Self-Organizing Map (SOM) for Adaptive Wavelet based Image Denoising

Jagmeet Kaur
Department of Computer Science
Baba Banda Singh Bahadur Engineering College
Fatehgarh Sahib, Punjab

Ishpreet Singh
Department of Computer Science
Baba Banda Singh Bahadur Engineering College
Fatehgarh Sahib, Punjab

Abstract—**In image processing, noise reduction is important to improve the quality of the image and further it is also helpful in analysis of the images. Nowadays it's a great challenge for researchers to find an efficient method for noise removal. In this paper, we study the Self Organizing Map(SOM) for wavelet based image denoising. The images corrupted by variable Gaussian noise are denoised using this method. SOM is meant for clustering purpose and wavelet thresholding is done to remove the noise from the image. At the end the inverse wavelet transform is done to obtain the original image and finally the PSNR value is calculated to compare the results. Impressive results are obtained by applying the technique.**

***Keywords*— Self Organizing Map, Image Denoising , Wavelet Transform, Soft Thresholding , PSNR value**

I. INTRODUCTION

An image can be defined as a two-dimensional function f(x, y), where x and y are spatial coordinates, and the f at any pair of coordinates (x, y) represents the intensity or gray level of the image at that point. An image is composed of number of elements which are known as pixels. [1]Images are very often affected by the different type of noises. Noise is introduced in the image either at the time of acquisition or at the time of transmission. The sources of noise in the digital images are insufficient light levels, interference in transmission channel, dust particles on camera etc. [2]Due to noise unwanted information gets induced into the images. The undesirable effects such as blurred objects, unseen lines, artifacts, unrealistic edges, corners are produced in the image due to noise; it also disturbs the background scenes. To reduce these undesirable effects, prior learning of noise models is essential for further processing. The various noise models are: a) Gaussian Noise Model b) Salt and Pepper Noise Model c) Poisson Noise Model d) Gamma Noise Model, The Gaussian Noise Model is additive in nature means each pixel in the noisy image is a sum of true pixel value and any random value. The Salt and Pepper Noise Model produces black and white dots on the noisy image. It represents either value 0 or 255. This noise arises due to sharp and sudden changes in the image intensities. The Poisson Noise is when number of photons sensed by the sensor is not sufficient to provide detectable statistical information. [2]The Gamma Noise occurs due to low pass filtering of the laser images. [1] It is very important to remove noise from the images in order to analyses the images, number of image denoising algorithms are available, but the best one is which removes the noise completely from the image and also preserves the necessary details of the image. [1] Algorithms can be broadly classified into two categories, Spatial Domain and Transform Domain Filtering. Operations that are performed directly on the image comprise of spatial domain filtering, whereas operations performed on transform domain of the image constitute transform domain filtering. [3] Two types of spatial domain filtering are, a) Linear Filter b) Non Linear Filter, Linear Filter which is commonly used for noise removal purpose is Averaging Filter. Averaging Filter calculates the average of the neighborhood pixels and replaces the center pixel with the average value, this process results removing the sharp transitions of the image and hence blurring the image. The Mean Filter is the commonly used Non Linear Filter, it is used to remove salt and pepper noise from the images. This filter works by replacing the center pixel with the median of the neighborhood pixels. [1] Depending on the choice of basis function, the transform domain filtering can be categorized. The basis function can be further categorized as non-data adaptive and data adaptive. The wavelet domain filtering is an example of non-data adaptive transform domain method. All wavelet transform denoising algorithms involve the following three steps in general

Forward Wavelet Transform: Wavelet coefficients are obtained by applying the wavelet transform.

Estimation: Clean coefficients are estimated from the noisy ones.

Inverse Wavelet Transform: A clean image is obtained by applying the inverse wavelet transform. [4]

In the recent years, image denoising using clustering has gained sufficient focus. Clustering is mostly used to group the noisy image into geometrically similar structures. [3] In this paper, we proposed a novel way to denoise images using SOM in the wavelet domain using adaptive multilevel soft-thresholding. The rest of the paper is subdivided into the following sections; Section 2 covers the literature survey regarding the research work, soft-threshold and K-Means

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Clustering, Section 3 explains the basic concepts, Section 4 discusses about the proposed methodology of our work, Section 5 covers Experiments Performed and Results obtained, Section 6 discusses the conclusion of the results obtained.

II. RELATED WORK

Kamboj P. *et al.* [1] studied the various types of noise models. The filtering techniques to denoise the images are also studied, each one of which have their own advantages and disadvantages. Agrawal Utkarsh *et al.* [3] proposed a method to denoise images using unsupervised learning technique i.e K means clustering in the wavelet domain using adaptive multilevel soft- thresholding. At the end the PSNR value of the denoised image is calculated for comparison purpose and impressive results are obtained. Bação Fernando*et al.*[5] proposed the Self Organizing Maps as the substitute for K-Means clustering. In its final stage of training SOM is same as K-Means. Bijalwan A. *et al.*deal with image denoising using wavelet thresholding. An effective method is proposed to calculate the threshold value. The proposed method is efficient as well as adaptive because subband data based parameter is used for calculating the threshold value.

III. THEORY

A. Self-Organizing Map

SOM maps the data patterns onto an n-dimensional grid of neurons or units. That grid is known as the output space, as opposed to the input space where the data patterns are. This mapping is done in a way to preserve the topological relations, i.e., patterns that are close in the input space will be mapped to units that are close in the output space, and vice-versa.The output space is usually 1 or 2 dimensional, to allow an easy visualization. [3]

Algorithm for Self Organizing Maps

Let X be the set of n training patterns $x1, x2, .. xn$, W be a $p \times q$ grid of units $wij$where i and j are theircoordinates on that grid. α be the learning rate, assuming values in]0,1[, initialized to a given initial learning rate.r be the radius of the neighborhood function $h(w_{ij}, w_{mn}, r)$, initialized to a given initial radius

Step1: Repeat

Step 2: For k=1 to n

Step 3: For all $w_{ij} \in W$, calculate $d_{ij} = || x_k - w_{ij} ||$

Step 4: Select the unit that minimizes d_{ij}as the winner w_{winner}

Step 5: Update each unit $w_{ij} \in W$: $w_{ij} = w_{ij} + \alpha\ h (w_{winner}, w_{ij}, r) || x_k - w_{ij} ||$

Step 6: Decrease the value of α and r

Step 7: Until α reaches 0. [3]

B. Thresholding

Based on the threshold parameters the clean coefficients of the wavelet can be determined. There are two main ways of thresholding the wavelet coefficients, namely the hard thresholding method and the soft thresholding method.

Hard Thresholding

If the absolute value of a coefficient is less than a threshold, then it is assumed to be 0, otherwise it is unchanged.

Hard thresholding is discontinuous. This causes ringing / Gibbs effect in the denoised image.

Soft Thresholding

To overcome this, soft thresholding method is introduced. In this technique if the absolute value of a coefficient is less than a threshold, then is assumed to be 0, otherwise its value is shrunk by threshold.

IV. SYSTEM ARCHITECTURE

The proposed system works in two phases, namely, Training phase and Testing Phase. During Training Phase the clustering is done in a way that the components having similar properties are allotted to same group and during Testing Phase the denoising of the images is done.

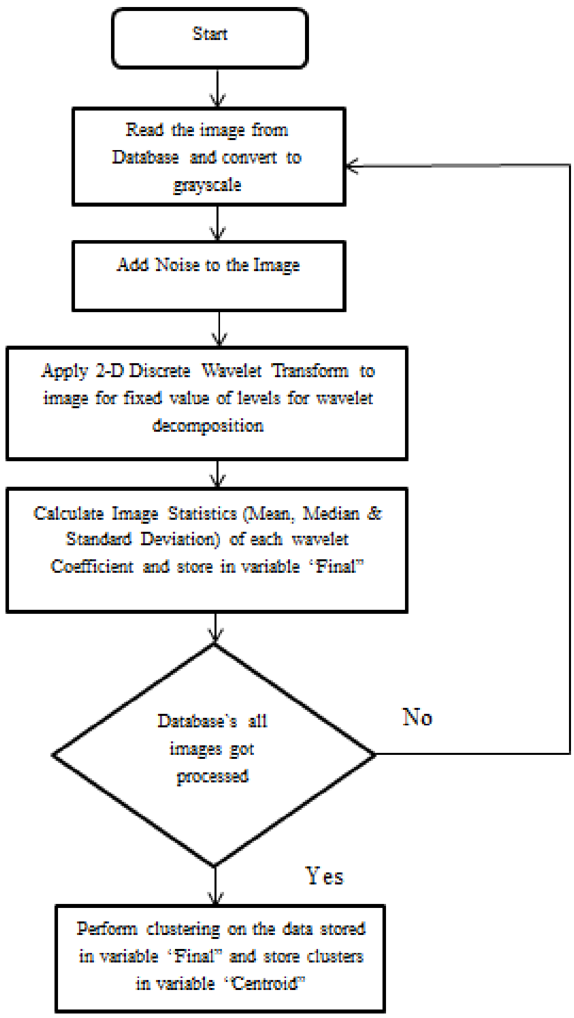

Fig. 1. Flowchart of the proposed method for the Training Phase

Step 1: Read Image "Img" from the database in a sequential manner and convert to grayscale "ImgGray"
Step 2: Add Gaussian Noise of variable mean and variance to "ImgGray" using non-overlapping blocks of size 3X3 neighborhood to generate the noisy image "ImgNoisy"
Step 3: Perform 2D- Discrete Wavelet Transform of noisy image for a fixed value of the number of levels for wavelet decomposition.
Step 4: Calculate Image statistics mean median and standard deviation of the wavelet coefficients at a given level and store in a variable "Final" to be used later for the clustering process.
Step 5: Repeat Steps 3 and 5 for different sizes of neighborhood of Gaussian noise addition such as 5X5, 7X7 and 9X9.
Step 6: Repeat Steps 1-6 for all the images present in the dataset to generate the training dataset for the clustering process.
Step 7: Execute clustering algorithm for the data stored in the variable "Final". And store the resulting Clusters obtained after applying SOM is stored in a variable "Centroids".

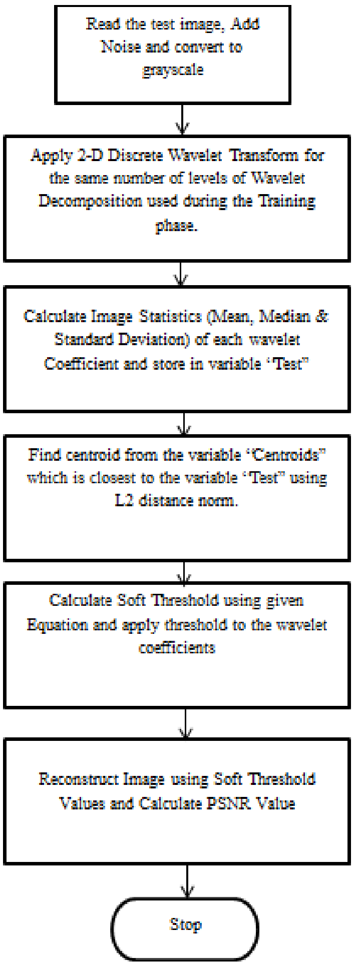

Fig. 2. Flowchart of the proposed method for Testing Phase

Step 8: Read noisy test image and convert into gray scale to generate the test image "ImgTest".

Step 9: Perform 2D- Discrete Wavelet transform of ImgTest for the same number of levels of Wavelet Decomposition used during the training phase.
Step 11: In a similar manner calculate image statistics such as mean, median and standard deviation of the noisy image for a particular level and store in a variable "Test".
Step 12: Find the centroid from the variable "Centroids" which is closest to the variable "Test" using L2 distance norm.
Step 13: Using this centroid calculate the value of soft-threshold according to equation no. 1

$$Threshold\ (T) = \frac{1}{2^{j-1}}\left(\frac{Standard\ deviation}{Mean}\right)(Median) \quad (1)$$

Soft Threshold the wavelet coefficients using the value of soft-threshold calculated above.
Step 14: Finally reconstruct the output image using the soft-thresholded wavelet coefficients, and calculate its Power Spectrum Noise Ratio (PSNR).

V. EXPERIMENTS AND RESULTS

The images of the dataset are processed using the proposed method as well as the base method. The resultant PSNR values obtained after denoising the images using base method and proposed method are as shown in Table 1. A general analysis of Table 1 shows that proposed method produces better results than the base method. The PSNR value in case of proposed method is high as compared to base method.

Table 1: Resultant PSNR values

Image	PSNR values obtained using base method	PSNR values obtained using proposed method
Image 1	28.4037	30.4005
Image 2	27.4789	29.0379
Image 3	23.4483	24.0425
Image 4	23.7724	24.3773
Image 5	25.2393	26.1063
Image 6	27.6978	29.3182
Image 7	24.6708	25.3912
Image 8	27.7676	29.5101

Some examples of results obtained are shown below:

Fig 3. Images denoised using base method

Fig 4. Images denoised using proposed method

VI. CONCLUSION

In this paper, the denoising problem is addressed using SOM as the clustering technique and further denoising the given image using wavelet based thresholding. Firstly, the system is trained on the given image dataset and then the testing phase starts in which any gray scale noisy image is denoised using the given method. The conclusion drawn from the above done work is that the SOM gives better results than K-Means, it can be observed from the PSNR value calculated at the end. For the future work, the same methodology can be implemented for the colored images.

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