THIS PAPER IS NOT TO BE REMOVED FROM THE EXAMINATION HALLS

UNIVERSITY OF LONDON **CO3355 ZB**

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.

Question 1 Maths and transformations

(a) Consider two generic vectors, **W** = $[x_W, y_W, z_W]$ and **U** = $[x_U, y_U, z_U]$ respectively, in 3D space. Using **W** and **U**, provide formulas to define:

(i) Vector subtraction. [2]

(ii) Uniform scaling. [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 **V** = $[1, 1, 2]^T$ 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)
$$\begin{bmatrix} 1 & 0 & 0 & 3 \\ 0 & 1 & 0 & 1 \\ 0 & 0 & 1 & 3 \\ 0 & 0 & 0 & 1 \end{bmatrix}$$

[2]

(ii)
$$\begin{bmatrix} 2 & 0 & 0 \\ 0 & 2 & 0 \\ 0 & 0 & 3 \end{bmatrix}$$

[2]

(iii)
$$\begin{bmatrix} 0.5 & 0.87 & 0 & 2 \\ -0.87 & 0.5 & 0 & 0 \\ 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 1 \end{bmatrix}$$

[3]

(d)

(i) Using homogeneous coordinates, provide a matrix that defines a generic combined transform that consists of a rotation followed by a translation, both along the y-axis. [2]

(ii) For a collection of transforms of this type, state whether or not the order of their application on a vector affects the result. [1]

(iii) Prove your previous statement. [5]

Question 2 Model to screen

(a) Describe what is meant by *Object coordinates* and *Camera coordinates*. How would you convert a model from the former to the latter?

[5]

(b) Provide **TWO** examples that illustrate how local coordinate systems can be helpful.

[4]

(c) "*The discrete representation of computer screens makes it impossible to draw ideal curves.*" Comment on this statement, describing the parameters that affect the quality of the result and illustrating your answer with an example.

[4]

(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) Does the order of drawing objects affect the efficiency of the z-buffer algorithm? Justify your answer.

[4]

(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 red-coloured sphere with a radius of 100 pixels. You can assume that P3D (or some other 3D renderer is in operation).

[2]

(b) Describe **TWO** issues of the immediate mode that are tackled by using graphics objects. Which class represents graphics objects in Processing?

[5]

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

[3]

(d) 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]

(e) Apart from GLSL, name **TWO** other shader programming languages. [2]

(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 the current element is fully transparent. [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 Red to Green, based on the vertical mouse position. [3]

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

Question 4 Lighting and display

(a) Describe what is meant by the term *specular reflection*. Use a diagram if appropriate.

[4]

(b) How does global illumination differ from local illumination?

[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 in a large outdoor space, as captured by a camera positioned at its centre. 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) What is meant by the term *image map*?

[2]

(b) Name the **TWO** main approaches to texturing a surface.

[2]

(c) What is the *heightfield* method in the context of Bump mapping?

[3]

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

[2]

(e) Consider the following mapping equations:

$$u=y;\ v=z$$

Identify the type of map shape and explain how it works. If points [1,10,10] and [-1,10,10] both belong to the object surface, how will the colours at these locations be related?

[4]

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

[6]

(g) "*Environment mapping is an approximation of true reflections.*" Discuss this statement.

[6]

END OF PAPER