A SURVEY ON IMAGE DENOISING WITH 2-D FIR FILTER

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***Abstract*: Different factors may be responsible for introduction of noise in the image insufficient light levels and sensor temperature may introduces noise in the image ,the image may also corrupted due to interference in the transmission channel, the noise in the image can also be introduced if dust particles are present on the scanner screen. Filtering in an image processing is a basic function that is used to perform many tasks such as noise reduction. Images are corrupted by random and unnecessary variations in intensity values called noise due to non perfect camera acquisition or environmental conditions.**

***Keywords*: Image Denoising, FIR Filter, Multi-Dimensional**

I. INTRODUCTION:

In today's, image processing area has attracted much attention for scientific as well as its applications and developments. This research field has been used in many areas from medical imaging to geographical application [1]. Moreover, the communication technologies that are based on the sending and receiving the collected images from one point to another point are developed in every day.

In the area of communication, biomedical imaging, space application, image acquisition and etc., one of the most important and common research topics is to eliminate different noises such as impulse or Gaussian [2]. Different methods and approaches have been proposed to the elimination of the various noises from the images. For example, a simple neuro-fuzzy method has been suggested to eliminate the impulsive noise by Yuksel [3]. Abadiet. al. has been used two-dimensional adaptive filter algorithms for image denoising [4].

Recently, two dimensional (2D) digital filters have found a wide range application in the image denoising application, image enhancement, space image processing, etc. [5-7]. In addition to these developments, the evolutionary and swarm intelligence based 2D digital filter design approaches have been introduced by Mastorakis et al., Das et al. and Kumar et al. [8-10].

In 2005, Karaboga has proposed the ant colony (AC) algorithm for numerical optimization problems [11]. In addition, AC algorithm was competed by Basturk and Karaboga with the other population-based optimization algorithms [12, 13] and they concluded that AC is simple to implement and also quite robust compared to that of the other algorithms. Moreover AC has been used to solve various problems from different areas such as noise elimination using FIR and IIR digital filter and the parameter extraction of the Schottky (SBD) diode [14-15].

This study is presented that a design method based on the AC algorithm is proposed for the elimination of the noise from digital image using 2D digital filter. In the 1970s, image denoising was studied by control theorist Nasser Nahi at USC and computer vision pioneers such as S. Zucker and Azriel Rosenfeld. In 1980, J. S. Lee published an important paper titled "Digital image enhancement and noise filtering by use of local statistics" [57]. The invention of wavelet transforms in late 1980s has led to dramatic progress in image denoising in 1990s. The Bayesian view towards image denoising was put forward by Simoncelli&Adelson in 1996 and since then, many wavelet-domain denoising techniques have been proposed [100]. The simple yet elegant Gaussian Scalar Mixture (GSM) algorithm published by Portilla et al. in 2003 [52] and the NonLocal Mean (NLM) algorithm by Buades et al. in 2005 have renewed the interest into this classical inverse problem. In the past three years, many more powerful denoising algorithms have appeared among them the patch-based nonlocal schemes, such as BM3D, have shown outstanding performance and its theoretic interpretation has been given by an expectation-maximization (EM)-based inference on stochastic factor graphs.

From a historical point of view, wavelet analysis is a new method, though its mathematical underpinnings date back to the work of Joseph Fourier in the nineteenth century. Fourier laid the foundations with his theories of frequency analysis, which proved to be enormously important and influential. The attention of researchers gradually turned from frequency-based analysis to scale-based analysis when it started to become clear that an approach measuring average fluctuations at different scales might prove less sensitive to noise. In 1909, the first recorded wavelet analysis was mentioned by Alfred Haarin his thesis. In the late nineteen-eighties, when Daubechies and Mallat first explored and popularized the ideas of wavelet transforms, skeptics described this new field as contributing additional useful tools to a growing toolbox of transforms [65]. One particular wavelet technique, wavelet denoising, has been hailed as "offering all that we may desire of a technique from optimality to generality" [14]. The inquiring skeptic, however maybe reluctant to accept these claims based on asymptotic theory without looking at real-world evidence. Fortunately, there is an increasing amount of literature now addressing these concerns that help us appraise of the utility of wavelet shrinkage more realistically.

Wavelet based methods are always a good choice for image denoising and has been discussed widely in literatures for the past two decades [61, 54, 58, 95, 27, 71, 22].The problem of image denoising is to recover an image that is cleaner than its noisy observations. M. C. Motwani et.al.analyzed that noise reduction as an important technique in image analysis which is the first step to be taken before the images are considered for further processing. D.L. Donoho and L.M. Johnstone introduced wavelet based denoising scheme, as wavelets give as superior image denoising due to the property of sparsity and multi resolution structure [30]. While applying wavelet based denoising, the noisy wavelet coefficients are modified accordingly M. Vatterili and J. Kovacevic analyzed that soft thresholding is one of the most well known rules due to its effectiveness and simplicity S. Gauangmin and L. Fudong introduced the main idea of soft thresholding by subtracting the threshold values T from all the coefficients larger than T and to set all other coefficients to zero [39].

II. OVERVIEW

Wavelets give a superior performance in image denoising due to properties such as sparsity and multi-resolution structure. The focus was shifted from the Spatial and Fourier domain to the Wavelet; a different class of methods exploits the decomposition of the data into the wavelet basis and shrinks the wavelet coefficients in order to denoise the data.

The wavelet based techniques use wavelets to transform the data into a different basis, where "large" coefficients correspond to the signal, and "small" ones represent mostly noise. The denoised data is obtained by inverse-transforming suitably the threshold or shrunk coefficients. Two dimensional versions of methods were implemented with that which were originally developed for one-dimensional signals and compared with the method proposed for images. Thus, there was a renewed interest in wavelet based denoising techniques since Donoho demonstrated a simple approach to a difficult problem.

A wide class of image processing algorithms is based on the DWT. The transform coefficients within the sub-bands can be locally modeled as independent identically distributed (iid) random variables with Generalized Gaussian Distribution (GGD) [65, 74, 90]. This model has been successfully used in image denoising and restoration. It approximates first order statistics of wavelet coefficients fairly well, but does not take higher order statistics into account and thus presents some limitations. The dependency that exists between wavelet coefficients have been studied in many years in the image compression community. Most wavelet models can be loosely classified into 2 categories. Those exploiting interscale dependency and those exploiting intra scale dependencies. These dependencies can be formulated explicitly (e.g., the EQ coder [62]), or implicitly (e.g., the morphological coder [96])

Donoho's wavelet denoising method performs well under a number of applications because wavelet transform has the compaction property of having only a small number of large coefficients. All the rest coefficients are very small. The denoising is done only on the detail coefficients of the wavelet transform. This algorithm offers the advantage of smoothness and adaptation but exhibits visual artifacts. This disadvantage was overcome by Coifman and Donoho [24] by proposing a Translation Invariant (TI) denoising scheme to suppress such artifacts by averaging over the denoised signals of all circular shifts. A better denoising scheme using multi-wavelet was proposed by Bui and Chen [15] than the TI single wavelet denoising. Cai and Silverman, (2001) proposed a thresholding scheme by taking the immediate neighborhood coefficient by motivating the idea that a large wavelet coefficient will probably have large wavelet coefficients as its neighbors [13].

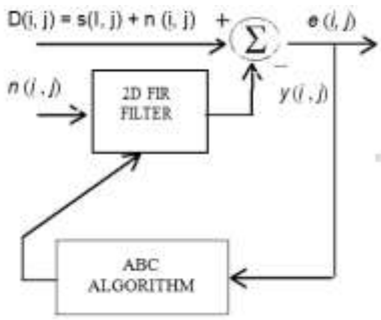

Figure 1. The scheme of noise elimination

The problem of wavelet based denoising can be expressed as the estimation of clean coefficients from noisy data with Bayesian estimation techniques, such as the maximum a posterior (MAP) estimator [31]. However, it has a weak model for wavelet coefficients of natural images because they ignore the dependencies between coefficients, and its major problem lies in the difficulties in determining a proper shrinkage function and threshold [39,124]. Tree structures ordering the wavelet coefficients based on their magnitudes, scale and spatial location have been researched. Then the use of the wavelet tree was found to be more efficient [129, 30]. The advantages and disadvantages of the filtering technique that is closest to NPFA are given below. One of the most well-known rules for Step 2 is soft thresholding which was analyzed by M. Vatterili, J. Kovacevic [132]. Due to its effectiveness and simplicity, it is frequently used in the literature. The main idea is to subtract the threshold value T from all coefficients larger than T and to set all other coefficients to zero [39]. Generally, these methods use the estimated threshold value to obtain good performance. Hence these wavelets based methods mainly rely on thresholding the Discrete Wavelet Transform (DWT) coefficients, which have been affected by Additive White Gaussian Noise (AWGN). Since [28,30,32,33] , there has been a lot of research based on the work of Donoho and Johnston and on the way of defining the threshold levels and their type (i.e. hard or soft threshold),researchers published different ways to compute the parameters for the thresholding of wavelet coefficients. Donoho's concept was not revolutionary; his methods did not require tracking or correlation of the wavelet maxima and minima across the different scales as proposed by Mallat [67]. Data adaptive thresholds [50] were introduced to achieve optimum value of threshold. Later efforts found that substantial improvements in perceptual quality could be obtained by translation invariant methods based on thresholding of an undecimated Wavelet Transform [24]. These thresholding techniques were applied to the non orthogonal wavelet coefficients to reduce artifacts. Multi wavelets were also used to achieve similar results. Data adaptive transforms such as Independent Component Analysis (ICA) have been explored for sparse shrinkage. Thus, there was a renewed interest in wavelet based denoising techniques since Donoho [31] demonstrated a simple approach to a difficult problem. Wavelet thresholding is a signal estimation technique that exploits the capabilities of wavelet transform for signal denoising. The idea is to transform the data into the wavelet basis, in which the large coefficients are mainly the signal and the smaller one represents the noise. By suitably modeling these coefficients the noise can be removed from the data. The classical soft threshold shrinkage function can also be obtained by a Laplacian probability density function (pdf) [95]. Many researchers have proposed the bivariatepdfs for modeling the interscale dependency [95, 106, 87, 1]. Though these pdfs improve the denoising results but they may lead to complicated algorithms. Intrascale dependency states that pdfs using spatial local parameters are able to better capture the statistical properties of wavelets [95, 71]. Mihcak proposes a Gaussian pdf with local variance for denoising and earns impressive results with his simple algorithm [71]. Laplacianpdf with local variance to model the heavy-tailed property, interscale and intrascale dependencies of wavelet coefficients are used in this thesis. This pdf is univariate and the local variance of each coefficients are estimated using its spatial adjacent and its parent's spatial adjacent to incorporate both inter and intrascale dependencies in this estimation. Regardless of the type of employed DWT, denoising is commonly done by wavelet shrinkage.

Wavelet shrinkage is a method of removing noise from images by shrinking the empirical wavelet coefficients in the wavelet domain and it is a non linear image denoising procedure to remove the noise. The most straight forward way of distinguishing information from noise in the wavelet domain consists of thresholding the wavelet coefficients. Thresholding method is a common shrinkage approach, which sets the wavelet coefficients with "small" magnitudes to zero while retaining shrinking in magnitude the remaining ones. Of the various thresholding strategies, soft-thresholding proposed by Donoho and Johnstone is most popular [31].

The use of the universal threshold to denoise images in wavelet domain is known as Visu Shrink. Although thresholding with a uniform per sub-band threshold is attractive due to its simplicity, the performance is limited and the denoising quality is often not satisfactory. Thus wavelet shrinkage methods using separate threshold in each sub-band have been developed over recent years namely Sure Shrink sub band adaptive systems having superior performance. Recently, another data driven sub band adaptive technique was proposed by Chang et al., namely Baye's Shrink which outperforms Sure Shrink and Visu Shrink [21]. They have also stated another two shrinkage methods known as Oracle Shrink and Oracle Thresh.

By using global thresholding of wavelet coefficients it was observed that the performance in real life images is not sufficiently effective. Later it was observed that the use of wavelet tree was found to be more efficient [129, 32, 30]. Some methods were proposed and investigated methods of selecting thresholds that are adaptive to different spatial characteristics and concluded adaptive approaches have been formed to be more effective than their global counter parts [21, 20, 19]. The basic idea in wavelet shrinkage technique is to model wavelet transform coefficients with priori probability distributions. In 1995, D.L. Donoho expressed the problem as the estimation of clean coefficients using a priori information with Bayesian estimation technique, like Maximum a Posterior (MAP) estimator [31]. In 1989, S.Mallat expressed that the transform coefficients with in sub-bands can be locally modeled as independent identically distributed (iid) random variables with Generalized Gaussian Distribution (GGD) [65, 74]. Also he expressed that the denoised coefficients may be evaluated by an MMSE (Minimum Mean Square Error) estimator in terms of the noised coefficients and the variances of signal and noise. In 1999 M. K. Mihcaket. al. derived a method in which the denoised coefficients are statistically estimated in small regions for every subband instead of applying a global threshold [72]. In 2000 S. G. Chang et. al. derived a similar spatially adaptive model via wavelet thresholding wavelet image coefficients [21].

In the wavelet decomposition, the magnitude of the coefficients varies depending on the decomposition level. If all levels are processed with universal threshold value the processed image may be overly smoothened so that the sufficient information, preservation is not possible and the image get blurry. In order to overcome the subband adaptive system having superior performance which is a data driven system and level dependent methods namely Baye's Shrink, Oracle shrink and Oracle thresh were proposed by Chan et al, (2000) [21]. These methods out performance sure shrink technique which is a sub-banded adaptive and data driven system proposed by D.L. Donoho et al (1995), [32]. Later ImanElyasi and SadeghZarmehi, (2009) [49] proposed different adaptive wavelet threshold methods like Modified Bayes Shrink (MBS) Normal Shrink (NS) for image denoising. They proved that in low noise NS yields the best results for denoising because it has maximum SNR and minimum MSE. In high noise MBS yields the best results. Also NS preserves edges better than noise removal.

All these thresholding techniques tend to kill too many wavelet coefficients that might contain useful image information. To overcome this G. Y. Chen et al.(2004),[22] proposed wavelet image thresholding by incorporating neighboring coefficients called Neigh Shrink which is an extension of Cai and silver man's [13] idea of considering the immediate neighbourhood coefficients into account. This method thresholds wavelet coefficient according to the magnitude of the square sum of the entire wavelet coefficient within the neighbourhood window. Due to the suppression of too many detail wavelet coefficients Neigh Shrink produces denoised image with more blurring. This problem was avoided by reducing the value of threshold itself. Hence modified shrinkage factor was introduced in Modi Neigh Shrink method proposed by S.KotherMohideen et al. (2008), Tan et al. [108] proposed a wavelet domain denoising algorithm by combining the expectation maximization scheme and the properties of the Gaussian scale mixture models. The algorithm is iterative in nature and the number of iterations depends on the noise variance. For high variance Gaussian noise, the method undergoes many iterations and therefore the method is computational-intensive.

In 2002, Shengqianet.al., proposed an adaptive shrinkage denoising scheme by using neighborhood characteristics and claimed that this method produced better results than Donoho's methods [98]. Later Sendur and Selesnick, (2002) had proposed bivariate shrinkage functions for denoising and indicated that the estimated wavelet coefficients depend on the parent coefficients, also they observed that the shrinkage is more when parent coefficients are smaller [87, 94]. Chen and Bui, (2003) extended this neighbor wavelet thresholding idea to the multiwaveletdenoising [87].

III. CONCLUSION:

This paper investigates noise models and includes an in-depth literature survey of denoising based on wavelets. Desirable features and complexities of denoising algorithms are discussed. In addition, it explains common mechanisms used to evaluate the performance of denoising algorithms. According to the current literature, denoising algorithms based on wavelet transform are the best choice for achieving the desired denoising performance. However, the computational complexity must also be considered. Thresholding techniques used with the Discrete Wavelet Transform are the simplest to implement. A universal denoising algorithm is a dream of researchers, although there are no universal method, in this study, the denoised results of the proposed algorithms and existing algorithms are compared under different noise models and variances by means of the evaluation methods introduced above.

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