TESTING THE EFFECTIVENESS OF THE CANNY ALGORITHM FOR EDGE

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Abstract
This paper presents measures the efficiency of edge detection algorithms based on the synthetic model for comparison. The first part of the paper describes the process of measuring. The testing method was carried out at the Canny algorithm. The results are given in the second part of the paper. The results were compared with results obtained by using the Sobel algorithm. The efficiency of the edge detection algorithms is determined by objective MSE, PSNR, and Merit (F), and subjective quality measures (visual comparison). The results are presented graphically.

Keywords: edge detection, testing, quality measures, canny algorithm.

INTRODUCTION

Edge detection is an essential tool in image processing. The edges in the image are important for determining the shape of the objects in the image as well as the boundaries between objects [1], [2]. The process of edge detection represents the first stage in image processing for object recognition, recognition of characters in the image, text, image quality correction, etc. The edge detector eliminates discontinued or independent pixels. The beginning of equal intensity valued pixels was marked for results. If a finder can detect edges without discontinuity, it succeeds [3]. In the last few decades, a large number of edge detection algorithms have been developed based on error minimization [4], application of fuzzy logic [5], genetic algorithms [6], neural networks [7], and Bayesian criterion [8].

The most often used algorithms that give the best results are based on gradient filtering such as Sobel's algorithm [9] and Cenny's algorithm [10]. The aim of the Canny algorithm is to satisfy the following criteria: a). Detection: The probability of detecting real edge points, which would achieve maximizing the signal-to-noise ratio; b). Localization: The detected edges are closed to the real edges; c) Number of responses: One real edge should respond with one detected edge.[11]

Measuring the quality and comparing edge detector operators is important. It can be performed on the basis of accuracy in results, edge continuity, noise level, edge relevancy, processing time, etc. In image processing, the most used quality measures are two metric standards that are universally followed, Mean Squared Error (MSE), and Peak Signal to Noise Ratio (PSNR). The MSE represents the cumulative squared error between the edge detected and the original image, and PSNR represents a measure of the peak error [4].

In the paper [3] author said that, if an operator gives a resultant image with less PSNR and high MSE, then comes to the conclusion that, the operator has high edge detection capability. In order to confirm this claim, the authors of this paper created image models and edge models. Using the model and using a subjective, visual quality of the detected edges, and an objective, algorithm for determining the matching of edges, the confirmation of using the mentioned measures (MSE and PSNR) can be established with certainty. As a measure of efficiency, the algorithm for determining the matching (Merit (F)) of edges defined in [12] was used.

This paper presents the results of applying Canny edge detection algorithms to synthetic images created by the author. A subjective (visual comparison of the original image and an image with detected edges) and objective (MSE, PSNR and *F*) analysis were performed, which includes the determination of the numerical value of the efficiency of the detected edges of the Canny algorithms. The results of the efficiency of the Canny algorithm are compared with the results of the efficiency of the Sobel algorithm obtained in the paper [13]. The results are shown graphically and the conclusion of the efficiency is given.

EDGE DETECTORS

An edge is a boundary between the object and its background. The goal of every detector is to avoid false edges, and detected edges should be the closest to true edges [5]. The detector works by plotting continuous points (lines) on the edges of the virtual boundary between two objects. Segmentation of the Sobel algorithm is performed based on this operation.

A. Canny algorithm

Canny's algorithm is based gradient operator used for finding edge strength and direction. The principle of the CANNY algorithm consists of three criteria of the edge detection. The first criterion is the criterion of SNR. The larger SNR represents the higher quality of the detection edge. The second criterion is the criterion of positioning accuracy. The larger the positioning accuracy represents the better result of edge detection. The third criterion is the criterion of the singleness edge response. This criterion gives information about it is ensure that the edge only have one response.

This algorithm is is executed in folowing steps [14]: 1) Use the Gaussian filter smoothing image to reduce the noise; 2) Use the finite difference of the first-order partial derivative for calculating the gradient magnitude $G(x,y)$ and the gradient direction $\theta(x,y)$ of the image; 3) Do non-macsimum supression for the gradient magnitude; 4) Double treshold; and 5) Edge linking. Edges are drawn in places where the gradient is the greatest.

B. Measuring method

In order to objectively measure the efficiency of edge detection algorithms and the quality of extracted edges, an approach that ensures the same is proposed. In order to objectively determine the quality of the algorithm, a test image with known edges was created. Based on the data determined in this way, the resulting images are shown with detected edges that were visually evaluated. After that, the quality measures, that are the most often applied in image processing, MSE:

$$MSE = \frac{\sum_{i=1}^{M}\sum_{j=1}^{N}\left(I_1(i,j) - I_2(i,j)\right)^2}{M * N} \quad (1)$$

and Peak Sigal to Noise Ratio, PSNR are applied:

$$PSNR = 10 \cdot \log_{10}\frac{R^2}{MSE} \quad (2)$$

where *R* is maximal variation in the input image data (for 8-bit image *R*=255).

Finally the merit measure (depicted as *F*), that was established to measure the efficiency of separated edges, [12] were applied:

$$F = \frac{1}{max\left(N_I, N_{ref}\right)}\sum_{i=1}^{N_{ref}}\frac{1}{1+\xi d_i^2} \quad (3)$$

where N_I-where is the number of pixels belonging to the edges (detected by tested algorithm), N_{ref} – the number of pixels belonging to the edges in the reference image, di the distance between the *i*-th pixel of the analyzed image that belongs to the set of edge pixels *I* and the closest pixel of the ideal edge. The ξ is a constant, which is equal to 1/9 [12], while $0 \leq F \leq 1$ is a measure of edge localization accuracy. Larger values of *F* represent greater efficiency of the algorithm.

EXPERIMENTAL RESULTS AND ANALYSES

In order to test the quality of detected edges using the Canny algorithm, an experiment was performed. A synthetic test image with 7 shades of gray was created, which was clearly separated by a black border (Fig. 1.a). Also, on the basis of this image, a synthetic edge image was created, which represents clearly defined edges (Fig. 1.b.).

A. Experiment

In the first part, the experiment was performed by changing the edge width (E_w). The edge width has been changed to determine how wide the border is recognized by the algorithm as a surface that has its own boundary. The width is varied in the range E_w={1,3,5,7,9}. After that, white gaussian noise (AWGN) was superimposed over the test image (with E_w=1). The noise is superimposed in the range of ratio with signal SNR = {-50, -20, -10, -5, -1, 0, 1, 5, 10, 20, 50, 100} (dB). The obtained results are presented visually, for the purpose of subjective assessment, and graphically using the measures, Mean Square Error (MSE) Peak Sigal to Noise Ratio (PSNR) and MERIT (F).

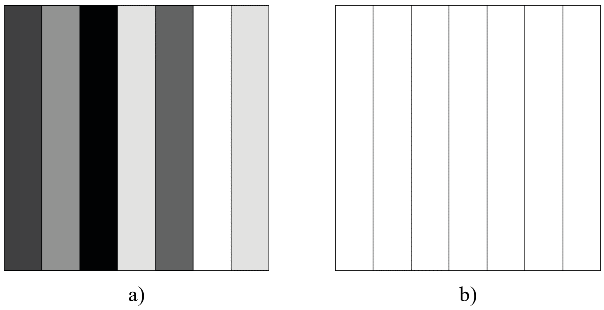

Fig. 1. *Syntetic image: a) gray image with shades, b) edge image.*

B. Experimental results

As a result of a performed experiment on fig 2. are presented images, created from the edge detected after performing Sobel (fig.2.-a,b) and Canny (fig.2.-c,d) algorithms. Fig 3. presents images, created from the edge detected after performing Sobel (fig.3.-a,b) and Canny (fig.3.-c,d) algorithms under images with superimposed AWGN noise. On fig.4. is presented quality measure F for detected edges with varied E_w, for Sobel and Canny algorithm in presence of noise. Fig.5. shows MSE and PSNR for detected edges with varied E_w, using Sobel and Canny algorithm in presence of noise.

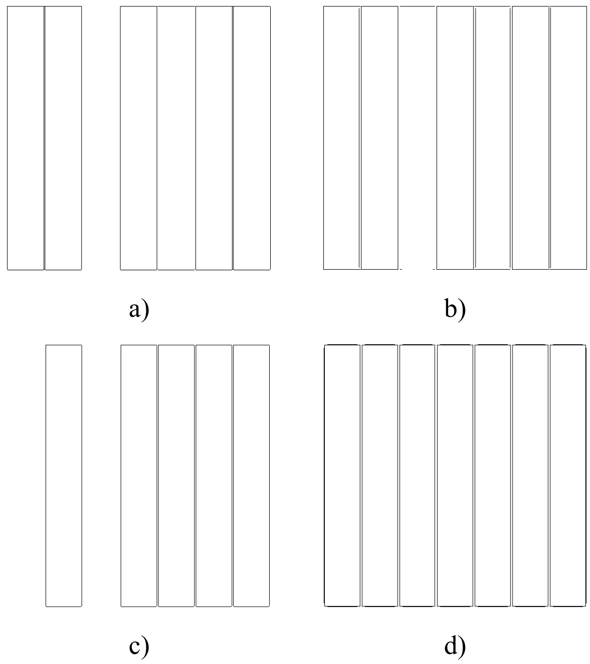

Fig. 2. *Edge image, and detected edges with: a) E_w=1 (Sobel), b) E_w=1 (Canny), c) E_w=3 (Sobel), and d) E_w=3(Canny).*

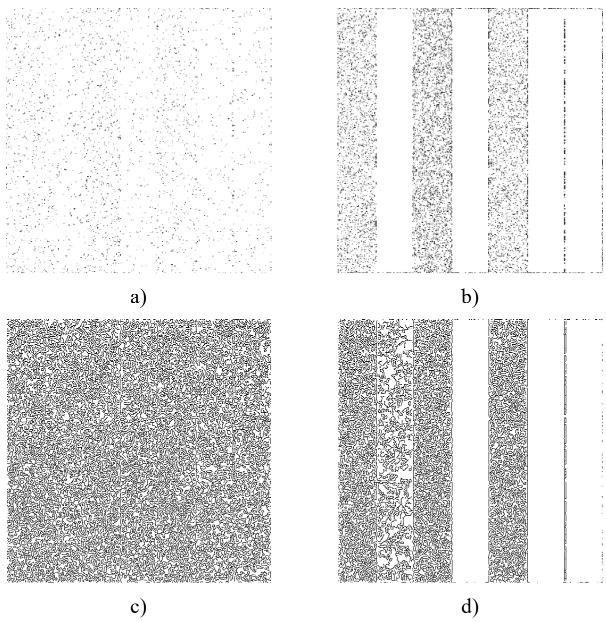

Fig. 3. *Image of detected edges (E_w=1 with AWGN ratio: a) SNR = - 50 (dB) (Sobel), b) SNR = - 20 (dB) (Sobel), c) SNR = - 50 (dB) (Canny), d) SNR = - 20 (dB) (Canny).*

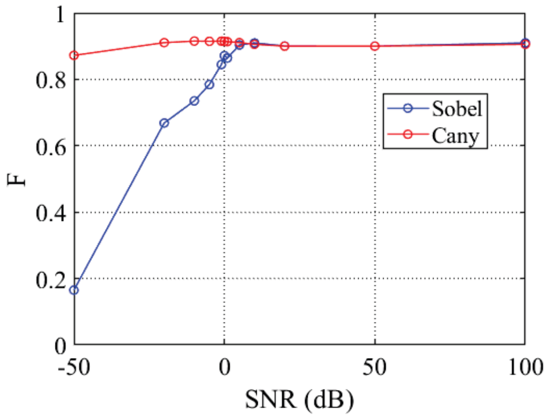

Fig. 4. *Merit (F) for edge detecting model with different SNR (for Sobel and Canny algorithm).*

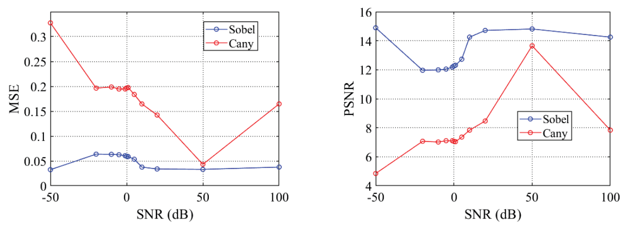

Fig. 5. *Quality measures for edge detected from the model with different SNR: a) MSE, and b) PSNR.*

C. Analysis of results

From the results presented on fig.3. we can conclude that: a) the edge between the field with the black color and the neighboring fields, and the field with the white color and real edge are not detected regardless of the edge width E_w when applying both algorithms, b) After applying a Sobel algorithm on the synthetic image with a border 3 pixels wide or more, edges are detected as edges of different field, while when applying the Canny algorithm is better edge detection.

From the results presented on fig.4. we can conclude that the Canny algorithm is detcting edges with more efficienci in presence of noise, regarding Sobel algorithm. At a signal-to-noise ratio of SNR=10 dB, the algorithms detects edges with same efficiency.

The results from the diagram in fig. 5 show that the MSE and PSNR for Canny algorithm have the values which shows to as that the edge detection for all values of SNR is more efficient.

CONCLUSION

This paper, are presented and tested Sobel and Canny algorithm for edge detection. In order to assess efficiency, objective and subjective quality measures were applied. By applying the synthetic model and combining the applied measures, by using quality assessment (MSE and PSNR) and MERIT (*F*) it was shown to as that the Canny algorithm is more efficient for edge detection in the presence of AWGN noise.

REFERENCE

[1] V. Nalwa and T. O. Binford, “On Detecting Edges,” IEEE Tran. Pattern Analysis and Machine Intelligence, Vol. 8, No. 6, pp. 699—714, November, 1986.

[2] A. Stevanovic, Z. Milivojevic and D. Brodic, “Performance of gravity algorithm for edge detection in the image,” INFOTEH-Jahorina, Vol.12, pp. 933-938, March 2013.

[3] D. Poobathy and R.M. Chezian, “Edge detection operators: Peak Signal to Noise Ratio based comparision,” I. J. Image, Graphics and Signal Processing, Vol.10, pp. 55-61., 2014.

[4] C. Spinu and J. Chassery, “Edge detection by estimation and minimization of errors,” Pattern Recognition Letters, Vol. 18, No. 9, pp. 695–704, August 1997.

[5] J. Wu, Z. Yin and Y. Xiong, “The fast multilevel fuzzy edge detection of blurry images,” IEEE Signal Processing Letters, Vol. 4, No. 5, pp. 344–347, May 2000.

[6] L. Caponetti, N. Abbattists and G. Carapella, “A genetic approac to edge detection,” in Int. Conf. Image Processing, Vol. 94, pp. 318–322, 1994.

[7] V. Srinivasan, P. Bhatia and S. Ong, “Edge detection using neural network,” Pattern Recognit., Vol. 27, No. 12, pp. 1653–1662, 1995.

[8] T. J. Hebert and D. Malagre, “Edge detection using a priori model”, in Int. Conf. Image Processing, Vol. 94, pp. 303–307, 1994.

[9] M. Jourlin and J. C. Pinoli, “Logarithmic Image Processing; The Mathematical and Physical Framework for the Representation and Processing of Transmitted Images”, Advances in Imaging and Electron Physics, Vol. 115, pp. 129—196, 2001.

[10] J. Canny, “A computational approach to edge detection,” IEEE Tranns. Pattern Anal. Machine Intell., Vol. PAMI-8, pp. 679–697, June 1986.

[11] B. Wang and S. Fan, "An Improved CANNY Edge Detection Algorithm," 2009 Second International Workshop on Computer Science and Engineering, pp. 497-500, 2009.
[12] G. Sun, Q. Liu, Q. Liu, C. Yuan and X. Li, “A Novel Approach for Edge Detection Based On the Theory of Universal Gravity”, Pattern Recognition, Vol. 40, No. 10, pp. 2766-2775, Oct. 2007.
[13] B. Prlincevic, Z. Milivojevic, N. Savic and D. Kostic, “A new approach for measuring the efficiency of edge detection algorithms”, 31st International Electrotechnical and Computer Science Conference Portorož, Slovenija, 19. - 20. september 2022 (in press).
[14] D. Pan and B. Wo, "An Improved Canny Algorithm", Proceedings of the 27th Chinese Control Conference, pp. 456-459, 2008.