Two hours

UNIVERSITY OF MANCHESTER
SCHOOL OF COMPUTER SCIENCE

M.Sc. in Advanced Computer Science

Computer Animation

Friday 18th January 2008
Time: 09:45 – 11:45

Please answer any THREE Questions from the FIVE questions provided
Each question is worth 20 marks
This is a CLOSED book examination

The use of electronic calculators is permitted provided they are not programmable and do not store text
1. a) The computer animation pipeline consists of the following steps:
   - Story
   - Storyboard
   - Modelling
   - Animation
   - Shading
   - Lighting
   - Rendering
   - Post Production

   i) Describe storyboards, giving details of what they are used for and what is required of a storyboard to be of maximum use to the animator. (3 marks)

   ii) Describe the tools and techniques that would typically be used by the animator to complete the modelling and animation steps. (6 marks)

   iii) In the lighting step several different lighting strategies are used. Describe three lighting strategies giving details of the effects that can be achieved with each strategy. (3 marks)

b) The RenderMan architecture was introduced by Pixar as an efficient and effective way to produce very high-quality images. It used a new rendering algorithm called micro-polygonalization in which geometric primitives were broken into small (sub-pixel) sized polygons before being considered for shading. Over the years, this style of "micropolygon-based" renderer has come in and out of favour as the best choice for doing high-quality rendering.

   i) What are the advantages and disadvantages of current micro-polygonalization techniques? (1 mark)

   ii) Discuss how current features in GPU hardware and shading languages could make micropolygon rendering the continued choice for high quality rendering. (7 marks)
2. a) i) A computer animation system may use Euler angles and quaternions to represent rotation. Describe these two representations of rotation and explain how a rotation in each representation can be applied to the vertices of an object to orient it in 3D space. (6 marks)

ii) Explain the term *gimbal lock*, giving an example of a rotation that causes gimbal lock to occur and explaining why it is a disadvantage for the animator. Suggest a feature that could be added to computer animation software to avoid gimbal lock (other than using quaternions). (4 marks)

b) An animation system allows the orientation of an object to change over time by interpolating from one orientation to another. The animator specifies these key orientations using Euler angles but the animation system uses quaternions internally within its interpolation algorithm.

i) Show how the two input Euler angle orientations are converted to quaternions. Assume the two input orientations are \((x_1, y_1, z_1)\) and \((x_2, y_2, z_2)\) where \(x_1\) is the rotation around the X axis for the first key orientation, and so on. (3 marks)

ii) Give an algorithm that interpolates between the two quaternions. Your algorithm should produce 20 intermediate orientations and each intermediate orientation should be passed to the rendering software as a matrix. You do not need to give matrix formulas and can assume that functions such as quaternionToMatrix(q) exist. (5 marks)

iii) Explain why gimbal lock doesn’t occur in the above animation system even though the animation system converts a quaternion to matrices prior to rendering. (2 marks)

3. a) i) Hierarchical articulated objects, such as human characters, are often animated in computer animation systems. Describe how such hierarchical objects are stored internally in a computer animation system. Include in your answer details of the geometric transforms that are stored in the system. (6 marks)

ii) Why is such a system useful to the animator when animating the human character? Explain what extra work the animator would have to do if the animation system did not use a hierarchical representation when animating objects such as human characters. (4 marks)

b) Assume a human character’s arm is being animated. The arm contains an upper arm model (the root), a forearm model (a child of the root) and a hand model (a child of the forearm).

What sequence of transformations is applied by the animation system to render the hand geometry? (4 marks)

c) The animator may use Inverse Kinematics (IK) to animate the human character. Describe the IK technique. Include in your answer a description of the Jacobian matrix used in the IK algorithm and a problem with the IK technique. (6 marks)
4. a) i) Explain the term Persistence of Vision and the purpose of motion blur in computer animation. 
   (2 marks)

   ii) There are two common techniques for creating motion blur within computer animation:

   • Convolution with a point spread function.
   • Temporal supersampling.

   Outline the implementation of these two techniques.  
   (6 marks)

   iii) Give the main disadvantage of using these two techniques and provide an alternative method that could be used to reduce this disadvantage.  
   (3 marks)

b) i) Briefly describe Non-Uniform Rational B-Splines (NURBS) and give two different examples of their use within computer animation systems.  
   (4 marks)

   ii) Give two disadvantages of NURBS and describe two advantages of the RenderMan subdivision surface technique that can be used instead of NURBS.  
   (2 marks)

   iii) A researcher wishes to use subdivision surfaces for a character's face to represent blotches and other skin defects. Discuss whether this is a suitable technique giving reasons why it may work or not. Give one other alternative method.  
   (3 marks)
5. a) i) What is the main difference between dynamic simulation and kinematic techniques when animating rigid bodies? Why might the animator use dynamics and give an example of what might be animated with this technique. (2 marks)

ii) Describe the update cycle used in a rigid body dynamics simulator. Include in your description details of the information that the animator must supply as input to the simulator. (5 marks)

iii) How might an animation system allow the animator to modify the motion generated by the simulator once the simulator has finished? (3 marks)

b) i) Optical motion tracking is a popular technique used in motion capture. Give a brief description of this technique. (2 marks)

ii) Assuming that data representing an actor’s movements have been captured, and the markers’ 3D positions have been reconstructed, describe how the data is mapped on to a character within a computer animation system. Include a description of a problem that may occur and how it is solved. (4 marks)

iii) A common problem with characters animated with motion capture data is that their feet penetrate through the floor. Using techniques from other areas of computer animation develop a technique that can be applied to the animated character to eliminate this problem. (4 marks)