Two hours

UNIVERSITY OF MANCHESTER
SCHOOL OF COMPUTER SCIENCE

Computer Graphics and Animation

Date: Thursday 26th January 2012
Time: 09:45 - 11:45

Please answer any THREE Questions from the FIVE questions provided

Each question is worth 20 marks

For full marks your answers should be concise as well as accurate.
Marks will be awarded for reasoning and method as well as being correct.

This is a CLOSED book examination

The use of electronic calculators is NOT permitted
1.
a) i) Digital compositing is used extensively in the production of 3D computer animated movies and in films that use CGI special effects. Give three advantages that compositing brings to the movie production pipeline.

(3 marks)

ii) In a 2½D rendering system what does the mask (or matte) specify?

(1 mark)

iii) The Over operator is typically used for digital compositing with an eight-bit matte:

\[
\begin{align*}
F_{\text{over}}B &= \alpha_F (1 - \alpha_B) + \alpha_B \\
C_{\text{over}} &= \frac{\alpha_F C_F + (1 - \alpha_F) \alpha_B B}{\alpha_F + (1 - \alpha_F) \alpha_B}
\end{align*}
\]

Where \( F \) is the foreground image, \( B \) is the background image, \( C \) is the colour of a pixel in the image, and \( \alpha \) is the eight-bit matte for that image.

Image X below contains a single triangle. The colour of each pixel in the triangle is dark grey – red, green, blue components are \((0.2, 0.2, 0.2)\). The alpha value of each pixel is 0.2. Image Y below also contains a single triangle. The colour of each pixel in the triangle is light grey – red, green, blue components are \((0.8, 0.8, 0.8)\). The alpha value of each pixel is 0.8. If the two images are composited, the triangles will exactly overlap.

Using the information that you know about Image X and Image Y, demonstrate that the Over operator is not commutative.

(6 marks)

(Question 1 continues on the following page)
(Question 1 continues from the previous page)

b)  
i) A key principle of the RenderMan architecture introduced by Pixar is the separation of the modelling domain from the rendering domain. Explain why this is a good approach for a scene description language.  

(2 marks)

ii) What other features of RenderMan make it a popular choice for the rendering system in movie production.  

(3 marks)

iii) Discuss how the current features in GPU hardware and shading languages could allow RenderMan compliant renderers to increase rendering performance by making use of the GPU.  

(5 marks)

Total: 20 marks

[PTO]
2.

a) Euler Angles is one method of representing rotation in a computer animation system. Describe the Euler Angles representation and give an advantage of the representation that makes Euler angles a popular choice in computer animation systems.

(3 marks)

ii) Explain the term gimbal lock and why this is a disadvantage of the Euler Angles representation.

(2 marks)

b) Quaternions are an alternative representation of rotation used in computer animation. Describe this representation of rotation, showing how a rotation through an angle $\theta$ about an axis $(x,y,z)$ is represented in quaternion form.

(3 marks)

ii) Given a point $\mathbf{P}$ on an object, give the equation that rotates the point using a quaternion $\mathbf{q}$, explaining the terms in the equation.

(2 marks)

iii) A disadvantage of quaternions is that it is difficult to represent them in a clear way in a user interface within a computer animation system. Explain how such software can combine Euler Angles and quaternions to provide the animator with a user interface for specifying and animating rotations.

(3 marks)

iv) Spherical linear interpolation is often used to perform the interpolation between two quaternions $\mathbf{q}_1$ and $\mathbf{q}_2$ specified at keyframes within an animation. Why may it be more desirable to interpolate between quaternions $\mathbf{q}_1$ and $-\mathbf{q}_2$? Include in your answer a method of choosing between using $\mathbf{q}_2$ and $-\mathbf{q}_2$.

(5 marks)

v) Computer animation systems usually convert quaternions to matrices before rendering an object with the new orientation. Why doesn’t gimbal lock occur when using this method?

(2 marks)

Total: 20 marks
3.
a) A computer animation system allows the animator to animate hierarchical models, such as human figures, using forward kinematics (FK) or inverse kinematics (IK).

i) What is the main difference between the two methods? (1 mark)

ii) An animator is asked to animate the walking motion of a dinosaur’s legs and the movement of its tail. For each motion state which method (FK or IK) you would recommend and why you have chosen the particular method. (2 marks)

iii) Why is a computer animation system that uses a hierarchical representation of a character to be animated helpful to the animator? (2 marks)

iv) Describe the IK algorithm, including in your answer the information that is related by the Jacobian matrix. (5 marks)

b)
i) A computer animation system uses parametric interpolation to create motion graphs that control the animation of objects. Explain what parametric interpolation is and why it is suitable for computer animation software. (4 marks)

ii) Bezier curves are often used in computer animation systems. One problem with these curves is that they do not have arc length parameterization. Explain what this means and describe the problem it creates in a computer animation system. (3 marks)

iii) Briefly described how the computer animation system solves the arc length parameterization problem. (3 marks)

Total: 20 marks
4.

a) A developer is required to produce a human hair modelling and rendering module in a computer animation system. It will allow different hair styles to be applied to a human character. A hair model is planned with up to half a million cut-able and distortable hairs.

i) In the user interface the developer plans to use half a million wire-frame control hairs. Explain why, in an interactive animation system, this may be inappropriate.

(2 marks)

b) The following four techniques are proposed as alternatives to the wire-frame control hairs. Briefly explain each technique, describing which hair styles or features it would be appropriate for and a problem with the method.

i) Using 2D texture maps for specific areas of hair (3 marks)
ii) Volumetric rendering of particles to look like hair strands (3 marks)
iii) Texture mapping using a 2D distorted card system (3 marks)
iv) A simple mass-spring model for each hair (3 marks)

c) Explain the process of using key hairs in order to speed-up the interaction and rendering time. In your discussion consider how many key hairs should be used for the 1/2 million hairs proposed, and also discuss how many control vertices may be needed.

(4 marks)

d) Give two modifications to the key hairs method you would make to allow it to be used to model and animate beards, explaining why the modifications are needed.

(2 marks)

Total: 20 marks
5.

a) Give a brief description of how optical motion capture systems work. (3 marks)

b) What are the advantages and disadvantages of optical motion capture systems? (3 marks)

c) One strategy for novel motion synthesis is to construct statistical models from motion capture data. What is the main idea behind these methods? What are their limitations? (3 marks)

d) What is a Motion Graph? (3 marks)

e) Describe the basic idea and the four main steps for constructing a motion graph from a database of motion capture clips. (6 marks)

f) What is a common problem when animating characters using motion capture data? Suggest a computer graphics technique that can be used (and briefly describe how) to overcome this problem. (2 marks)

Total: 20 marks

END OF EXAMINATION PAPER