Restoration of Images Based on Patch Processing

G Vismaya, Soorej K S

Department of Electronics and Communication Engineering, Jawaharlal College of Engineering and Technology, Mangalam, Lakkidi, Ottapalam, Palakkad, Kerala, India

***Abstract* – It is observed that there is a great increase in use of images in all fields. The different source has different formats for image and can introduce some kind of distortion in it. The increase in use of images increases the need to develop technology of restoration of clear image from corrupted one. In recent times, image processing methods using local patches has become very common. Patch is generally a small rectangular piece of an image. These are small pixel areas and powerful primitives in image processing. The proposed method implements an image restoration depicting the cases of image denoising and inpainting using patch processing. The work flow is formulated in such a way that for a corrupted image, we may extract patched and reorder them in such a way that they are placed in a shortest path of possibility. Then depending on the quality of the images that is, noisy or containing missing pixels, operations that may smoothen image such as filtering or interpolation is applied to the reordered patches to get a good recovery of the image. PSNR and MSE are analyzed as image quality assessments. Then we may permute the image many times under various iterations (the number of iterations for a denoising is two and for inpainting is three) and may observe the improvement of peak signal to noise ratio and the decrement of Mean square error as the image quality improvement.**

***Keywords* – Patch based processing, denoising, inpainting, patch based permutations, PSNR, MSE**

I. INTRODUCTION

An image worth thousands of words and during the process of acquisition of the image, it may be degraded due to various reasons. The increase in the use of images nowadays increases the need of developing a technology to restore the clear image from the corrupted one. Thus image restoration has become a challenging topic in the image processing field. The primitive methods of image restoration techniques include inverse filtering, wiener filtering, mean filters, constrained least square filtering etc and these techniques has its own disadvantages also. The proposed method implements an image restoration scheme depicting the cases of image denoising and inpainting using patch processing. Instead of processing the whole image at once, we divide the image into patches. The dimensions of the patches will be very low compared to the original image. The work flow is formulated in such a way that for a corrupted image, we may extract patches and reorder them in such a way that they are placed in a shortest possible path solving issues like travelling salesman problem. Patch is a small rectangular piece of an image. These are small pixel areas and powerful primitives in image processing. Patch based image models can be generally classified in to two- descriptive and generative models. Descriptive models mainly focus image classification and recognition whereas generative models emphasis on compression and restoration techniques. As we are focusing on image restoration, this is a generative based method. After the extraction of the patches, patches have been ordered using a patch reordering algorithm. Operations such as filtering (for denoising) and interpolation (for inpainting) is applied to the reordered patches to obtain a good and clear image. The similar or primitive approaches include NL-Means, clustering based approach etc. in the non local means approach, image is converted into patches and the any random pixel is considered for the starting and then weighted patches are arranged as per similar distances. The drawback of NL means approach is the performance issues for larger images. In the clustering based approach, patches with similarities were grouped into clusters and treated disjoint sets and each set is treated separately and the drawback is the implementation complexity and scalability issues. Here we also demonstrates path through patches and smoothness of the image when it is patch ordered via patch reordering algorithm and raster scan method. The core idea of the work is that, we may extract all the patches and may reorder it and permute the image many times under different iterations. The number of iterations for a denoising case is set to be two and for an inpainting case is three. The number of permutations for each iteration is set to be ten. Peak signal to noise ratio and mean square error are used as the image quality assessment measures. Higher the value of PSNR and lower the value of MSE better will be the quality of the image. The increment of PSNR and decrement of MSE are observed under each iteration and improvement in the quality of images are analyzed

The work flow steps are shown below

1. Take the image to be reconstructed (which may be noisy or contain missing pixels)
2. Divide the image into patches
3. Add some Additive White Gaussian Noise (mean=0, variance = σ^2)
4. Create a Permutation matrix of size N that smoothens the distorted image
5. Apply one dimensional smoothing operator (interpolation/ filtering)
6. Apply inverse Permutation to get reconstructed image
7. Repeat step 5 for K different permutation matrix
8. Examine PSNR (Peak Signal to Noise Ratio) and MSE (Mean Square Error)
9. The value of PSNR increases with each permutation and MSE decreases with each permutation (we can choose the number of permutations)

10. As PSNR increases, the quality of image also increases and when MSE decreases the quality of image increases
11. For de noising we are performing 2 iterations and for in painting we are performing 3 iterations
12. Perform 10 permutations in each set of iterations.

A. Theory

Proposed system mainly consists of six modules. The steps include preprocessing stage, processing by applying permutations, inverse permutation and sub image averaging; reorder in to original image and obtaining the clean result by analyzing the values of PSNR and MSE. Preprocessing mainly consists of two steps. The first step mainly includes dividing of the image in to small patches whose size is small comparing to the original image. In our case the size of the patches varies with noise standard deviations. The second step is the setting of patch size, number of permutations etc. The input image is considered as the stacked version. This is similar to the vector transformation operation or converting the patches in to a column vector. Consider an input image Z having size of S1 X S2 as the input and the corrupted version of this image Z is denoted by R. R is the image which is affected by noise or may have some missing pixels in the input image. Let the values z and r represents the staked version of Z and R respectively. Then corrupted image equation will be

$$r = P\,z + c$$

In the above equation P is the permutation matrix of order SXS. The value c will be additive white Gaussian noise with zero mean and is independent of z. permutations are performed on the image pixels. We have to retain the value of z from r; so that we are applying permutation matrix of order SXS. For each and every patch apply permutation to get different values of z which produce a smoothed signals. Then for the good renovation of the clean image, we move on to one dimensional smoothing operators like mean filtering for denoising process and cubic spline interpolation for inpainting process. In the final stage we may join all the sub images or patches extracted using simple averaging. The distances between the patches are calculated using Euclidean distances. The equations for Euclidean distances are given as:

$$W(X_i, X_j) = \frac{1}{n}\,\| X_i - X_j \|^2$$

Where Xi and X j are two patches and n is defined as the number of points. The other popular patch similarity measures include pixel based distance, normalized correlation between the patches, descriptor distance, probabilistic matching etc. There are various image assessment measures to check the quality improvement of an image like histogram, similarity ratio etc. The image quality measures used here are PSNR and MSE. Our aim is to reorder the patches and we may permute the image many times under different iterations. The figure below shows the smoothness in differences between raster scan and patch reordering

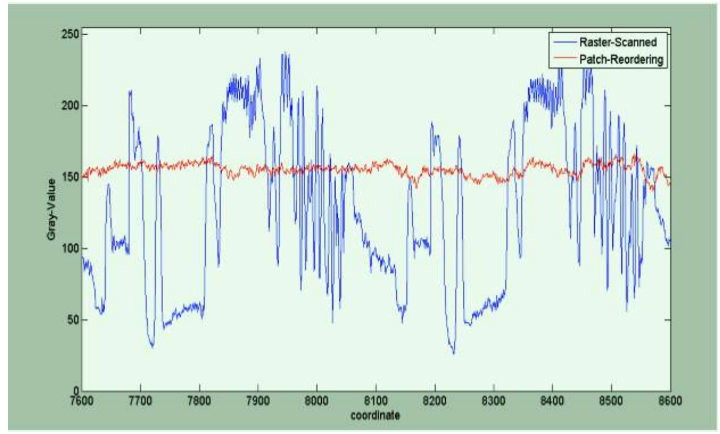

Fig. 1 Output of raster scan and patch reordering

B Image Denoising

We may move to image denoising process. The noise affecting the image is AWGN noise. The first step is the loading of the noisy image to be corrupted. As this is patch based, the first step is the extraction of the patches. We can choose the number of rows in the square patch area. We can denoise the image in various noise standard deviations like (5, 10, 15, 20, 25, 50, 75, and 100). The size of the patch varies with the noise varies with the noise standard deviations. In the denoising case we are performing two iterations; the second iteration is for the little better quality of the image in which all the processing stages remain the same, but the difference is that permutation matrices for second iteration are built using extracted patches for the first iteration clean result.

The noise we are dealing with is AWGN Noise. The main reason for the occurrence of Gaussian noise is mainly the acquisition problem or the noise due to sensors caused by the illumination problems. The filter used is simple mean filtering. Mean filtering is one of the accurate filters for the smoothing based imaging needs.

The figure shows block diagram of image denoising.

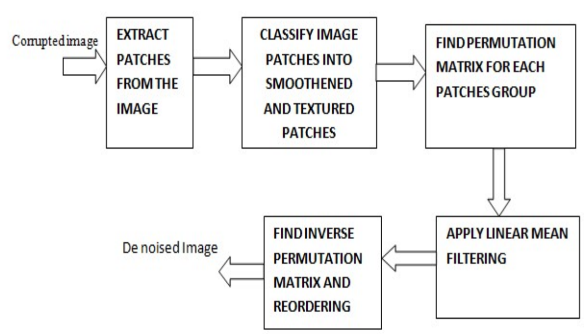

Fig. 2 Denoising Block Diagram

We can also decide the number of permutations in both the iterations; performing ten number of permutations in each iteration. Any noisy image contains smooth patches and unsmooth patches. The smooth areas in the image and areas with textures or edges are treated differently. The patches are classified into smooth and non smooth patches by converting the image into binary. The smooth patches are considered as the patches with more number of 0s where as the non smooth patches contains more number of 1s. Usually smooth patches are white and unsmooth patches are white. The distance between the patches is calculated using Euclidean distance. There are two filters named as hs (for smooth patches) and he (for unsmooth patches) to switch between the patch content. Here filtering is considered as the smoothing operator. We will analyze the changes and variations for both the filters under various standard deviations. We obtain the graphs of filters hs and he with samples and amplitude on its X and Y axis. Permutation matrices are calculated for both patch contents. When noise standard deviation increases we need a large patch to make the patch comparison robust enough. Our goal is to reconstruct a good image from its noisy versions and for this purpose we use permutation matrix. An assumption is made such that when permutation matrix is applied to the target signal, it produces a smoothened signal. We rearrange the patches in order to gain the quality of the image using patch reordering algorithm. The image exporter will transform the selected modified patch that is most suitable as a resultant sub image. After reconstruction, we want to perform inverse permutation to obtain the original image. We then make an analysis of PSNR and MSE.

Figure 2 depicts the image denoising images for standard deviations 25, 50, 75, 100. Increment of PSNR and decrement of MSE are labeled clearly below each images.

C Image Inpainting

Next is the case of image inpainting. Here we deal with images that have more than 80 % missing pixels. Inpainting is the technique of modifying an image in an undetectable form. If we consider the image to be a diagonal matrix, 1 in the principle diagonal corresponds to existing pixels and 0 corresponds to missing pixels. The applications and needs of inpainting process are many, from the restoration of damaged images, to the replacement of selected objects in an image. The first step is the loading of the image (containing missing pixels) to be corrupted. As this is patch based, the first step is the extraction of patches we may divide the images in to patches. We can choose the number of rows in the square patch area. In the inpainting case we are performing three iterations; the different iterations are for the little better quality of the image.

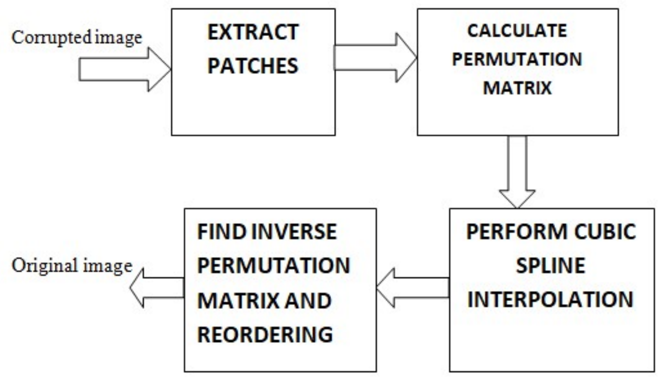

Fig.3 Inpainting Block Diagram

We can also decide the number of permutations in all the iterations; we are performing ten numbers of permutations in each of the iteration. We may reconstruct an image from its corrupted version of images which contain missing pixels by using the patch reordering algorithm. In the denoising case we use filtering as the smoothing technique; here we use cubic interpolation to recover the missing pixels. Interpolation techniques usually guess the intensity values at missing locations. After reconstruction perform inverse permutation to obtain the original image. Likewise in image denoising, we then make an analysis of PSNR and MSE.

Figure 1 shows the image inpainting images and the increment of PSNR and decrement of MSE are clearly labeled.

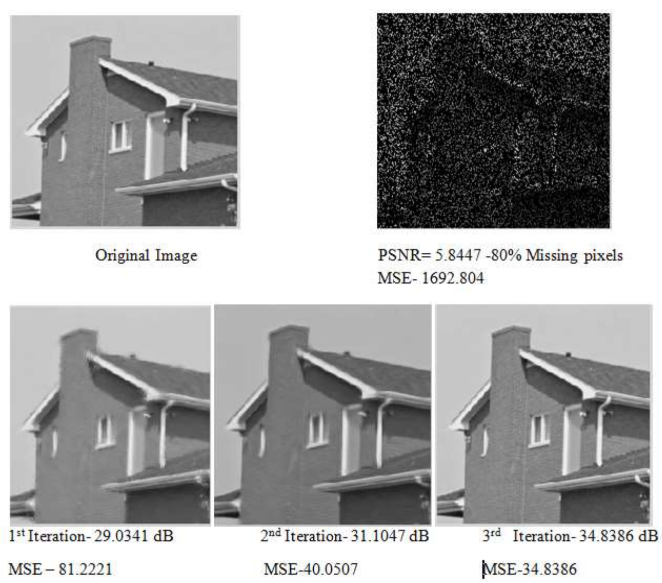

Fig. 4 Output of Image Inpainting

PSNR= 20.19 (σ=25) PSNR=29.7559 PSNR= 25.998

MSE= 623.0995 MSE=37.6649 MSE= 35.9313

PSNR= 14.17 (σ=50) PSNR=26.2906 PSNR= 26. 747

MSE= 2492.403 MSE=78.7037 MSE= 74.0509

PSNR= 10.65 (σ=75) PSNR=24.257 PSNR= 24. 823

MSE= 5609.903 MSE=133.6746 MSE= 120.0357

PSNR= 10.65 (σ=100) PSNR=22.728 PSNR= 23.347

MSE= 9696.603 MSE=200.1226 MSE= 167.0882

Fig .5 Output of Denoising (25, 50, 75,100)

Table I PSNR & MSE for various Standard Deviations- Denoising

Noise Standard Deviations	PSNR Noisy Image (in dB)	PSNR 1st Iteration	PSNR 2nd Iteration	PSNR Improvement	MSE Noisy Image	MSE 1st Iteration	MSE 2nd Iteration	MSE Decrement
5	34.17	37.5665	37.6179	3.4479	24.9240	9.0236	8.6325	16.2915
10	28.14	34.0759	34.2102	6.0702	99.6959	17.7170	17.0105	82.6854
15	24.63	32.1359	32.338	7.708	224.3158	25.1627	23.7706	200.5452
20	22.13	30.8031	31.062	8.932	398.7837	31.8243	30.3087	368.475
25	20.19	29.7559	29.998	9.808	623.0995	37.6649	35.9313	587.1682
50	14.17	26.2906	26.747	12.577	2492.403	78.7037	74.0509	2418.3521
75	10.65	24.257	24.8228	14.1728	5609.903	133.6746	120.0357	5487.8673
100	8.15	22.728	23.3478	15.1978	9696.603	200.1226	167.0822	9529.5208

Table II PSNR and MSE Analysis- Image Inpainting

PSNR Noisy Image	5.8447	MSE Noisy Image	1692.804
PSNR 1st Iteration	29.0341	MSE 1st Iteration	81.2221
PSNR 2nd Iteration	31.1047	MSE 2nd Iteration	40.0507
PSNR 3rd Iteration	34.8336	MSE 3rd Iteration	34.8386
PSNR Improvement	28.9889	MSE Decrement	1657.9654

The patches are reordered using a patch reordering algorithm. The aim is the reordering of the image patch Xj where j is defined to be 1, 2, and 3…n. In the initialization stage we may choose a value of random index j and also defines the set Ὰ (1) = {j}. In the iteration process perform k different iterations where the value of k= 1, 2, 3, 4…..N-1 and set Ak to be the set of indices. This defines three cases. The case one discuss about Ak\Ὰ = 1 and thus we set Ὰ (k+1) to be Ak\Ὰ. In the case two, it discuss about Ak\Ὰ ≥ 2. In this case, we may find Xj1 which is the nearest neighbor of XὈ (k) such that j1 is an element of Ak and j2 is not an element of Ὰ. Similarly find Xj2 the second nearest neighbor of XὈ (k) such that j2 is an element of Ak and j2 is not an element of Ὰ and so on.The third case discuss about Ak\Ὰ = 0. Find the value of Xj1 which is the nearest neighbor of Ὰ such that j1 is not an element of Ὰ. Similarly find Xj2 second nearest neighbor of XὈ (k) such that j2 is not an element of Ὰ and so on. Set the value of Ὰ(k+1) with probability value of point j1 is given by P1α exp [-W { XὈ(k),Xj} ⁄ ε] and probability value of j2 is given by P2= 1-P1 α exp [-w { XΩ (k), Xj }/ ε] assuming the condition P1+P2 = 1. We can visit the patches using this approach which are at east, west, north and south directions.

P1 (EAST) α exp [-W {XΩ (k), Xj +1} / ε]

P1 (WEST) α exp [-W {XΩ (k), Xj -1} / ε]

P1 (NORTH) α exp [-W {XΩ (k), Xj + 1} / ε]

P1 (SOUTH) α exp [-W {XΩ (k), Xj – 1} / ε]

II. CONCLUSIONS

The proposed method implements an patch based image restoration method and made the image to permute under many times under different iterations. Using permutation matrices and operations such as linear filtering and interpolation the scheme can be used for image denoising and inpainting. For image denoising, mean filter gives a good result for medium and high noise levels. For image inpainting, it uses cubic interpolation scheme, which yields better results comparing to previous methods.

CASE I IMAGE DENOISING

Denoising case has been done for various noise standard deviations. For example, for the highest standard deviation that we have used that is 100, PSNR of the noisy image is 8.144 dB; PSNR has improved to 25.118 dB in first iteration to 26.9015 in the second iteration. Likewise in the case of MSE, for the highest noise standard deviation 100, the noisy image has MSE of 9696.603; MSE has decremented to 200.1226 in first iteration and 167.0822 in the second iterations.

CASE II IMAGE INPAINTING

In the inpainting case, we deal with images having more than 80 percent of missing pixels having a noisy image PSNR of 5.8447 dB, improved to 29.0341 in the first iteration, 32.1047 in the second iteration and 32.7102 in the third iterations

Likewise in the case of MSE, noisy image has an error of 1692.804, decremented to 81.2221 in the first iteration, 40.0507 in the second and 34.8386 in the third iterations.

In the future, the proposed method can be extended in many ways. The first idea is the use of distance measure between the patches not only to find the ordering but also in the sub image reconstruction. Another idea is the patch revisiting more than once in the locations.

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