ISSN No: 2348-4845
International Journal & Magazine of Engineering, Technology, Management and Research
A Peer Reviewed Open Access International Journal

Adaptive Novel Fuzzy Filter for Random Impulse Noise Removal in a Color Video

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Abstract:
Now a day's digital image processing applications are widely used in various fields such as medical, military, satellite, remote sensing and even web applications also. In any application denoising of image/video is a challenging task because noise removal will increase the digital quality of an image or video and will improve the perceptual visual quality. In spite of the great success of many denoising algorithms, they tend to smooth the fine scale image textures when removing noise, degrading the image visual quality. To address this problem, a new fuzzy filter for the removal of random impulse noise in color video is presented. By working with different successive filtering steps, a very good tradeoff between detail preservation and noise removal is obtained. The experiments show that the proposed method outperforms other state-of-the-art filters both visually and in terms of objective quality measures such as the mean absolute error (MAE) and the peak-signal-to-noise ratio (PSNR).

INTRODUCTION:

Images and videos captured from both digital cameras and conventional film cameras will affected with the noise from a variety of sources. These noise elements will create some serious issues for further processing of images in practical applications such as computer vision, artistic work or marketing and also in many fields. There are many types of noises like salt and pepper, Gaussian, speckle and passion. In salt and pepper noise (sparse light and dark disturbances), pixels in the captured image are very different in intensity from their neighboring pixels; the defining characteristic is that the intensity value of a noisy picture element bears no relation to the color of neighboring pixel Generally this type of noise will only affect a small number of pixels in an image. When we viewed an image which is affected with salt and pepper noise, the image contains black and white dots, hence it terms as salt and pepper noise. In Gaussian noise, noisy pixel value will be a small change of original value of a pixel. A histogram, a discrete plot of the amount of the distortion of intensity values against the frequency with which it occurs, it shows a normal distribution of noise. While other distributions are possible, the Gaussian (normal) distribution is usually a good model, due to the central limit theorem that says that the sum of different noises tends to approach a Gaussian distribution. In selecting a noise reduction algorithm, one must consider several factors:

PROPOSED FRAME WORK:

The filtering framework presented in this paper is intended for color video corrupted by random impulse noise.

If we respectively denote the original (noise-free) sequence by I_o, the t_{th} frame of that sequence by $I_o(t)$ and the red, green and blue component of the color $I_o(x,y,t)$ of the pixel at the x_{th} row and y_{th} column in that frame by $I_o^R(x,y,t)$, $I_o^G(x,y,t)$ and $I_o^B(x,y,t)$ (i.e., $I_o(x,y,t) = \left(I_o^R(x,y,t), I_o^R(x,y,t), I_o^R(x,y,t)\right)$, then the noisy sequence $I_n(t)$ is determined as follows [1], [2]:

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then the noisy sequence $I_n(t)$ is determined as follows [1], [2]:

$$I_n^c(x,y,t) = \begin{cases} I_O^c(x,y,t), \textit{with } 1-p \\ \eta^c(x,y,t), \textit{ with } p \end{cases}$$

Where $c\epsilon\{R,G,B\}$ *and* $p\epsilon[0,1]$ denotes the probability that a pixel component value is corrupted and replaced by a identically distributed independent random noise value $\eta^c(x,y,t)$ coming from a uniform distributed on the interval of possible color component values. For the color videos used in the Experiments of this paper, 8 bits are used for the storage of the color component values and we work with a uniform distribution on the interval [0, 255]. Further, the probability that a given color component value is corrupted is independent on whether the neighboring values or the values in the other color components are corrupted or not. The proposed filtering framework consists of three successive filtering steps as depicted in Fig. 1. By removing the noise step by step, the details can be preserved as much as possible. Indeed, if a considerable part of the noise has already been removed in a previous step, and more noise-free neighbors to compare to be available, it will be easier to distinguish noise from small details.

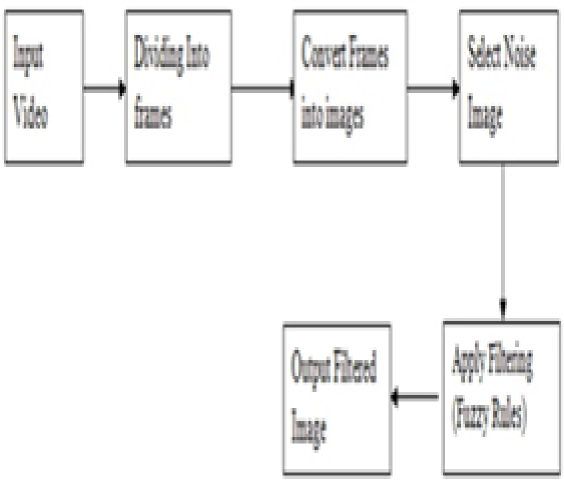

Fig1. Block diagram of proposed fuzzy filter for images

In the first step (with output denoted by I_(f_1)), we calculate for each pixel component a degree to which it is considered noise-free and a degree to which it is considered noisy. If the noisy degree is larger than the noise-free degree, the pixel component is filtered, otherwise it remains unchanged. The determination of both degrees is mainly based on temporal information (comparison to the corresponding pixel component in the previous frame).

Note, however, that only in non-moving areas can large temporal differences be assigned to noise. In areas where there is motion, such differences might also be caused by that motion. As a consequence, and as can be seen in Fig. 2, impulses in moving areas will not always be detected in this step. They can, however, be detected in the second step (output I_ (f_2)). Analogously as to the first step, again a noise-free degree and a noisy degree are calculated. However, the detection is now mainly based on color information. A pixel component can be seen as noisy if there is no similarity to its (spatiotemporal) neighbors in the given color, while there is in the other color bands.

The third step (outputI_f), finally, removes the remaining noise and refines the result by using as well temporal as spatial and color information. For example, homogeneous areas can be refined by removing small impulses that are relatively large in that region, but are not large enough to be detected in detailed regions and that thus have not been detected yet by the previous general detection steps. The results of the different successive filtering steps are illustrated for the 20th frame of the "Salesman" sequence.

First Filtering Step

Detection:

In this detection step, we calculate for each of the components of each pixel a degree to which it is considered noise-free and a degree to which it is thought to be noisy. A component for which the noisy degree is larger than the noise free degree, i.e., that is more likely to be noisy than noise-free, will be filtered. Other pixel components will remain unchanged.

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International Journal & Magazine of Engineering, Technology, Management and Research
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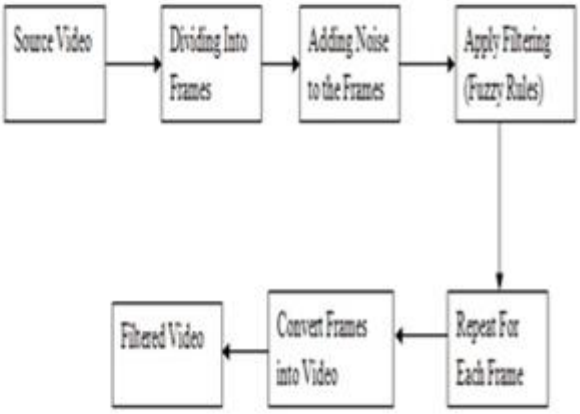

Fig2. Block diagram of proposed work for videos

The noise-free degree and the noisy degree are determined by fuzzy rules as follows.

We consider a pixel component to be noise-free if it is similar to the corresponding component of the pixel at the same spatial location in the previous or next frame and to the corresponding component of two neighboring pixels in the same frame. In the case of motion, the pixels in the previous frames cannot be used to determine whether a pixel component in the current frame is noise-free. Therefore, more confirmation (more similar neighbors or also similar in the other color components) is wanted instead. For the noise-free degree of the red component (and analogously for the other components), this is achieved by the following fuzzy rule.

Fuzzy Rule 1:

$$IF\left(\left(\left|I_n^R(x,y,t) - I_f^R(x,y,t)\right| \text{ is NOT LARGE POSITIVE OR } \left|I_n^R(x,y,t) - I_n^R(x,y,t+1)\right| \text{ is NOT LARGE POSITIVE}\right) \text{AND, there are two neighbors } (x+k,y+l,t)(-2 \le k,l \le 2 \text{ and } (k,l) \ne (0,0)) \text{ for which } \left|I_n^R(x,y,t) - I_n^R(x+k,y+l,t)\right| \text{ is NOT LARGE POSITIVE}\right)$$

To represent the linguistic value large positive in the above rule, a fuzzy set is used, with a membership function as depicted in Fig. 3 (see Section III-A for the determination of the parameters).

For the conjunctions (AND), disjunctions (OR) and negations (NOT) in fuzzy logic, triangular norms, triangular conforms and involutivenegators [26] are used. In this paper, we will use the minimum operator, the maximum operator and the standard negator (N_s (x))=1-x,x [0,1] respectively.

Those operators are simple in use and yielded the best results, but the difference compared to the results for another choice of operators is neglectible. The outcome of the rule, i.e., the degree to which the red component of the pixel at position (x,y,t) is considered noise-free, is determined as the degree to which the

Antecedent in the fuzzy rule is true:

$$\mu_{noisyfree}^R(x,y,t) = max\begin{pmatrix} min\left(max(\alpha_1(x,y,t),\alpha_2(x,y,t)), M_2(x,y,t)\right), \\ max\left(M_4(x,y,t), M_{2b}(x,y,t)\right) \end{pmatrix}$$

Where

$$\alpha_1(x,y,t) = \left(1 - \mu_{LP}\left(\left|I_n^R(x,y,t) - I_f^R(x,y,t-1)\right|\right)\right)$$

$$\alpha_2(x,y,t) = \left(1 - \mu_{LP}\left(\left|I_n^R(x,y,t) - I_n^R(x,y,t+1)\right|\right)\right)$$

and where M_2 (x,y,t)and M_4 (x,y,t)respectively de-note the degree to which there are two (respectively four) neighbors for which the absolute difference in the red component value is not large positive, that is determined as the second largest element in the set

$$\{1 - \mu_{LP}(\left|I_n^R(x,y,t) - I_n^R(x+k,y+l,t)\right|) \parallel -2 \le k,l \le 2 \text{ and } (k,l) \ne (0,0)\}$$

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And $M_{2b}(x,y,t)$ denotes the degree to which there are two neighbors for which the absolute differences in the red component and one of the two color components are not large positive, determined as the second largest element in the set

$$\{min(1-\mu_{LP}(|I_n^R(x,y,t)-I_n^R(x+k,y+l,t)|), max(1-\mu_{LP}(|I_n^G(x,y,t)-I_n^G(x+k,y+l,t)|), 1-\mu_{LP}(|I_n^B(x,y,t)-I_n^B(x+k,y+l,t)|))) \mid -2 \leq k,l \leq 2 \text{ and } (k,l) \neq (0,0)\}$$

Analogously, a degree to which the component of a pixel is considered noisy is calculated. In this step, we consider a pixel component to be noisy if the absolute difference in that component is large positive compared to the pixel at the same spatial location in the previous frame and if not for five of its neighbors the absolute difference in this component and one of the other two color bands is large positive compared to the pixel at the same spatial location in the previous frame (which means that the difference is not caused by motion). Further, we also want a confirmation either by the fact that in this color band, there is a direction in which the differences between the considered pixel and the two respective neighbors in this direction are both large positive or large negative and if the absolute difference between those two neighbors is not large positive (i.e., there is an impulse between two pixels that are expected to belong to the same object) or by the fact that there is no large difference between the considered pixel and the pixel at the same spatial location in the previous frame in one of the other two color bands. For the red component (and analogously the other components) this leads to the following fuzzy rule. In this subsection, we discuss the filtering for the red color band. The filtering of the other color bands is analogous. We decide to filter all red pixel components that are considered more likely to be noisy than noise-free, i.e., for whichμ_noisy^R (x,y,t)>μ_noisefree^R (x,y,t). The red components of the other pixels remain unchanged to avoid the filtering of noise-free pixels (that might have been incorrectly assigned a low noisy degree, but for which the high noise-free degree assures us that it is noise-free) and thus detail loss. On the other hand, noisy pixel components might re-main unfiltered due to an incorrect high noise-free degree, but those pixels can still be detected in the next filtering step.

Second Filtering Step: In our aim to preserve the details as much as possible, the noise is removed in successive steps. In this step, the noise is detected based on the output of the previous step (I_ (f_1)) . Also in this second filtering step, a degree to which a pixel component is expected to be noise-free and a degree to which a pixel component is expected to be noisy, is calculated. In the calculation of those degrees, we now take into account information from the other color bands. A color component of a pixel is considered noise-free if the difference between that pixel and the corresponding pixel in the previous frame is not large in the given component and also not large in one of the other two color components. It is also considered noise-free if there are two neighbors for which the difference in the given component and one of the other two components are not large. So, the other color bands are used here as a confirmation for the observations in the considered color band to make those more reliable.

Third Filtering Step: The result from the previous steps is further refined based on temporal, spatial and color information. Namely, the red component (and analogously the green and blue component) of a pixel is refined in the following cases:

In non-moving areas, pixels will correspond to the pixels in the previous frame, which allows us to de¬tect remaining isolated noisy pixels. If (x,y,t) lies in a non-moving 3×3 neighborhood, i.e., (with Δ(x,y,t)=|I_(f_2)^c (x,y,t)-I_f^c (x,y,t-1) |

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EXPERIMENTAL RESULTS:

The experimental results have been done in MATLAB 2011a version and tested with different color image sequences and color videos also. The proposed work has been applied to a color video 'salesman.avi', and observed the denoising results in following figures. Original frame from a color video has shown in fig.1 and the noisy image which is corrupted by random impulse noise is shown in fig2. And the denoised images after successive filtering steps have been shown in fig.3 (a) first filtering output (b) second stage output and fig4 shows final filtering step output. Also calculated the Peak Signal to Noise Ratio (PSNR) and Mean Absolute Error (MAE) for the comparison of different filtering steps in terms of the visual quality of denoised images

Fig.1 Original frame of input color video

Fig.2 Noisy image

(b)

Fig3. (a) Output of fuzzy filter after first filtering step (b) output of fuzzy filter after second filtering step

Fig4. Output of final filtering step

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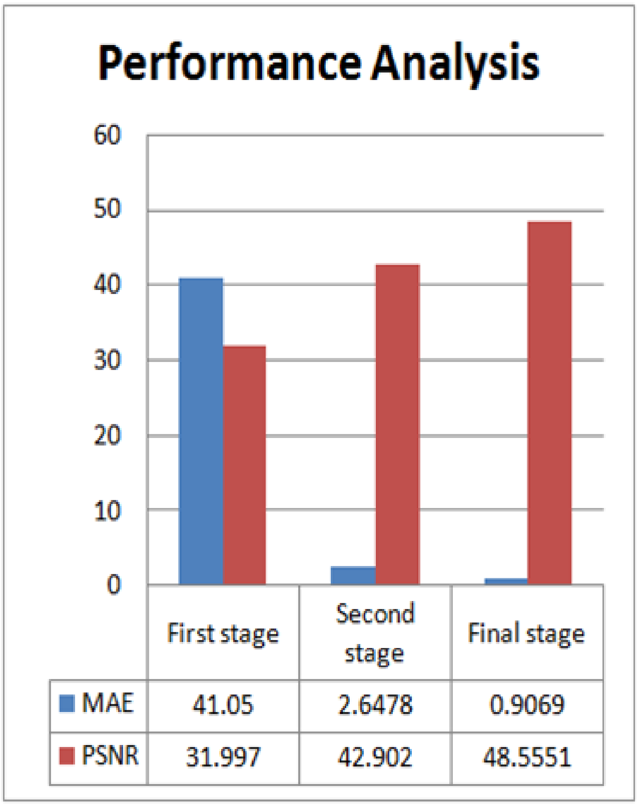

Fig5. Performance analysis of proposed filtering work

CONCLUSIONS:

Here in this letter, we had presented a novel fuzzy filtering framework for color videos, which has been corrupted by random impulse noise. To improve the efficiency, we followed a step by step process. Noised video has been denoised in successive filtering steps using proposed fuzzy rules. The experiments showed that the proposed method outperforms other state-of-the art methods both in terms of objective measures such as MAE and PSNR and visually.

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