Chapter 1

Introduction

With lot of developments in computer technologies and technologies related to communication, information technology has entered a new era with spawning of numerous image processing techniques. Major source of information in our daily life involves generation, transmission and storage of number and variety of digital images. They may be natural images, images of digital commercial television, magnetic resonance images, computer tomography as well as geographical information systems and astronomy. However, when images are created, transmitted and decoded, they are always distorted by different types of noise [1]. Hence, noise reduction has become a very essential step for any sophisticated algorithms like computer vision, medical imaging and diagnostics. However, a tradeoff is always necessary between removing noise and blurring the image. How to strike a balance between denoising and blurring and obtain denoised clean images is a big issue in computer vision and image processing. This issue has emerged as a challenge for a long time, but till date there is no completely satisfactory solution. The works under this thesis focuses on noise denoising techniques for different types of images like natural images, satellite images and telescopic astronomical images.

1.1 Motivation behind the Present Work

During the past several decades, considerable research has been carried out on denoising of signals especially images. Different algorithms are used depending on the noise models. Most of the regular available images are assumed to be
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corrupted by additive random noise, which usually is modeled as Gaussian noise.

There are many approaches to deal with additive noise present in the images, such as average filters and mean filters. Even though linear filters are useful in a wide variety of applications, there are some situations in which they are not adequate. Linear filters do not take into account any structural information in images. Therefore, linear filters tend to blur sharp edges, destroy lines and other fine image details, and in consequence, perform poorly in the presence of noise.

However, nonlinear filters, [2]-[4] can be successfully applied to achieve the capability of preserving details while removing noise in an image since they adopt the local features of the image. Non-linear spatial filters employ a low pass filtering on groups of pixels with the assumption that the noise occupies the higher region of frequency spectrum [5], [6]. Low-pass filters will not only smooth away noise but also blur edges in images while the high-pass filters can make edges even sharper and improve the spatial resolution but will also amplify the noisy background.

In general, image denoising imposes a compromise between noise reduction and preserving significant image details. To achieve a good performance in this context, a denoising algorithm has to adapt to image discontinuities. The wavelet representation naturally facilitates the construction of such spatially adaptive algorithms. It compresses the essential information in a signal into relatively few, large coefficients, which represent image details at different resolution scales i.e., multiresolution scales. Most existing denoising algorithms based on wavelets focus on exploiting the advantages of their multiresolution structure to capture more detailed information, or building wavelet coefficient statistical models to represent inter-scale dependencies and intra-scale correlations. It can not be denied that these algorithms can provide better performance than those algorithms using single layer wavelets and treating wavelet coefficients as independent.

But, in wavelet thresholding the problem experienced is generally smoothening of edges. The bilateral filter was proposed in [7] as an alternative to wavelet thresholding. It applies spatial weighted averaging without smoothing edges. This is achieved by combining two Gaussian filters; one filter works in spatial domain, the other filter works in intensity domain. Therefore, not only the spatial distance but also the intensity distance is important for the determination of weights [8].
Hence, these types of filters can remove the noise in an image while retaining its edges. However, the filter may not be very efficient in removing any noise in the texture part of the image. It is not being able to remove salt and pepper type of noise. Also there is no theoretical works on the optimal values of the filter parameters.

Further, the key factors for success in denoising images using wavelet based filters are the value of the thresholding parameter and its choice and the way of thresholding. But this poses major challenges as the relationship between noises and textual contents in an image is not explicitly linear.

In view of the above, this investigator felt motivated to develop novel hybrid denoising models using wavelet based soft thresholding and bilateral filters so that the meritorious features of both the approaches can be exploited and at the same time their limitations are overcome. In view of the reported excellent capability of finding optimal solutions for highly non-linear optimization problems, Genetic algorithm especially the floating point GA (FPGA) is proposed to be used here for the optimization of the different parameters of the proposed model.

In addition, it is also proposed to use fuzzy soft thresholding technique, which is more capable in dealing with non-linearities, uncertainties and noises at the same time without spoiling the original image characteristics. And the same FPGA algorithm is proposed to optimize the fuzzy soft thresholding function.

1.2 Scope and Objectives of the Present Work

In view of the above the main objectives of the work are:

(i) To develop hybrid filters through hybridization of wavelet thresholding and bilateral filters in different configurations for the denoising of the different types of images.

(ii) To tune the parameters of both the wavelet based filter and bilateral filter by trial and error to optimize their performance for filtering the same types of images as in step (i).

(iii) To compare the performance of the filters developed in step (i) with those in step (ii) in denoising different types of images.
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(iv) To develop FPGA based programs to tune the parameters of the models formed by integration of wavelet based filter and bilateral filters in different forms to optimize the performance of the considered models for denoising different types of images. Also, to optimize the parameters of other conventional filters like only wavelet and only bilateral filters for drawing comparison.

(v) To draw the comparison in performance among the models considered in step (iv) in denoising different types of images and comparative performance is also drawn with respect to the same models with parameters optimized with manual trial and error method.

(vi) To develop a model in line with the best model obtained in step (v) using fuzzy soft thresholding technique and optimize the performance of the model using FPGA for denoising different types of images.

(vii) To draw the comparison in performance in between the model considered in step (vi) in denoising different types of images and the best model found in step (v) with wavelet soft thresholding (instead of fuzzy soft thresholding).

1.3 Achievements

In a modest way, the following contributions have been made in this thesis work:

1. Hybrid denoising models are designed and developed through hybridization in different configurations and their performances are tested on different types of noisy images. The performance of the models is evaluated in terms of PSNR and IQI and comparison is drawn. Out of 48 models experimented with, only three models (models 4, 20 and 36) are found to be comparatively better than all other models. It is observed that model 36 is more uniform and consistent in its performance in all the types of images tested with in terms of PSNR and IQI. It is also observed that application of bilateral filters on wavelet decomposed subbands in any combination with wavelet thresholding deteriorates the performance of the model, whereas, application of bilateral filters before or after or on both before and after decomposition.
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enhances the performance. So, the model 36, wherein the bilateral filter is applied before decomposition, is found to be the most consistent. Thus, model 36 is recommended as a well competent model for denoising any type of images.

2. The filter parameters of all filters including hybrid denoising models developed through hybridization in three apparently best configurations are optimized using FPGA and the performances of the thus GA based optimally designed filters are tested on different types of noisy images. The performance of the models is evaluated in terms of PSNR and IQI. Comparison is drawn in the performance of all the six models with filter parameters optimized using trial and error method with those with filter parameters optimized using FPGA. It has been observed that the performance of all the models improves with FPGA optimized filter parameters even though the amount of improvement in different models is different. The overall observation of the results reveals that the use of bilateral filters in different configurations along with wavelet based thresholding filters on all the decomposed subbands worsens the performance of the filter, whereas the bilateral filter before or after or both sides of the decomposition (not on decomposed subbands) followed by reconstruction of an image as used in models 4, 20 and 36, improves the performance of the filter in denoising noisy images which is in line with the inference claimed in the previous achievement. However, amongst the three models 4, 20 and 36, the performance of model 4 is quite competitive with reference to model 36, which is better and more consistent on all the images except astro2 type images. So, the model 36, wherein the bilateral filter is applied before decomposition, is recommended as a well competent model for denoising any type of images.

3. The performance of the model 36, which is the best hybrid model found so far, improves greatly with fuzzy soft thresholding technique instead of wavelet based soft thresholding even in the case of mostly corrupted images. The modified model is optimized with the help of FPGA and compared with the performance of the model 36. For high degree of noise, the modified model outperforms the previous one.
1.4 Thesis Outline

This thesis work contains six chapters.

Chapter 2 provides background information, a literature survey on noise reduction, and mechanisms used to evaluate denoising algorithms. The different aspects of wavelet theory and denoising techniques based on it as well as theory and uses of bilateral filter in denoising are described. The performance measurement criteria is also discussed in this chapter.

Chapter 3 discusses about the workings of the models (some existing and some newly designed) and their performances on different types of images. The most effective and efficient hybrid denoising model out of all newly designed models is evaluated.

Chapter 4 introduces the background theory of the Genetic Algorithm and its application on different denoising models that are performing in a good manner in the previous chapter. The floating point genetic algorithm (FPGA) is used for the optimization of the models in this thesis work.

Chapter 5 discusses about the fuzzy logic and fuzzy logic systems. A thresholding technique using the fuzzy membership function (Fuzzy soft thresholding technique) is used on the best model found in chapter 4. The performance of the model with fuzzy soft thresholding is compared with that of the same model with wavelet soft thresholding.

Chapter 6 is the concluding chapter. This chapter concludes that the proposed model performs better than the existing and traditional filters and state-of-the-art denoising algorithms in terms of the chosen evaluation tools, such as mean squared error (MSE), peak signal to noise ratio (PSNR) and image quality index (IQI). Several major areas of future research are also listed in this chapter.