

IDENTIFICATION OF THE NATURE OF NOISE AND ESTIMATION OF ITS STATISTICAL PARAMETERS BY ANALYSIS OF LOCAL HISTOGRAMS

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ABSTRACT

This paper deals with the problem of identifying the nature of noise and estimating its standard deviation from the observed image in order to be able to apply the most appropriate processing or analysis algorithm afterwards. In this study, we focus our attention on three classes of degraded noise images, the first one being degraded by an additive noise, the second one by a multiplicative noise and the latter by an impulsive noise. First, in order to identify the nature of the noise, we propose a new approach consisting of characterizing each class by a parameter obtained from histograms computed on several homogeneous regions of the observed image. The homogeneous regions are obtained by segmenting images. Then, the estimation of the standard deviation is achieved from the analysis of an histogram of local standard deviations computed on each of the homogeneous regions.

1. INTRODUCTION

The identification of the nature of the noise affecting an image is an important stage in all information interpretation systems by vision when the nature of the degradation is unknown. The majority of filtering algorithms (Lee, Kuan,...) [1] [2] and certain algorithms of contour detection (Canny, Deriche, ...) [3] [4] found in literature, assume that the nature of the noise and its statistical parameters are known. Whereas in most practical cases we have not *a priori* knowledge on these data [5]. For this reason the statistical parameters of the noise must be estimated as they condition the quality of the filtering or the analysis of the images [6]. Indeed, when one wishes, to apply a contour detector insensitive to the additive noise, whilst the image is degraded by a multiplicative noise, the result of the detection will not be optimal.

Thus, in this paper, we are interested in the problem of identifying the nature of the noise from the observed image with a view to applying the processing or analysis algorithm, whichever is the most appropriate. We are limiting ourselves to the problem of identifying either additive, multiplicative or impulsive noises.

In [7], we proved that it is possible to identify the nature

of the noise by recording variations of local statistics (the standard deviation as a function of the average) computed in the homogeneous regions of the observed image. If the recording is parallel to the average axis, then the noise is declared as an additive one and its standard deviation is equal to the sampling average of the different values of the local standard deviation. If the recording can be assimilated by a line passing through zero, then the noise is declared as a multiplicative one and its standard deviation is given by the slope of the line. And finally, if the recording can not be viewed as a line passing through zero, then the noise is declared as an impulsive one.

The previous methods presented in [7] [8] [9] are based on the criterion of maximum likelihood for the selection of the most homogeneous masks (Lee, Nagao etc.), from which the value of the local standard deviations are calculated. However, the disadvantage with this approach is the estimation of parameters from pixels belonging to masks *a priori* defined. This means that the estimates of standard deviations are sometimes necessarily biased and the final identification rates inevitably decreased in the case of images degraded either by a weak multiplicative or an impulsive noise.

In order to increase the rate of identification and to improve the estimation of statistical noise parameters, we propose a new method. The principle of this method firstly consists in roughly segmenting and labelling the noisy image. The image of the labels is then used for the selection of homogeneous regions which will be considered during the successive identification and the estimation procedures. This new step offers the advantage of not using an *a priori* cut-out defined by the masks. The identification step, involves the introduction of decision criteria using parameters obtained from local histograms of the homogeneous regions of the observed image.

2. DEVELOPED METHOD

As precised before, the segmentation step is carried out in two stages. The first stage automatically classes the image pixels by using a multi-thresholding technique. The different thresholds are determined by the analysis of the global histogram built from the thresholds of locally transformed histograms [10]. The transformation brings to the fore the

different modes of each local histogram and thus facilitates the research of thresholds. The second stage merges the regions which present similar brightness and configuration dynamics by minimizing a similarity criterion and allocates to them the same label (each region is said to be homogeneous if all pixels have the same label).

In order to identify the nature of the noise and estimate its standard deviation, a block of size $m \times m$ is considered for each pixel of the observed image and the image of labels, and is noted respectively as L_i and B_i ($1 \leq i \leq N$). Each block L_i thus corresponds to the block B_i as it is shown in figure 1.

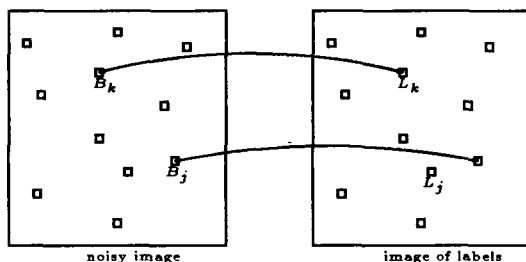


Figure 1. Correspondence between the blocks of the noisy image and the image of labels.

Each block L_i possesses one or several labels, because each block B_i possesses one or several homogeneous regions (figure 2).

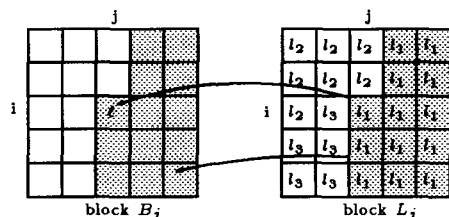


Figure 2. Correspondence between the pixels of each pair of blocks.

2.1. Identification criteria

The identification method is carried out in two stages. In the first stage, a criterion is used to detect the presence of the impulsive noise. If the result is negative, the image is then submitted to a second criterion in order to identify either the additive or multiplicative nature of the noise.

2.1.1. Detection of the impulsive noise

The principle of detection is based on an analysis of the dynamics $D(n)$ of the grey levels of the M local homogeneous regions of the observed image ($1 \leq n \leq M$). M is fixed by the number of regions of the image of labels which possesses at least S pixels (S is fixed to 128).

The detection criterion of the impulsive noise is defined as follows :

$$\text{the noise is an impulsive one if } \frac{\text{mean}(D(n))}{\text{max}(D(n))} > \lambda$$

where $\text{mean}(D(n))$ and $\text{max}(D(n))$ are respectively the mean value and the maximum value of the dynamics $D(n)$.

In the ideal case, each homogeneous region gets the same dynamic and $\lambda = 1$. However, in practical cases, this dynamic lightly differs from a region to another one, so that, we have decided to take $\lambda = 0.9$.

As a result, the noise is an impulsive one if the distribution of $D(n)$ is uniform and close to 255; if not, it is either an additive one or a multiplicative one.

The figure 3 illustrates the distribution of the dynamic $D(n)$ of an image degraded by an impulsive noise with a uniform probability equal to 0.1 and taking its values inside the interval of the luminance dynamic of the observed image.

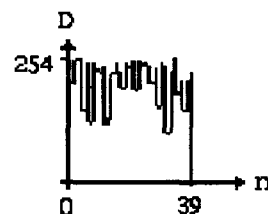


Figure 3. $D(n)$ of an image degraded by an impulsive noise with probability equal to 0.1.

2.1.2. Identification of the additive or multiplicative noise

Through conserving the hypothesis defined in [7] specifying that a uniform zone of the original image corresponds to a homogeneous zone in the noisy image, the observed image is thus divided into a set of several blocks denoted B_k of size 5×5 (or 7×7) centred on a pixel of grey level ℓ . The subscript k belongs to $[1, N_\ell]$ where N_ℓ is the number of grey level equal to ℓ . Each group G of pixels belonging to B_k with the same label ℓ than that of the centred pixel in the corresponding block L_k of the image of labels is characterized by a histogram noted $H_\ell(q)$ (q : grey level of pixel belonging to G). The figure 4 shows a test image formed by 3 grey levels, 200 (the background), 150 (the square) and 50 (the rectangle), degraded by a centred additive noise with a standard deviation equal to 12, and its $H_{50}(q)$ histogram.

As a result, each histogram can be described by a gaussian distribution and the dynamic Δ of the histogram gives an estimation of the standard deviation of this distribution law. The study of behaviours of dynamics allows the additive and multiplicative nature of the noise to be easily characterized.

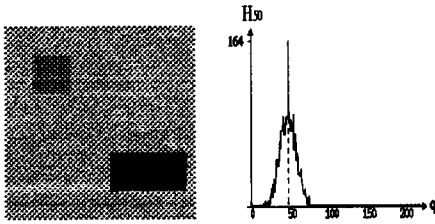


Figure 4. A test noisy image and its $H_{50}(q)$ histogram

Case of the additive noise : we can prove that in a homogeneous region, the dynamic $\Delta(\ell)$ calculated on each histogram $H_\ell(q)$ is independent of ℓ . The evolution of $\Delta(\ell)$ thus fluctuates around a constant value (figure 5).

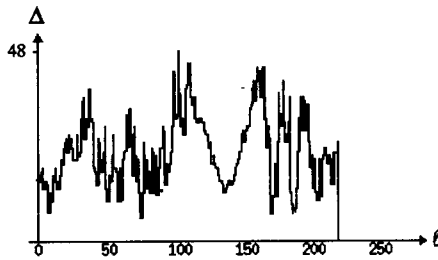


Figure 5. Histogram characterizing the presence of additive noise in an image

Case of the multiplicative noise: we can prove that the dynamic $\Delta(\ell)$ increases with ℓ so, we deduce that the curve $\Delta(\ell)$ fluctuates around a line practically passing through 0 (figure 6).

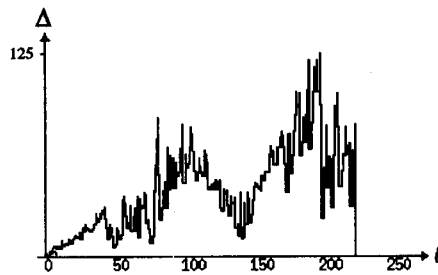


Figure 6. Histogram characterizing the presence of multiplicative noise in an image

This can be resume in the following decision criterion for the identification procedure of the additive or multiplicative nature of the noise. It consists in the possible approximation of the recording $\Delta(\ell)$ by the following models :

$$Y = AX + B \quad (\text{generalized model})$$

$$Y_1 = CX \quad (\text{multiplicative noise model})$$

$$Y_2 = D \quad (\text{additive noise model})$$

As a result, a simple comparison of the estimated values of A with C and of B with D allows one to know if the general equation of the line tends towards the line passing through 0 (multiplicative noise) or towards the parallel line at the abscissa axis (additive noise).

The decisional criterion is thus as follows :

The noise is a multiplicative one if $\frac{A}{C} > \frac{B}{D}$;

otherwise, it is an additive one.

2.2. Estimation of the noise standard deviation

Local standard deviations are computed on homogeneous region noted B_{hi} of each block B_i . The pixels of B_{hi} which are taken into account in this computation are the pixels of the block B_i to which the most frequent label in the block L_i corresponds (figure 2). If the block L_i only possesses one label then the local standard deviation is calculated on all the pixels of the block B_i .

The histogram of the N local standard deviations allows the determination of the sampling average of the local standard deviations (σ_m) and of the local standard deviation which has the highest appearance frequency (σ_f). For an additive noise the histogram is created from local standard deviations calculated on each region B_{hi} . For a multiplicative noise the histogram is made up of local standard deviations divided by the average of the grey levels of each region B_{hi} .

The figure 7 illustrates the local standard deviations histograms of an image degraded by an additive noise with a standard deviation equal to 10 (fig. 7.a) and the same image degraded by a multiplicative noise with a standard deviation equal to 0.1 (fig. 7.b).

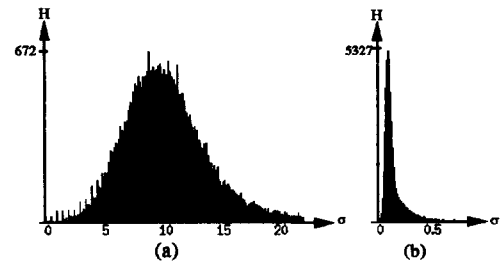


Figure 7. Histogram of local standard deviations ($n = 3$); (a) case of an additive noise; (b) case of a multiplicative noise

The parameters $\sigma_m(n)$ and $\sigma_f(n)$ are obtained for different block sizes ($n=3, 5, \dots$). The standard deviation $\sigma_f(n)$ minimizing the difference $|\sigma_m(n) - \sigma_f(n)|$ corresponds to the estimate of the noise standard deviation. Thanks to the use of the histogram the insignificant local standard deviations are not considered when estimating the value of the noise

standard deviation.

For impulsive noise, it is not worth estimating its statistical parameters, as the filters which can be found in the literature to reduce this type of noise do not need or use any information about such parameters.

3. COMPARISON AND CONCLUSION

The performances of our new method are compared to those of the previous methods [8] [9]. The algorithm is tested on different types of images, on one hand, for several probabilities of impulsive noise and different standard deviations in case of additive and multiplicative noises and on the other hand, for both uniform and gaussian noises in the case of additive and multiplicative noises.

The method for identifying the nature of the noise is tested with 50 images degraded by an additive noise, 50 images degraded by a multiplicative noise and 25 images degraded by an impulsive noise. The table 1 gives the identification rates obtained from the set of noisy images.

identification rates	add	mul	imp
additive noises	50	0	0
multiplicative noises	2	46	2
impulsive noises	1	0	24

Table 1. Identification rates of the nature of noises obtained from artificially degraded images.

The average identification rate for additive and multiplicative noises is 96%, this corresponds to a 5% increase in connection with the method explained in [9]. The identification rate of the impulsive noise is 96%, this corresponds to a 56% increase in connection with the approach proposed in [8]. The identification rates of the method of histograms are greater to those obtained by the approach computing the local statistics on the *a priori* defined masks. Finally, the estimation of noise standard deviations is more accurate than those of the other methods [7] [8]. Table 2 (resp. 3) gives the standard deviations which have been estimated on a degraded image by additive noise (resp. multiplicative noise) with uniform or gaussian distribution.

distr. of the noise	simulated	estimated
uniform	6.0	5.63
gaussian	10.0	9.97

Table 2. Estimation of the standard deviation in the case of additive noise.

The proposed method offers several advantages:

i) it does not use *a priori* masks for the detection of homogeneous regions, ii) it improves the identification rate and the estimation of the noise standard deviation, iii) finally, this

distr. of the noise	simulated	estimated
uniform	0.3	0.319
gaussian	0.1	0.101

Table 3. Estimation of the standard deviation in the case of multiplicative noise.

method is simple to implement and gives an opportunity to the user to apply the most appropriate filter or contour detector, contributing thus towards a better filtering or image analysis afterwards.

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