An Efficient Salt and Pepper noise Removal and Edge preserving Scheme for Image Restoration

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Abstract

Noise Suppression from images is one of the most important concerns in digital image processing. Impulsive noise is one such noise, which may corrupt images during their acquisition or transmission or storage etc. Removing noise from any processed image is very important noise should be removed in such a way that important information of image should be preserved. For removing salt and pepper noise from corrupted image we are using so many algorithms. In this paper we propose two phase scheme for removing salt and pepper noise and edge preservation; in the first phase Adaptive median filter is used to detect corrupted pixel and preserving the edges. In the second phase Non-Local Means algorithm is used in order to have better quality of reconstitution. The proposed algorithm works well in removing salt and pepper noise at high density and preserving edges smoothly and fine detail of image compare to others. Obtained results show that the implementation of this proposal gives considerable noise suppression, even with high noise densities.

1. Introduction

Digital image are often corrupted by different types of noise, namely, additive white Gaussian noise, impulse noise and mixed (Gaussian and impulse) noise [1-4]. Noises are added in the image during acquisition by camera sensors and transmission in the channel. Hence, image de-noising is one of the most common and important image processing operations in image and video processing applications.

Although the field of digital image processing is built on a foundation of mathematical and probabilistic formulation human eyes and analysis play a central role in the choice of one technique versus another, and this choice is often made based on subjective and visual judgments. The impulse noise called salt and-pepper [7] causes white and black points appears in digital gray scale images, which chaotically scattered along image area.

The median filter has been widely used for impulse noise suppression due to its ability to preserve edges [8]. However, this does not always happen in images with high noise density, and because of that reason there have been numerous proposals on this issue, as the one presented by Wang and Zhang [7] proposed an iterative algorithm focused on the detection of pulses, just filtering pixels considered as noise. Subramanian et al. proposed a methodology divided into two stages, the first one is the use of a median filter based on decisions and the second one in determining the midpoint of a vector, obtained after eliminating extreme values. Yuan and Tan [8] proposed a noise detector based on the difference of the corrupted image and estimate of the restored image, which is obtained by applying the standard median filter on the corrupted image, than this algorithm filters
candidate pixels to be noise, through an adaptive median filter. Chan et al. [6] presented an interesting work which proposes the removal of salt and pepper noise by using a two-phase scheme. At the first phase an adaptive median filter is used in order to identify pixels that can be considered as noise. In the second phase, the image is restored by a regularization method which eliminates noise and preserves edges by minimizing a functional which consists of a data fidelity term as well as a regularization term that preserves edges.

Median filter, the most prominently used impulse noise removing filter, provides better removal of impulse noise from corrupted images by replacing the individual pixels of the image as the name suggests by the median value of the gray level of the pixels from a chosen neighborhood. The median of a set of values is such that half of its values in the set are below the median value and half of them are above it and so is the most acceptable value than any other image statistics value for replacing the impulse corrupted pixel of a noisy image for if there is an impulse in the set chosen to determine the median it will strictly lie at the ends of the set and the chance of identifying an impulse as a median to replace the image pixel is very less. For a current image f which is noisy, the median filter is a sliding square window of odd size that moves over the entire image, replaces individual pixel of the image by the median of all the pixels of the window.

2. Related Work

In order to reduce noise in digital images, a great number of algorithms have been presented. One of the most common ways to remove noise is convolving the image with a mask that represents a low-pass filter (e.g. gaussian filter), performing a smoothing operation through a weighted average of neighbors, where the weights decrease with distance from the central pixel on filter window. Often, the use of smoothing filters cause significant blurring of edges. Recently, Buades et al. [9] proposed interesting work in which they use the Non-Local Means algorithm, supported on the idea that images contain repeated structures, and averaging this structures, noise can be reduced.

In this paper we proposed two phase scheme for removing salt & pepper noise and preserving edges. In the first step (Algorithm I) we are using Adaptive median filter to detect noisy pixel in the image and replace the noisy pixels with median pixel value and on the other hand it preserve edges smoothly (algorithm I (B) shows) and in the Second step (Algorithm II) We are using Non Local Means Algorithm for better refinement of restored image and preserving fine details of image. Non Local Means Algorithm has two parts in the first part estimation of \( y^c \) of the denoised image of N pixels is computed through Adaptive Median Filter. In the second part we do refinement in the estimated image.

The idea behind using NLM Algorithm we could take advantage of structural features in neighbourhoods in order to refine previously estimated image. Using this algorithm we can restore 95\% of original image (table I). It is also help to recover the detail of original image from the noisy image. Due to its ability to remove noise while preserving great detail and the result shows that NLM algorithm is highly successful way of refinement of image.

3. PROPOSED APPROACH

Algorithm I

A. Adaptive median filter:-

To avoid the damage of good pixels in the image, we propose a novel adaptive median filter that employs the switching scheme based on local statistics characters, which realizes the impulse detection by using the difference between the standard deviation of the pixels within the filter window and the current pixel of concern. The output of median filter applied to a pixel \( X_{ij} \) is described as

\[
Y_{ij} = \text{median} \left( \{ X_{i-s, j-t} \mid (s, t) \in W \} \right)
\]

Where \( W \) is a window of size \( w \) defined in terms of the image coordinates symmetrically surrounding the current or original pixel \( (i, j) \) as follows,

\[
W = \{(k, l): |k-i| = w \text{ and } |j-l| = w\}
\]

Adaptive median filter employed in this paper, perform the following steps for each pixel location \( (i, j) \). Initialize \( w = 3 \)

1. Compute \( s_{ij}^\text{med, w} \), \( s_{ij}^\text{max, w} \), and \( s_{ij}^\text{min, w} \), which are the minimum, maximum and median of the pixel values in \( s_{ij}^w \) respectively
2. If \( s_{ij}^\text{min, w} < s_{ij}^\text{med, w} < s_{ij}^\text{max, w} \), then go to step 4. otherwise increment \( w \) by 2
3. if \( w \leq w_{\text{max}} \), go to step 1. Otherwise replace \( Y_{ij} \) by \( s_{ij}^\text{med, wmax} \)
4. if $s_{ij}^{\min,w} < Y_{ij} < s_{ij}^{\min,w}$ then $Y_{ij}$ is not noisy candidate, else replace $Y_{ij}$ by $s_{ij}^{\med,w}$.

The adaptive structure of the filter ensures that most of the impulse noises are detected even at a high noise level provided that the window size is large enough. Notice that the noise candidates are replaced by the median $s_{ij}^{\med,w}$ while the remaining pixels are left unaltered. However, the replacement methods in this denoising scheme cannot preserve the features of the images; in particular the edges are smeared.

**B. Edge preserving Regularization:**

After applying the adaptive median filter to the noisy image $X$ in the first phase, the noisy pixels in filtered image $Y$ takes values in the set $\{s_{\min}, s_{\max}\}$ we define the noise candidate set as,

$$N = \{(i,j) \in A : Y_{ij} \neq X_{ij} \text{ and } X_{ij} \in \{s_{\min}, s_{\max}\}\}$$

Where $A$ is a size of the image. The set of all uncorrupted pixels is $N_c = A \setminus N$. Considering a noise candidate, at $(i, j) \in N$, each of its neighbors $(m, n) \in V_{ij}$ is either a correct pixel or corrupted pixel the neighborhood $V_{ij}$ of $(i, j)$ is thus split as $V_{ij} = (V_{ij} \cap N_c) \cup (V_{ij} \cap N)$. Noise candidates are restored by minimizing the objective function restricted to the noise candidates set $N$,

$$F_{y|N}(u) = \sum_{(i,j) \notin V_{ij}} [u_{ij} - y_{ij}] + \frac{\beta}{2} (S_1 + S_2)$$

Where $S_1 = \sum_{(m,n) \notin V_{ij} \cap N_c} 2 \delta (u_{ij} - y_{mn})$ and $S_2 = \sum_{(m,n) \in V_{ij} \cap N} \delta (u_{ij} - u_{mn})$

$$\delta (\cdot) = \sqrt{\alpha + \varepsilon^2}, \quad \alpha > 0$$

$$\delta (\cdot) = |\cdot|, \quad 1 < \alpha \leq 2$$

With choice of $\beta$, the minimizer $u$ of $F_y$ satisfies $u_{ij} = y_{ij}$ for most of corrupted pixels $y_{ij}$. Furthermore all pixels $u_{ij}$ such that $u_{ij} \neq y_{ij}$ are restored so that edges and local features are well preserved, provided that is an edge preserving potential function.

$$F_{y|N}(u) = \sum_{(i,j) \notin V_{ij}} [u_{ij} - y_{ij}] + \frac{\beta}{2} (S_1 + S_2)$$

Algorithm II

**A. Non -Local Means Algorithm**

Buades et al. [9] proposed the Non-Local Means algorithm, based on the idea that images contain repeated structures and, averaging these structures, the noise of an image can be reduced. In other words, instead of using averages of similar pixel intensity values, this method averages neighbors with similar neighborhoods.

Given a discrete image with noise $y$, the restored value $x^m_{mn}$ for the pixel at location $(m,n) \in A$ is corrupted as the weighted of all pixel of image.

$$x^m_{mn} = \sum_{(i,j) \in A} w_{ij}^{m,n} y_{ij}$$

Where the family of weight $\{w_{ij}^{m,n}\}$ depend on the similarity between pixel at position $(m,n) \in A$ and $(i,j) \in A$. These weight must satisfy the condition $0 \leq w_{ij}^{m,n} \leq 1$ and

$$\sum_{(i,j) \in A} w_{ij}^{m,n} = 1$$

Similarly between $y_{ij}, y_{mn}$ depend on the similarity between vectors $V(\Omega_{ij})$ and $V(\Omega_{mn})$, where $\Omega_{k,l}$ denotes fixed size neighborhood. This neighborhood is defined as the pixels within the window of size $W \times W$, centered at the position $(k,l) \in A$, that can be expressed as

$$\Omega_{k,l} = \{y_{ij} : \text{i-(W-1)/2} \leq k \leq \text{i+(W-1)/2}, \text{j-(W-1)/2} \leq j \leq \text{j+(W-1)/2}\}$$
V(Ω_{k,l}) represent the vector containing the pixel that belong to neighborhood Ω_{k,l}.

Similarity between the above mentioned vectors is measured by a decreasing function of Euclidean distance
d_{i,j}^{m,n} = | V(Ω_{m,n}) - V(Ω_{i,j}) |^2

Pixels with similar neighborhood to V (Ω_{m,n}) will have large weight, which are defined as-
w_{i,j}^{m,n} = 1/Z_{m,n} e^{-d_{i,j}^{m,n}/H^2} \quad (3)

Where Z_{m,n} is the normalization constant

Z_{m,n} = \sum_{(i,j)\in A} e^{-d_{i,j}^{m,n}/H^2} \quad (4)

And the parameter H acts as a filtering degree, that is, it controls the decay of weights as a function of distances. The implementation of the original proposal of the Non-Local Means algorithm involves a high computational cost. This trouble can be reduced by using a window W_l used to compute the average with a limited number of neighbors instead of averaging all pixels of the image; and a window of size W_s which define the structure of neighborhood and the size of vector V (Ω_{k,l}) some improvement for this algorithm have been presented in general, the Non-Local Means algorithm gives good results in terms of image restoration. The results of applying our algorithm are, this work is considered as state of the art on salt and pepper noise corrupted images restoration. The results of applying our algorithm are, in general, similar o better than those reported by Chan et al. [8] but our approach taking more computational time comparative to chan et al. and other recently proposed algorithm But it can be further improves. The Non local Means Algorithm divided into two parts in the first step we are estimating the noisy pixel and then refinement in the image. We are using Non Local Means Algorithm for better refinement of restored image. Using this algorithm we can restore 95% of original image (table I). It is also help to recover the detail of original image from the noisy image. Due to its ability to remove noise while preserving great detail and the result shows that NLM algorithm is highly successful way of refinement of image.

If the size increases to reach a maximum size of window W_{max}, Central pixel value is replaced by the median value of all pixels in neighborhood.

After obtaining the image estimation, the second stage of the algorithm is refinement. For this purpose, we use the Non-Local Means algorithm. The idea behind using this proposal lies in the fact that we could take advantage of structural features in neighbourhoods in order to refine previously estimated image. This refinement is performed by calculating the weights of the pixels in the neighbourhood for a corrupt pixel candidate (whose position belongs to the set Γ) according to expression (3); then, weights greater than an established threshold, \text{TW}, are stored in a vector \text{VW}. Their corresponding intensity values are stored in a vector \text{YV}. Later, vector \text{VW} is normalized. Thus, the restored value x_{i,j}^{\text{max}} is the element-wise product of vectors \text{VW} and \text{YV}. In this way, only pixels with very similar structures to the pixel in question are involved in the computation of the new intensity value unlike original Non-Local Means algorithm. This algorithm work well in the presence of salt & pepper noise it estimate image first and then perform refinement.

It can be observed that reconstitution is quite good for all Experiments. As comparative purposes, we show in table I. this work is considered as state of the art on salt and pepper noise corrupted images restoration. The results of applying our algorithm are, in general, similar o better than those reported by Chan et al. [8] but our approach taking more computational time comparative to chan et al. and other recently proposed algorithm But it can be further improves. The Non local Means Algorithm divided into two parts in the first step we are estimating the noisy pixel and then refinement in the image. We are using Non Local Means Algorithm for better refinement of restored image. Using this algorithm we can restore 95% of original image (table I). It is also help to recover the detail of original image from the noisy image. Due to its ability to remove noise while preserving great detail and the result shows that NLM algorithm is highly successful way of refinement of image.
4. EXPERIMENTAL RESULTS AND ANALYSIS:

The Proposed Algorithm is tested using 512×512 8-bit gray scale image of Cameraman and Boat in the simulation. The image will be corrupted by salt & pepper noise with equal probability. The performance of proposed algorithm is tested for various levels of noise corruption and compared with standard filter namely Median filter, Rank-Based Adaptive Median Filter (RAMF) and Switching Median Filter. Each time test image corrupted by salt & pepper noise of different density ranging from 20 to 90. Proposed algorithm found to perform quit well on image corrupted with salt & pepper noise compared to other filter. The performance of proposed algorithm and other standard is quantitatively measured by the following parameters such Peak Signal to Noise Ratio (PSNR), Mean Absolute Error (MAE), Mean Square Error (MSE and Computational Time(CT))

$$\text{PSNR} = 10 \log_{10} \frac{255^2}{\text{MSE}}$$

$$\text{MSE} = \frac{1}{MN} \sum_{i} \sum_{j} (r_{ij} - x_{ij})^2$$

$$\text{MAE} = \frac{1}{MN} \sum_{i} \sum_{j} |r_{ij} - x_{ij}|$$

Where $r_{ij}$ and $x_{ij}$ denote the pixel value of the restored image and the original image respectively and $M \times N$ is the size of image.

Fig.1 Original images used for analysis Boats

Fig.2 Shows images restored by Median Filter, RAMF, Switching Median Filter and Our Approach respectively in each row against various levels of noise as follows:(a)Noise ratio at 20%(f)Noise ratio at 60%(k)Noise ratio at 90%
## 5. CONCLUSION

In this paper, we propose a new efficient Algorithm for removing salt & pepper noise and preserving edges in Digital image for image restoration. The Non-Local Means algorithm is used for refinement of image and preserving detail of image while removing the noise. Experimental result shows that the proposed method restores the original image much better than standard median-based filter, RAMF, Switching Based Median Filter and some of the recently proposed algorithms. It can restore 95% of original image but it is taking slightly more computational time comparatively to other filter shows in table I. but we can further improve the computational time of the proposed approach.

## 6. REFERENCES


### TABLE I

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<tr>
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