Closed Book Examination

COMP60321

Two hours

UNIVERSITY OF MANCHESTER
SCHOOL OF COMPUTER SCIENCE

M.Sc. in Advanced Computer Science

Computer Animation

Wednesday 28th January 2009

Time: 14:00 – 16:00

Please answer any THREE Questions from the FIVE questions provided

Each question is worth 20 marks

The use of electronic calculators is permitted provided
they are not programmable and do not store text
1. a) List and describe three of the twelve principles of traditional animation that are also commonly used in computer animation. (3 marks)

What principle of traditional animation has the artist used in the key frame of Donald Duck below? (1 mark)

b) Digital compositing attempts to combine multiple 2D images of 3D scenes so as to approximate the visibility of the combined scenes. Describe a simple 2½D rendering method that can be used to composite two images using a one-bit occlusion mask. (3 marks)

c) What improvements can be made to the compositing process if you use an eight-bit matte instead of a one-bit occlusion mask? (2 marks)

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

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

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)

d) The Over operator is one of many methods that can be used to combine images. The simplest operator is Add, every pixel in image X is added to its corresponding pixel in image Y. Thus:

\[ O \text{ (output image)} = X + Y \]  \hspace{1cm} (equation 1)

You have been asked to develop a Mix operator that will produce the weighted, normalized addition of two images. In other words, the two images are averaged together, usually with one of the images contributing a larger percentage to the resultant image. What formula could you use to represent the Mix Operator? Use the same notation as in equation 1. (Hint: think about how the Over operator combines values). (5 marks)
2. a) Euler Angles is one method of representing rotation in computer animation systems. Describe the Euler Angles representation and indicate how a point P on an object can be rotated in this representation (you do not need to give complete rotation matrices). (4 marks)

Explain the term *gimbal lock* and describe why this is a disadvantage of the Euler Angles representation. (2 marks)

Describe how a computer animation system can interpolate from one orientation to another using Euler Angles. Include in your answer advantages and disadvantages of the technique. (4 marks)

b) Quaternions are another model of rotation used in computer animation. Describe quaternions showing how an orientation is represented using quaternions. Give two advantages of quaternions over Euler Angles. (3 marks)

Given a point \( P \) on an object and a quaternion \( q \), give the formula for rotating the point by the quaternion, explaining the terms in the formula. (1 mark)

A disadvantage of quaternions is that it is difficult to represent them in a user interface in computer animation software. Explain how such software can combine Euler Angles and quaternions to provide the animator with a user interface. (3 marks)

Explain why, when interpolating between two quaternions \( q_1 \) and \( q_2 \), it may be more desirable to interpolate between quaternions \( q_1 \) and \( -q_2 \). (3 marks)
3. Forward kinematics (FK) and inverse kinematics (IK) are two techniques used to animate hierarchical figures in computer animation.

   a) What is the main difference between the two techniques? (1 mark)

   b) Explain why hierarchical transforms are used when rotating the joints of a hierarchical figure. Use a simple model of a human leg in your answer and explain what extra work the animator would need to do if hierarchical transforms were not used. (4 marks)

   c) Hierarchical models are often represented internally within a computer animation system using a tree of nodes and arcs. Explain what information is stored in a node and arc in this representation. (4 marks)

   d) Describe an algorithm that traverses the hierarchical representation so that the animation system can render the hierarchical figure. (5 marks)

   e) What information is related by the Jacobian in the IK technique and how is this information used by the IK algorithm? (2 marks)

   f) You have been asked to develop a tool to assist the animator in animating walk cycles of multi-legged creates such as humans or spiders for example. Describe how the IK technique can be used and combined with other animation techniques in such a tool, and what input would be required from the animator when using the tool. (4 marks)

4. a) Explain the use of a particle system within an animation system. Include in your description:

   i) The common states that are stored with each particle (3 marks)

   ii) The five steps involved in the life cycle of a particle (5 marks)

   iii) The application of physics equations to models of a particle (2 marks)

   b) Explain how you may render a particle system to mimic a flame or explosion, and describe in particular how particles can be used to render a sparkler with trails. (5 marks)

   c) A researcher wants to use a particle system to model fractures and breaks during a simulated earthquake by making all particles represent a clump of soil. These would then be connected before being split by Newton’s attraction and repulsion forces. Explain why this may be an inefficient solution. (2 marks)

   Describe an alternative solution that may solve this problem for the researcher. (3 marks)
5. a) What is the main difference between the dynamics and kinematics animation techniques? (1 mark)

A particle system considers only the properties of points. What additional information about an object is considered if points are to be extended to rigid bodies for use in a rigid body simulator? (3 marks)

Explain how the forces acting on a body are used to determine the new position of the body in a rigid body simulator. Comment on the accuracy of the technique. (5 marks)

Name two techniques to calculate the response to a collision between rigid bodies. (1 mark)

b) Describe and compare magnetic and optical motion capture techniques. Give details of the data produced by the techniques, when such techniques would be used and the problems of data capture associated with each method. (6 marks)

Assuming the 3D positions of the markers attached to an actor have been reconstructed from a motion capture session, describe a problem that might occur when mapping the data to a character in a computer animation system. Give a solution to the problem. (2 marks)

An animator is required to use motion capture data in a computer game to animate a character playing tennis. Describe a post processing technique the animator could use to assist in creating animation for the game. (2 marks)

END OF EXAMINATION