



The
University
Of
Sheffield.

Data Provided: None

DEPARTMENT OF COMPUTER SCIENCE

Autumn Semester 2015-2016

3D COMPUTER GRAPHICS

2 Hours

Answer THREE questions only.

All questions carry equal weight. Figures in square brackets indicate the percentage of available marks allocated to each part of a question.

1. a) A scene graph is required to represent a solar system, which consists of a sun at the centre of the system, three planets that orbit the sun, and moons that orbit some of the planets. The first planet has no moons, the second has one moon and the third has two moons. Assume that all orbits are circular and that the sun, planets and moons can each be represented as spheres. Also, each planet and each moon continually rotates about an axis through its respective centre.

(i) Draw an appropriate scene graph for the solar system.

[10%]

(ii) You are now required to write pseudocode to draw the sun, the second planet and the moon for the second planet. Your pseudocode should make use of methods called `drawSun()`, `drawPlanet2()` and `drawMoon()` which each draw spheres of the appropriate size with a coordinate origin at the centre of the sphere. You need to include all the transformations necessary to draw this portion of the solar system. Do not consider any other part of the solar system. You will need to use both rotate and translate transformations in your solution. Specific parameters for the transformations do not need to be given. As an example, '`rotate(); drawSun();`' can be used rather than '`rotate(angle, x,y,z); drawSun();`'. The important aspect is that you include each separate transformation that is required and think carefully about the use of `glPushMatrix()` and `glPopMatrix()`.

[20%]

- b) In an extraordinary feat of engineering, a spaceship has been built to resemble the shape of a teapot (Figure 1). This is composed of four pieces – the body, the spout, the handle and the lid – each of which can be created using the technique called sweeping to produce a surface mesh of triangles. Choose one of the pieces and describe how to produce it using a sweeping technique. In your answer, describe how parameters could be used in the sweeping technique to control the number of triangles produced.

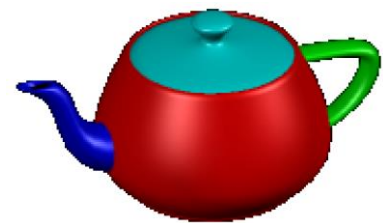


Figure 1.

[20%]

- c) Given (x,y,z) positions for the vertices of the triangle mesh produced from 1(b), describe how you would calculate the associated vertex and triangle normals.

[20%]

- d) The spaceship in 1(b) now lands on a moon, which has a very fine lunar soil making up its surface. As it does so, clouds of dust are created. Discuss a computer graphics technique that could be used to model this effect.

[30%]

2. a) The Phong local reflection model incorporates three components, an ambient, a diffuse and a specular term. Describe what lighting effect each of these is modelling and then state how the diffuse and specular terms are calculated using the information shown in Figure 2. (Note: This is the Phong model, not the Blinn-Phong model.)

[20%]

- b) Making use of your answer from 2(a), write the equation for the Phong reflection model for multiple light sources.

[5%]

- c) Making use of your answer from 2(a), write the equation for the Phong reflection model that incorporates atmospheric attenuation.

[5%]

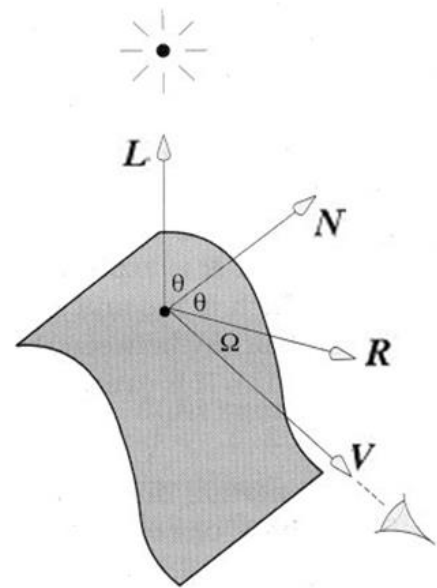


Figure 2.

- d) Assume that the Phong local reflection model is being employed in a rendering system. Using the following criteria, compare and contrast (i.e. discuss similarities and differences between) Gouraud and Phong interpolative shading for producing rendered images:

- (i) Cost of each algorithm, i.e. number and type of calculations required;

[20%]

- (ii) Specular highlights – consider both static and animated scenes.

[10%]

- e) Consider a point light source, located at (5,5,0), shining on a sphere of radius 1.0 which has its centre at the world origin. In each of the following, illustrate your answer with a simple diagram.

- (i) Assume the sphere is perfectly diffuse. If a viewer was positioned at (0,5,5) and looking towards the world origin, briefly discuss whether or not they would be able to see the point on the surface where maximum reflected light occurs. You must give reasoning in your answer.

[10%]

- (ii) Assume the sphere is perfectly specular. If a viewer was positioned at (0,5,5) and looking towards the world origin, briefly discuss whether or not they would be able to see the point on the surface where maximum reflected light occurs. You must give reasoning in your answer.

[10%]

- f) Describe how three memory buffers are used in a shadow z-buffer (also called shadow mapping) approach to shadow computation.

[20%]

3. a) A client has a computer graphics model of a restaurant. She wishes to show the appearance of a wooden floor in the restaurant and a trail of dirty footprints left after a person wearing muddy shoes has walked across the floor. Describe the texturing technique known as 2D texture colour mapping (also known as diffuse colour mapping) and discuss how it could be used in producing a rendering of the surface of the floor and of the muddy footprints.
[20%]
- b) Discuss an approach that could be used in conjunction with 2D texture colour mapping to produce renderings of the scene in 3(a) at a range of distances, whilst dealing with the problem of aliasing.
[20%]
- c) (i) An animation is to be produced of a robot which is made of a body and a moving head and two moving arms attached to the body. All the parts of the robot are made from shiny, reflective metal. The robot will move through the restaurant model of 3(a) and wave its arms as it moves. In addition, there is a shiny, reflective metal teapot on one of the tables in the restaurant. Describe a texture mapping approach that could be used to make it appear as if the robot and the teapot were both reflecting the restaurant scene in their respective surfaces.
[20%]
- (ii) Outline three potential complications that arise in using this texture mapping approach to produce the required effects for this particular animated scene.
[15%]
- d) The surface of the robot in 3(c) has a pattern of dimples on it. Discuss a texture mapping approach that could be used to produce the pattern of dimples on the robot's surface. As part of your answer, state whether or not this approach has any impact on the approach used in 3(c) where the robot reflects its surroundings.
[25%]

4. a) Consider a scene that contains a set of objects, some perfectly diffuse, some that are perfectly reflective (e.g. a mirror-like surface) and some that are a mix of diffuse and reflective. Describe how a standard naïve ray tracer would render this scene. Include in your answer a consideration of how each of the three different kinds of objects would be handled during the rendering process. [35%]
- b) Standard naïve ray tracing is impractical. Briefly discuss how bounding volumes can be used to make it practical. [15%]
- c) Consider a robot which is made of a body and a moving head and two moving arms attached to the body. Contrast the use of a single bounding volume and a hierarchical set of bounding volumes for this object to increase ray tracing speed. In your answer, also consider a way to measure the effectiveness of any bounding volume approach. [20%]
- d) Consider a computer graphics model of a restaurant, which contains a set of robot waiters (such as those described in 4(c)) moving around the tables and serving customers. At one point in the animation, one of the robot waiters bumps into a table and knocks everything off the table onto the floor. Compare and contrast the following two approaches for increasing ray tracing speed for this scenario: (i) a combination of bounding spheres and space partitioning; (ii) a solution that only uses bounding spheres. You should consider using sketches to help illustrate your answer. [30%]

END OF QUESTION PAPER