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A COMPARATIVE EVALUATION OF EDGE DETECTORS AND IMPROVEMENT OF EDGE DETECTION VIA PREPROCESSING IN THE PRESENCE OF NOISE

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RÉSUMÉ

Résumé. Dans cette étude, les performances de différents algorithmes pour la détection de côtés sous la présence du bruit sont comparées, en plus préprocès et les méthodes pour la réduction du bruit basées sur la performance de la détection de côtés sont aussi évaluées. Il est évident d'utiliser les algorithmes de préprocès qui tendent à préserver l'information de côtés en réduisant le bruit afin d'améliorer la performance du détecteur des côtés.

ABSTRACT

Abstract. In this paper, the performances of various edge detection algorithms in the presence of noise have been compared, and preprocessing and noise reduction methods have also been evaluated based on edge detection performance. It is crucial to utilize preprocessing algorithms that tend to preserve edge information while reducing the noise in order to improve edge detector performance.

1. INTRODUCTION

Edge detection is a vital part of many image understanding and processing systems, especially in detection, segmentation, and identification applications. As features, they are very important because they contain all the necessary information, eliminating the redundant information in the original image, and are easily recognizable by humans, whereas other features are not. Since edge detection is essentially a differentiation operation which emphasizes the abrupt changes within an image (the edges), it is very sensitive to noise. For this reason, the noise performance of some edge detectors have been considered in this study. Although such performance studies have been encountered in the literature for specific edge detectors, similar performance analyses applied to preprocessing algorithms have been rarely met. The ones that we have come across were usually realized with the intention of evaluating a specific algorithm or a family of algorithms (generally proposed by the author). The main purpose of this study is to compare a broad range of algorithms against each other. [1], [2], [5], [7].

A wide range of noise types were also considered. These are impulsive noise, Additive Gaussian noise, and multiplicative noise. Impulsive noise is expressed as percentage of pixels degraded by noise. On the other hand, a dB scale is used to measure the level of additive Gaussian noise indicating the SNR (Signal to Noise Ratio). The amount of multiplicative noise is expressed by the ratio of the maximum possible noise value to the maximum intensity in the original image. Three images were used in this study. The first one (girl image) is a natural portrait, while the other two are synthetic images; the checkerboard image encountered commonly in many edge detection studies and the "cage" image devised for this study.[1].

Two performance measures are used in the evaluation of the algorithms.[5], [6]. The first one is simply the ratio of the missed or extra edge points to the true edge points given by the edges of the noiseless image. This can also be called the error rate criterion and is defined by the equation,

$$P_e = \frac{n_e}{n_o} \qquad (1)$$

where n_e is the number of erroneous edge pixels and n_o is the number of original edge pixels [5]. The second criterion can be called the localization criterion and is a cumulative measure of the distance between the detected edge pixels and the original edge pixels. Mathematically,

$$P_L = \frac{1}{\max(n_o, n_d)} \sum_{i=1}^{n_d} \frac{1}{1+\alpha d_i^2} \quad (2)$$

where n_d is the number of detected pixels, d_i is the distance between a detected pixel and the nearest original edge pixel, and a is a calibration constant [5].

The methodology used is given below as a block diagram. The edges of the three images are detected using each edge detector chosen for this study. For each original image, the three kinds of noise are added separately, at various levels. The degraded images are processed using each of the selected algorithms and the edges are detected using the corresponding detector. The two edge maps are compared taking the edges of the noiseless image as the original edge map.

2. EDGE DETECTORS

Gradient-based edge detectors utilize the first directional derivatives of the image for edge detection. The 3x3 masks used for this case are the Prewitt, Sobel, and isotropic detectors. All of these yield so called "thick" edges which have to be thinned afterwards. The performance of the Sobel edge detector was found to be superior to the other two, while other edge detectors outperformed the gradient based methods.

Laplacian edge detectors use zero-crossings of the second derivative. It is well known that the Laplacian edge detector is very sensitive to noise and produces many false edges. The remedy for this problem is to use local standard deviation thresholding. The Laplacian edge detector is used as standard in this study for comparing the performances of pre-processing algorithms against each other.

The general equation of a NOS filter is given below: [3], [4].

$$y = f\left[\frac{\sum_{i=1}^{N} a_i g_{(i)}(x_i)}{\sum_{i=1}^{N} a_i}\right] \quad (3)$$

where g(.) and f(.) are memoryless single valued nonlinear functions, and a_i are the weights which may or may not be independent of x_i, i=1, 2, ..., N. The numbers $g_{(i)}(x_i)$ are the numbers $g_{(i)}=g(x_i)$ ordered according to their magnitudes. The NOS edge detectors studied are the full-range and the quasi-range detectors. The quasi-range edge detector is defined as follows:

$$W_{(i)} = x_{(N+1-i)} - x_{(i)} \quad (4)$$

The full-range edge detector is a special case of the quasi-range edge detector where i=1.

3. PREPROCESSORS

3.1 Impulsive noise filtering

NOS filters [3], [4] will constitute most of the filters discussed in the remaining parts of this study. These filters were chosen because of many reasons like ease of computation, edge preserving properties, and being a recently introduced type of filter that outperforms other similar ones. Simple linear filters cannot preserve the edges and cannot remove impulsive noise effectively; therefore, nonlinear filtering is preferred.

Median filtering (which is a form of NOS filters) is the standard solution to impulsive noise filtering. However, the computational load is excessive. As a result, separable median filtering, whose computational load is lighter by orders of magnitude and whose performance is comparable, can be preferred for applications where time is critical. a-trimmed mean filtering (which is again a form of NOS filters) performs better for high noise levels, while median filtering has a higher performance at lower noise levels.

3.2 Additive Gaussian noise filtering

Low-pass filtering was taken as a basis for additive Gaussian noise filtering. The well-known fact that Wiener filtering is the optimal solution for additive Gaussian noise is supported by our results. NOS filters are also used for additive noise filtering; namely, arithmetic mean, L_p mean, contraharmonic mean which performed poorly compared to the low pass filter. Decision directed NOS filter has comparably good performance with the low-pass filter. This filter is a combination of various filters in that it first detects hypothetical edge points using a full-range edge detector and applies median filtering to edge points to preserve edge information. Arithmetic mean filtering is applied to non-edge points. To improve the performance, this filter was modified so that arithmetic mean filtering is substituted by low-pass filtering. This modification has indeed increased the performance and made it superior over low-pass filtering[1]. Another filter was developed here in keeping with the spirit of NOS filters. This filter was named the adaptive hyperbolic tangent mean filter because it uses the hyperbolic tangent function due to its "soft clipping" properties beyond certain "knee" values[1]. These knees were chosen adaptively by using the local statistics of the image under consideration. Some statistical filters were also studied. Among these are filters using local statistics [9] and those using global statistics[11]. Global statistics filtering was particularly successful among these algorithms.

3.3 Multiplicative noise filtering

Two filters were applied for this case. The well-known logarithmic mean filter which is a form of NOS filters converts multiplicative noise to additive noise and reduces the additive noise. A kind of filter using local statistics was also implemented and this filter proved to have a better performance compared with logarithmic mean filtering [10].

3.4 Image enhancement methods

It is well-known that image enhancement techniques can be grouped under two main headings; namely, point processes and spatial processes. The aim in this study is to implement enhancement algorithms which will enhance transitions and hence make edge detection easier, while keeping noise enhancement at a minimal level. One algorithm is to use Fuzzy sets to group grey levels into several categories [8] and as a result emphasize grey level transitions. Two methods devised by Wallis, which try to bring the local mean and variance to certain desired values, were used in conjunction with low-pass filtering as pre-processors.[12]. The combination of these methods with low-pass filtering yield very good results.

4. CONCLUSION

In this study, edge detectors have been evaluated in conjunction with suitable preprocessors, and as one picture is worth a thousand words, the results have been illustrated widely with performance curves. The area of edge detection lacks ready to use formulas and mathematical analysis techniques. The reason is the heavy dependence of the results on the nature of the image being processed. Therefore, it would have been misleading to conclude that one approach or the other is superior based on the results of a few images. However, similar results may be obtained for images with similar statistics. In our case, this is true for "portraits" and geometric shapes with high contrast. For a specific application, performance measurements should be made using typical images for the best results.

5. REFERENCES

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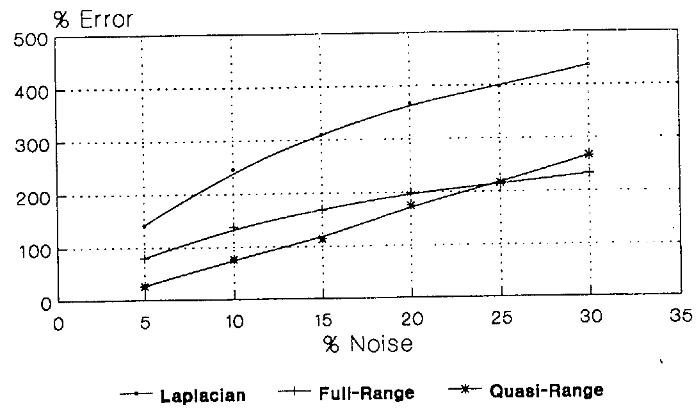
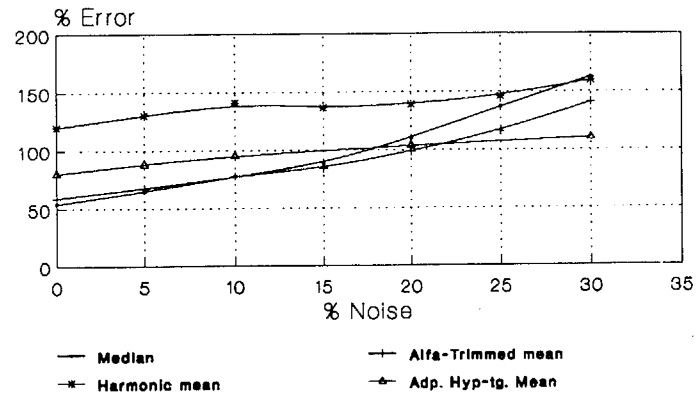
Edge Detectors Under Impulsive Noise



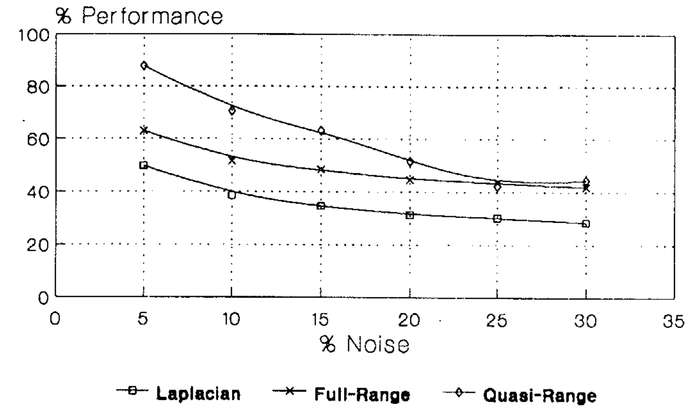
The Girl Image, Error Rate

Laplacian Edge detector on Pre-processed Impulsive Noise

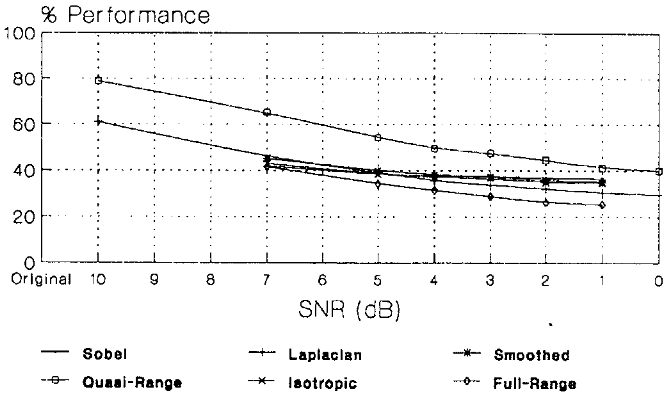


The Girl Image, Error Rate

Edge Detectors Under Impulsive Noise

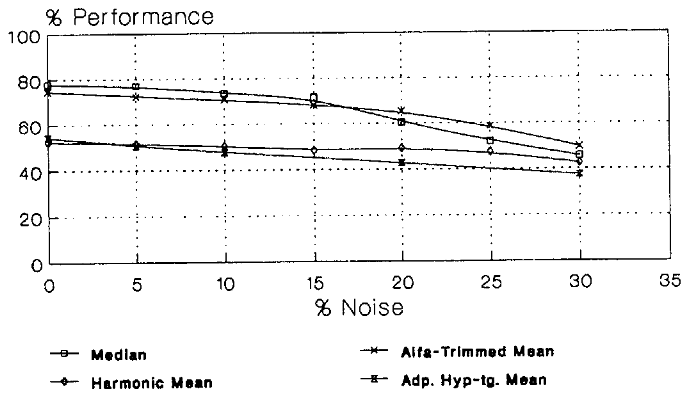


Performance of Edge Detectors with Gaussian White Noise



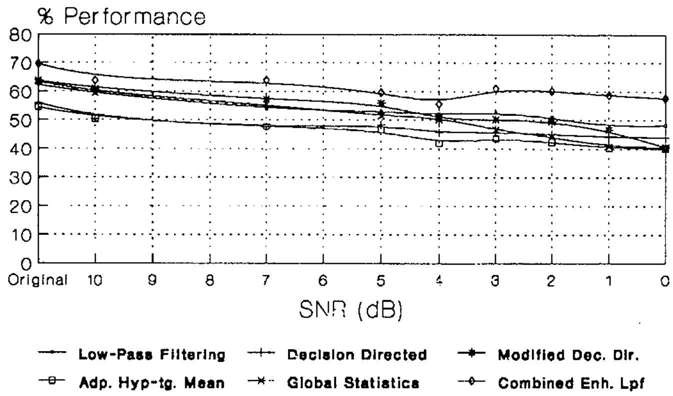
The Girl Image, Local Performance

Laplacian Edge detector on Pre-processed Impulsive Noise



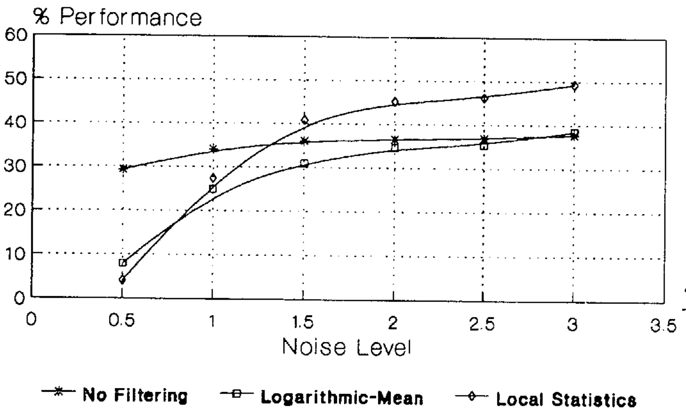
The Girl Image, Local Performance

Laplacian Edge Detector on Pre-Processed Gaussian White Noise



The Girl Image, Local Performance

Laplacian Edge Detector on Pre-Processed Multiplicative Noise

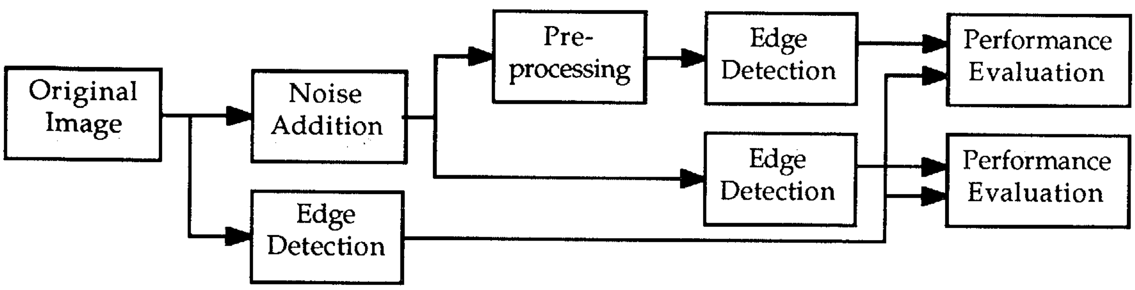


The Girl Image, Local Performance

Edges of Preprocessed Noisy Image (Modified Decision Directed Filter)

Edges of Noisy Image

The Girl Image, Local Performance



Block Diagram of the procedure

Original Image