Closed book examination

Two hours

UNIVERSITY OF MANCHESTER
SCHOOL OF COMPUTER SCIENCE

Advanced Computer Graphics

Date: Friday 29th January 2010
Time: 09.45 – 11.45

Please answer THREE questions in total – answering at least ONE from each section.

Use a SEPARATE answer book for each section

The use of electronic calculators is NOT permitted.
1. Using diagrams, describe the process of ‘reverse ray tracing’ a simple scene containing two coloured glass spheres, an opaque cuboid, and a single spot light source. Illustrate your answers with diagrams – you need neither derive nor use geometric equations. In your description, you should explain:

a) The overall process of ray tracing, and why, in practice, ray tracing is typically carried out ‘in reverse’. (4 marks)

b) The role of shadow feeler rays. (3 marks)

c) What happens as rays interact with different kinds of material including opaque, transparent and mirrored surfaces. (3 marks)

A local café bar is planning some major renovation, which will involve removing the current ‘modern’ open-plan bright lighting, glass and chrome furniture, and replacing these with ‘traditional’ soft furnishings and more gentle per-table lighting to give a more atmospheric and cosy experience. When their ‘modern’ furniture was installed some years ago, they were given ray traced static images of what the café would look like once finished – but the company that provided these no longer exists. Aware that computer graphics have moved on, this time, they would like a real-time interactive walkthrough of their new design, for which they already have the CAD models. You have been approached to provide this walkthrough. Bearing in mind that your clients are not computer graphics experts, explain why a radiosity solution is better suited to their needs. In your answer make sure you cover

d) A description of the radiosity process. (3 marks)

e) An explanation of why radiosity is likely to be more suited to the new style of décor. (4 marks)

f) A discussion of why and how radiosity can be applied to real-time interactive situations. (3 marks)
2. a) What is the purpose of Volume Rendering? Give two distinct examples of its use.
   (2 marks)

   b) Describe, using diagrams, the process of Direct Volume Rendering, referring to the following aspects.

   i) A suitable data structure. (2 marks)
   ii) The classification of voxels according to the source data. (2 marks)
   iii) A method for calculating the composite value of a pixel. (4 marks)
   iv) A simple lighting model. (4 marks)

   c) Briefly describe a technique for Indirect Volume Rendering. What are the advantages and disadvantages of Direct Volume Rendering compared with Indirect Volume Rendering? Compare the performance and accuracy of the two techniques, and describe situations where each technique could be appropriate. (6 marks)

3. a) What is the purpose of spatial enumeration? Describe its use in the context of a 3D video game in which the player moves through a series of small rooms, interacting with a variety of flying objects. (2 marks)

   b) Compare the pros and cons of using spheres, bounding cubes, and bounding cuboids to form hierarchical bounding volumes in the case of the video game above. (3 marks)

   c) Describe, using diagrams, the following spatial enumeration structures. Discuss their pros and cons and comment on their space and time complexity. (3 marks each)

   i) Gridcell
   ii) Octree
   iii) Hierarchical Bounding Volume
   iv) Axis aligned BSP tree
   v) Polygon aligned BSP tree
Section B
Answer at least ONE question from this section

4. Kajiya’s rendering equation is a high-level representation of global illumination:

\[ L_o(x, \omega) = L_e(x, \omega) + L_r(x, \omega) \]

a) Explain the meanings of the terms in the equation. Use a diagram to aid your explanation. (3 marks)
b) One method for implementing part of the equation is photon tracing. Describe how photon-tracing works, using diagrams to illustrate your answer. (10 marks)
c) Explain how the different parts of the photon tracing approach relate to the terms in the rendering equation. (2 marks)
d) How does photon-tracing deal with specularly reflecting surfaces, such as a shiny billiard ball, or even a mirror? (2 marks)
e) What are the strengths and weaknesses of photon tracing? When, and why, would you choose to use photon tracing, and when, and why, would you choose not to use it? (3 marks)
5. Appearances of real-world objects can be very complicated to describe and remain challenging for modelling in computer graphics modelling and rendering. Effects such as colour, surface texture, reflective materials, transparency and translucency are all commonly encountered. The bi-directional reflectance distribution function (BRDF) is one way to describe a subset of these effects at a point on a surface. The equation for the BRDF is:

\[
L_o(x, \omega_o) = \int_{\Omega} f_r(x, \omega_i, \omega_o) L_i(x, \omega_i) (\omega_i \cdot n) d\omega_i
\]

a) Explain the meanings of the terms in the equation, using a diagram to aid your answer. (5 marks)

b) Describe how you would use the BRDF, or some alternative function, in conjunction with a suitable rendering method, to simulate the following effects. Use diagrams to aid your explanations, and state any assumptions, advantages, or disadvantages of your chosen methods.

i) Surface roughness or bumpiness. (5 marks)

ii) Translucent materials, such as marble. (5 marks)

iii) Materials such as woven cloth. (5 marks)