Volume 3, Issue 8, August 2013 ISSN: 2277 128X

International Journal of Advanced Research in Computer Science and Software Engineering

Research Paper

Available online at: www.ijarcsse.com

Empirical Study of Various Edge Detection Techniques for Gray Scale Images

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Abstract- Edge Detection is an important task in Digital Image Processing. It is important to point out true edges because every technique is sensitive to different type of edges. So it is important to choose an edge detector that is best suited for the application. In this paper we study the various existing edge detection techniques.

Keywords- Edge detection, Sobel, Canny, Mask, Orientation

I. Introduction

Unlike the real world, images do not have edges. An edge is sharp change in intensity of an image. But, since the overall goal is to locate edges in the real world via an image, the term edge detection is commonly used. An edge is not a physical entity, just like a shadow. It is where the picture ends and the wall starts, where the vertical and the horizontal surfaces of an object meet. If there were sensor with infinitely small footprints and zero-width point spread functions, an edge would be recorded between pixels within in an image. In reality, what appears to be an edge from the distance may even contain other edges when close-up looked. The edge between a forest and a road in an aerial photo may not look like an edge any more in a image taken on the ground. In the ground image, edges may be found around each individual tree. If looked a few inches away from a tree, edges may be found within the texture on the bark of the tree. Edges are scale-dependent and an edge may contain other edges, but at a certain scale, an edge still has no width. If the edges in an image are identified accurately, all the objects are located and their basic properties such as area, perimeter and shape can be measured. Therefore edges are used for boundary estimation and segmentation in the scene. Since computer vision involves the identification and classification of objects in an image, edge detection is an essential tool.

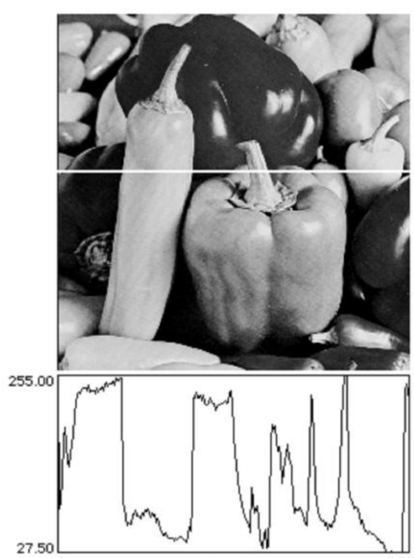

Fig.1 Sharp changes in intensity of image

A. Types of Edges

All edges are locally directional. Therefore, the goal in edge detection is to find out what occurred perpendicular to an edge. The following is a list of commonly found edges.

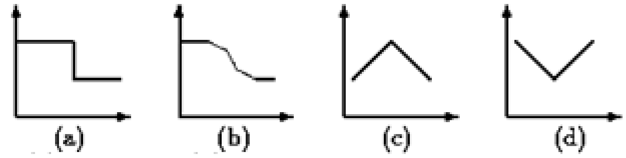

Fig. 2 Types of Edges (a) Sharp step (b) Gradual step (c) Roof (d) Trough

A Sharp Step, as shown in Fig. 2(a), is an idealization of an edge. Since an image is always band limited, this type of graph cannot ever occur. A Gradual Step, as shown in Fig. 2(b), is very similar to a Sharp Step, but it has been smoothed out. The change in intensity is not as quick or sharp. A Roof, as show in Fig. 2(c), is different than the first two edges. The derivative of this edge is discontinuous. A Roof can have a variety of sharpness, widths, and spatial extents. The Trough, also shown in Fig. 2(d), is the inverse of a Roof. Edge detection is very useful in a number of contexts. Edges characterize object boundaries and are, therefore, useful for segmentation, registration, and identification of objects in scenes.

B. Criteria for Edge Detection

There are large numbers of edge detection operators available, each designed to be sensitive to certain types of edges. The Quality of edge detection can be measured from several criteria objectively. Some criteria are proposed in terms of mathematical measurement, some of them are based on application and implementation requirements. In all five cases a quantitative evaluation of performance requires use of images where the true edges are known.

1) *Good detection:* There should be a minimum number of false edges. Usually, edges are detected after a threshold operation. The high threshold will lead to less false edges, but it also reduces the number of true edges detected. [2]
2) *Noise sensitivity:* The robust algorithm can detect edges in certain acceptable noise (Gaussian, Uniform and impulsive noise) environments. Actually, and edge detector detects and also amplifies the noise simultaneously. Strategic filtering, consistency checking and post processing (such as non-maximum suppression) can be used to reduce noise sensitivity. [2, 5]
3) *Good localization:* The edge location must be reported as close as possible to the correct position, i.e. edge localization accuracy (ELA). [2, 4]
4) *Orientation sensitivity:* The operator not only detects edge magnitude, but it also detects edge orientation correctly. Orientation can be used in post processing to connect edge segments, reject noise and suppress non-maximum edge magnitude. [2, 5]
5) *Speed and efficiency:* The algorithm should be fast enough to be usable in an image processing system. An algorithm that allows recursive implementation or separately processing can greatly improve efficiency.

Criteria of edge detection will help to evaluate the performance of edge detectors. Correspondingly, different techniques have been developed to find edges based upon the above criteria, which can be classified into linear and non linear techniques.

II. Techniques for Edge Detection

Edge detectors can be classified into two broad categories [4]

A. First Derivative operators [4]

1) Sobel Operator: The Sobel operator [10] consists of a pair of 3×3 convolution kernels as shown in Figure. One kernel is simply the other rotated by 90°.

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

Gx

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

Gy

These kernels are designed to respond maximally to edges running vertically and horizontally relative to the pixel grid, one kernel for each of the two perpendicular orientations. The kernels can be applied separately to the input image, to produce separate measurements of the gradient component in each orientation (call these *Gx* and *Gy*). These can then be combined together to find the absolute magnitude of the gradient at each point and the orientation of that gradient. The gradient magnitude is given by:

$$|G| = \sqrt{Gx^2 + Gy^2}$$

Typically, an approximate magnitude is computed using:

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

which is much faster to compute.

The angle of orientation of the edge (relative to the pixel grid) giving rise to the spatial gradient is given by:

$\theta = \arctan(Gy/Gx)$

2) Robert's cross operator: The Roberts Cross operator[10] performs a simple, quick computation to compute, 2-D spatial gradient measurement on an image. Pixel values at each point in the output represent the estimated absolute magnitude of the spatial gradient of the input image at that point. The operator consists of a pair of 2×2 convolution kernels as shown in Figure. One kernel is simply the other rotated by 90°. This is very similar to the Sobel operator.

+1	0
0	-1

0	+1
-1	0

These kernels are designed to respond maximally to edges running at 45° to the pixel grid, one kernel for each of the two perpendicular orientations. The kernels can be applied separately to the input image, to produce separate measurements of the gradient component in each orientation (call these *Gx* and *Gy*). These can then be combined together to find the absolute magnitude of the gradient at each point and the orientation of that gradient. The gradient magnitude is given by:

$$|G| = \sqrt{Gx^2 + Gy^2}$$

although typically, an approximate magnitude is computed using:

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

which is much faster to compute.

The angle of orientation of the edge giving rise to the spatial gradient (relative to the pixel grid orientation) is given by:

$\theta = \arctan(Gy/Gx) - 3\pi/4$

3) Prewitt's operator: Prewitt operator[10] is similar to the Sobel operator and is used for detecting vertical and horizontal edges in images. It is a fast method for edge detection.

$$h_1 = \begin{bmatrix} 1 & 1 & 1 \\ 0 & 0 & 0 \\ -1 & -1 & -1 \end{bmatrix}$$

$$h_3 = \begin{bmatrix} -1 & 0 & 1 \\ -1 & 0 & 1 \\ -1 & 0 & 1 \end{bmatrix}$$

B. Second Derivative's Operator [4]

1)Laplacian of Gaussian: The Laplacian[10] is a 2-D isotropic measure of the 2nd spatial derivative of an image. The Laplacian of an image highlights regions of rapid intensity change and is therefore often used for edge detection. The Laplacian is often applied to an image that has first been smoothed with something approximating a Gaussian Smoothing filter in order to reduce its sensitivity to noise. The operator normally takes a single gray level image as input and produces another gray level image as output.

The Laplacian *L(x,y)* of an image with pixel intensity values *I(x,y)* is given by:

$$L(x,y) = \frac{\partial^2 I}{\partial x^2} + \frac{\partial^2 I}{\partial y^2}$$

Since the input image is represented as a set of discrete pixels, we have to find a discrete convolution kernel that can approximate the second derivatives in the definition of the Laplacian. Three commonly used small kernels are shown in Figure.

0	1	0
1	-4	1
0	1	0

1	1	1
1	-8	1
1	1	1

-1	2	-1
2	-4	2
-1	2	-1

Fig. 3 Three commonly used discrete approximations to the Laplacian filter.

2) Canny Operator: The Canny edge detection algorithm[10] is known to many as the optimal edge detector. The canny edge detector first smoothes the image to eliminate noise. It then finds the image gradient to highlight regions with high spatial derivatives. The algorithm then tracks along these regions and suppresses any pixel that is not at the maximum. In order to implement the canny edge detector algorithm, a series of steps must be followed. The first step is to filter out any noise in the original image before trying to locate and detect any edges. And because the Gaussian filter can be computed using a simple mask, it is used exclusively in the Canny algorithm. Once a suitable mask has been calculated, the Gaussian smoothing can be performed using standard convolution methods.

A convolution mask is usually much smaller than the actual image. As a result, the mask slid over the image, manipulating a square of pixels at a time. The larger the width of the Gaussian mask, the lower is the detector's sensitivity to noise. The localization error in the detected edges also increases slightly as the Gaussian width is increased.

After smoothing the image and eliminating the noise, the next step is to find the edge strength by taking the gradient of the image. The Sobel operator performs a 2-D spatial gradient measurement on an image. Then, the approximate absolute gradient magnitude (edge strength) at each point can be found. The Sobel operator uses a pair of 3x3 convolution masks, one estimating the gradient in the x-direction (columns) and the other estimating the gradient in the y-direction (rows). They are shown below:

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

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

The magnitude, or edge strength, of the gradient is then approximated using the formula:

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

III. Applications

Various applications of Edge Detection are Machine Vision Gauging, Remote Sensing [6], Automated Driving, Edge Detection on large oil sand ore, Detection of the Bright Band in Radar data, Astronomy, Medicines, Feature Extraction and many more.

IV. Conclusion

After studying the above edge detection techniques researches show that Sobel operator and Canny operator are best suitable in First order derivative and Second order derivative respectively. In future work we will propose and implement a novel algorithm after working on the disadvantages and advantages of the existing techniques.

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