CS_217
COMPUTER GRAPHICS I: IMAGE PROCESSING AND SYNTHESIS
(*Attempt 2 questions out of 3*)

Question 1

(a) Given a 3x3 sub-image of pixels:

$$I_{ij} = \begin{bmatrix} p_{11} & p_{12} & p_{13} \\ p_{21} & p_{22} & p_{23} \\ p_{31} & p_{32} & p_{33} \end{bmatrix}$$

and a 3x3 filter kernel:

$$M_{ij} = \begin{bmatrix} m_{11} & m_{12} & m_{13} \\ m_{21} & m_{22} & m_{23} \\ m_{31} & m_{32} & m_{33} \end{bmatrix}$$

what is the equation for calculating the new intermediate value at pixel p_{22}?

Given the following 5x5 image (grey-level 0-255 image):

$$\begin{bmatrix} 100 & 110 & 120 & 130 & 140 \\ 120 & 120 & 130 & 130 & 140 \\ 130 & 140 & 150 & 150 & 160 \\ 140 & 150 & 150 & 160 & 170 \\ 150 & 160 & 170 & 180 & 190 \end{bmatrix}$$

and 3x3 filter kernel:

-1	-1	-1
-1	8	-1
-1	-1	-1

what is the result of applying the filter kernel to the image using the process of convolution? Your answer should give the intermediate values for all possible pixels, indicate what choices could be made at pixels the filter cannot be operated on, calculate the maximum and minimum intermediate values, show the normalisation equation, and use the normalisation equation to create the final pixel values.

What differences occur when a 4x4 filter is used, and when a 5x5 filter is used? What difference is made when a colour image needs to be convolved?

Name some applications of convolution. What is a hi-pass filter and what is a low-pass filter and when should they be used? Identify the filter given in the question.

[**16 marks**]

(b) How does the recursive flood fill algorithm work? You should mention boundary and interior defined objects, 4-connected and 8-connected pixels, and give pseudo-code for the algorithm for one of the cases.

[**5 marks**]

(c) State the two-dimensional line equation. From this equation derive the basic line incremental algorithm for the situation where the slope m lies in [-1,1] and use it to demonstrate the drawing of the line (2,4) to (6,6).

[**4 marks**]

Question 2

(a) Show, using diagrams, how each of the effects of *shadows*, *reflections*, and *transparency* can be achieved in ray tracing. Describe what recursive ray tracing is. Why does recursive ray tracing lead to *ray explosion*? How are objects defined, and how are ray-object intersections calculated? What is needed to calculate the colour according to the light source at a known intersection point?

[**8 marks**]

(b) Explain, with an example, why ray tracing can be computationally expensive. (You should include some example calculations). How can bounding volumes lead to better computational times? (Again use your example to demonstrate by showing some calculations). Discuss a hierarchy of bounding volumes constructed manually and the automatic method of organising a scene using an *octree*. In your discussion, you may wish to mention, to what depth is an octree created, how the octree accelerates ray tracing, how it can be used to ray trace a scene, what benefits the octree offers and the complexity of the ray-intersection algorithm when an octree is employed.

[**8 marks**]

(c) Which applications result in a three-dimensional volume of data? Discuss either blobby modelling or distance fields as a source of three-dimensional volume data. Describe the process of volume rendering when applied to a three-dimensional voxel data set. You may wish to include the pseudo-code for the volume rendering process in your answer. Your answer should also include the concepts of light source, transparency / opacity, attenuation of light source and sampling using trilinear interpolation.

[**9 marks**]

Question 3

(a) Using the image below, show what the results would be if we tried to display it on a bi-level device using *thresholding*. Calculate the error between the original and the bi-level images. What are the advantages and disadvantages of using such a method?

90	100	100	110	125
95	110	120	130	140

Demonstrate the results of using the *standard error-diffusion* method. Calculate the error between the original and the new image. What are the advantages and disadvantages of this method, and what extension exists that improves upon it? What feature of the standard error-diffusion process retains error in the local area? (In all cases assume a 0-255 grey-level image).

[**10 marks**]

(b) How is a histogram computed for an image and what does it represent? What effect does uniformly brightening or darkening an image have on the histogram? Describe the procedure for histogram equalisation and indicate the situations when it should be used and the effect it produces.

[**6 marks**]

(c) Write precise descriptions (½ to 1 page) about three of the following five topics:
RGB and HSV colour models;
Genetic programming for animation;
Event programming;
Linear interpolation;
Particle systems. [**9 marks**]