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An Improved Nonlinear Decision based Algorithm for Removal of Blotches and Impulses in Color Images

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Abstract - In this paper, a novel and effective method

for removal of blotches and impulse noises in corrupted color images is discussed. The new method consists of two phases. The first phase is a noise detection phase where a nonlinear decision based algorithm is used to detect impulse noise pixels. The second is a noise filtering phase where a new algorithm based on performing vector median first in RGB .. The results of simulations performed on a set of standard test images on a wide range of noise corruption show that the proposed method is capable of detecting all the impulse noise pixels with almost zero false positive rates and removes noise while retaining finer image details. It outperforms the standard procedures and is yet simple and suitable for real time applications.

Keywords— Decision based filter; blotches; impulse noise; adaptive median filter..

I.INTRODUCTION

The field of image processing has wide and important uses. Any field of work that involves images or videos has uses for research in this area. Digital image processing is the use of computer algorithms to perform image processing on digital images. In image enhancement, the aim is to improve the interpretability or perception of information in images for human viewers, or to provide `better' input for other automated image processing techniques.

In remote sensing, artifacts such as strip lines, drop lines, blotches, band missing occur along with impulse noise. In this paper the removal of botches in the presence of impulse noise is addressed. Blotches are characterized for being impulsive, randomly distributed, with irregular shapes of approximately constant intensity. They are originated by dust, warping of the substrate or emulsion, mould, dirt or other unknown causes. Blotches in film sequences can be either bright or dark spots. If the blotch is formed on the positive print of the film, then the result will be a bright spot, however if it is formed on the negative print, then in the positive copy, we will see a dark spot [1].

In addition to blotches, images are often corrupted by impulse noise due to transmission errors, malfunctioning of the pixel elements of the camera sensors, faulty memory location, timing errors in analog to digital conversion [2]. Two common types of impulse noise are the salt-and-pepper noise and the randomvalued noise.

In the presence of impulse noise, linear filters are quite ineffective. Nonlinear filtering techniques are preferred as they can cope with the nonlinearities of the image

formation model and also take into account, the nonlinear nature of the human visual system [3]. These filters effectively preserve edges and details of images, while methods using linear filters tend to blur and distort them [4].

Median filters are a class of nonlinear filters and have produced good results where linear filters generally fail. Median filters are known to remove impulse noise and preserve edges [2]. There are a wide variety of median filters in the literature.

Noise suppression or noise removal is an important task in image processing. The median filter is often applied to gray value images due to its property of edge preserving smoothing. The median filter is a nonlinear operator that arranges the pixels in a local window according to the size of their intensity values and replaces the value of the pixel in the result image by the middle value in this order. The extension of the concept of scalar median filtering to color image processing is not a simple procedure. One essential difficulty in defining the median in a set of vector values is the lack of a "natural" concept of rank regarding vectors. The problems occurring here are outlined based on the following example.

Consider the following example: three color pixels in the *RGB* color space are defined by the three color vectors $\mathbf{p}_1 = (10,40,50)T$, $\mathbf{p}_2 = (80,50,10)T$, and $\mathbf{p}_3 = (50,100,150)T$. If the median filter is applied separately to each vector component, the resulting vector is $\mathbf{p}'=(50,50,50)T$. This vector does not exist in the input data and it represents an achromatic gray value. Furthermore, the separate median filtering may cause different shifts of the local maxima in the particulars color components [12]. This problem is illustrated in the following on the basis of a one-dimensional linear vector signal with two entries (see Fig. 1).



The original signal represents three segments: left band bounded-right at n1, the middle band bounded-left by n1 and bounded-right by n2, and right band boundedleft by n2. Both entries are contaminated by impulse noise: one at the position n1 - 3 and the other at n2 + 1 (see Fig. 1(a)). The result of separate filtering with a window size of five pixels is shown in Fig. 1(b). The impulse at n1 - 1 in entry 1 is reduced and the

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distinction, which separates two segments in the original image, is shifted by one pixel position to the left. A shift also occurs at n^2 in entry 2. From this observation, one may conclude that individual processing does not remove the

impulse noise. Instead, it moves the noise position to affect its neighbor values in the image [12].

II. NOISE MODEL

Let **I** denote an image of size $M \times N$ and x(i,j) is its pixel value at position (i,j) i.e. $I = \{x(i,j): 1 \le i \le M, 1 \le j \le N\}$ having 8-bit gray scale pixel resolution i.e. $I \in [0,255]$. Blotches are the regions of usually different homogenous gray levels. Distortion of blotches looks like small coherent image area of pixels with almost similar gray values. The distortion of blotches can be well modeled as burst of impulsive distortions [2]. We assume that each pixel at x(i,j) is corrupted with probability p independent of whether other pixels are corrupted or not.

The noise model considered is

$$y(i,j) = x(i,j) \times (1 - b(i,j)) + b(i,j) \times n(i,j)$$
(1)

where

v(i,i) is the observed intensity in the corrupted region x(i,j) is the original pixel value b(i,j) is a binary flag pixel value which is set to 1 whenever pixels are corrupted and 0 otherwise

n(i,j) is the corrupted pixel intensity

If b(i, i) = 1.

then
$$y(i,j) = x(i,j)(1-1) + 1 \times n(i,j) = n(i,j)$$
 (2)
If $b(i,j) = 0$,

then $y(i,j) = x(i,j)(1-0) + 0 \times n(i,j) = x(i,j)$ (3)The image corrupted with blotches and impulse noise is now modeled as

 $y(i.j) = \begin{cases} n(i.j) \\ x(i,j) \end{cases} \quad with$ with p with (1 - v)

III. IMPLEMENTATION DETAILS

The algorithm is developed in two stages, first is the detection of corrupted pixels in the image, and the second stage is the replacement of only corrupted pixels with the estimated values, with the uncorrupted pixels left unaltered.

2.1 Detection of Corrupted Pixels

The detection is based on the assumption that a corrupted pixel takes a gray value which is substantially different than the neighboring pixels in the filtering window, whereas uncorrupted regions in the image have locally smoothly varying gray levels separated by edges. In the median filter, the difference of the median value of pixels in the filtering window and the current pixel value is compared with a threshold to decide the presence of the noise. Now a 3×3 or a larger window $W_x^{i,j}$ depending on the density of noise, is taken whose central pixel is x(i,j). For detection of corrupted or uncorrupted pixel, a binary flag image b(i,j) is constructed

such that b(i,j)=1, when the pixel x(i,j) is corrupted and b(i,j)=0 for uncorrupted pixel.

$$b(i,j) = \begin{cases} 1; if |m_x^{i,j} - x(i,j)| > THRESHOLD\\ 0; & OTHERWISE \end{cases}$$

Where $m_x^{i,j}$, represents the median value of the pixels inside the filtering window as applied in standard median filter. Now in the next stage, the corrupted pixels are replaced by the median/mean of the pixels, depending on the number of corrupted pixels in the window $W_x^{1,j}$. The threshold value is calculated in such a way that the edges or finer details are not modified as in standard median filters. The threshold value is calculated as $(x_{\min} + x_{\max})/4$, where x_{\min} and x_{\max} are the minimum and maximum values of the pixels in the window $W^{i,j}_{*}$ respectively.

2.2 Filtering of Corrupted Pixels

A. Vector Median Filter

One important characteristic of the median filter consists of the fact that it does not produce values for a pixel that do not exist in the original image. This characteristic is not always guaranteed during the adaptive scalar median filtering. One way to overcome this problem consists in the application of a vector median filter [4]. For a set of *N* vectors *x*1,..., *xN* within a right-angled window and any vector norm $| \cdot |$, \cdot the vector median filter VM is defined by the equation (see [1])

$$VM\{\mathbf{x}1,\mathbf{x}2,\ldots,\mathbf{x}N\}=\mathbf{x}VM,\qquad(4)$$

$$\mathbf{x}VM\left\{\mathbf{x}_{1},\mathbf{x}_{2},\ldots,\mathbf{x}_{N}\right\} \in (5)$$

where

$$\sum_{i=1}^{N} \|\mathbf{x}_{VM} - \mathbf{x}_{i}\|_{L} \le \sum_{i=1}^{N} \|\mathbf{x}_{j} - \mathbf{x}_{i}\|_{L}, \quad j = 1, 2, ..., N.$$

The result of this filter operation selects that vector in the /window, which minimizes the sum of the distances to the other N-1 vectors regarding the L-norm. Additionally, weightings can be specified for the vector median filter. Generally distance weights wi, i = 1, ..., N = and component weights vi, $i = 1, \dots, N =$ can be defined. The result of the weighted vector median filter is the vector x_{WVM} with xп

$$WVM \in \{\mathbf{x}_1, \mathbf{x}_2, \dots, \mathbf{x}_N\}$$

and

$$\sum_{i=1}^{N} w_i \| v_i \otimes (\mathbf{x}_{HTM} - \mathbf{x}_i) \|_{L} \le \sum_{i=1}^{N} w_i \| v_i \otimes (\mathbf{x}_j - \mathbf{x}_i) \|_{L}, \quad j = 1, 2, ..., N.$$

The point-wise multiplication is denoted with \otimes , i.e. if c $=a\otimes b$ then $ci = ai \cdot bi$ holds for all vector components. If several vectors fulfill quations (5) and/or (6), then that vector that is closest to the vector in the center of the window, is selected. The result of these filter operations is on one hand

not unambiguous and beyond that also dependent on the selected *L*-norm. Additionally, the weightings have an influence on the result when the weighted filter is applied. Thus, weightings must be selected very carefully; otherwise the characteristic of edge preservation can be lost. In each constellation it is however guaranteed that the filtering produces no additional new color vector. An investigation on the influence of the weighting on the processing result is to be found in [11].

The vector median may be computed through two different classes of algorithms, depending on the way in which the sorting is performed: absolute sorting or relative sorting. The methods belonging to the first class use the same strategy for the median choice as in the scalar case: a scalar rank value is first associated with each vector on which the sorting is made. A different choice (relative sorting) to implement the VMF may involve decomposing the minimum operation in (2) into two different steps:

• Find
$$\underline{X}_{PROT} \equiv \{ \text{prototype vector within the set } W \}$$

• $\underline{X}_{MED} = \arg \min_{j \in W} \left\| \underline{X}_{PROT} - \underline{X}_{j} \right\|$

The main advantage of absolute sorting methods is that in step it is possible to compute the VMF in only one step, so they exhibit a much higher computational efficiency than the relative sorting methods. A further consideration concerns the fact that the absolute sorting can be easily extended to other kinds of filters, such as rank-order filters or morphological filters. In this paper, we propose a new vector sorting approach. To this end, the concept of space filling curves is exploited. The proposed approach is of the absolute type, so the necessity for choosing a reference vector for sorting can be avoided. The problem of mapping a multidimensional space into 1-D space has long been considered an important one in the Image Processing literature. Space filling curves represent a possible solution to this problem. Space filling curves can be defined as a set of discrete curves that make it possible to cover all the points of a p-dimensional vectorial space. In particular, a space filling curve must pass through all the points of the space only once, and makes it possible to realize a mapping of a p-dimensional space into a scalar interval.

B. Reduced Vector Median Filter

The computation of the vector median for the entire color image is quite timeconsuming. Regazzoni and Teschioni [13] suggest an approximation of the vector median filtering, which they call "reduced vector median filtering" (RVMF). They use for this so-called "space filling curves", as are also partly used with scanners, in order to map the threedimensional color vectors into a one-dimensional space. In this one-dimensional space the median is then determined in conventional way (as in gray value images). A detailed representation of the RVMF technique may be found in [13]. Due to [13] the signal to noise ratios related to the nondistorted original images and the filtered distorted images are similar to those of the original vector median filtering. The signal to noise ratios for the reduced vector median filter are however both for Gaussian noise and for impulse noise always worse than the values for the "original" vector median filter.

.IV. SIMULATION RESULTS

The proposed algorithm is tested with different variety of color images. The performance of the algorithm is evaluated quantitatively using the measures viz. mean square error (MSE), Mean absolute error(MAE) and Normalized Color Distance (NCD). MATLAB 7.0 (R14) on a PC equipped with 2.13-GHz CPU and 2 GB of RAM memory has been employed for the evaluation of computation time of all algorithms.

In order to evaluate the performance of the filters, three effectiveness and one efficiency criteria are employed. The effectiveness criteria are:

1. Mean Absolute Error (MAE)

$$MAE = \frac{1}{3 \cdot M \cdot N} \sum_{i=1}^{M} \sum_{j=1}^{N} [|R(i,j) - \hat{R}(i,j)| + |G(i,j) - \hat{G}(i,j)| + |B(i,j) - \hat{B}(i,j)|],$$

where *M* and *N* represent the image dimensions,

 $_R_i, j_-, G_i, j_-, B_i, j_-$ and $_R^{\uparrow}_i, j_-, G^{\uparrow}_i, j_-, B^{\uparrow}_i, j_-$ are the RGB coordinates of the pixel $_i, j_-$ in the original and the filtered images, respectively. MAE is a measure of the detail preservation capability of a filter.

2. Mean squared error (MSE)

$$MSE = \frac{1}{3 \cdot M \cdot N} \sum_{i=1}^{M} \sum_{j=1}^{N} [(R(i,j) - \hat{R}(i,j))^2 + (G(i,j)) - \hat{G}(i,j))^2 + (B(i,j) - \hat{B}(i,j))^2], \quad ($$

MSE is a measure of the noise suppression capability of a filter.

3. Normalized Color Distance (NCD)

$$\text{NCD} = \frac{\sum_{i=1}^{M} \sum_{j=1}^{N} \sqrt{[(L_{ab}^{*}(i,j) - \hat{L}_{ab}^{*}(i,j))^{2} + (a^{*}(i,j) - \hat{a}^{*}(i,j))^{2} + (b^{*}(i,j) - \hat{b}^{*}(i,j))^{2}]}{\sum_{i=1}^{M} \sum_{j=1}^{N} \sqrt{L_{ab}^{*}^{*}(i,j) + a^{*2}(i,j) + b^{*2}(i,j)}},$$

where $_Lab * _i, j_, a*_i, j_, b*_i, j_$ and $_L ^ab * _i, j_, a^*_i, j_, b^*_i, j_$ are the *CIE* L*a*b* coordinates of the pixel $_i, j_$ in the original and the filtered images, respectively. NCD is a perceptually oriented metric that measures the color preservation capability of a filter.

The results of simulations performed on a set of standard test images on a wide range of noise corruption show that the proposed method is capable of detecting all the impulse noise pixels with almost zero false positive rates and removes noise while retaining finer image details International Journal of Advanced Information Science and Technology (IJAIST)ISSN: 2319:2682Vol.2, No.10, October 2013DOI:10.15693/ijaist/2013.v2i10.50-54





OUTPUT IMAGE



Pixel info: (X, Y) [R G B]

Figure 1. (a) Original lena Image (b) lena Image with Blotches and 50% Impulse Noise (d) Padarray Image (f) Output of Proposed Algorithm



Figure 2. (a) Original Image (b) Image with Blotches and 50% Impulse Noise (d) Padarray Image (f) Output of Proposed Algorithm **V. CONCLUSION**

A nonlinear decision based algorithm for removal of blotches in the presence of impulse noise in images is developed. It is a two stage algorithm, in the first stage pixels are detected as corrupted or not. The detection is based on the concept of switching threshold technique with the help of binary flag. If the pixels are uncorrupted they are left unaltered, processing is done only if the pixels are corrupted in the second stage. The filtering of corrupted pixel value is found by the vector median filter first in RGB. The performance of the algorithm is analyzed using MSE, MAE, NCD and computation time. The obtained results are compared with other algorithms. The simulation results and subjective analysis show that the proposed algorithm gives better performance as compared to other algorithms.

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