HW 03 – REPORT

소속: 정보컴퓨터공학부

학번: 20255501

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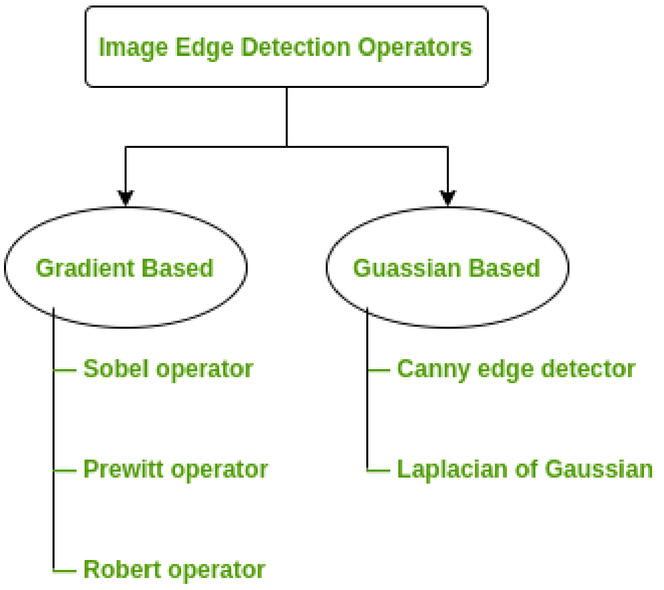
1 Introduction

1.1 Edges

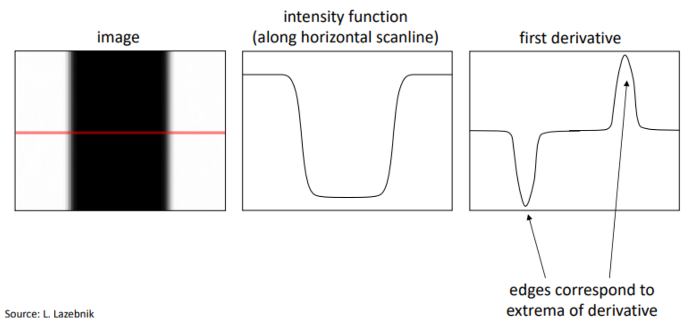
Edges are significant local changes of intensity in a digital image. An edge can be defined as a set of connected pixels that forms a boundary between two disjoint regions. There are three types of edges: Horizontal, Vertical and Diagonal edges.

1.2 Edge detection

Edge detection is an image processing technique for finding the boundaries of objects within images. It works by detecting discontinuities in brightness. These points where the image brightness varies sharply are called the edges (or boundaries) of the image. Edge detection allows users to observe the features of an image for a significant change in the gray level. This texture indicating the end of one region in the image and the beginning of another. It reduces the amount of data in an image and preserves its structural properties.



- Gradient – based operator which computes first-order derivations in a digital image like, Sobel operator, Prewitt operator, Robert operator.
- Gaussian – based operator which computes second-order derivations in a digital image like, Canny edge detector, Laplacian of Gaussian



1.3 Canny edge detection:

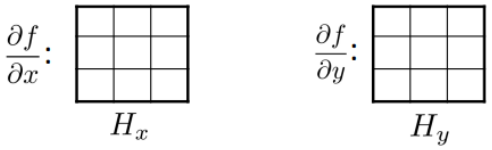
The Canny edge detector is an edge detection operator that uses a multi-stage algorithm to detect a wide range of edges in images. It was developed by John F. Canny in 1986. The Canny edge detection algorithm is composed of 5 steps:

1. Noise reduction (Gaussian filter)
2. Gradient calculation (Sobel operator)
3. Non-maximum suppression
4. Double threshold
5. Edge Tracking by Hysteresis.

1.3.1 Image gradient

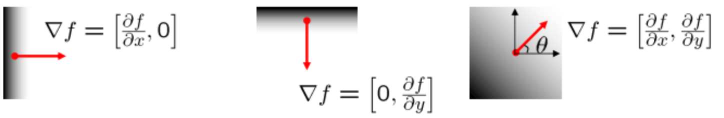
$$\frac{\partial f}{\partial x}[x, y] \approx F[x+1, y] - F[x, y]$$

How would you implement this as a linear filter?



- The *gradient* of an image: $\nabla f = \left[\frac{\partial f}{\partial x}, \frac{\partial f}{\partial y}\right]$

The gradient points in the direction of most rapid increase in intensity



The *edge strength* is given by the gradient magnitude:

$$\|\nabla f\| = \sqrt{\left(\frac{\partial f}{\partial x}\right)^2 + \left(\frac{\partial f}{\partial y}\right)^2}$$

The gradient direction is given by:

$$\theta = \tan^{-1}\left(\frac{\partial f}{\partial y} \Big/ \frac{\partial f}{\partial x}\right)$$

- how does this relate to the direction of the edge?

Source: Stev

1.3.2 Sobel operator

The Sobel operator performs a 2-D spatial gradient measurement on an image and so emphasizes regions of high spatial frequency that correspond to edges. Usually, it is used to find the approximate absolute gradient magnitude at each point in an input **grayscale** image. Sobel filtering involves applying two 3 x 3 convolutional kernels (also called filters) to an image. The kernels are usually called Gx and Gy. These two kernels detect the edges in the image in the horizontal and vertical directions.

-1	0	+1
-2	0	+2
-1	0	+1

Gx

+1	+2	+1
0	0	0
-1	-2	-1

Gy

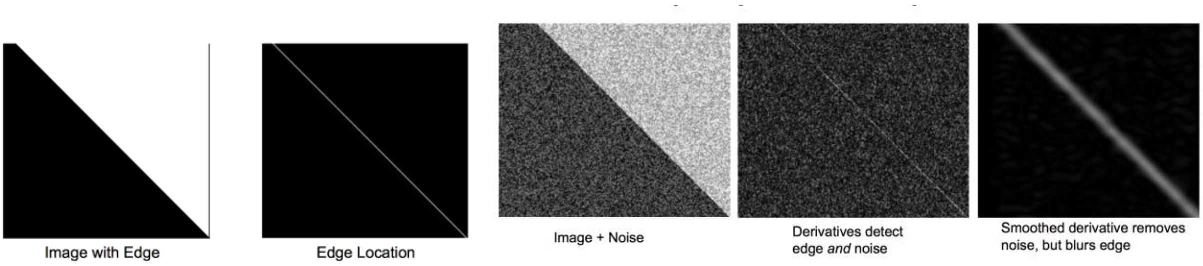
One kernel is simply the other rotated by 90°. The kernels are applied separately to the input image and then combined to find the absolute magnitude of the gradient at each point and the orientation of that gradient. The gradient magnitude is given by (output value):

$$|G| = |Gx| + |Gy|$$

Where the Gx and Gy terms are computed by multiplying each filter value by a pixel value and then summing the products together.

The angle of orientation of the edge: $\boldsymbol{\theta} = \ \textbf{arctan}\ (\boldsymbol{Gy}/\boldsymbol{Gx})$

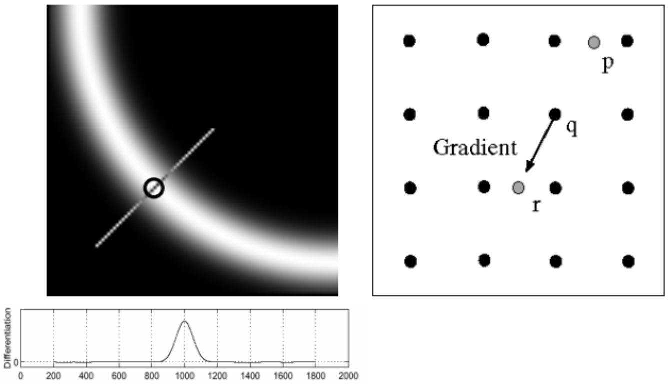
Orientation 0 is taken to mean that the direction of maximum contrast from black to white runs from left to right on the image, and other angles are measured anti-clockwise from this.



1.3.3 Edge thinning by Non max suppression

Non-Maximum Suppression (NMS) is a technique used for selecting one entity out of many overlapping entities. Non-maximum suppression is often used along with edge detection algorithms. The image is scanned along the image gradient direction, and if pixels are not part of the local maxima, they are set to zero. This has the effect of suppressing all image information that is not part of local maxima.

Gradient non-maximum suppression is an edge thinning algorithm that extracts thin contours of objects in an image. The output of this image processing algorithm is contouring curves that are one pixel wide. Non-maximal suppression is a post-processing step of gradient edge detection operators. The principle is simple: the algorithm goes through all the points on the gradient intensity matrix and finds the pixels with the maximum value in the edge directions.



- Check if pixel is local maximum along gradient direction
  - requires *interpolating* pixels p and r

Step 1: Apply an edge detector such as: Prewitt or Sobel.

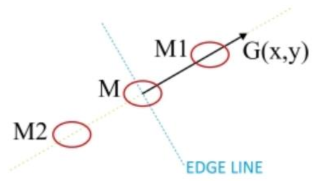
Step 2: For each pixel in the image, we select two of its neighbors based on the direction of the gradient.

Step 3: Compare the strength of the current pixel with the other two as in the image below.

$$|G(M2)| < |G(M)| >= |G(M1)|$$

If the pixel's intensity is lower than one of its two neighbors, suppress it by making it zero (black/background). Otherwise, leave it unchanged and continue with the next one.

1.3.4 Thresholding edges



Significant edge neighbors based on gradient direction

The double threshold step aims at identifying 3 kinds of pixels: strong, weak, and non-relevant.

Strong pixels are pixels that have an intensity so high that we are sure they contribute to the final edge. Weak pixels are pixels that have an intensity value that is not enough to be considered as strong ones, but yet not small enough to be considered as non-relevant for edge detection. Other pixels are considered as non-relevant for the edge.

1.3.5 Edge tracking by hysteresis

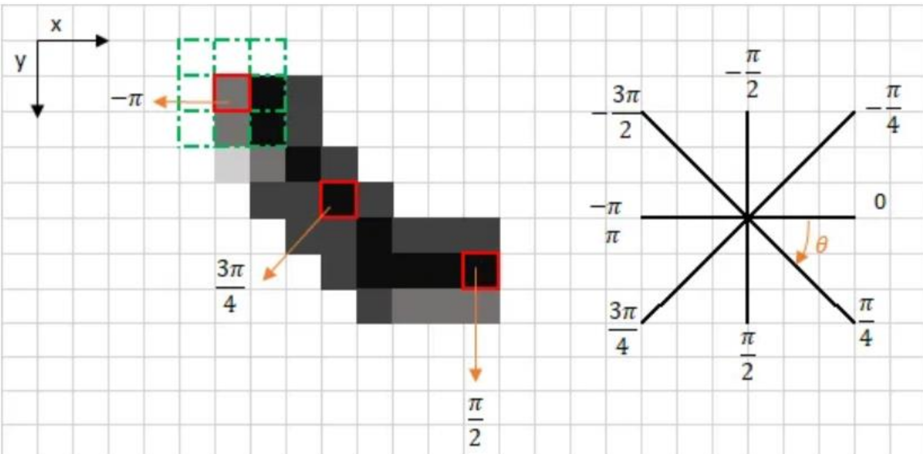
This stage decides which are all edges are really edges and which are not. For this, we need two threshold values. Hysteresis counters streaking by setting an upper and lower edge value limit. Considering a line segment, if a value lies above the upper threshold limit it is immediately accepted. If the value lies below the low threshold it is immediately rejected. Points which lie between the two limits are accepted if they are connected to pixels which exhibit strong response. The likelihood of streaking is reduced drastically since the line segment points must fluctuate above the upper limit and below the lower limit for streaking to occur. Canny recommends the ratio of high to low limit be in the range two or three to one, based on predicted signal-to-noise ratios.

2. Program description

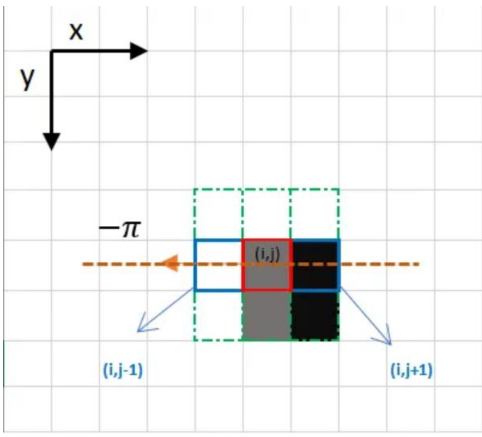
2.1 Noise reduction

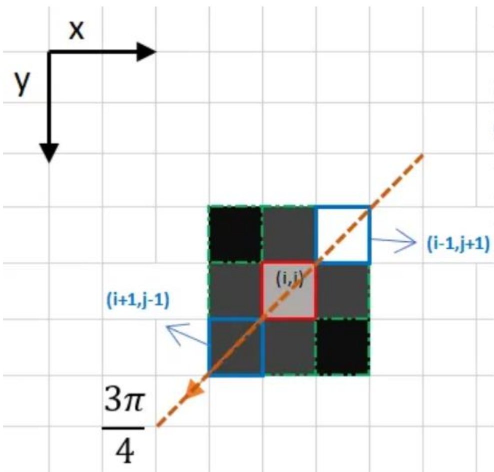
2.2 Finding the intensity gradient of the image

2.3 Non-Maximum Suppression

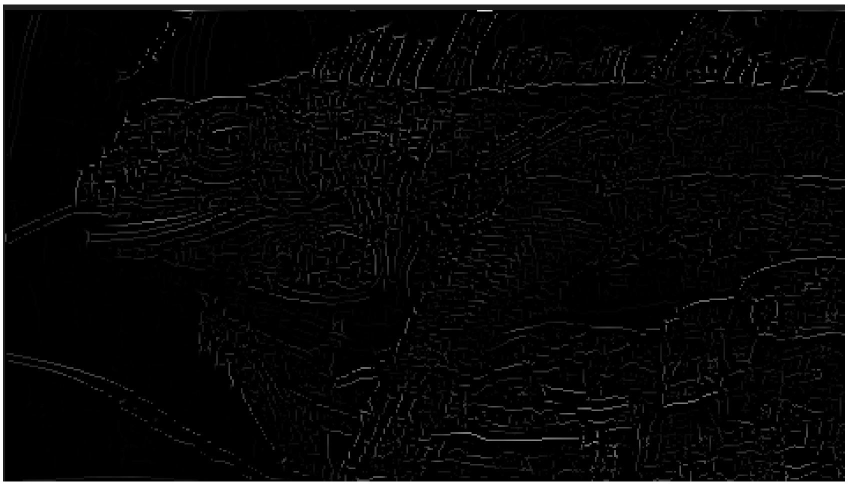


The upper left corner red box present on the above image, represents an intensity pixel of the Gradient Intensity matrix being processed. The corresponding edge direction is represented by the orange arrow with an angle of -pi radians (+/-180 degrees). The edge direction is the orange dotted line (horizontal from left to right). The purpose of the algorithm is to check if the pixels in the same direction are more or less intense than the ones being processed.





- Create a matrix initialized to 0 of the same size of the original gradient intensity matrix.
- Identify the edge direction based on the angle value from the angle matrix.
- Check if the pixel in the same direction has a higher intensity than the pixel that is currently processed.
- Return the image processed with the non-max suppression algorithm.



2.4 Double threshold

2.5 Edge Tracking by hysteresis

3. Conclusion

Through this assignment we learned about Cany edge detection and how to apply it to images.s