THIS PAPER IS NOT TO BE REMOVED FROM THE EXAMINATION HALLS

UNIVERSITY OF LONDON **CO3355 ZA**

BSc Examination

COMPUTING AND INFORMATION SYSTEMS AND CREATIVE COMPUTING

Advanced Graphics and Animation

Monday 21 May 2018: 10.00 – 12.15

Time allowed: 2 hours and 15 minutes

There are **FIVE** questions on this paper. Candidates should answer **THREE** questions. All questions carry equal marks and full marks can be obtained for complete answers to **THREE** questions. The marks for each part of a question are indicated at the end of the part in [.] brackets.

Only your first **THREE** answers, in the order that they appear in your answer book, will be marked.

There are 75 marks available on this paper.

A handheld calculator may be used when answering questions on this paper but it must not be pre-programmed or able to display graphics, text or algebraic equations. The make and type of machine must be stated clearly on the front cover of the answer book.

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Question 1 Maths and transformations

(a) Given a vector **W** = [x,y,z] in 3D space, provide equations to calculate:

(i) The length of **W**. [2]

(ii) The unit vector in the same direction. [2]

(b)

(i) Briefly describe what is meant by the term *homogeneous coordinates* and identify which of the previous matrices are in that form. [2]

(ii) Explain why homogeneous coordinates are useful for performing matrix-based 3D transformations. [4]

(c) Consider a vector $\mathbf{V} = [0.5, 2, 1]^T$ in 3D space. Apply each of the following transform matrices to **V** and provide the result. Describe the kind of transform performed in each case.

(i) $\begin{bmatrix} 3 & 0 & 0 \\ 0 & 2 & 0 \\ 0 & 0 & 1 \end{bmatrix}$ [2]

(ii) $\begin{bmatrix} 1 & 0 & 0 & 1 \\ 0 & 1 & 0 & 1 \\ 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 1 \end{bmatrix}$ [2]

(iii) $\begin{bmatrix} 0.7 & 0.7 & 0 & 2 \\ -0.7 & 0.7 & 0 & 0 \\ 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 1 \end{bmatrix}$ [3]

(d) Consider

1. A collection of 3D translation transforms $T_1, T_2, \ldots T_N$.
2. A collection of 3D scaling transforms $S_1, S_2, \ldots S_N$.

(i) For each case above, state whether or not the order of the application of the transforms will affect the result. [2]

(ii) Prove your previous statements, using homogeneous coordinates and generic transforms. [6]

Question 2 Model to screen

(a) Explain the functionality of the following matrices and describe the coordinate systems involved in each case:

(i) ModelView matrix. [3]

(ii) Projection matrix. [3]

(b) What prevents us from combining the two matrices in (a) into a single matrix? [2]

(c) "*The discrete representation of computer screens makes it impossible to draw ideal lines.*" Comment on this statement, describing the parameters that affect the quality of the result, identifying any possible exceptions and illustrating your answer with a diagram as appropriate. [6]

(d) State what is meant by *culling* and briefly describe how it is performed. How does culling contrast to *clipping*? How would you implement culling in Processing? [5]

(e) Name **THREE** algorithms that aim to solve the hidden surface removal problem. [3]

(f) How many control points are needed to define a cubic Bézier curve? Describe them. [3]

Question 3 Graphics Programming

(a) Write Processing commands to create a cube with an edge length of 100 pixels, making sure that only the edges are drawn. You may assume that P3D (or some other 3D renderer) is in operation.

[2]

(b) What are the properties that a graphics object contains? Which class represents graphics objects in Processing?

[4]

(c) In one or two sentences explain what is meant by *graphics state* in Processing. Provide **TWO** example commands.

[3]

(d) Explain why modern graphics programs are written for the GPU rather than the CPU.

[3]

(e) When compared to the traditional, fixed GPU functionality, programmable shaders allow us to create a vast range of effects. Provide **THREE** examples of such effects.

[3]

(f) Consider the code below that sets the colour of the current element.

(i) Identify the type of shader and describe the result of its execution.

[2]

(ii) Modify the code so that colour opacity is set to medium.

[1]

(iii) Assume the code is stored in a file named "shader.glsl". Provide Processing commands that will load the shader and set the `mousePos` variable to the coordinates of the mouse position. Make sure they are scaled according to the window size so that they range between 0 and 100.

[4]

(iv) Modify the shader code so that the colour progressively changes from Blue to Red, based on the horizontal mouse position.

[3]

```
#ifdef GL_ES
precision mediump float;
#endif
uniform vec2 mousePos;
vec4 color;
void main() {
        color  = vec4(1.0,0.0,1.0,1.0);
        gl_FragColor = color;
}
```

Question 4 Lighting and display

(a) What is *ambient illumination*? What does it approximate from physical reality? [4]

(b) Describe what is meant by the term *diffuse reflection*. Use a diagram if appropriate. [4]

(c) How can the BRDF (Bidirectional Reflectance Distribution Function) value of a specific surface be determined? [3]

(d) Suppose you wanted to illuminate and represent a scene that takes place inside a room, as captured by a camera positioned at the centre of the room. The camera is mounted on a tripod and is continuously panning horizontally along the tripod axis. If your decision was solely based on the computational cost, and not the representation quality, would you choose radiosity or ray tracing for this purpose? Why? [6]

(e) Devise an example of a scene where Phong shading and Gouraud shading would produce very different results. Provide a drawing to illustrate your arguments. [8]

Question 5 Texturing

(a) Texturing helps produce a more realistic representation by modelling imperfections. Is it possible to achieve similar levels of realism with plain shading? Explain your answer.

[4]

(b) What is the difference between `noise()` and `random()` functions in Processing?

[3]

(c) What does a *map shape* determine?

[2]

(d) Consider the following mapping equations:

$$u=x;\ v=z$$

Identify the type of map shape and explain how it works. If points [1,0,0] and [1,50,0] both belong to the object surface, how will the colours at these locations be related?

[4]

(e) How can interpolation be useful in texture mapping? Provide an example of such a situation. Which type of uniform variable is used in GLSL for this purpose?

[6]

(f) Suppose you want to render a scene that contains a large very shiny object and you can choose between environment mapping and ray tracing. Identify the factors you would take into account and explain how they would affect your decision.

[6]

END OF PAPER