error is $< \epsilon$. The procedure may take many iterations so best to stop after some fixed number of steps in case error metric is not achieved.

This is a root finding technique so a better method is to use one of the variants of Newton's method, such as Regula Falsi (see Numerical Methods book). The disadvantage is that this method requires the gradient, which if computed numerically requires 6 calls to the filter fall off function, F. The advantage is that the method converges faster than binary search, so it could easily be worth the extra computation per step.

(c) Implicit skeletal point primitives V and W each have a radius of influence of 1.0. The primitives are placed with their centres 1.5 units apart. The filter fall off function used is: $f(r) = 1 - (r/R)^2$ where r is the distance from the primitive to the point E, whose field value is to be calculated. Visualize the iso-surfaces of the two primitives at a small (close to zero) positive iso-value ϵ. How should the scalar values generated by each primitive be combined if boolean intersection of the two surfaces is desired? By taking a few sample values, sketch the corresponding iso-surface. 3

Answer:

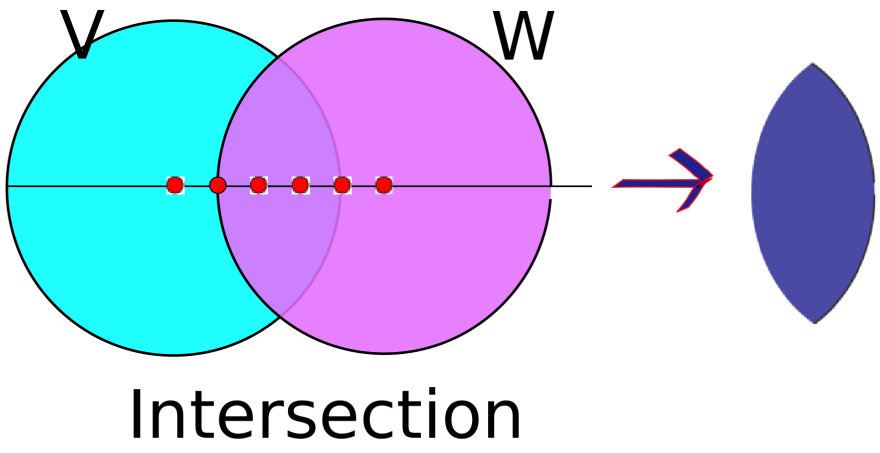

Figure 3: Question 1-3 implicit intersection

D_V	$field_V$	D_W	$field_W$	Min
0	1	1.5	0	0
0.125	0.984375	1.375	0	0
0.25	0.9375	1.25	0	0
0.375	0.859375	1.125	0	0
0.5	0.75	1	0	0
0.625	0.609375	0.875	0.234375	0.234375
0.75	0.4375	0.75	0.4375	0.4375
0.875	0.234375	0.625	0.609375	0.234375
1	0	0.5	0.75	0
1.125	0	0.375	0.859375	0
1.25	0	0.25	0.9375	0
1.375	0	0.125	0.984375	0
1.5	0	0	1	0

Table 1: Field values and the combination for Intersection

It is clear from the table 1 that the only positions where the $f(r) > 0$ is where the two shapes intersect. Everywhere else the field is zero.

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

Ray-tracing

(a) Describe uniform space subdivision as a method of speeding up ray tracing. What are the advantages and disadvantages of this method? 2

(b) Using the fast cell skipping algorithm for uniform voxels, estimate the number of arithmetic operations executed when a ray traverses 10 empty voxels before it hits an object in the eleventh. [2]

(c) Joe Hackquick has built a ray tracer, and has to include cylinder-ray intersection. He has a method to intersect the ray with a cylinder in modelling space, where the cylinder's long axis is aligned with the $Y - axis$. The cylinder is transformed from modelling to world space using a geometric transformation matrix, M. Describe how Joe might find the intersection point, P, of ray R in world space, with the transformed cylinder using instancing. How is the normal vector to the surface at the point of intersection calculated in world space? [2]

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

Scene Graph

(a) Design a scene graph to represent a 2D robot consisting of 2 feet, 2 legs, 2 arms and a head. Each of the components can be represented as a rectangle. The design should ensure that a rotation matrix for each joint rotates the joint locally with respect to the pivot point. [3]

(b) Show the structure and transformations you would use for placing ten robots in a circle. Describe the traversal algorithm that produces the required output. [3]

Question 4 ..... *(7 points)*

(a) Having failed to model a snake, Joe Hackquick gets a new job as a pirate. He is trying to sneak up on another ship, and cannot be seen provided he stays south of a particular line defined by an implicit equation. He knows his position as an (x, y) coordinate. Show how he finds out which side of the line his ship is positioned. [2]

(b) Joe left a silver coin in a very flat part of the desert. Standing on a 100m high hill, 200m west of the coin he looks due east to watch the sun rise. Given that in Joe's world the Phong light model holds, sketch a graph of the intensity he observes at the centre of the coin as the sun rises until it is directly overhead. State any assumptions you make. [2]

(c) The reflection vector from a surface is $\mathbf{R}(0, -1, 0)$ to a surface whose normal is $\mathbf{N}(\frac{-1}{sqrt(2.0)}, \frac{1}{srqt(2.0)}, 0)$. Calculate the direction to the light source. [2]

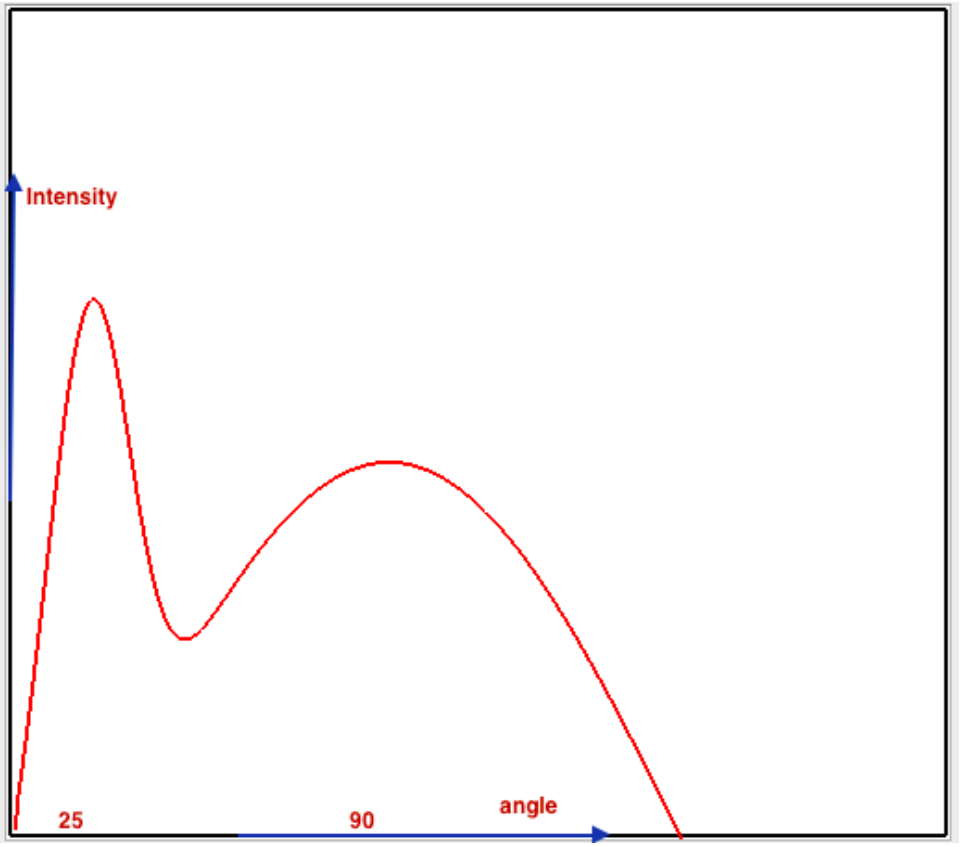

Figure 4: Joe Hacquick in the desert

See Figure 4

(d) Bonus Question: answer a) At which US university was the first computer graphics teapot made? [1]

or b) Joe Hackquick thinks he knows the answer to life the universe and everything, but he is only half right. What is joe's answer?

a) University of Utah (Bezier patches)
b) 42 or 42/2= 21

Question 5 ..... *(6 points)*

Splines

(a) Two 1-dimensional piecewise cubic curve segments, $A(t)$ and $B(t)$, are defined on the unit interval, $t = [0, 1]$. Segment A is joined to B so that the end point of A becomes the start point of B. Show that the segments are G^0 and G^1 continuous. Are they G^2 continuous? [3]

$$A(t) = 5t^3 - 7t^2 + 4$$
$$B(t) = 5t^3 - 8t^2 + t + 2$$

(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 $\boldsymbol{T_1} = [2, 3, \sqrt{3}]$ What is the angle between the old and new tangents? Calculate the axis around which $\boldsymbol{B_0}$ and $\boldsymbol{N_0}$ will be rotated. You can calculate to 2 significant figures.

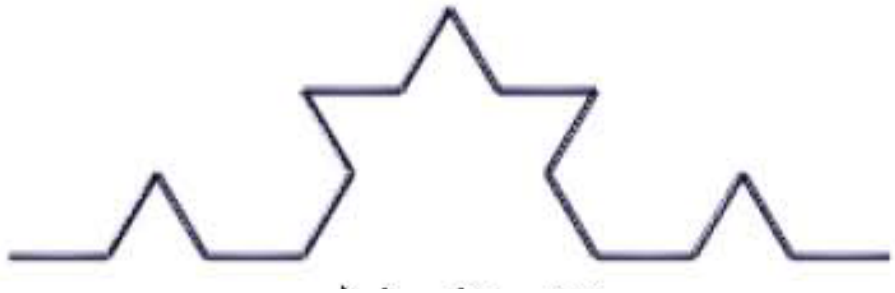

Figure 5: Question 5

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

Theory

(a) What is meant by a *ray signature*? 1

(b) 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

(c) 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

(d) In implicit modelling, why is the *filter fall off function* used to generate scalar field values, instead of simply using the distance? 1

(e) The pirate, Joe Hackquick, stole a shiny gold sphere. He models the sphere with a triangle mesh and tries to render it with Gouraud shading. Why doesn't the sphere look shiny? 1

(f) Calculate the fractal dimension of the Koch snowflake curve. (See Figure 5) 1

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