Computer Animation

Date: Wednesday 27th January 2010
Time: 09.45 – 11.45

Please answer any THREE Questions from the FIVE questions provided
Each question is worth 20 marks

The use of electronic calculators is NOT permitted
1. a) i) Disney animators introduced twelve principles of traditional animation that can also be applied to computer animation. Two of these principles are Timing and Arcs. Describe these two principles and the effects an animator can achieve with them. (4 marks)

ii) The principle of Anticipation is often used to create a “thinking character” where a character’s actions are driven by its thoughts. Explain how anticipation can be used to create such a character, giving an example of an action a character may perform that demonstrates anticipation. (3 marks)

iii) Describe an action where anticipation would not be used by the animator. (1 mark)

b) Storyboards and Lighting are two stages in the animation production pipeline.

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) In the lighting stage several different lighting strategies are used. Describe Key and Fill lights explaining the effect they are used for and how they should be positioned in the scene. (4 marks)

c) i) A key principle of RenderMan is the separation of the modelling domain and the rendering domain. Explain why this is a good approach for a scene description language. (2 marks)

ii) You have access to a RenderMan compliant renderer. Outline how you would set about creating a hair model. Include information on which RenderMan primitives are appropriate to use. (3 marks)
2. a) i) Euler Angles is one method of representing rotation in a computer animation system. Describe the Euler Angles representation. (2 marks)

ii) Explain the term *gimbal lock* and explain why this is a disadvantage of the Euler Angles representation. In your answer give an example of a rotation that can lead to gimbal lock. (2 marks)

b) i) Quaternions are an alternative representation of rotation. A quaternion is of the form

\[ q = [s, v] \]

where \( s \) is a scalar and \( v \) is a vector. If the quaternion \( q \) is to represent a rotation through an angle \( \theta \) about an axis \((x, y, z)\), give the equations for \( s \) and \( v \) in the quaternion \( q \). (2 marks)

ii) Given a point \( P \) on an object, give the equation that rotates the point using the quaternion \( q \), explaining the terms in the equation. (2 marks)

c) An animation system allows the orientation of an object to change over time by interpolating from one key 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 two quaternions. Your algorithm should produce 30 intermediate orientations and each intermediate orientation should be passed to a rendering function as a matrix. You do not need to give matrix formulae and can assume that functions such as *quaternionToMatrix(q)* exist. (5 marks)

iii) Explain why, when interpolating between two quaternions \( q_1 \) and \( q_2 \), it may be more desirable to interpolate between quaternions \( q_1 \) and \(-q_2\). (4 marks)
3. a) A hierarchical model, such as a human figure, is represented internally in a computer animation system using a hierarchy of nodes and arcs.

i) Explain why this representation is used rather than simply treating each limb of the human figure as an independent object. (2 marks)

ii) What information is stored in a node and in an arc in this internal representation? (4 marks)

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

b) i) For an animator manipulating a human figure in a computer animation system, how does the Inverse Kinematics (IK) method of animating a hierarchical figure differ from the Forward Kinematics (FK) method? (1 mark)

ii) What information is related by the Jacobian in the IK algorithm? (1 mark)

iii) Briefly describe the IK algorithm. Include in your answer a problem that can arise with this method. (4 marks)

c) Describe how IK and FK can be combined to animate a human figure riding a bike. In your answer describe how various objects would be animated. What other animation technique would be useful in this example? (3 marks)
4. a) A popular method for simulating cloth dynamics is to use the mass-spring model. The following diagram shows a simple layout for connecting four cloth vertices v1, v2, v3 and v4 with springs.

![Diagram of mass-spring model]

i) Describe clearly which springs are the Structural Springs and which are the Shear Springs and explain their purpose in the mass-spring model.

(4 marks)

ii) Explain how this model could allow extreme bending and folding to occur. Include a diagram if necessary.

(2 marks)

iii) Describe an extension to the mass-spring model that would prevent this extreme bending from occurring.

(2 marks)

iv) For a large mesh defining a cloth garment, explain why collision detection is important. Describe the technique of using hierarchical bounding boxes to make this process more efficient. Consider the case when a piece of the cloth intersects and ends up inside another object and describe one method for recovering from this situation.

(5 marks)

b) i) An animator wants to use Implicit Surfaces to model a character’s face, body and clothing. Describe implicit surface modelling and show mathematically how you can combine two implicit surfaces.

(3 marks)

ii) Implicit surfaces may offer a fast collision detection method. Explain why this may be the case. Also give two comments why modelling and animation may prove difficult using implicit surfaces and give one alternative solution.

(4 marks)
5. a) i) Explain why rigid body simulation is used by animators and describe how it differs from the kinematic techniques. Give examples of what may be animated with the rigid body simulator. (3 marks)

ii) A particle system considers only the properties of points. These properties include position, linear velocity and mass. 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)

iii) Describe the update cycle of a rigid body simulator and comment on the accuracy of the algorithm. (5 marks)

iv) An animator may wish to manually modify the motion generated by a rigid body simulator within an animation system. For example, small changes to an object’s motion may be needed to make it come to rest slightly closer to the main character. What features would you add to the animation system to allow the animator to do this efficiently? (3 marks)

b) i) Flocking systems are often used to animate large groups of animals. Explain why particle systems are not sufficient for this and describe the characteristics of motion seen in flocking systems that is not seen in particle systems. (4 marks)

ii) Describe a method that allows the animator to control the overall motion of the flock so that the flock can be used in a predictable manner in a scene from an animated film. (2 marks)