PRIFYSGOL CYMRU; UNIVERSITY OF WALES

DEGREE EXAMINATIONS MAY/JUNE 2002

SWANSEA

Computer Science

CS 217 Computer Graphics I

Attempt 2 questions out of 3

Time allowed: 2 hours

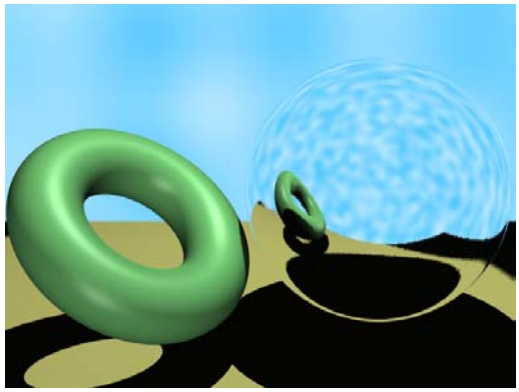
Students are permitted to use the dictionaries provided by the University

Students are permitted to use the calculators provided by the University

CS_217
COMPUTER GRAPHICS I: IMAGE PROCESSING AND SYNTHESIS
(*Attempt 2 questions out of 3*)

Question 1

(a) The image below has been produced using ray tracing and demonstrates many of the fundamental effects: *shadows*, *reflections*, and *transparency*. Show, using diagrams, how each of these effects can be achieved, and describe what recursive ray tracing is. Why does recursive ray tracing lead to *ray explosion*?



What are regarded as the fundamental primitives for defining objects for ray tracing? Describe how ray tracing determines object intersections.

Illustrate the difference between parallel and perspective projection of a scene.

[10 marks]

(b) Explain, with an example, why ray tracing can be computationally expensive. (You should include some example calculations). How can bounding volumes lead to better computational times? (Again use your example to demonstrate).

Describe the method of organising a scene using an *octree*. To what depth is the octree created? How does the octree accelerate ray tracing and how can it be used to ray trace a scene? What benefit does the octree offer over bounding volumes? What is the complexity of the ray-intersection algorithm when an octree is employed?

[8 marks]

(c) How does the recursive flood fill algorithm work? You should mention boundary and interior defined objects, 4-connected and 8-connected pixels, and give psuedo code for the algorithm for one of the cases. Briefly describe an iterative method for filling. Indicate which method would be better and why.

[7 marks]

Question 2

(a) Using the image below (which is in the range 0 to 255), show what the results would be if we tried to display it on a bi-level device using *thresholding*. What are the advantages and disadvantages of using such a method?

100	120	120	125	126
90	119	121	126	127
80	116	120	124	150
90	120	130	140	150

Now demonstrate the results of using the *standard error-diffusion* method. (You may carry out the method on just the first two rows). What are the advantages and disadvantages of this method? You may wish to consider the total error of the top two rows of the image in both the thresholding and error-diffusion case. What extension exists that improves upon it, and describe how that method works (although you do not need to carry it out on the image). Pay particular attention to the edges of the image in both cases.

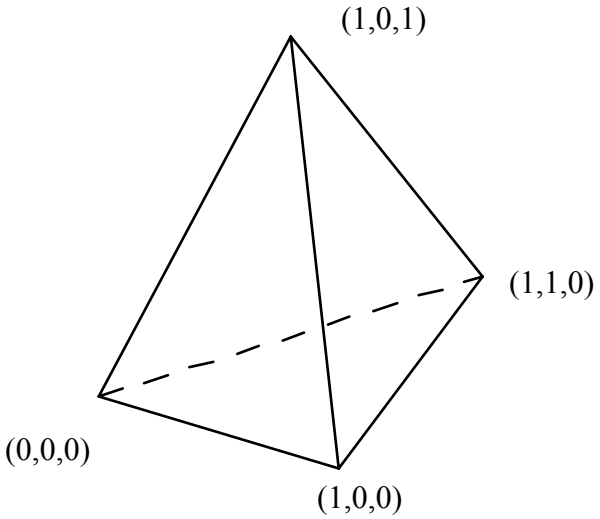
[13 marks]

(b) Write *detailed* (½-1 page each) descriptions of *four* out of the following six topics:
RGB and HSV colour models;
Interpolation;
Histogram equalisation;
Homogenous coordinates;
Particle systems (including flocking rules);
JPEG2000.

[12 marks]

Question 3

(a) Show the following tetrahedron can be represented in three different ways. What are the benefits and drawbacks for each method in terms of calculations and drawing operations? Which method is the most widely used and why?



[5 marks]

(b) Write a *detailed* account (at least 1 page) about *one* of the following advanced topics:
Volume rendering;
Adaptive under-sampling;
Distance fields;
Gradient shading.

[6 marks]

(c) Describe the production process for creating an animation for film. Where in the production process do *key-frame animation* and *physically based modelling* feature, and what do they represent?

[7 marks]

(d) In the context of user interface design and development, show what a bad methodology would be for creating an application. Contrast this to a good methodology. What other design concepts should we bear in mind whilst creating an application? You should include examples in your description of each concept.

[7 marks]

Question 1

(a) ***[Bookwork / Understanding]***
*Show a diagram for each of shadows, reflections and transparency. Show incoming ray, secondary ray (to light source, reflected about angle of incidence, or refracted through object respectively). Show combined diagram for recursive ray tracing. State that 1 ray can spawn many rays, each of which is ray traced (recursion). (**6 marks**)*

*Objects defined using spheres, triangles, cylinders etc. Ray intersected with each primitive by solving equation of 3D line with object. Closest hit indicates object. Picture of ray originating from each pixel, or from centre of projection and going through each pixel. (**4 marks**)*

(b) ***[Bookwork / Understanding / Some worked examples]***
*e.g. use 1000x1000 image and 1000 primitives=1 billion intersecions, place cylinders around chess pieces etc. to cut calculations. Talk about the fit of the bounding volume. (**3 marks**)*

*Octree-cut each axis in two, divide primitives into appropriate node, continue until depth reaches predefined amount, or less than predefined amount of primitives in each node. Trace a ray, if it intersects with box, intersect it with each of 8 nodes. Continue until leaf is reached, then intersect it with primitives. Can cut out much of the scene, i.e all the primitives contained in boxes not intersected by ray. Automatic algorithm rather than manual as above (**5 marks**).*

(c) ***[Bookwork / Understanding / Part advanced topic]***
Mention everything in question (**3 marks**), and give code for recursive fill, e.g. 4-connected boundary fill (**2 marks**). Mention span-filling algorithm. Mention issue of stack overflow for complicated boundaries. (**2 marks**)

Question 2

(a) ***[Bookwork / understanding / practical application / error analysis]***
Thresholding, easy to compute and code, disadvantage – area which is approx. 50% grey is now only fractionally white:

0	0	0	0	0
0	0	0	0	0
0	0	0	0	1
0	0	1	1	1

(**3 marks**)
Error diffusion using first two rows:
100->0, gives 100 error. 120+100=220->1, gives –35 error. 120-35=85->0, gives 85 error, 125+85=210->1, gives –45 error. 126-45=81->0, gives 81 error, move down to next row and work right to left. 81+127=208->1, gives –47 error. 126-47=79->0, gives 79 error. 121+79=200->1, gives –55 error. 119-55=64->0, gives 64 error. 90+64=154->1, gives –101 error. (**5 marks**)
This gives B&W image

0	1	0	1	0
1	0	1	0	1

For top two rows, Original grey scale = 1174, thresholded=0 (error=1174), Error Diffusion=1275 (error=-101) i.e. error is verified. (**3 marks)**

Improved method is Floyd-Steinberg (give ratios). (**2 marks)**

(b) ***[Bookwork / understanding / application]***
HSV/RGB – The models should be drawn, and a short description about what happens when values are adjusted for each axis.

Interpolation – Equation for linear interpolation, draw diagram indicating how bilinear and trilinear interpolation are carried out.

Histogram equalisation – Histograms should be described (perhaps giving code). Process should be described (again perhaps giving code). Bonus marks for mentioning advanced use (12 bit medical data to 8 bit grey-scale images).
Homogenous coordinates – demonstrate homogenous coordinates, mention premultiplication of matrices to save calculations.

Particle systems – information for each particle, suggest equations of motion, state some of the flocking rules. State used for animations.

JPEG2000 – mention lossy compression, wavelets, progressive detail, better than JPEG.
(Pick **4**, and get **3 marks each**)

Question 3

(a) ***[Bookwork / understanding / application]***
*1 mark each (**3 marks** total) for correct demonstration of explicit representation, pointers to a vertex list representation, pointers to an edge list representation. **2 marks** for correctly mentioning advantages and disadvantages of each method (space used, computation required to display).*

(b) ***[Bookwork / understanding of advanced topic]***
*All three topics are slightly harder to understand and require effort to learn, and therefore are rewarded appropriately. Explanation required of why method is needed, and exactly how it is carried out. (**6 marks**)*

(c) ***[Bookwork / understanding / linking topics together]***
Storyboard (creation of story or hand drawings), design and modelling (laborious creation of models), scene composition and animation (manual positioning or complex designing of paths), rendering (choice of light sources, textures, colours and camera path), colour calibration (making sure colours on resulting medium match what are required), final filming (sheer computation effort). Describe key-frame animation and physically based modelling (i.e. removing need for manual positioning of objects). (**7 marks**)

(d) ***[Bookwork / understanding]***

Bad methodology - write code, write interface, train users.

Good methodology - ask users how they perform task, write interface, write code. (**2 marks**)

Cover design concepts such as metaphors, feedback, prototyping, familiar concepts, visual information, group related information, consistency, simplicity, quick-start, user tailorability. (1/2 mark each for 10=**5 marks**)