

EDGES DETECTION METHODS BASED ON FILTERING FOLLOWED BY APPLICATION OF DIFFERENTIAL OPERATORS FOR FINGERPRINT

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Abstract:

This article presents the advantages of edge detection methods using filtering operations followed by application of differential operators fingerprint an image. When using methods based on differential operators when applying intensity variations can be detected by differentiation, but if noisy signals differentiation is dangerous due to the effect of amplifying the high frequencies. To eliminate this disadvantage must be designed optimal edge detectors (Canny) which satisfy the following criteria: accurate detection, correct location and a single response to a single edge.

Keywords: edge detectors, filter, differential operators, fingerprint

JEL Classification: C 61

INTRODUCTION

This article approaches the issue of improving the performances of edges detectors by noise filtering followed by application of differential operators. It has been proposed the design of an optimal edge detector (Canny), namely, the finding of the filter with the best performances in relation to three criteria: accurate detection, correct location and a single response to a single edge.

EDGES DETECTION AND MARKING

The edge detection is technique that tries to identify areas with rapid variations of intensities. Each technique is characterized by a set of operators also called edges detectors.

Correct detection of edges is a very important issue in any biometric system. The edge detection process serves at simplifying the analysis of images by strongly reducing the amount of data by preserving useful structural information about images contours of the fingerprint. Most component modules of the biometric system are directly or indirectly dependent of the edges detector performances used.

According to the principle used for edges detection, they are classified into:

- Methods based on the application of differential operators;
- Methods based on filtering followed by application of differential operators;
- Methods based on approximation by one-dimensional surfaces with a similar profile to the edge;
- Residues method.

After the manner of execution of the derivation and filtering operations the methods are classified into:

- Methods working with discrete surfaces using discrete approximation of differential operators by finite differences;
- Methods working with approximated surfaces through a continuous function and use the analytical form of differential operators.

Edges detection techniques have two distinct stages:

- Marking of the points characterized by rapid variations of intensities;
- Selection of edge points.

METHODS BASED ON THE APPLICATION OF DIFFERENTIAL OPERATORS

Methods based on application of differential operators consist in the use of differentiation in

order to highlight the points where there are rapid variations of intensity, followed by application of a threshold in order to eliminate insignificant points. Rapid variations of intensity can be increased in an isotropic or anisotropic manner using derivative operators of even or uneven order.

Disadvantages

Intensity variations can be detected by differentiation but for noisy signals the differentiation is dangerous due to its effect of amplifying the high frequencies. In conclusion, the signal requires prior filtering. On the other hand, the filtering can be a dangerous operation because it can eliminate, besides the noise, the useful signal. The basic problem of edge detectors is to sense if there is or not, in the proximity, a signal variation. If the operator is working on a proximity too high, it may overlap over more than one edge or over the edge of a complex shape, so that the response may be wrong. If working on a proximity too small, the parameter estimation is not reliable. It is necessary to correlate the operators' sizes with the united details sizes of the image.

Another disadvantage consists in the necessity of an additional step, generally not taken into account in the method assessment, consisting in edges thinning and removing of points with insignificant variations.

Therefore, we will present the methods based on filtering followed by application of differential operators.

METHODS BASED ON FILTERING FOLLOWED BY APPLICATION OF DIFFERENTIAL OPERATORS

The question concerns the design of an optimal edge detector. Canny tried to find the filter that has the best performances in relation to the following criteria:

- **Accurate detection**

There must be a low probability of unmarking a real edge point and a low probability of marking a false edge point. These probabilities are monotonically increasing functions of the signal – noise ratio. This criterion corresponds to maximizing the signal – noise ratio.

- **Correct location**

The points marked as edge points should be as close to the real point.

- **A single response to a single edge**

This criterion has been introduced because the mathematical form of the first criterion can not sense the situation of multiple responses. He gave a mathematical form to the three criteria, found the filter that maximizes them with a complicated expression, and showed that the first derivative of the Gaussian is very close to it (Figure no. 1). A similar result can be achieved with the second derivative of Gaussian.

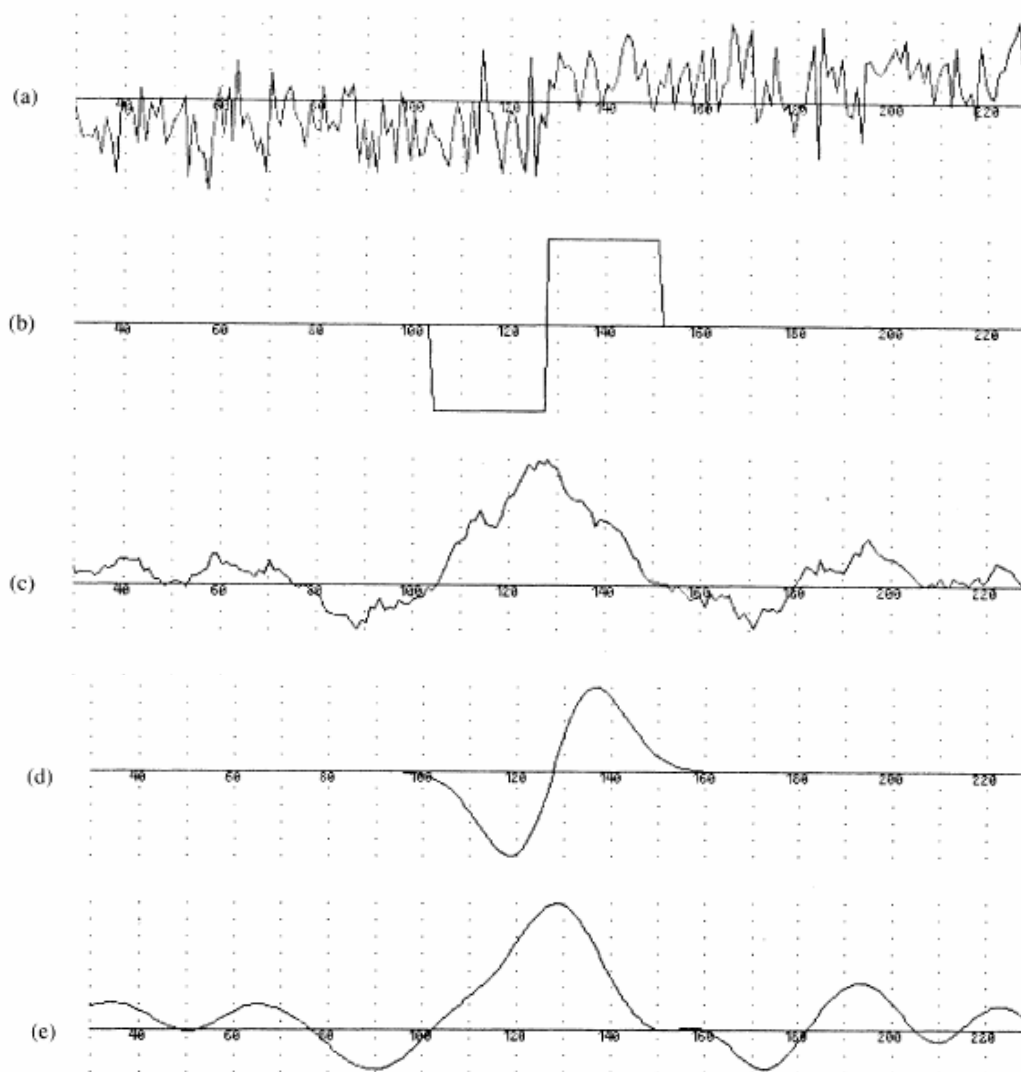


Figure no. 1. a)real edge; b) ideal edge of height h; c) unit step signal summed with a white noise of 0 average and standard deviation of 0.50 b; d) first derivative of Gaussian; e) filter response [2]

ANALYSIS OF TWO-DIMENSIONAL SITUATION

For one-dimensional case, the edge position is characterized by its coordinate. For the two-dimensional case, the edge direction is also associated to the edge point in this point.

The generalization for two-dimensional case can be made using as a filtering operator a two-dimensional Gaussian type operator:

$$G(x, y) = e^{-\frac{x^2+y^2}{2\sigma^2}} = g(x) * g(y) \quad (1)$$

As a derivation operator it can be used the gradient [4] or the second directional derivative [2], [5], [4]. As an alternative to the second directional derivative it is used the Laplacian, mainly for the calculation advantages [6], [7]. It should be noted that the zero crossings of the Laplacian do not always coincide with the gradient peaks, especially in areas with circular symmetries and corner areas [1], [3].

The highlighting of the edge points can be made by marking the maximum points of the filtered image gradient by marking the zero crossings of the second order directional derivative in the direction of the filtered image gradient or of the filtered image Laplacian.

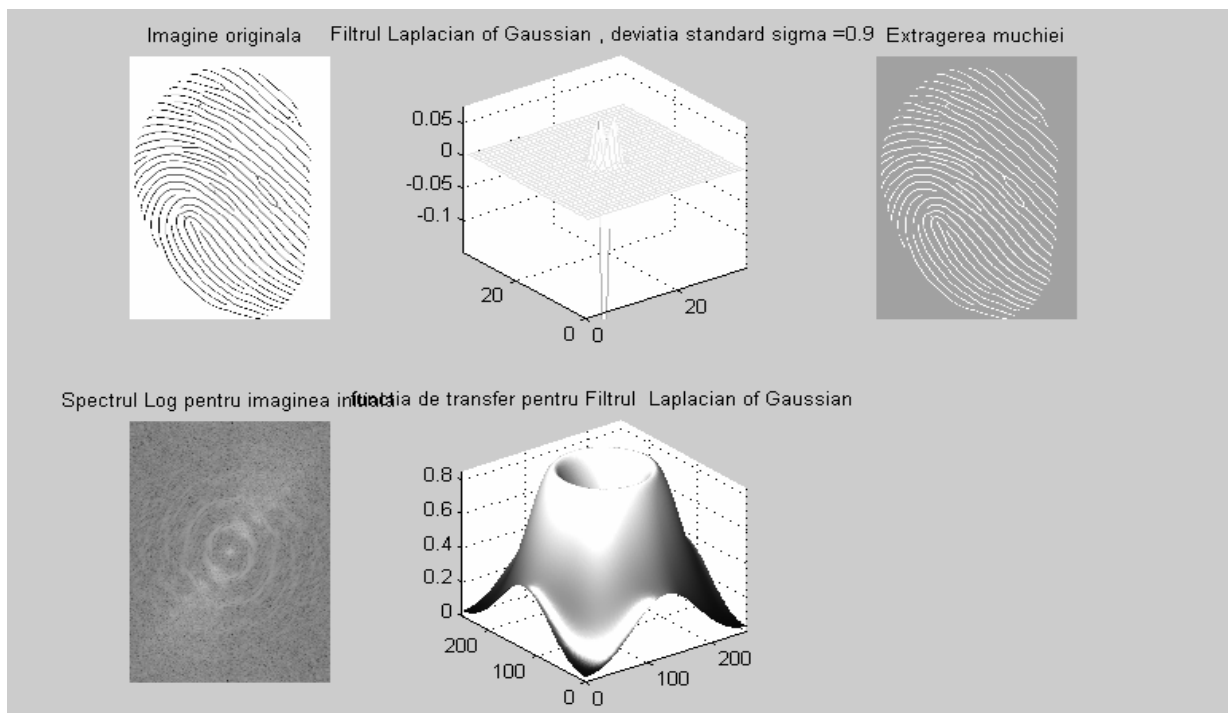
LAPLACIAN ZERO CROSSING

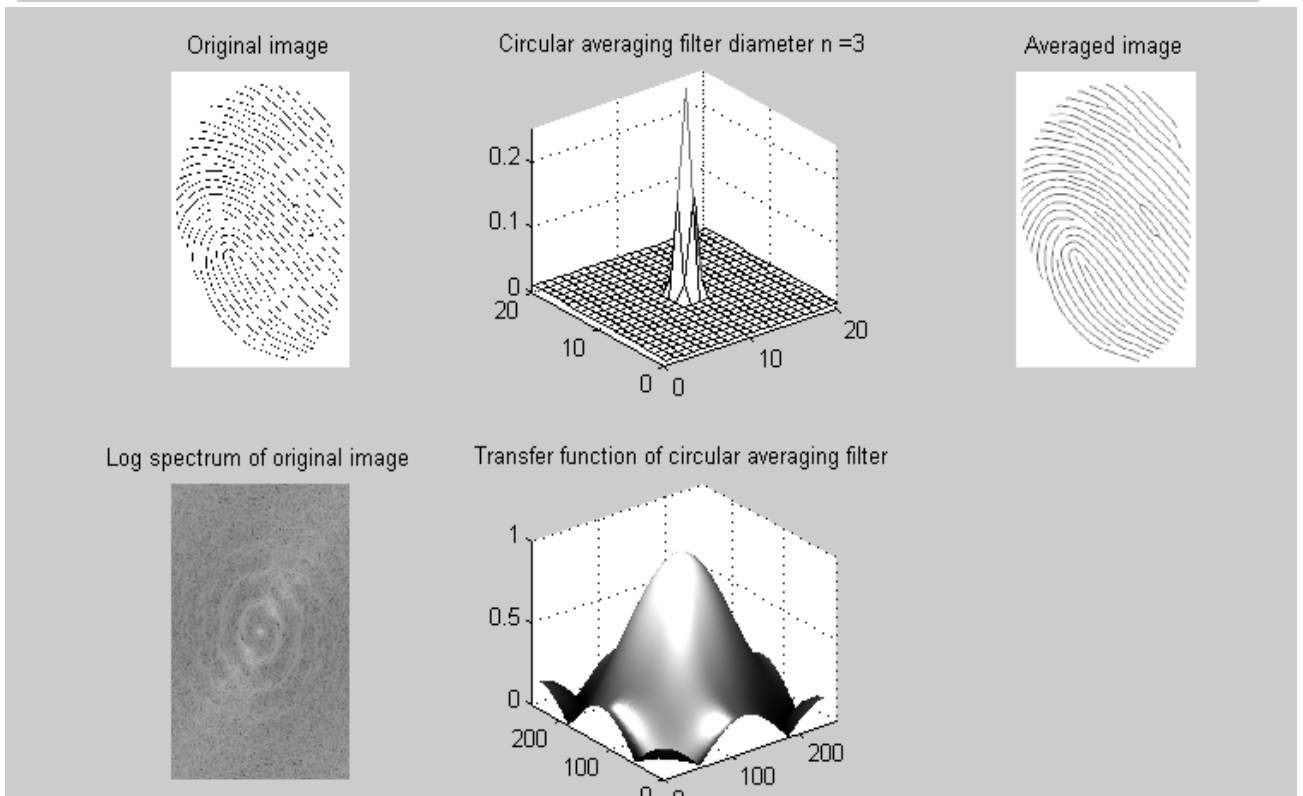
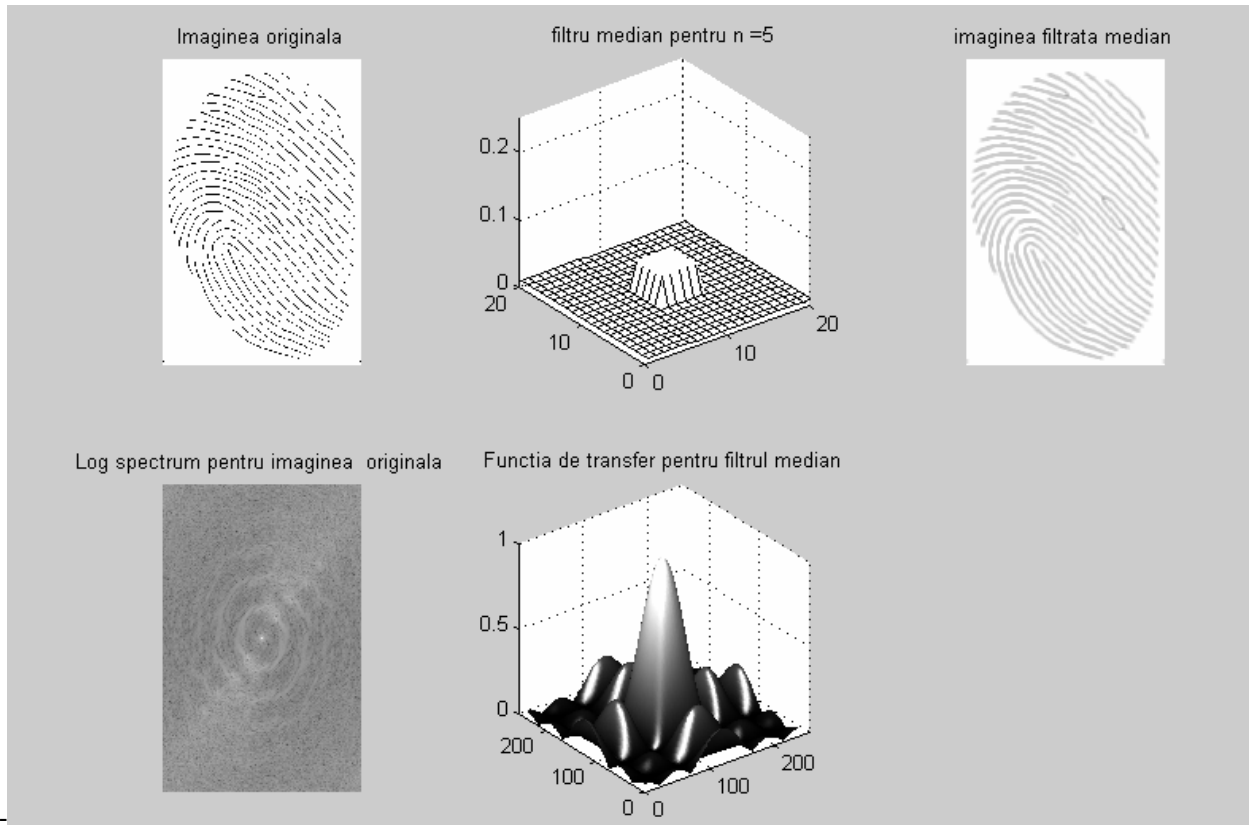
The problem of edge points detection within the two-dimensional space, by filtering followed by application of differential operators, was first discussed by Marr and Hildreth [7]. They have noted that the information present in visual stimuli occur at different scales or resolutions. In order to detect this information at different resolutions, they have proposed a band pass filter consisting of Laplacian of Gaussian:

$$\nabla^2 \cdot G = \frac{x^2 + y^2 - 2\sigma^2}{\sigma^4} e^{-\frac{x^2 + y^2}{2\sigma^2}}, \quad (2)$$

where σ is the standard deviation of Gaussian and is the spatial constant used to determine the scale at which the image will be filtered.

The idea of using the Gaussian is to selectively filter the image without removing the significant variations of intensity. The filtering only removes the details with a scale smaller than the filter width. For detection of edge points it has been used the Laplacian because it is an isotropic operator, and allows use of a single convolution that will generate orientative information. The choice of the filter width is important in determining the filtered dimensions at different scales (figure no. 2). A low filter width will highlight many edge elements, whereas a high value will refer only to the edges corresponding to high variations of intensity (figure no. 3). The use of filters at different scales creates some advantages. Thus, by tracing the zero crossings at different scales, it is possible to construct a surface of the stairs area, that will tie the massive changes to the fine details. This surface is an image fingerprint.





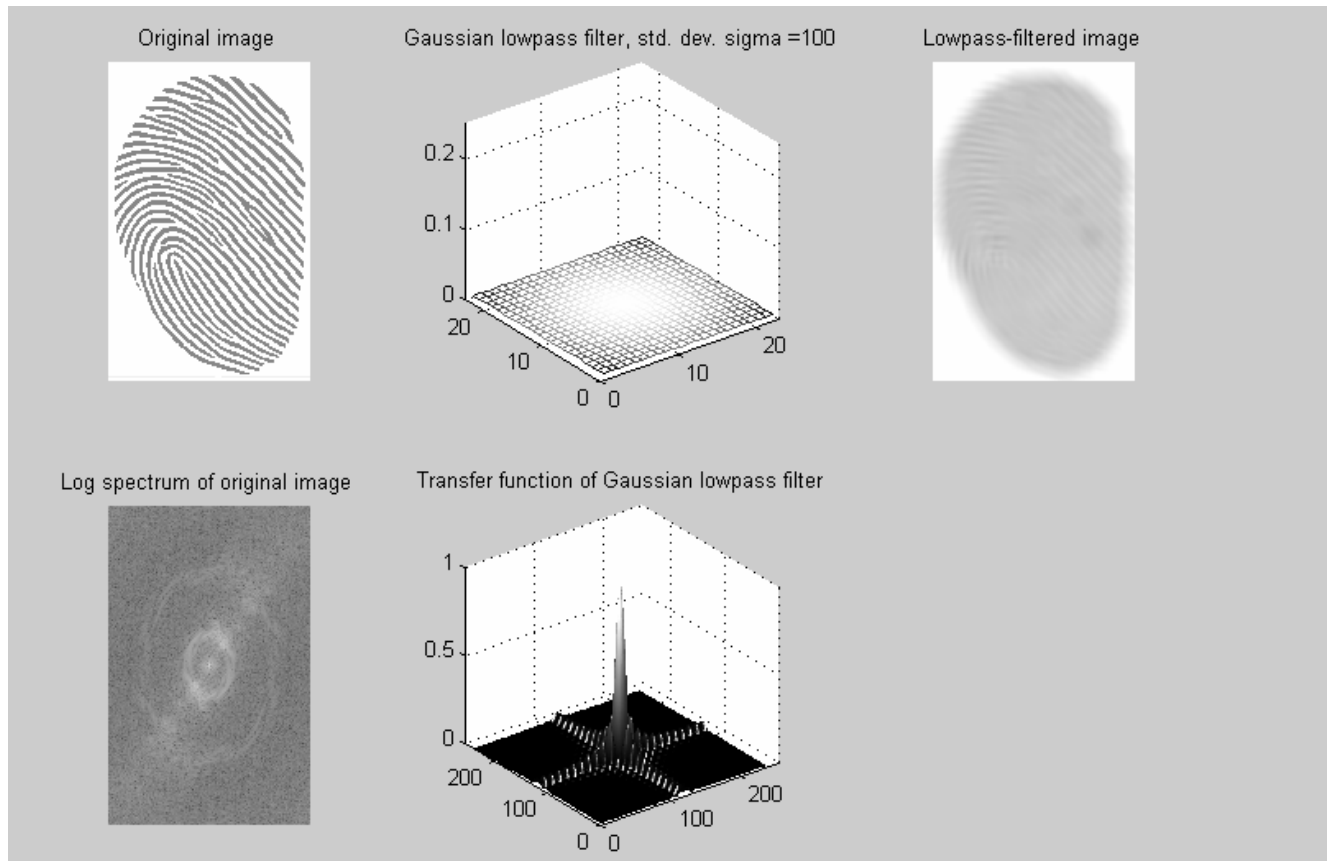


Figure no. 2. (a) Log filter and its transfer function; b) Median filter and its transfer function; c) Circular filter and its transfer function; d) Gaussian filter and its transfer function.

	$\sigma = 0.7$	$\sigma = 1.8$	$\sigma = 5.00$
Log Filter			
Transfer function			

Figure no. 3. Log Filter (Laplacian of Gaussian) and transfer function for different values of σ (0.70, 1.80, 5.00)

CONCLUSIONS

This article approaches the issue of improving the performances of edges detectors by noise filtering followed by application of differential operators. It has been proposed the design of an optimal edge detector, namely, the finding of the filter with the best performances in relation to three criteria:

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