Removal of Salt and Pepper Noise from Satellite Images

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Abstract

In this paper, a new adaptive weight algorithm is developed for the removal of salt and pepper noise particularly in satellite images. Satellite images are corrupted when acquired by a defective sensor or when transmitted through a faulty channel. Salt and pepper noise can be commonly found in the sensor or transmission channel during acquisition and transmission of digital satellite images. This algorithm can be worked in two phases. During the first phase, detecting the noise pixel according to the correlations among image pixels and in second phase adaptive weight algorithm is used to remove the noise. Simulation results based on Matlab show that this method can eliminate the salt and pepper noise in satellite images efficiently and preserves edges and details information of the image. Also this method can remove noise for highly contaminated image with noise level as large as 70%, it still can get the better performance.

Keywords

salt and pepper noise; adaptive weight algorithm; Peak Signal To Noise Ratio (PSNR); Mean To Error (MTR).

1. Introduction

Digital image processing is study of digital images by the computer system. Digital images are electronic and mathematical representations of various types of images such as satellite images, medical images, personal images, forest images etc. that are stored electronically on a computer system. Image processing is a way of enhancing data images prior to computational process. Image filtering is one of the pre-processing operations which allow applying various updations on the images, to remove the noise, preserves edges and improve the quality of the image [1]. Satellite images include photographs of the earth taken through an artificial satellite revolving around the earth. The process of correcting these satellite images for haze, cloud and sensor induced defects within satellite image and overlaying 2D satellite image on 3D surface of the earth is called satellite image processing [13]. Processed satellite images have different scientific and need based applications in the field of agriculture, geology, forestry, biodiversity conservation, regional planning, education, intelligence and warfare [13].

Images obtained from satellites are useful in many environmental applications such as tracking of earth resources, geographical mapping, prediction of agriculture crops, urban growth, weather, flood and fire control etc. Space image application includes recognition and analysis of objects in the images, obtained from deep space-probe mission [8].

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Noise is the undesired data or pixel information that contaminates an image. Noise appears in images from various forms. The digital image acquisition process, which converts an optical image into a continuous electrical signal that is then sampled, is primary process by which noise appears in images. There are several ways which noise can be introduced in the image, depending on how the image is being created.

Satellite image containing the noise signals and lead to a distorted image and not being able to understand and study it properly, requires the use of appropriate filters to limit or reduce various noises from the images. It helps the possibility of better interpretation of the content of the image.

If there is introduction of salt and pepper noise in the satellite images that contains random occurrences of both black and white intensity values and often caused by threshold of noise image. The noise which sprinkles on the satellite images like black and white dots significantly reduces the visual effect of the satellite image. The common filtering is not enough to remove such type of noise and improve the image quality; it's very important to keep the details and edges as well as removing noise in satellite images so that these images are useful in future. The common salt and pepper noise filtering algorithms includes traditional median filter, extreme median filter, switching median and adaptive median filter etc. All the algorithms are sensitive to various noise levels. In many of the proposed algorithms for removing salt and pepper noise, we prefer to use adaptive weight algorithm [2] for removing the noise from satellite images. In [2], a decision based adaptive weight algorithm is proposed for the removing the salt and pepper noise in the images. This paper we shows that the modified decision based algorithm can also effectively been applied with the satellite images to remove salt and pepper noise at various noise density levels.

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2. Related work

In research paper [4], a new median-based filter, progressive switching median (PSM) filter, is proposed to restore images corrupted by salt–pepper impulse noise. The algorithm is developed by the following two main points: 1) switching scheme—an impulse detection algorithm is used before filtering, thus only a proportion of all the pixels will be filtered and 2) progressive methods—both the impulse detection and the noise filtering procedures are progressively applied through several iterations. Simulation results demonstrate that the proposed algorithm is better than traditional median-based filters and is particularly effective for the cases where the images are very highly corrupted.

In [5], a new impulse noise detection technique for switching median filters is presented, which is based on the minimum absolute value of four convolutions obtained using one-dimensional Laplacian operators. Extensive simulations show that the proposed filter provides better performance than many of the existing switching median filters with comparable computational complexity. In particular, the proposed filter is directed toward improved line preservation.

Recently prosed research paper [2], A new adaptive weight algorithm is developed for the removal of salt and pepper noise. It consists of two major steps, first to detect noise pixels according to the correlations between image pixels, then use different methods based on the various noise levels. For the low noise level, neighborhood signal pixels mean method is adopted to remove the noise, and for the high noise level, an adaptive weight algorithm is used. Experiments show the proposed algorithm has advantages over regularizing methods in terms of both edge preservation and noise removal, even for heavily contaminated image with noise level as high as 90%, it still can get a significant performance.

Many numerous algorithms were proposed and researches have been conducted to remove the salt and pepper noise. Among these noise reduction techniques, majority splits the noise removal procedures into preliminarily detection of pixels corrupted by impulse noise followed by filtering the noise detected on the previous phase [4]. The common salt and pepper noise filtering algorithms includes: Traditional Median(TM) filter algorithm; Extreme median(EM) filter algorithms; Switching median (SM) filter algorithm[4]; Adaptive median(AM) filter algorithms[6] etc. TM filter algorithm is simple and speed, but it does not have ability of effectively removing salt and pepper noise and protection for edges and details in high noise density case [5]. EM, SW and AM filter algorithms are sensitive to different noise density. Their filtering properties get worse with noise density increasing. In [12], an adaptive weight (AW) approach was proposed [2], in which the output is a weighted sum of the image and a de-noising factor, these weighting coefficients depends on a state variable. The state variable is the difference between the current pixel and the average of the remaining pixels in the surrounding window. Because the coefficients are various, it is difficult to select an appropriate one.

3. Methodology

3.1 The Proposed Method

The decision based adaptive weight algorithm is based on the following steps as

1. It checks for the pixels that are noisy in satellite image i.e. pixels with the values 0 or 255 are to be considered.
2. For each such noisy pixel P, a window size of 3x3 neighbouring the pixel P is taken.
3. Find the absolute differences between the pixel P and the neighbouring pixels of P.
4. The arithmetic mean of the differences for a given pixel P is calculated.
5. The arithmetic mean is then compared with the threshold value to detect whether the pixel P is signal pixel or corrupted by noise.
6. If the arithmetic mean is greater than or equal to the threshold value the pixel P is considered as noisy.
7. Otherwise the pixel P is considered as signal pixel.

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Median filters produce the best result for the mask of size 3x3 at low noise densities up to the 30%.Though the image is considerably blurred.

The filter fails to perform well at higher density levels and hence the new adaptive weight algorithm [2] can be used for highly corrupted satellite images. The adaptive weight algorithm is as follows

1. Noise is detected by the noise detection algorithm mentioned above.
2. Filtering is applied only at those pixels that were detected as noisy.
3. Once a given pixel P is found to be noisy the following steps are applied
4. A 3x3 mask is centred at the pixel P and founds if there exists at least one signal pixel around the pixel P.

5. If found, the pixel P is replaced by the median of the signal pixels found in 3x3 neighbourhood of P.
6. The above steps are repeated if noise still there in the output image for better results.

Peak Signal to Noise Ratio (PSNR) and Mean to Error (MTE) of the output image are computed to analyze the performance of the given algorithm as a removal of salt and pepper noise from the satellite images.

Figure 1 shows the working of the adaptive weight algorithm, as this algorithm is work in two phases. In first phase, it can detect the noise density level in the satellite image and make decision which algorithm to be applied. If the noise density level is less than 30% then the median filter can be used to remove the noise from the satellite image otherwise the adaptive weight algorithm cane to use. In second phase, the algorithm can use to remove the salt and pepper noise from satellite images.

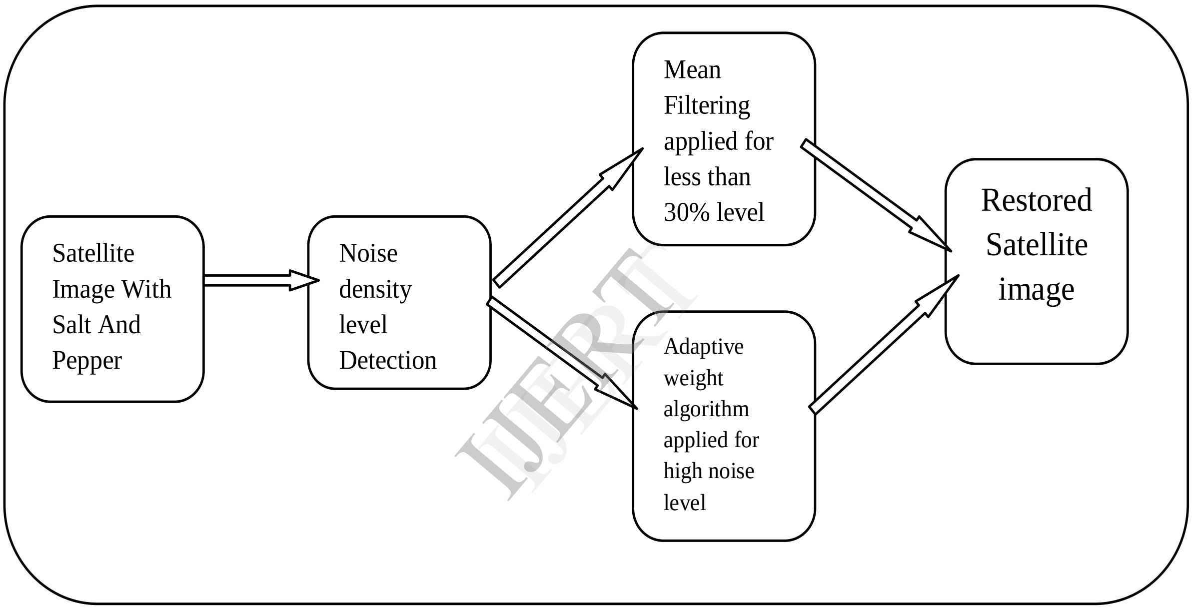


Figure 1. Adaptive Weight Filtering Algorithm Block Diagram

4. Simulation results and discussions

4.1 Simulation Results

The performance of the proposed improved adaptive weight algorithm is evaluated on various noise density levels, in which this method also proves superior by giving good results even at high density level for a satellite image. This method depicts the performance on various satellite images. These algorithms i.e. mean filtering for low density noise levels and adaptive weight algorithm to pre-process satellite image data for various satellite images with different noise density such as 5%, 10%, 20% and more than 30%. Algorithm simulated with MATLAB.

We select Peak signal to noise ratio (PSNR), Mean to error (MTE) as objective parameters with the purpose of increasing the assessment objectivity for denoised image quality.

The parameters are defined as follows

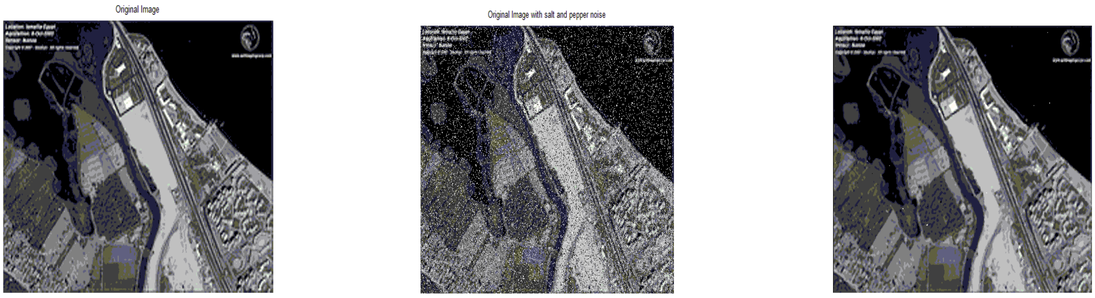
1. Peak Signal To Noise Ratio (PSNR)

$$\text{PSNR} = 10 \log \frac{255^2}{\frac{1}{MXN}\sum_{i=1}^{m}\sum_{j=1}^{n}(y_{i,j}-x_{i,j})^2}$$

2. Mean to Error (MTE)

$$\text{MTE} = \sqrt{\sum_{i=1}^{m}\sum_{j=1}^{n}(y_{i,j} - x_{i,j})2}$$

Figure 2, figure 3 and figure 4 shows the result of removal of salt and pepper noise from the satellite image with the lower noise density level as well as with the high noise density level (10 %, 25 % and 50 % respectively). The algorithm tested for various satellite images and calculates the Peak to Noise Ratio and mean error. Results are obtained for the different noise density level such as 5%, 10%, 25%, 50% etc. and observer the PSNR and MTE for all the density levels.



(a) (b) (c)

Figure 2. (a) Original Satellite image (b) Image with 10 % of noise density level (c) Restored image using median filter

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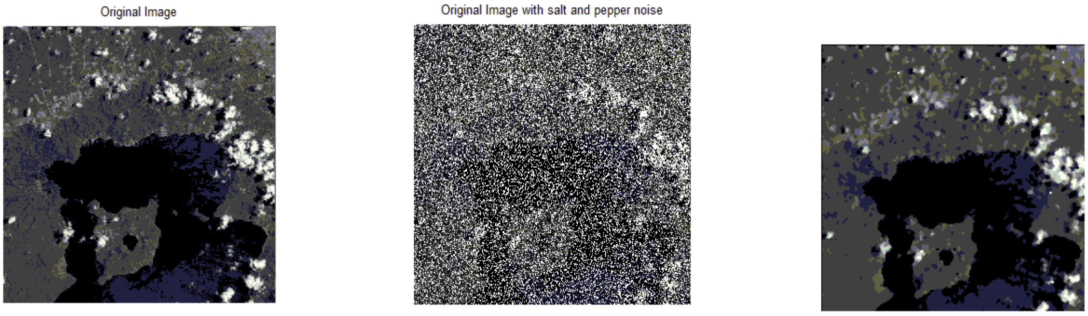
(a) (b) (c)

Figure 3. (a) Original Satellite image (b) Image with 25 % of noise density level (c) Restored image using median filter.



(a) (b) (c)

Figure 4. (a) Original Satellite image (b) Image with 50 % of noise density level (c) Restored image using adaptive weight algorithm.

4.2 Performance Analysis

Table 1. Peak to Noise Ratio

NOISE LEVEL in %	VALUES OF PSNR
5	20.3049
10	20.2062
20	20.3935
30	19.5847
35	14.6605
40	14.7838
50	15.2192
55	15.1559
60	14.6458
70	13.2517
75	12.0491

As per discussed in Different satellite images have been studied. After finding the salt and pepper noise in satellite image median filtering applied for low noise density up to 30% and adaptive weight algorithm for high noise density levels as 75% and it works better for the highly contaminated image.

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Table 2. Mean To Error

NOISE LEVEL in %	VALUES OF MTE
5	536.9509
10	535.6469
20	543.7897
30	715.7967
35	1.9206e+003
40	1.9304e+003
50	1.9551e+003
55	1.9847e+003
60	2.2310e+003
70	3.0755e+003
75	4.0567e+003

After applying the salt and pepper noise at 10% to 30% noise level, it found that PSNR remains constant to 20.30 and MTE increases regularly as the level increases in satellite images. After applying the salt and pepper noise at high noise level as 35% to 70%, it found that PSNR remains constant to 15.00 and MTE increases regularly as the level increases in satellite images as shown in Table 1 and Table 2.

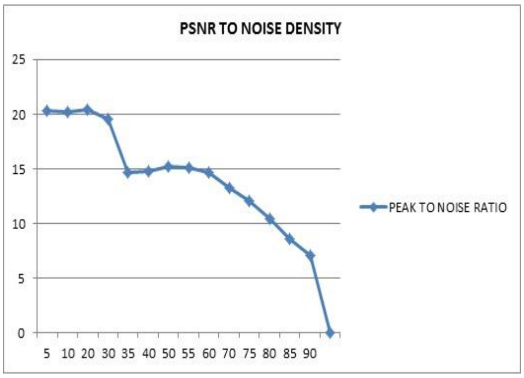

Figure 5. PSNR to Noise density level

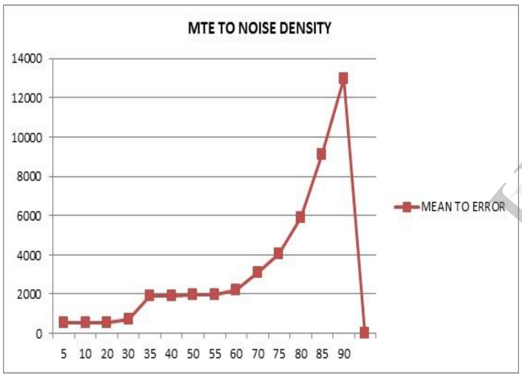

Figure 5. MTE to Noise density level

5. Conclusion

In this paper, the adaptive weight algorithm is proposed which gives better performance at high noise density levels for removal of salt and pepper noise from satellite images. Also the parameters like Peak signal to Noise Ratio (PSNR) and Mean to error (MTE) prove to give satisfactory results even at high levels of noise in satellite images. Hence the proposed adaptive weight algorithm as effective for removal of salt and pepper noise in satellite images even at high noise densities.

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