CARDIFF UNIVERSITY
EXAMINATION PAPER

Academic Year: 2007/2008

Examination Period: Autumn

Examination Paper Number: CM0304

Examination Paper Title: Graphics

Duration: 2 hours

Do not turn this page over until instructed to do so by the Senior Invigilator.

Structure of Examination Paper:

There are 3 pages.

There are 4 questions in total.

There are no appendices.

The maximum mark for the examination paper is 100% and the mark obtainable for a question or part of a question is shown in brackets alongside the question.

Students to be provided with:

The following items of stationery are to be provided:

ONE answer book.

Instructions to Students:

Answer THREE questions.

The use of calculators is not permitted in this examination. The use of translation dictionaries between English or Welsh and a foreign language bearing an appropriate school stamp is permitted in this examination.

1. **Lighting and Shading**

   (a) Using Phong's illumination model, we wish to render a scene containing a single point light source at position l, which emits monochromatic light consisting of ambient, diffuse and specular light. For each light type explain in detail how to compute the intensity of the light observed by a viewer at position v, which is reflected at a point p on a surface with normal n, $\|n\| = 1$. You may assume that the light emitted by the light source is not attenuated.

   [10]

   (b) Describe the difference between Gouraud shading and Phong shading. What are the advantages and disadvantages of Phong shading relative to Gouraud shading?

   [9]

   (c) Consider a flat surface with tiny scratches that run in parallel across the surface in direction t. It is lit from a directional light source with direction d. The intensity of specular light reflected by this surface depends on the angle between d and t: it is maximal if d is orthogonal to t and minimal if d is parallel to t. Why is Phong's illumination model insufficient to render such surfaces with one polygon? Suggest a modification of the illumination model to handle such surfaces.

   [6]

   Total: [25]

2. **Casting Shadows**

   (a) Describe how elementary transformations (translation, rotation, perspective projection, etc.) may be combined to compute the shadow of a polygon cast onto the x-y plane, $y = 0$, from a point light source at position l. Based on this give a formula to compute this shadow projection for a vertex p.

   [6]

   (b) A light source very far away from the objects in a scene can be treated as a directional light source. The shadow of a polygon from such a light source cast on a plane can be computed by parallel projection. Derive the homogeneous transformation matrix to compute the parallel projection of a vertex p in direction r onto a plane given by the equation $n^t x - d = 0$.

   [14]

   (c) An extended light source is a light source which emits light from a polygon, e.g. a square. Why are shadows computed as polygon projections as above not realistic for such light sources? How could you in principle extend a real-time rendering engine to create more realistic shadows for such light sources?

   [5]

   Total: [25]

3. **Clipping Polygons**

(a) Describe a data structure for representing a 3D polygon which allows us to distinguish between the front and the back of the polygon. Describe an algorithm which uses your data structure to determine whether a viewer at position v is looking at (1) the front, or (2) the back of a polygon, or (3) looking at it edge on.

[10]

(b) Describe a 2D clipping algorithm to clip a 2D polygon against a triangular window with vertices t_0, t_1, t_2 based on the Sutherland-Hodgeman approach. You may assume that you are given a suitable line-line intersection algorithm in 2D. Provide details for all other necessary computations.

[10]

(c) In general the intersection of two 2D polygons may consist of several polygons (including no or one polygon). How many polygons does the intersection of two convex polygons consist of at most? Justify your answer.

[5]

Total: [25]

4. **Ray Tracing with BSP-Trees**

(a) What is a BSP-tree? Outline how it can be constructed in principle for a scene consisting of simple, flat polygons in 3D. There is no need to provide formulae for any of the computations.

[8]

(b) How can a BSP-tree be used to improve the speed of a standard ray tracing algorithm? Explain in detail how the BSP-tree has to be traversed to do this and describe all necessary computations for the traversal. There is no need to discuss how to compute ray-object intersections.

[12]

(c) Outline how in principle fog of varying density in a scene could be represented and rendered within a ray tracing algorithm.

[5]

Total: [25]