A Classified and Comparative Study of Edge Detection Algorithms

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Abstract

Since edge detection is in the forefront of image processing for object detection, it is crucial to have a good understanding of edge detection algorithms. This paper introduces a new classification of most important and commonly used edge detection algorithms, namely ISEF, Canny, Marr-Hildreth, Sobel, Kirsch, Lapla1 and Lapla2. Five categories are included in our classification, and then advantages and disadvantages of some available algorithms within this category are discussed. A representative group containing the above seven algorithms are the implemented in C++ and compared subjectively, using 30 images out of 100 images. Two sets of images resulting from the application of those algorithms are then presented. It is shown that under noisy conditions, ISEF, Canny, Marr-Hildreth, Kirsch, Sobel, Lapla2, Lapla1 exhibit better performance, respectively.

Keywords: *Edge Detection, Image Processing, SNR, Zero Crossing, Classification.*

1. Introduction

Edge detection is one of the most commonly used operations in image analysis. An edge is defined by a discontinuity in gray level values. In other words, an edge is the boundary between an object and the background. The shape of edges in images depends on many parameters: The geometrical and optical properties of the object, the illumination conditions, and the noise level in the images [1].

The importance of the classification is that it simplifies several problems in Artificial Vision and Image Processing, by associating specific processing rules to each type of edges [2]. The Classification that we introduce in this paper is based on the behavioral study of these edges with respect to the following differentiation operators:

- Gradient edge Detectors (first derivative or classical)
- Zero crossing (second derivative)
- Laplacian of Gaussian (LoG)
- Gaussian edge detectors
- Colored edge detectors

From each category in the classification, at least one algorithm has been chosen for implementation. Totally seven edge detectors are tested using 10 real image sequences, containing a total of 100 images. Two shorter sequences among the best 30 ones are derived from each original sequence and two sets of resultant images are presented here.

2. Classification of Edge Detectors

Edge detectors may well be classified into 5 categories as follows:

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1) **Gradient edge detectors:** Which contains classical operators and uses first directional derivative operation. It includes algorithms such as: Sobel (1970), Prewitt (1970), Kirsch (1971), Robinson (1977), Frei-Chen (1977), Deatsch and Fram(1978), Nevatia and Babu(1980), Ikonomopoulos (1982), Davies(1986), Kitchen and Malin(1989), Hancock and Kittler(1990), Woodhall and Linquist (1998) and Young-won and Udpa (1999)[1,6,10].

2) **Zero Crossing:** Which uses second derivative [5] and includes Laplacian operator and second directional derivative.

3) **Laplacian of Gaussian (LoG):** Which was invented by Marr and Hildreth (1980) who combined Gaussian filtering with the Laplacian.This algorithm is not used frequently in machine vision. Those who continued his way were Berzins (1984), Shah, Sood and Jain (1986), Huertas and Medioni (1986) [5, 10].

4) **Gaussian Edge Detectors:** Which is symmetric along the edge and reduces the noise by smoothing the image. The significant operators here are Canny and ISEF (Shen-Castan) which convolve the image with the derivative of Gaussian for Canny and ISEF for Shen-Castan.[5,10].

5) **Colored Edge Detectors:** Which are divided into three categories output Fusion methods, Multi-dimensional gradient methods and Vector methods [11].

3. Advantages and Disadvantages of Edge Detectors

As edge detection is a fundamental step in computer vision, it is necessary to point out the true edges to get the best results from the matching process. That is why it is important to choose edge detectors that fit best to the application. In this respect, we first present some advantages and disadvantages of algorithms [1, 5, and 7] within the context of our classification in Table 1.

Operator	***Advantages***	***Disadvantages***
Classical (Sobel, Prewitt, Kirsch,…)	Simplicity, Detection of edges and their orientations	Sensitivity to noise, Inaccurate
Zero Crossing (Laplacian, Second directional derivative)	Detection of edges and their orientations, Having fixed characteristics in all directions	Reresponsing to some of the existing edges, Sensitivity to noise
Laplacian of Gaussian (LoG) (Marr-Hildreth)	Finding the correct places of edges, Testing wider area around the pixel	Malfunctioning at corners, curves and where the gray level intensity function varies, Not finding the orientation of edge because of using the Laplacian filter
Gaussian (Canny, Shen-Castan)	Using probability for finding error rate, Localization and response, Improving signal to noise ratio, Better detection specially in noise conditions	Complex Computations, False zero crossing, Time consuming
Colored Edge Detectors	Accurate, More efficient in object recognition	Complicated, Complex Computations

Table 1: Some Advantages and disadvantages of edge detectors

4. Comparison of Edge Detectors

In the past two decades several algorithms have been developed to extract edges within digital images but their functionalities and performances are not the same. In spite of all the efforts, none of the proposed operators are fully satisfactory in real world. The availability of well-defined quality criteria is important; these criteria should consider Precision, Resolution and Accuracy [3, 7].

Signal to Noise Ratio (SNR) and Average Risk (AVR) [8, 9] are our chosen criteria to compare different algorithms. Seven edge detectors in the context of the above mentioned classification, which are more commonly in use, are selected and then tested. Two sets of images resulting from the applying of those seven algorithms are presented next. Table 2 describes the corresponding values of the SNR for each edge detector. To provide the same comparable basis for all the results, a standard deviation equal to 1.8 is considered.

Image	*Algorithm*	*Noise*	*SNR=6*	*SNR=2*	*SNR=1*
Chess	ISEF	1.0000	0.9182	0.5756	0.5147
Car	Canny	1.0000	0.5152	0.5402	0.5687
	Marr-Hildreth	0.9966	0.7832	0.6988	0.7140
	Kirsch	0.9727	0.9727	0.1197	0.0490
	Sobel	0.9727	0.9690	0.1173	0.0617
	Lapla2	0.9727	0.8743	0.0622	0.0421
	Lapla1	0.9650	0.5741	0.0510	0.0402

Table 2: Comparison of edge detectors

The resultant images from application of the selected algorithms to the original Chess image are shown in Figure 1.

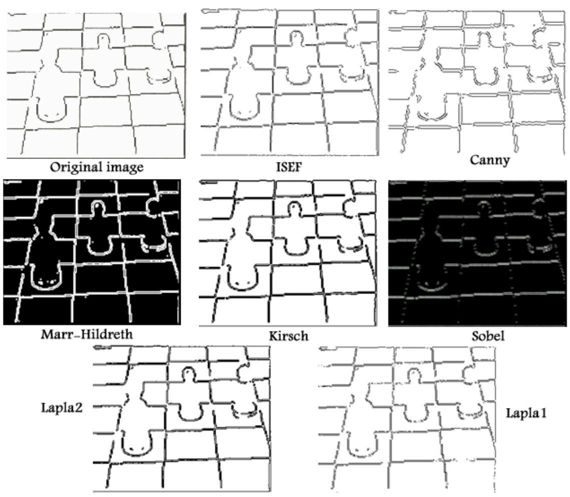

Figure 1: Edge detection results, derived for Chess Image

Another set of images in Figure 2 shows the resulting images after applying the same algorithms to another sample, Car Image.

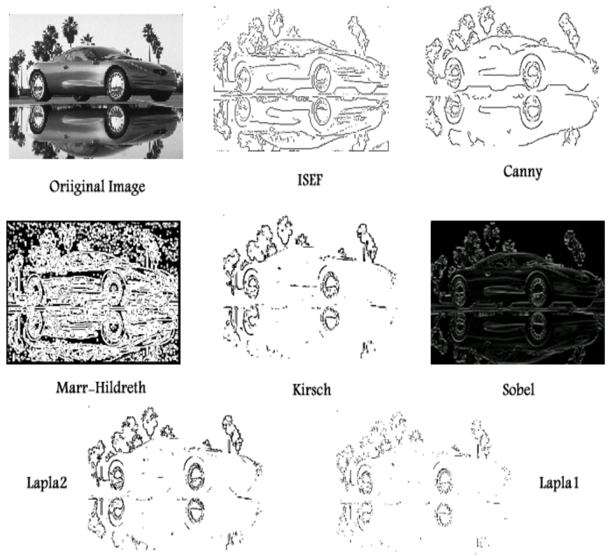

Figure 2: Edge detection results, derived for Car Image

The visual comparison of the above two sets of images (in Figures 1 and 2) can lead us to the subjective evaluation of the performances of selected edge detectors. Applying these seven operators to a noisy image shows that with noisy images, second derivative operators, like ISEF and Canny, exhibit better performance but require more computations because of smoothing an image with a Gaussian function first and then computing the gradient.

Canny has specified three issues that an edge detector must address in order to better detect edges in noise conditions: Error rate, Localization and Response. But the comparison between Canny and ISEF does depend on the parameters selected in each case and evaluations should find a better choice of parameters. In some cases the Canny will come out ahead and in others the ISEF method will win. The best set of parameters for a particular image is not known, and so ultimately the user is left to judge the methods. In Marr-Hildreth, locality is not especially good and the edges are not always thin, still this edge detector is much better than the classical ones in cases of low signal to noise ratio followed by Kirsch, Sobel, Lapla2 and Lapla1 respectively. ROC curve of the comparison is shown in Figure 3, wherein Average Risk (AVR) versus

Signal to Noise Ratio (SNR) of seven mentioned operators is illustrated.

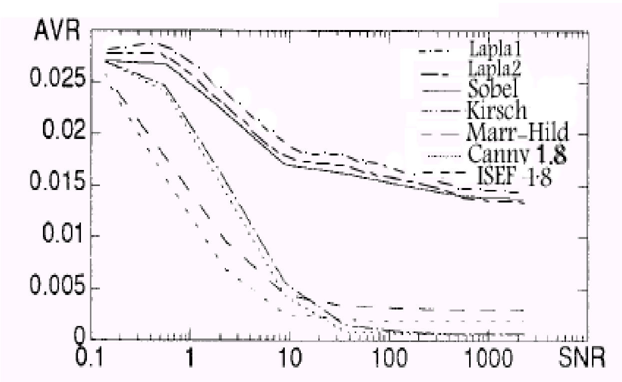

Figure 3. AVR versus SNR for some operators.

5. Conclusions

Since edge detection is the initial step in object recognition, it is necessary to know the differences between edge detection algorithms. In this paper we classified the most commonly used algorithms into five category, then seven algorithms have been applied to 30 images and lastly two sets were presented. Subjective evaluation of images showed that under noisy conditions ISEF, Canny, Marr-Hildreth, Kirsch, Sobel, Lapla2 and Lapla1 exhibit better performances, respectively.

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