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Performance Analysis of Different Edge Detection Techniques for Image Segmentation

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Abstract

Objectives: This paper provides the performance analysis of three edge detection operators on the basis of intensity value and high gradient. **Methods:** Edge detection is considered to be the building blocks of image processing for object detection and it is an important technique in image segmentation. Sobel, Prewitt and Roberts are some of the edge detection operators discussed in this paper. MATLAB R2013a is used to analyze the performances of these operators using an input image. **Findings:** In order to classify the operators, the limitations are identified and the performance analysis is done on the basis of obtained results. Based on the intensity value, Prewitt produces better result than Sobel and Roberts. At the same time, Sobel locates the edges with high gradient. Likewise, Roberts produces quick result due to small filter. **Application/Improvement:** The performance of these operators has been analyzed and realized that each operator is recognized as the best under various conditions.

Keywords: Edge Detection Operators, Image Segmentation, Prewitt, Roberts, Sobel

1. Introduction

An image is a visual representation of things. An image can be created or reproduced and stored in an electronic form. The images are considered as a medium to transmit information. This information's are extracted from the image using image processing technique[1]. Image segmentation is an integral part of image processing and the applications of image segmentation in this digital world are enormous[2]. It ranges from medical (virtual surgery simulation, measuring tissue volume, locate tumors and other pathologies), Machine vision (surface inspection, classification of non-woven fabrics, food packs checks, engine parts inspection, packaging inspection, Robot guidance and checking orientation of components), Recognition tasks (Face recognition, Iris recognition, Fingerprint recognition)[3], Object detection (Locate objects in satellite images such as roads, forest, building, etc)[4]. Image segmentation is the process of splitting a digital image into individual pixels and extract meaningful information from the pixel[5]. Image segmentation is the vital step in image analysis. If necessary image de-noising and filtering is done before image segmentation to remove noise from the image[6]. To get a better result, high quality images are used in image segmentation. Until now various image segmentation techniques are designed and no appropriate technique is followed for any kind of image[7]. A particular image segmentation technique is determined on the basis of image character.

Image Segmentation is classified as follows into two categories on the grounds of image property[8].

- Based on Discontinuity
- Based on Similarity.

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Based on discontinuity the images are spliced when an abrupt change in intensity that occurs in the edges of an image. Edge detection technique falls in this category[9]. Based on similarity the images are spliced into similar region on the basis of set of predefined criteria. Thresholding, Region Growing, Region Split and Merge techniques are falling under this category[10]. Figure 1 illustrates various image segmentation techniques, among which this paper focuses on edge detection techniques.

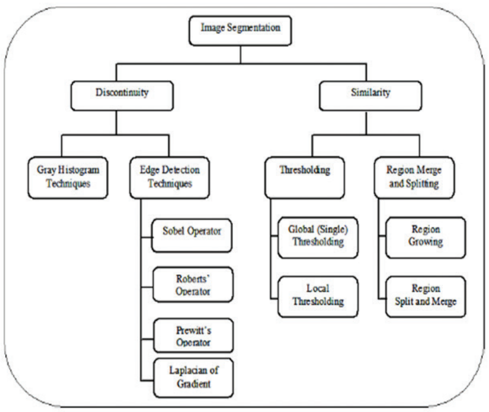


Figure 1. Classification of image segmentation.

There are numerous works carried out in image segmentation. Gong[11] introduced trade off weighted fuzzy factor and a kernel metric to enhance Fuzzy C–Means (FCM) algorithm. Tradeoff weighted fuzzy factor grounds on the space distance between the neighboring pixel and their grey level difference. This factor accurately measures damping extent of neighboring pixel. Kernel metric is used to reinforce its robustness against noise and outliers. Tradeoff weighted fuzzy factor and a kernel metric are parameter free. The result of this algorithm is effective and efficient, relatively independent of noise. Suzuki *et al.*,[2] performed computational image analysis to find the human intestinal parasites. It identifies few species and images free from fecal impurities. The fecal impurity problem is addressed using Bright field microscopic images. In this computational image analysis, image segmentation is executed using ellipse matching and image foresting transform similarly. Object representation is carried out by multiple object descriptors and their optimal combination of genetic programming. Finally, object recognition is done by optimum-path forest classifier. The result illustrates that it is favorable approach against fully automation of the enteroparasitosis diagnosis.

2. Edge Detection Techniques

An edge is considered to be an outer limit between an object and the background. The edge representation of an image is done in order to reduce the amount of data to be processed and still it preserves vital information pertaining to the shapes of objects in an image[13,14]. Edge detection is a process to locate the discontinuity of intensity in an image. This technique is said to be a primitive step in image analysis[15,16]. The basic steps of edge-detection process are:

- Filtering: It is used to cut off the noise from an image without spoiling the true edges.
- Enhancement/Sharpening: Strength of a particular pixel is increased when a considerable change in local intensity occurs.
- Localization: Detects the accurate locations of an edge in an image. Generally, Edge thinning and linking are the pre-requisites for edge localization.

$W_{-1,-1}$	$W_{-1,0}$	$W_{-1,1}$
$W_{0,-1}$	$W_{0,0}$	$W_{0,1}$
$W_{1,-1}$	$W_{1,0}$	$W_{1,1}$

Figure 2. 3 x 3 Masks.

Figure 2 shows how to locate edges in an image using 3 x 3 masks. There are various problems in analyzing the edges from an image such as false edge detection, producing thin or thick lines, noises, etc. In this paper, we inspected through visual comparison of various operators such as Sobel, Prewitt, Roberts about the production of thin or thick line edges.

2.1 Sobel Operator

Sobel operator locates the edges containing highest gradient. It is used to locate the approximate absolute gradient magnitude at each point of the input image[17,18]. The Sobel operator consists of a pair of 3 × 3 convolution kernels as shown in Figure 3. One kernel is simply the other rotated by 90°. These kernels are designed in such a way that to respond the edges which are running vertically and horizontally relative to the pixel grid[19]. The kernels are applied individually to the input image in-order to generate measurements of the gradient components in the respective orientation (Gx and Gy)[20].

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

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

Figure 3. Sobel operator's 3 x 3 masks.

The gradient magnitude is represented as follows:

$$|G| = \sqrt{Gx2 + Gy2}$$

An approximate magnitude is computed as below:

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

Here, computation is done faster.

The angle of gradient vector is derived from $\partial = \arctan(Gy / Gx)$

Sobel Edge Detection Method – Steps
Input: A Sample Image
Output: Detected Edges
Step 1: Obtain the input image
Step 2: The mask Gx,Gy is applied to the input image
Step 3: The Sobel edge detection algorithm is applied
Step 4: Gradient magnitude is calculated
Step 5: Approximate magnitude is computed to obtain the result
Step 6: The angle of gradient vector is the output edges

2.2 Prewitt Operator

The Prewitt edge detector is considered to be the relevant way to calculate the magnitude and orientation of an image[21]. Prewitt is comparably similar to Sobel operator and is widely used to detect the vertical and horizontal edges of an image[22]. The basic idea behind edge detection is to find places in an image where the intensity changes rapidly. The Prewitt operator consists of pair of 3 x 3 convolution kernels that are given Figure 4.

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

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

Figure 4. Prewitt operator's 3 x 3 masks.

The maximum response of all 8 kernels for a pixel location is used to calculate the local edge gradient magnitude:

$$|G| = \max(|Gi|: i=1 \text{ to } n)$$

Here, Gi-The response of the kernel i at the appropriate pixel position

n -The number of convolution kernels.

The local edge orientation is estimated with the orientation of the kernel that yields the maximum response[23]. Figure 5 shows the process of Prewitt edge detection operator.

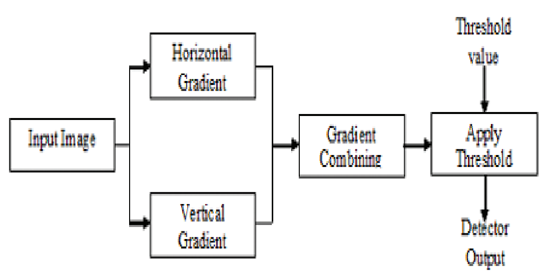


Figure 5. Operation of Prewitt Operator.

2.3 Roberts Edge Detection

The Roberts edge detection was proposed by Lawrence Roberts in the year 1965 and it was the first edge detection technique. The performance of this operator is very simple and the computation is done in no time[24,25]. It is a 2-D spatial gradient measurement. Gray scale image is the mode of input and output of this operator. The output of this operator exhibits the complete magnitude of the input image[26]. Figure 6 represents a pair of 2 × 2 convolution kernels of the operator.

1	0
0	-1

Gx

0	1
-1	0

Gy

Figure 6. Roberts operator 2 x 2 masks.

The gradient component of each orientation (Gx and Gy) is calculated by applying the convolution matrices to the input image[27]. The calculation of gradient magnitude is as follows:

$|G| = |Gx| + |Gy|$ (or) $|G| = \text{sqrt}\,(Gx * Gx + Gy * Gy)$.

The angle of orientation is given by:

$\partial = = \arctan\,(Gy / Gx) - 3 / 4$.

3. Experimental Results and Discussion

In this paper some of the edge detection operators such as Sobel, Prewitt and Roberts are applied to an image using MATLAB R2013a. An image given in Figure 7 is the input to all the above mentioned three operators. The same image is used as the input for all the three operators to observe the sharpness of the edges clearly.

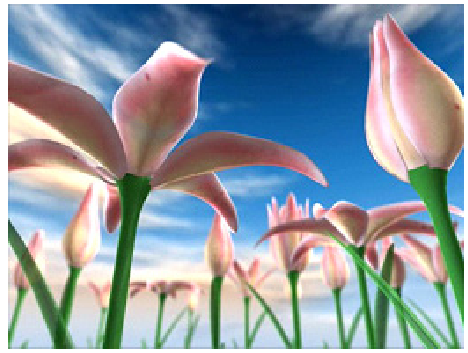
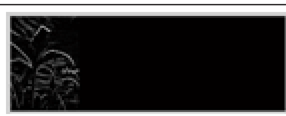
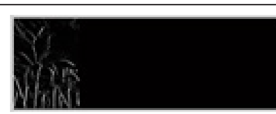
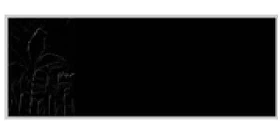


Figure 7. Image used for edge detection analysis.

Initially, the input image is doubled and converted to grayscale (or) a binary image. The gradient is the change in the intensity with direction. The gradient of grayscale image is obtained by using appropriate masks. Sobel and Prewitt uses 3 x 3 mask, whereas Roberts uses 2 x 2 mask. For each pixel the intensity is measured as Gx and Gy where 'x' and 'y' are the directions. Further, the magnitude of the gradient is calculated by |G| = |Gx| + |Gy|. Finally, the input image is directed by threshold, which identifies the pixel location as edges.

Sobel and Prewitt finds more edges as it responds to an average change in intensity value. Roberts finds edges when there is a sharp change in the intensity value. The

Table 1. Results for Sobel, Prewitt and Roberts operator

Direction / Operation	Gx	Gy	Gx + Gy
Sobel			
Prewitt			
Roberts			

result of these operators are shown in Table 1.

4. Performance Analysis of Edge Detection Operators

The outputs of Sobel, Prewitt, Robert operators are analyzed and it is observed that each operator works well under various conditions. They all need simple calculations for finding edges. However, due to noise, these operators produced inaccurate edge detection and hence they yield poor results in a noisy condition. The performance of these operators is analyzed based on the threshold parameter. Though Sobel and Prewitt are similar, the former is more responsive to diagonal edges than horizontal and vertical edges and it detects several numbers of pixels. As Prewitt operator uses maximum directional gradient, it marks horizontal and vertical edges easily and hence it marks few numbers of pixels. Roberts works preeminent with binary images and it gives information about edge orientation. Though these techniques exhibit their pros, they have some limitations also. The following Table 2 illustrates the pros and cons of these techniques.

5. Conclusion

Image segmentation is one of the most vital steps to analyze and extract meaningful information from an image. In this paper, we have discussed some of the edge detection operators. In addition, we have implemented these operators for the given input using MATLAB R2013a. An individual edge detection output is produced for them. As well as performance analysis is also carried out. Prewitt showcases better result than Sobel and Roberts based on intensity value. While Sobel provides a better approximation to gradient magnitude, it locates the edges containing highest gradient. Since the filter is small, Roberts produces results very quickly than Sobel and Prewitt. Finally from the above analysis, it is observed that each operator is considered as the best under various conditions. In future, apart from the above mentioned operators, edge detection will be carried out with some other operators such as Canny, Laplace of Gaussian for the set of images.

Table 2. Comparison of Image Segmentation Operators

Operators	Comparative Study	Parameter	Advantages	Disadvantages
1. Sobel	It produces thin edges. It does not offer detailed information.	Threshold	It is simple. Better approximation to gradient magnitude.	Sensitivity to Noise. Not accurate in locating edges. Accuracy descends when magnitude of the edges decreases.
2. Prewitt	More sensitive to horizontal and vertical edges.	Threshold	Detection of edges and their orientations are high.	Inaccurate. Size of the coefficient and kernel filter is fixed and cannot be changed to a given image.
3. Roberts	Works with binary images only. Does not detect edges when a minimal change in gray scale value.	Threshold	It is simple and fast. Detects thicker edges.	Localization is not good.Weak response to genuine edge.

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