Two hours

UNIVERSITY OF MANCHESTER
SCHOOL OF COMPUTER SCIENCE

Advanced Computer Graphics

Wednesday 21st January 2009
14:00 – 16:00

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.
SECTION A
Answer at least ONE question from this section

1. You have been engaged as a consultant on a ‘virtual heritage’ project which aims to reconstruct a photorealistic three dimensional model of a town recently damaged by extreme weather. Many of the buildings are in ruins; others range from partially damaged to essentially intact. The group have assembled a set of floorplans, and have rescued a number of artefacts such as statues and monuments that they are keen are included in the reconstructed model. A substantial amount of film and still footage of the town has been retrieved. The project has a significant budget, some of which has already been spent on software capable of rendering, in real-time, large textured polygonal models, and some of which has been earmarked for laser range finding equipment.

Write an initial report for the project explaining how the model of the town could be reconstructed using the resources available. Break each task down into stages, and describe the algorithms and techniques necessary in each. For budgeting purposes, make sure you describe any stages that can be sensibly automated, and any stages that are going to require manual intervention. Also describe any limitations of the techniques you propose. In particular, describe in the context of this particular reconstruction task how:

a) laser range finding equipment allows the capture of geometry. (4 marks)

b) geometry may be extracted from film and photographs. (6 marks)

c) polygonal meshes from a) and b) can be prepared and textured for use in their rendering software. (10 marks)

Break each task down into stages, and describe the algorithms and techniques necessary in each. For budgeting purposes, make sure you describe any stages that can be sensibly automated, and any stages that are going to require manual intervention. Also describe any limitations of the techniques you propose.
2. a) What is meant by Spatial Enumeration? Describe its use in the context of a virtual-reality style walkthrough of a large model such as a complex cityscape. (2 marks)

b) What role do bounding volumes play in spatial enumeration? Consider the use of spheres, object aligned bounding boxes and axis aligned bounding boxes, and describe the pros and cons of each, illustrating your answer with diagrams. (3 marks)

c) Describe using diagrams the following spatial enumeration structures. Discuss their pros and cons and compare their efficiency in terms of space and time complexity.

i) Gridcell (3 marks)
ii) Octree (3 marks)
iii) Hierarchical Bounding Volumes (3 marks)
iv) Axis Aligned BSP Tree (3 marks)
v) Polygon Aligned BSP Tree (3 marks)

3. a) What is 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 for holding the source data (2 marks)
ii) the classification of voxels according to the source data (2 marks)
iii) calculating the composite value of a pixel (4 marks)
iv) illuminating the 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 would be appropriate. (6 marks)
SECTION B
Answer at least ONE question from this section

4. a) Using diagrams where appropriate, describe in detail the concept of photon tracing. What important characteristics make it truly a global illumination algorithm? (8 marks)

b) What is Russian roulette, and how is it used in photon tracing? How can it be adapted for surfaces with different reflection coefficients for red, green and blue wavelengths? (4 marks)

c) Explain how photon tracing can be used to model light sources (luminaires) with arbitrary shapes and emission distributions. Describe a technique for improving the efficiency of modelling such light sources. (6 marks)

d) How can the technique be further refined to ensure that caustics are rendered accurately? (2 marks)

5. a) The rendering equation was first proposed by James Kajiya. In the lectures it was presented as the equation:

\[ L_o(x, \omega) = L_e(x, \omega) + \int \frac{f_s(x, \omega', \omega) L_i(x, \omega') (\omega' \cdot \hat{n})}{4\pi} \omega' \ d \omega' \]

Using a diagram to aid your explanation, describe the meaning of each of the terms in the rendering equation. (12 marks)

b) This version of the equation takes no account of occlusions. How can it be extended to account for the blocking of energy transfer by occluding objects? (4 marks)

c) What is a BRDF, and how is it used in global illumination algorithms? In the above equation, how could the terms in the BRDF be extended to evaluate an anisotropic material? (4 marks)

END OF EXAMINATION