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A Comparison of Canny, Robert edge detection filters and their superposition

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Abstract: Edge detection technique is one of the most commonly used operations in image analysis particularly in the areas of image segmentation. An edge represents the boundary between an object and the image background, hence if high accuracy edges are identified in an image then all its objects can be located and an image's basic property can also be measured [1]. An edge can also be defined as a group of pixels connected together which forms a boundary between two disconnected regions can also be defined as an edge. Edge detection is basic method of segmenting an image into different regions of discontinuity. Edges are considered for prime importance in image processing as they characterize boundaries. Edge detection filters out noise and useless data while preserving the important structural properties in an image. Since edge detection is in the front line of image processing for object detection [2], it is necessary to have a good understanding of edge detection methods. In this paper a comparison of Canny, Robert Image Edge Detection methods and their superposition approach are presented. This comparative study shows which among the above approach provides a better result.

General Terms: Filters, Hybrid filters, Edge detection, Robert Filter, Canny Filter, Intensity Gradients
Keywords: Canny, Laplacian, Robert

1. Introduction

The main objective of edge detection is to identify and mark the points in an image at which the luminous intensity changes sharply. These sharp changes in image properties reflect important events and changes in properties of the world [3]. These include discontinuities in surface orientation, discontinuities in depth, and changes in material properties and variations in scene illumination. Edge detection being a research field within image processing and computer vision, is particularly in the area of feature extraction. There are many methods for edge detection. Edge detection of an image reduces the amount of data and filters out the information that is irrelevant, preserving the important structural properties of an image. Derivative is used to detect edge pixel or edge elements are detected by taking derivative followed by thresholding and they also incorporate noise cleaning scheme.

Two dimensional derivatives are computed by means of edge masks. Edges may be viewpoint dependent - edges may change as the viewpoint changes, and typically reflecting the geometry of the scene, objects occluding one another and so on. Edges may also be viewpoint independent - generally reflecting properties of the viewed objects such as surface markings and surface shape. An edge might be the border between a block of two different colors, in contrast a line can be a number of pixels of a different color on an otherwise different background.

There will be one edge on each side of the line. Edges play an important role in many applications of image processing. Considering an edge to be intensity changes taking place over a number of pixels, edge detection algorithms generally compute a derivative of this intensity change. For simplicity, we can consider a one dimensional detection of an edge. In this instance, our data is a single line of pixel intensities. The edge detection methods that have been published differ mainly in the smoothing filters that are applied to the image and the way the measures of edge strength are computed. As many edge detection methods depend on the computation of image gradients, they also differ in the types of filters used for computing gradients in the x- and y-directions.

An edge detector filters out the useless information and preserves the useful information in image. The three steps involved in edge detection are [6]:

1. Noise reduction by image smoothing: it involves improving the performance of edge detector by filtering the image.

2. Detection: This step involves extraction of all edge points that are potential candidates to become edge point.
3. Edge localization: It involves selecting only those points that are true members of set of points comprising an edge from the candidate edge points

Edge detection techniques are broadly classified into two categories gradient edge detection and Laplacian edge detection [6].

Gradient method detects the edges by looking for the maximum and minimum in the first derivative of the image. Sharpening an image results in the detection of fine details as well as enhancing blurred ones [8]. The Laplacian method searches for zero crossings in the second derivative of the image to find edges.

2. Gradient based Edge Detection:

This method uses gradient to detect the edge points in the image. The gradient is a tool for finding the edge strength and the direction at location f [4], and is denoted by Δf, and defined as the vector,

$$\Delta f = grad(f) = \begin{bmatrix} Gx \\ Gy \end{bmatrix} = \begin{bmatrix} \frac{\partial f}{\partial x} \\ \frac{\partial f}{\partial y} \end{bmatrix}$$

This vector always points in the direction of maximum rate of change at location (x, y). The magnitude of the vector can be given as,

$$M(x, y) = \sqrt{Gx^2 + Gy^2}$$

An angle, θ(x, y) gives the direction of the gradient vector. Consider the one-dimensional signal with an edge shown by jump in intensity as shown in figure 1.1:

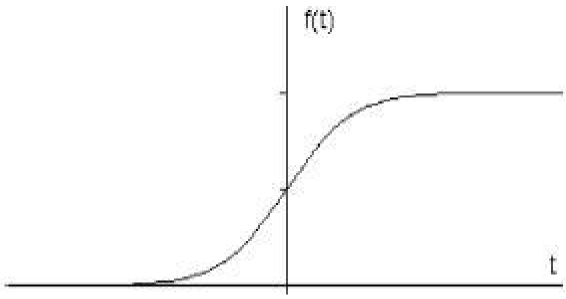

Fig 1.1: A signal representation

The gradient of this signal (which is the first derivative with respect to t in one dimension) we get the shape as shown in Figure 1.2:

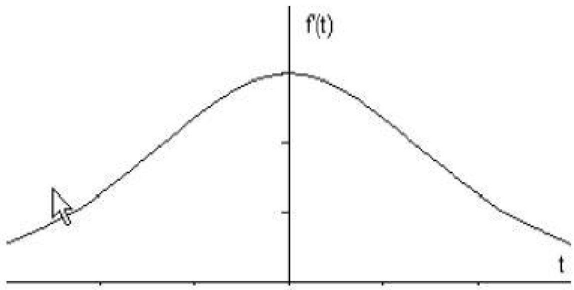

Fig. 1.2 First Derivative of the example Signal

The first derivative of the signal clearly shows that the maximum is located at the center of the edge in original signal.

3. Laplacian based Edge Detection

This method looks for zero crossing in the second derivative of the image. If the first derivative is maximum, then it's second derivative will be zero [4]. This phenomenon gives rise to an alternate method for edge detection known as Laplacian method. Hence, we can detect the edges by searching for zero crossings in the 2nd derivative, Figure 1.3 shows second derivative of the signal.

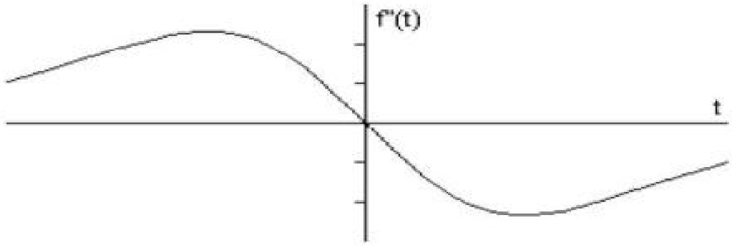

Fig. 1.3 Second Derivative of example Sign

4. Robert's Cross Operator:

The Roberts Cross operator presents a simple, quick to compute, 2-D spatial gradient measurement on an image. It thus results in highlighting regions of high spatial frequency which often correspond to edges. In its most common usage, a grayscale image is the input to the operator is, as is the output. Pixel values at each point in the output represent the spatial gradients estimated absolute magnitude of the of the input image at that point. It uses 2×2 convolution masks. The operator consists a pair of 2×2 convolution kernels as shown in Figure 3. One kernel is simply the other rotated by 90°. This is very similar to the Sobel operator

-1	0
0	+1

G_x

0	-1
+1	0

G_y

Figure 3: Masks used for Robert operator.

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

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

Although typically, the magnitude is computed using:

$$G = Gx + Gy$$

This is much faster to compute.

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

$$\theta = arctan\left(\frac{Gy}{Gx}\right) - \frac{3\pi}{4}$$

4 Canny Edge Detector:

John F. Canny in 1986 developed Canny edge detector which uses a multi-stage algorithm to detect wide range of edges in the images. Canny also produced a computational theory of edge detection explaining why the technique works.

4.1Development of canny algorithm

Canny edge detection technique extracts useful structural information from different vision objects and dramatically reduces the amount of data to be processed [5]. It has been widely applied in various computer vision systems. Canny has found that the there is similarity in the requirements for the application of edge detection on diverse vision systems. Thus, an edge detection solution can be implemented to address these requirements in a wide range of situations. The general criteria for edge detection include [5]:

1. Detection of edge with minimum error rate, which means that the detection should accurately detect as many edges shown in the image as possible.
2. The edge point detected should accurately localize at the center of the edge.
3. A given edge in the image should be marked only once, and where possible, image noise should not create false edges.

To satisfy the above requirements Canny used the calculus of variations– a technique that detects the function which optimizes a given functional. The optimal function is described by the sum of four exponential terms, but it can be approximated by using the first derivative of Gaussian.

Among the edge detection methods developed so far, Canny edge detection algorithm is one among the most strictly defined methods that provides good and reliable detection. Owing to its optimality to meet the three criteria’s of edge detection and the simplicity of process for implementation, it becomes one among the most popular algorithms for edge detection.

4.2 Process of Canny edge detection

The 5 steps in the process of Canny edge detection algorithm are [5]:

1. Smooth the image in order to remove the noise by applying Gaussian filter。
2. Calculate the intensity gradients of the image.
3. Apply non-maximum suppression to get rid of specious response to edge detection.
4. To determine potential edges apply double threshold.
5. Hysteresis to track edge: finalize the detection of edges by suppressing all the other edges that are weak and not connected to strong edges.

5. Superposition of two filters

In this section, a new edge detection approach for extracting edge and smooth areas from an image is proposed which integrates Canny edge detection proposed by Canny in 1986 and enhanced by Robert edge detector filter.

As we know that the greatest advantage of edge detection technique is that it can be applied as base of another segmentation technique [7]，but here we are trying to apply two edge detection filters on same image to enhance the output with less loss of information.

In this approach the Canny edge detection filter is first applied to a grey scale image and to the same image Robert filter is later applied (Canny-Robert approach) and the vice versa (Robert canny approach) is done to see the difference in output.

6. Experimental observation and results

Here different kind of combination of Canny and Robert edge filter has been applied on different images using MATLAB 2013 and their results have been observed.

Case 1: Image of a coin

Fig 2: Original image

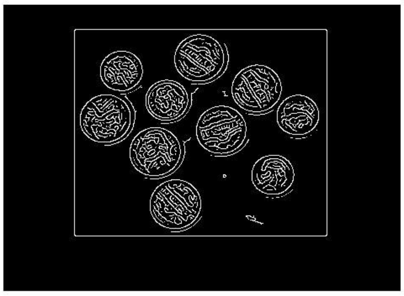

Fig 3: Canny filter on the image

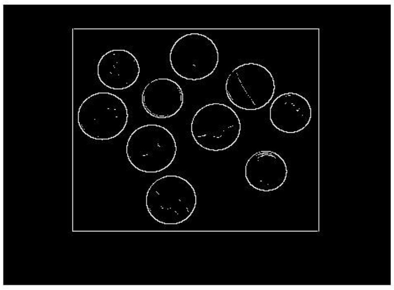

Fig 4: Robert filter on the image

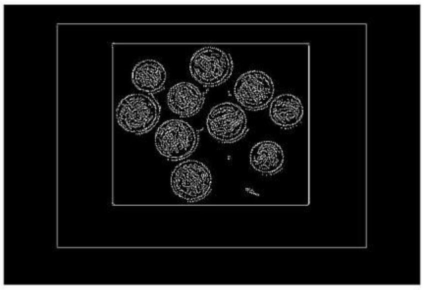

Fig 5: Canny - Robert approach

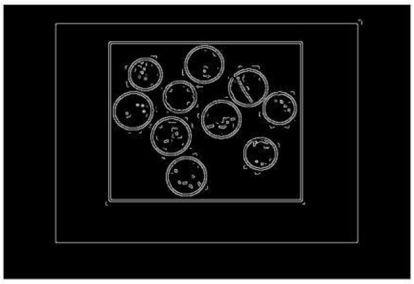

Fig 6: Robert - Canny approach

Case2: Image of flower

Fig 7: Original image

Fig 8: Canny filter on the image

Fig 9: Robert filter on the image

Fig 10: Canny - Robert approach

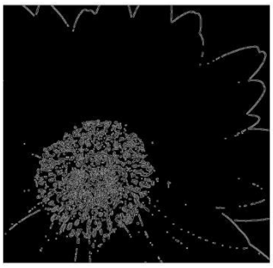

Fig 11: Robert - Canny approach

7. Conclusions

From the above results we can conclude that the Canny algorithm is adaptable to various environments. Its parameters allow it to be applied for recognition of edges of differing characteristics depending on the particular requirements of a given implementation [5]. The Robert filter highlights the area of high spatial gradient which often corresponds to edges but majority of the information is lost. From this we can conclude that Canny filter provides a better result than Robert.

Though Canny provides a better information and output, certain edges are not continuous as seen. Therefore if Robert filter is applied on to the image on which canny is already applied i.e. Canny Robert superposition approach it will provide a better result comparatively as seen in the figure.

The Canny when merged with other filters apart from Robert was seems to dominate the noise instead of only improving the result. Therefore Canny and Robert superposition approach was chosen which provides better result compared to Canny approach, Robert approach, Robert Canny approach.

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