Computer Graphics and Image Processing
Breadth Exam

Computer Science Department
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Instructions: This is a closed-book, closed-notes exam. Answer ***all questions*** below. Show all your work on the paper provided. Make sure you write your name on each of your answer sheets, and number them in order in the upper right hand corner.

1. Hardware and 2D Graphics

A. A liquid-crystal display (LCD) has six layers: vertical polarizer, vertical grid wires, liquid-crystal layer, horizontal grid wires, horizontal polarizer, and the reflective layer. To display a dot at (x1, y1), one applies a negative voltage to the vertical grid wire x1 and a positive voltage to the horizontal grid wire y1. To display dots at (x1, y1) and (x2, y2), one can not simply apply negative voltage to the vertical wires x1 and x2 and positive voltage to the horizontal grid wires y1 and y2. Why?

B. A graphics program usually uses "event mode" as the input mode. For each event type, one needs to create an event handler (callback function) to handle the event. In openGL, can one register two callback functions for each event type? Why?

C. What is "double buffering" and why would "double buffering" avoid flickering in animation?

2. Geometric Objects and Transformations

A. What is an affine space, what is an affine transformation, and what is the relationship between affine transformations and homogeneous coordinates?

B. Using homogeneous coordinates, all the transformations in the 2D or 3D viewing transformation process can be accumulated into a single matrix. Why?

C. It is possible to use a Face table and a Vertex table to represent a 3D scene consisting of 3D polyhedra. The question is, would such a representation provide all the information we need in processing the 3D scene such as:

- Given a vertex, would you be able to find all adjacent vertices, edges, and faces?
- Given a face, would you be able to find all adjacent faces?
- Given an edge, would you be able to find all adjacent edges and faces?

D. Given the CSG representation of a 3D solid, how would you generate a wire-frame drawing of the solid, i.e., generate all the visible edges of the object?

3. Curves, Surfaces, and Animation

A. Forward differencing is the most efficient method to render a cubic parametric curve such as a Bezier curve or a B-spline curve. Why? Is this a good method though? Why or why not?

B. Bezier and B-spline curves/surfaces can be used to represent smooth objects. Can they be used to represent object with sharp corners and edges? Why or why not?

C. Interpolation is a frequently used method in computer animation to generate intermediate frames between key frames. This process is relatively simple if the shapes are defined by piecewise curves such as Bezier curves or B-spline curves. Why?

4. Image Filtering

A. You are given an image set that is *blurry*. You would like to digitally sharpen the images so that they appear less blurry. At the same time, you would like to increase the intensity of the entire image by a constant factor because the images are too dark. Explain how to do this. Formulate your answer so that there is a parameter of control over the degree of sharpening, and explain how that parameter controls the sharpening process.

B. You receive a fax via the Internet. The fax has a substantial amount of speckle noise. Explain a reasonable filtering mechanism that can remove the noise.

C. You are given a truncated JPEG image; specifically, in each 8x8 block, all of the DCT coefficients are zero *except* the first one (the DC coefficient). When this JPEG image is decoded, it appears lossy. Explain how it would appear, and explain very precisely the relationship of the truncated, lossy JPEG image to the original.

5. The Histogram

A. Define the image histogram

B. Draw the general shape of the histogram of an image that is black on the left half and white on the right half (bi-level). Now suppose the image is changed to be the image of an 8x8 checkerboard, with ½ the squares black and the other half white. How will the histogram change? Explain.

C. Draw the general shape of the histogram of an image that is too bright.

D. Show how the histogram for the image above (the one that was too bright) will change when a constant value (say 50) is subtracted from each pixel in the image.

6. Stereo Reconstruction

You are given a pinhole camera and a pinhole projector that together observe (illuminate) the same static scene. The projector is made to project a line into the scene, which is observed by the camera.

A. The camera observes a single point in 3D that is illuminated by the line. What information is necessary in order to determine the 3D Euclidean coordinates of that point? How do you use the information to calculate the 3D coordinates?

B. Assume that the camera's resolution is much higher than the projector's resolution, so that the line in the camera's image plane appears to be many pixels wide. Explain how to determine where the center of the line is.

C. Suppose you are given a second camera, but the light projector is taken away. You identify the projection of a 3D point in one camera's image plane and would like to find its (corresponding) projection in the second camera's image plane. Without constraints, this is a 2D search problem (search the second camera's entire 2D image to find the most likely corresponding point). Explain the *epipolar* constraint. How does it affect the 2D search problem? What information is necessary in order to apply it?