Q1. (1) What is an edge in an image? (2) We learned four different factors that could cause edges in an image. For each of these factors, please find and label two segments of edges caused by it in the image below. (3) What is the relation between the direction of image gradients and that of edges. (20pt = 4pt + 12pt + 4pt)

1) **What is an edge in an image?**

Edges in images refer to a boundary or a sharp change in intensity (brightness) or color values within the image. They signify notable changes in texture, brightness, or color within an image, effectively outlining the shape and boundaries of objects.

2) **Causes of Edges in Images**

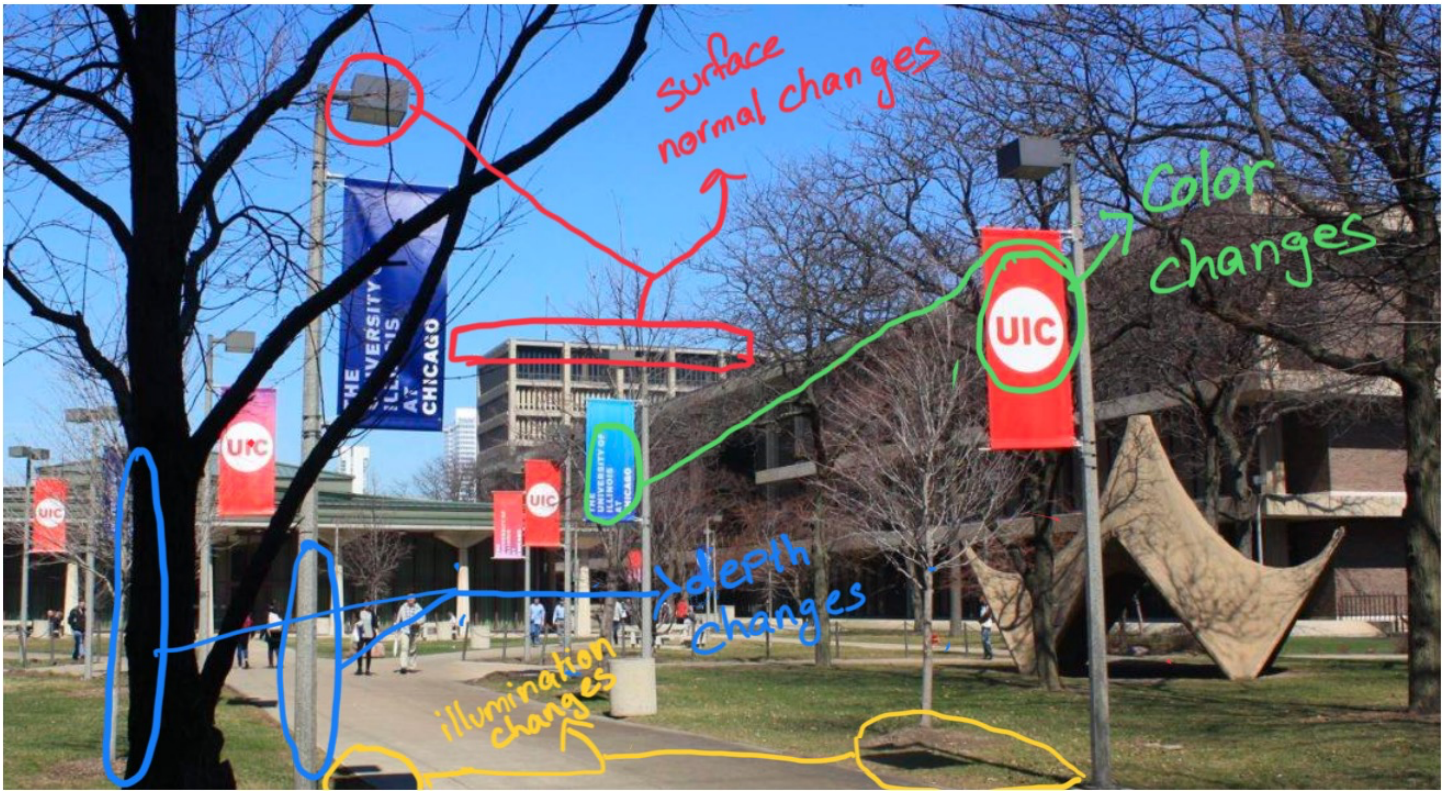
There are four primary factors that can lead to the presence of edges in images:

1. Surface normal changes: Edges are created when there are changes between distinct objects within the image, such as the boundaries of buildings and sculptures against the sky.

2. Depth Changes: Variations in surface texture, like the depth of tree bark and the depth of poles, can result in the formation of edges.

3. Illumination Changes: Edges are formed due to differences in light and shadows, as seen in the contrasting shadowed regions under trees and poles versus the sunlit areas on the pathway.

4. Color Changes: Variations in color within a scene contribute to the creation of edges, such as the transitions between the red "UIC" banners and the blue "University of Illinois at Chicago" banners.

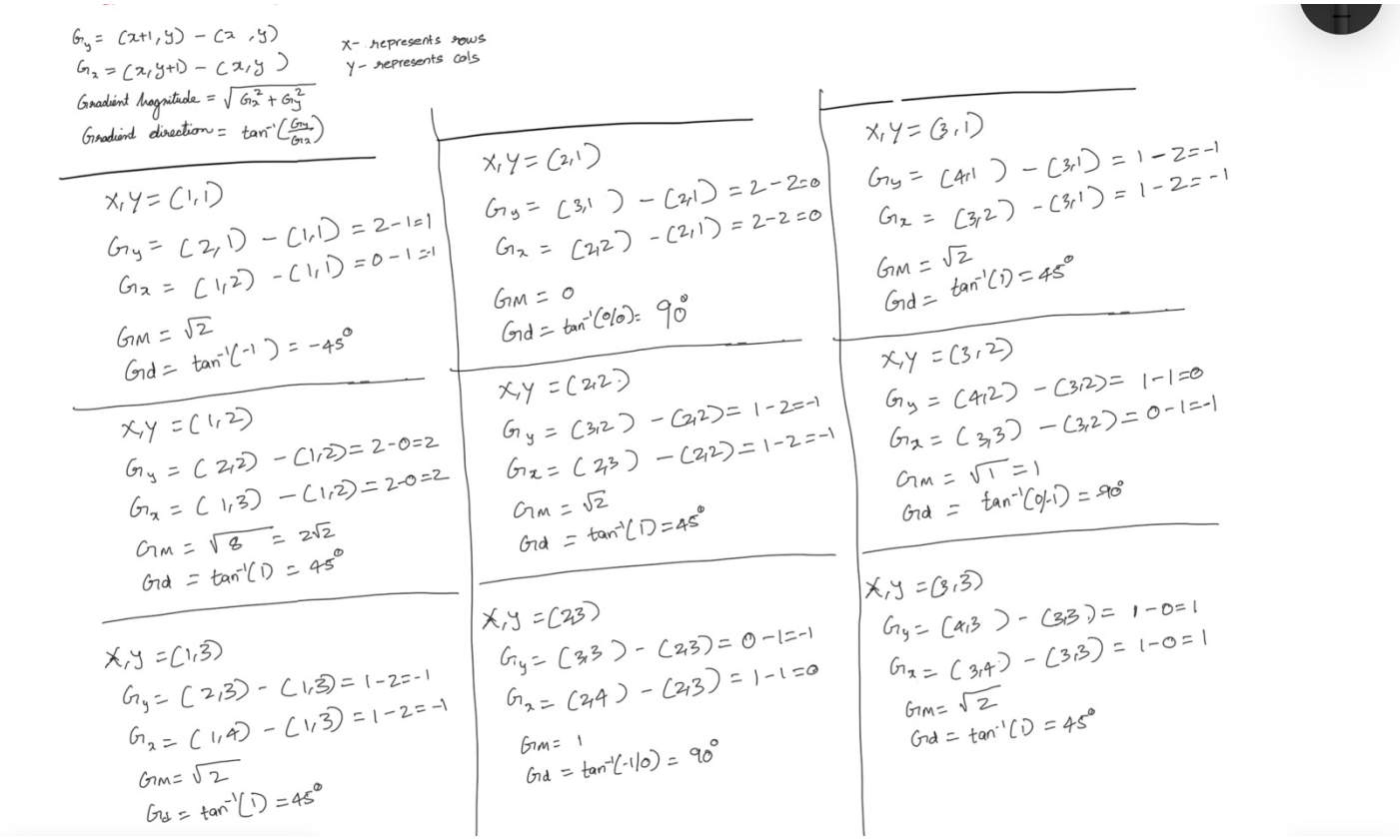


3) **What is the relation between the direction of image gradients and that of edges?**

In an image, the gradient measures the intensity change at a specific point. The direction of the gradient vector at any point is perpendicular to the edge, pointing from a lower-intensity region toward a higher-intensity region. Essentially, image gradients aid in detecting and outlining edges by highlighting these intensity transitions.

Q2. Given a 5x5 image below, calculate the gradient of each pixel in the 3x3 central region (highlighted in blue) via finite difference. For the same region, calculate the gradient magnitude and gradient direction for each pixel. You can keep the square root and any trigonometric functions in the answer. (25 pt)

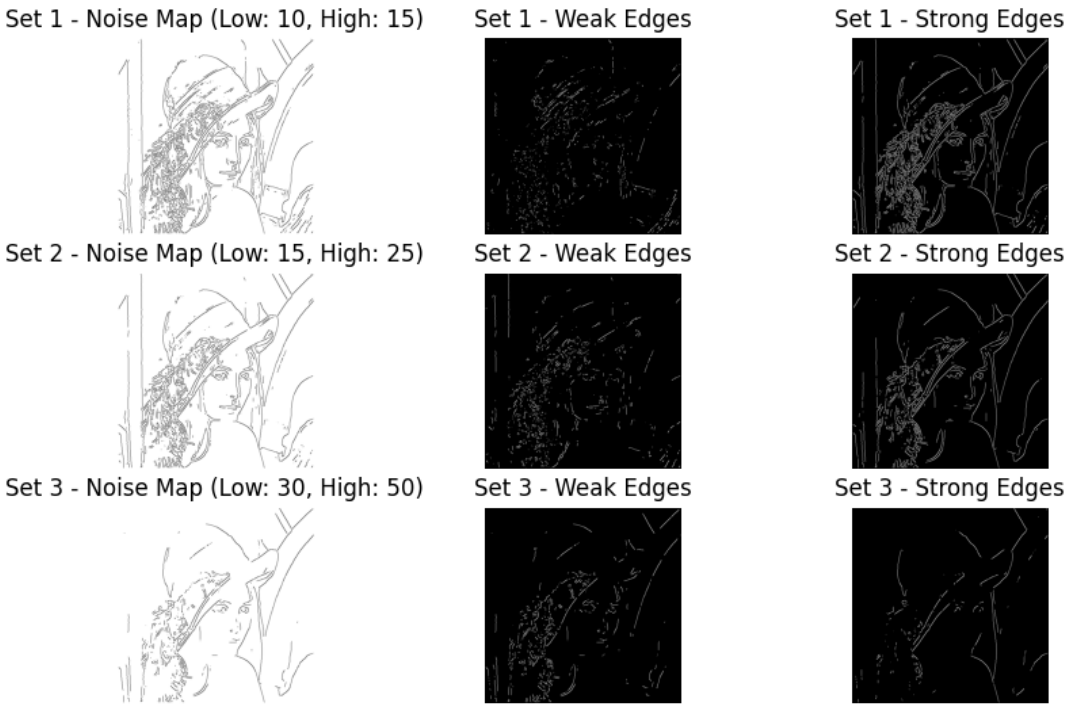
1 1 1 1 1
1 1 0 2 1
1 2 2 1 1
1 2 1 0 1
1 1 1 1 1



Q3. Why is the normal form of a line a better choice than the slope intercept form in Hough transforms for line detection? (5 pt)

The **normal form** of a line is preferred in Hough transforms over the **slope-intercept form** because it provides a bounded and uniform parameter space, enabling efficient accumulation of votes and handling of vertical lines without undefined slopes. This makes the Hough transform more robust and computationally feasible for detecting lines in various orientations

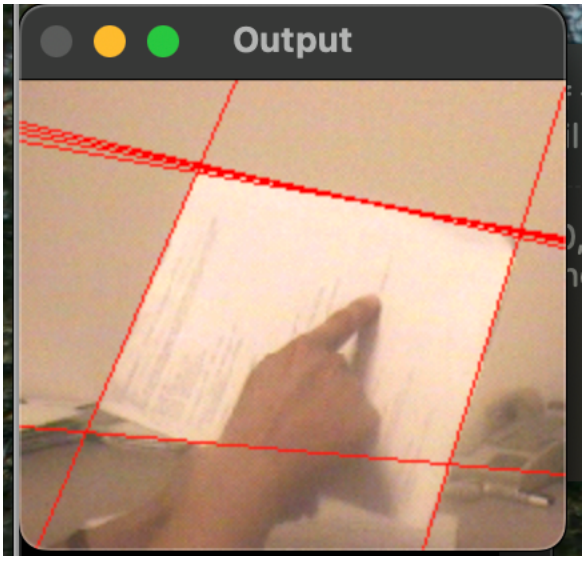
Outputs for the Programming Assignment:



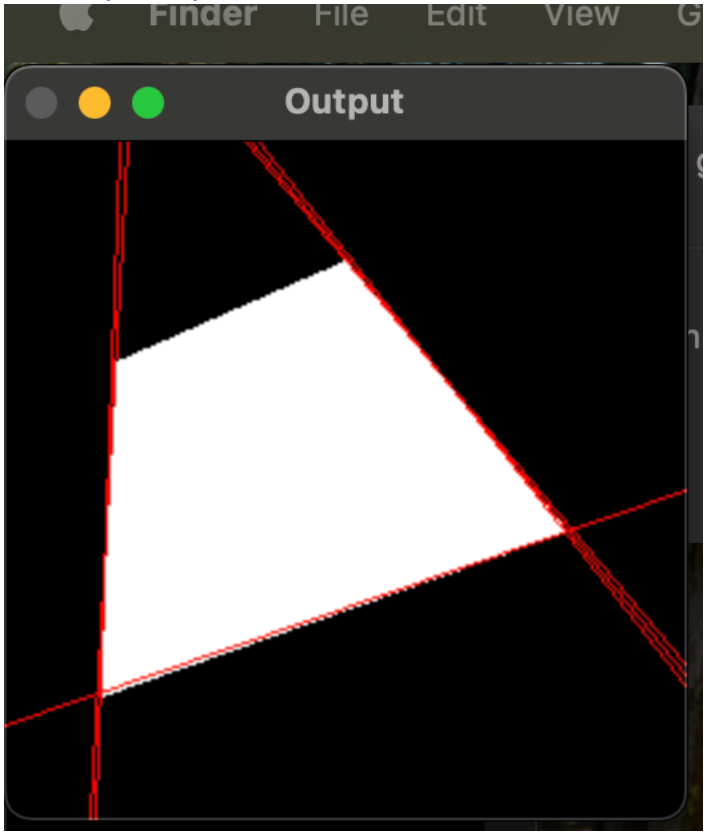
1.

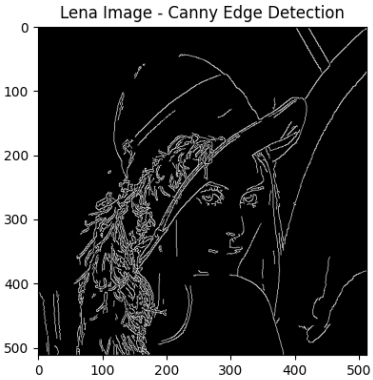
2. 

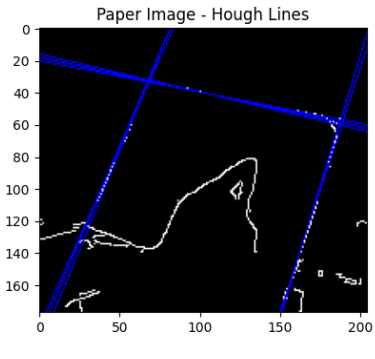
3. Paper output

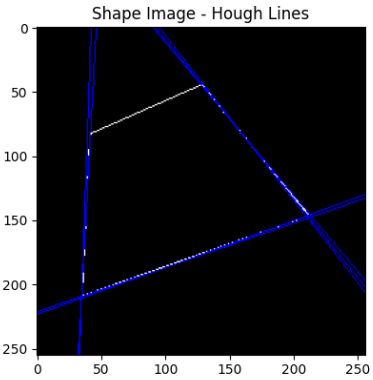
a. 

b. Shape output




Lena Image - Canny Edge Detection
0
100
200
300
400
500
0
100
200
300
400
500


Paper Image - Hough Lines
0
20
40
60
80
100
120
140
160
0
50
100
150
200


Shape Image - Hough Lines
0
50
100
150
200
250
0
50
100
150
200
250

4.