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A Survey on Filtering Technique for Denoising Images in Digital Image Processing

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Abstract: Image processing is defined as an image denoising process. In image denoising techniques, image filtering algorithms are applied on images to remove the different types of noise that are either present in the image during capturing or injected into the image during transmission. The certain image denoising filters are based on the median filters. At present there are a variety of methods to remove noise from digital images, such as Gaussian filtering, Wiener filtering etc. Due to certain assumptions made about the frequency content of the image, many of these algorithms remove fine details from images in addition to the noise.

Keywords: Denoising, Image Filtering, Median Filters, Gaussian noise, Salt & Pepper noise and Speckle noise.

I. INTRODUCTION

Image denoising is one of the most important concepts in computing field. It is widely used in various image-related applications like, MRI analysis, 3-D object detection etc. The digital images contain some degree of noise. The goal of image denoising is to restore the details of an image by removing unwanted noise. The denoised image should not contain noise.

Over the years, many denoisng techniques have been proposed. The denosing methods include Gaussian filtering and Wiener filtering etc. However, these methods tend to lose fine detail of the image which leads to blurring. A non-local means approach performs image denoisng while preserving most of the fine detail of the noisy image. This method will then be compared with two other denoising methods using different criteria on the denoised images. As suggested by Buades [1], method noise, which is the difference between the image and the demolished image, will be used as one of the criteria.

Digital images get noised when acquired by a defective sensor or when transmitted through a faulty channel. The noise removal image processing is an important pre-processing step which involves the removal of noise from digital images so that restored images can be applied to subsequent phases of segmentation [2]. Impulsive noises can be commonly found in the sensor or transmission channel during the acquisition and transfer procedure. Salt-and-pepper noise is a typical kind of impulsive noise. The nonlinear filter algorithms are often adopted for the salt-and-pepper noise removal [3].

It is well known that linear filtering techniques fail when the noise is non-additive and are not effective in removing impulse noise. This has led the researchers to use nonlinear signal processing techniques. The widely used nonlinear digital filters are median filters. Median filters are known for their capability to remove impulse noise. The main drawback of a standard median filter (SMF) is that it is effective only for low noise densities. At high noise densities, SMFs often exhibit blurring for large window sizes and insufficient noise suppression for small window sizes [4].

Fig. 1: from left to right: original image, noisy image.

II. MEDIAN FILTER

The median is a statistical concept whereby in a given sorted list of numbers, the median is the center value of the list. The use of the median in signal processing was first introduced by J. W. Tukey. If the count of the list is even, there could be multiple center values. If the count of the list is odd, there is one unique median value; therefore, it is convenient to use odd list sizes when looking for a median. The Median Filter is performed by taking the magnitude of all of the vectors within a mask and sorting the magnitudes. The pixel with the median magnitude is then used to replace the pixel studied. The Simple Median Filter has an advantage over the Mean filter in that it relies on median of the data instead of the mean. As single noisy pixel present in the image can significantly skew the mean of a set. The median of a set is more robust with respect to the presence of noise.

The standard median(SM) filter is simple and efficient in removing the impulse noise. It has been very popular for decades. In this method, there is a square window for filtering, and the window size is variable. The center pixel in the window is the one to be de-noised. Its gray value will be changed into the value of the standard median value of the square window which has been sorted.

The adaptive median filter is based on the following steps:

1. It checks for pixels that are noisy in the image, i.e. pixels with values 0 or 255 are considered.
2. For each such pixel P, a window of size 3×3 around the pixel P is taken.
3. Find the absolute differences between the pixel P and the surrounding pixels.
4. The arithmetic mean (AM) of the differences for a given pixel p is computed.
5. The AM is then compared with the ―threshold to detect whether the pixel p is informative or corruptive.
   a) If AM is greater than or equal to the threshold the pixel is considered noisy.
   b) Otherwise the pixel is considered as information. Median filters produce the best result for a mask of size 3×3 at low noise density levels though the image is considerably blurred.

The filter fails to perform well at higher noise densities. When noise density is high it is highly unlikely that there might be more informative pixels than corruptive pixels. The proposed method overcomes the limitations of normal median filter at high noise densities by considering only those pixels that are informative in the neighborhood.

The algorithm for the adaptive median filtering is as follows

1. Noise is detected by the noise detection algorithm as mentioned above.
2. Filtering is done only at those pixels that were detected as noisy.
3. Once a given pixel p is found to be noisy the following steps are followed.
   a) A 3×3 mask is centered at the pixel p and finds if there exists at least one informative pixel around the pixel P.
   b) If found so, the pixel p is replaced by the median of the informative pixels found in the 3×3 neighborhood of P.
4. The above steps are repeated if noise still persists in the output image for betterment.

Peak Signal-to-Noise Ratio (PSNR) and Mean square error (MSE), universal quality index (UQI), Structural similarity index mean (SSIM) of the output image are computed to analyze the performance of the proposed filter as a denoising technique.

III. THE MEAN FILTER

The Mean Filter is a linear filter which uses a mask over each pixel in the signal. Each of the components of the pixels which fall under the mask are averaged together to form a single pixel. This new pixel is then used to replace the pixel in the signal studied.

The mean filter proposed in [5] is a new type of filter. The main difference between median filter and mean filter is that it uses the mean value for replacing the center pixel which is to be filtered. There are three steps of this method. Firstly, creating a given size $N*N$ (e.g. N=3) window, supposing $I'(i,j)$ is the center of the window (Fig. 2). Sum all the pixels in the square window, recorded as S. $S = \sum\sum I'(i, j)$. Secondly, detecting the maximum and the minimum pixel value in this window, subtracting the $^{i=1/j}$ value$^{=1}$ of those pixels from S, recorded as S'. At the same time, the number of the rest pixels in the window is marked as x. Computing the mean value with the equation: $M = S'/x$. In the third step, replacing the value of $I'(i,j)$ with M.

$(i-1, j$ □ $1)$	$(i, j$ □ $1)$	$(i$ □ $1, j$ □ $1)$
$(i-1, j)$	(i, j)	$(i$ □ $1, j)$
$(i-1, j-1)$	$(i, j-1)$	$(i$ □ $1, j-1)$

Fig.2. 3*3 window

As we saw, the median filter and the mean filter change all of the pixels, no matter it is a noise spot or a signal spot. It is inevitable to smooth the sharp edges, and add the calculated amount. So the new algorithm proposed in this paper will firstly separate the probable noise spots from the signal spots. The same work has been done in [6]. In [6], the paper supposes that the spot is pepper noise when the gray value equals to 0, and salt noise when the gray value equals to 255. In this paper, considering the error scope, we suppose the pixel value ranging from 0 to 5 be the pepper noise, 250 to 255 be the salt noise. The two intervals are: [0, 5] and [250,255]. It means that the pixel value falls in these two intervals will be treated as the probable noise. In the processing phase, the filter will just process those pixels, without processing all of the pixels in the image.

Also the proposed algorithm takes two variable thresholds, T_1 and T_2. T_1 and T_2 are adaptive selected from 0 to 255. In the processing phase, T_1 and T_2 will separate the pixels with different gray value into three different processing states. In brief, our paper uses two noise intervals for detecting probable noise spots firstly. And then takes two thresholds T_1 and T_2 to check whether it is a real noise spot or not in the detecting phase, and determine which state the pixels should belong to. Finally, in the processing phase, the mean filter and median filter will be combined together to process the different state of the pixels processed by T_1 and T_2.
Figure 3 represents some common filtering approaches.

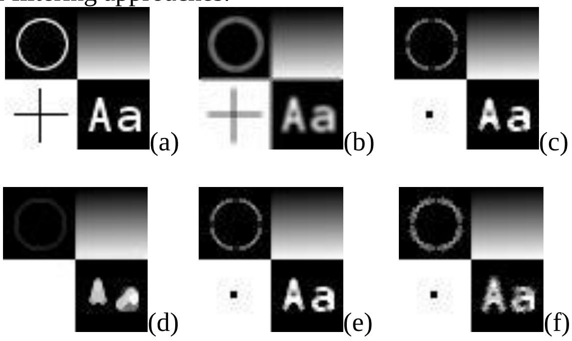

Figure 3. Examples of common filtering approaches. (a) Original Image (b) Mean Filtering (c) Median Filtering (d) Root signal of Median Filtering (e) Component-wise Median Filtering (f) Vector Median Filtering

Image filtering algorithms are applied on images to remove the different types of noise that are either present in the image during capturing or injected into the image during transmission. The review work deals with performance comparison of Median and Wiener Filters in image de-noising for Gaussian noise, Salt & Pepper noise and Speckle noise.
The median filter and the mean filter are combined for changing the value of the corrupted pixels. The filter can preserve the fine details of image while suppressing the impulsive-type noise.

IV. CONCLUSION

After the analysis of the test results, the non-local means algorithm proved to be a better algorithm for image denosing, than its predecessors. The Gaussian filtering performed poorly on all the test cases. The denoised images still contained significant amount of noise. The Wiener filter managed to perform a little better than the Gaussian filter. However, the denoised images still appeared to be blurry. It was able to recover much more detail of the original image from the noisy image. Due to ability to remove noise while preserving great detail, the NLM method is a highly successful way of approaching image denosing. In this review paper we have reviewed two new filters for removing impulse noise from images.
The non-local means algorithm assumes the concept of self-similarity, instead of making the above mentioned assumptions. This concept of self-similarity is used in the NLM algorithm to perform image denoising.

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