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A Real Time Adaptive Multiresolution Adaptive Wiener Filter Based On Adaptive Neuro-Fuzzy Inference System And Fuzzy evaluation

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Abstract

In this paper, a real-time denoising filter based on modelling of stable hybrid models is presented. The hybrid models are composed of the shearlet filter and the adaptive Wiener filter in different forms. The optimization of various models is accomplished by the genetic algorithm. Next, regarding the significant relationship between Optimal models and input images, changing the structure of Optimal models for image denoising is modelled by the ANFIS. The eight hundred digital images are used as train images. For eight hundred training images, Sixty seven models are found. For integrated evaluation, the amounts of image attributes such as Peak Signal to Noise Ratio, Signal to Noise Ratio, Structural Similarity Index, Mean Absolute Error and Image Quality Assessment_are evaluated by the Fuzzy deduction system. Finally, for the features of a sample noisy image as test data, the proposed denoising model of ANFIS is compared with wavelet filter in 2 and 4 level , Fast bilateral filter, TV-L1, Median, shearlet filter and the adaptive Wiener filter. In addition, run time of proposed method are evaluated. Experiments show that the proposed method has better performance than others.

Keywords: Genetic algorithm, denoising, Fuzzy deduction system, image processing, wavelet transformation, adaptive bilateral filters, adaptive neuro-fuzzy inference system.

1. Introduction

Image processing science is one of the high-applied sciences in engineering which has been improved noticeably in the recent years.Ultrasonic imaging, CT, MRI and other imaging methods are

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useful for clinical diagnosis. Because the ultrasound imaging method is non-invasive, it is safer than other imaging methods. In addition, this type of noise has decreased the quality of ultrasound images and limited the development of automatic diagnostic techniques. For example, about 500,000 women die from cancer of the breast every year because of unclear breast ultrasound images. Therefore, denoising is an important step of pre-processing. In the recent decade, several techniques have been suggested to image denoising. Some methods use only a filter to remove noise. T. Loganayagi et al [1] proposes a robust denoising method for ultrasound kidney image by BF. In addition, Manoj Kumar et al proposes a CT image denoising using tetrolet wavelet [2]. Since the BF is a single resolution, the different frequency components of the image are unavailable. In order to overcome this problem, the WF is effective to form a scale-space for the noisy image. Moreover, hybrid filter can use the benefits of together BF and WF. Ju Zhang at al proposed ultrasound image denoising by helping a combination of FBF and stationary wavelet for real-time application [3]. Speckle noise in the low-pass approximation and high-pass detail is filtered by the FBF and wavelet thresholding, respectively. In addition, the same structure is used to remove noise in CT images [4]. M.Zhang et al [5] studied BF's parameters and proposed the MBF. Moreover, Indulekha N R et al studied denoising of medical image using three dimensional discrete wavelet and BF [6]. Suhaila Sari et al. [7] Propose the development of a denoising method through sequent applying of BF and wavelet thresholding. In these mentioned hybrid paper, wavelet decomposition is used to dividing the information of an image into the approximation sub-band and detail sub-bands. Thus, in order to denoise, the BF is applied on approximation sub-band and the wavelet threshold are applied at the detail sub-bands. However, the findings by investigator indicate that the BF is appropriate for all kinds of image noise [1]. Therefore, it is more appropriate to study BF impact on the details sub-bands. Nidhi Chandrakar et al in [8] and Sudipta Roy et al in [9] study hybrid denoising methods to find the best possible denoising solution. The results show that the BF application before and after the wavelet decomposition improves the performance. But, this method only focuses on some hybrid filters. Moreover, for avoiding more complexity, only some of hybrid denoising methods on the first level of wavelet decomposition are studied. In addition, using the BF is not suitable for real-time applications. Due to the mechanical pressure on the muscle [10] or the type of image such as the CT images [11] input noise may be unstable. Given that wavelets are non-optimal when dealing with piecewise regular multivariable functions, and this implies that wavelet thresholding does not provide a minimax MSE in this situation. But, a denosing estimator based on shearlet thresholding has the ability to achieve a minimax MSE for images with edges [12]. Therefore, Wavelets are not very effective in dealing with multidimensional signals containing distributed discontinuities such as edges [13]. Ehsaeyan at al This paper develops an effective shearlet-based denoising method with a strong ability to localize distributed discontinuities to overcome this limitation. The approach introduced here presents two major contributions: (a) Shearlet Transform is designed to get more directional subbands which helps to capture the anisotropic information of the image; (b) coefficients are divided into low frequency and high frequency subband. Then, the low frequency band is refined by Wiener filter and the high-pass bands are denoised via NeighShrink model [13].

In this paper, a hybrid filter is presented in a condition of unstable noise. In the first section, the eight hundred digital images are used that have low, intermediate and complex tissues. Then, wide ranges of different combination of the two filters for each image are optimized by a GA algorithm.

In the second section, the features of the images and models are sent to ANFIS as training data. By the help of the modeling, the proposed method does not depend on the original image in GA optimization. The impact of each model and filters after image denoising is evaluated by PSNR, SNR, SSIM, IQI and MAE image attribute. Using of five attributes leads to the most accurate evaluation. However, the large number of models and attributes lead us towards an automated assessment.

Because there is no linear relationship between the values of an attribute and noise intensity, it is more appropriate to use the fuzzy deduction system for the model and attribute evaluation. After training the ANFIS, we send features of thirty sample noisy images to ANFIS as test data. Based on the input image, ANFIS extracts the estimates models. Next, the ANFIS estimates models are applied to noisy images. In the end, the cost of denoising in the proposed method compares with other methods of denoising. Fig.1 shows the diagram of the proposed method. The rest of this paper is structured as follows: GA, shearlet filter and the adaptive Wiener filter will be explained in section 2 and 3.Then, in section 4 and 5, the proposed method and simulation are explained. Finally, in section 6, conclusion will be explained.

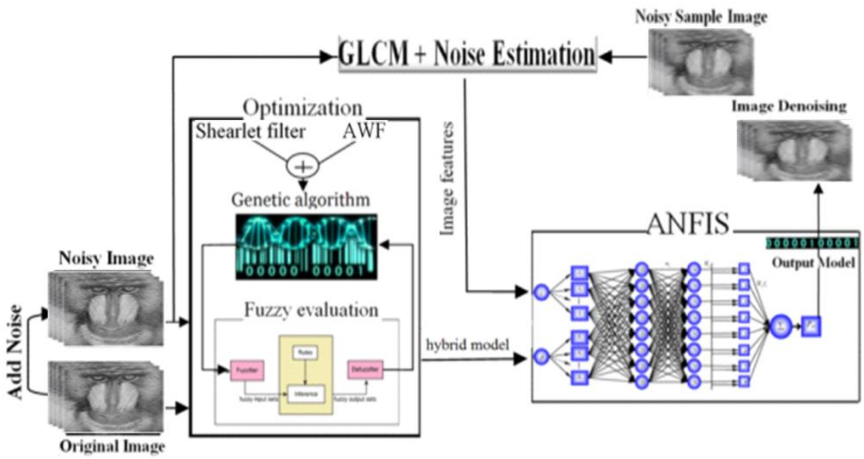


Figure 1: Diagram of proposed method

2. Genetic algorithm

Genetic Algorithms were developed by Prof. John Hollandand it is used for discrete optimization commonly. Some of the attribute of this algorithm are not fast and are good ingenious for combinatorial problems. The performance of the genetic algorithm is the way that a new generation is produced by mutation and crossover of the parents. Important terms used in this algorithm have been expressed as follows:

- Chromosome: A sequence of the bits is known as a chromosome.
- Gene: Each of the bits inside the chromosome is known as a gene.
- Crossover operator: crossover of chromosome in two or a few parents in order to produce offspring.
- Mutation: mutation of a gene in a chromosome [14].

3. Shearlet Transform

The shearlet transform is unlike the traditional wavelet transform which does not possess the ability to detect directionality, since it is merely associated with two parameters, the scaling parameter and the

translation parameter. The idea is to define a transform, which overcomes this vice, while retaining most aspects of the mathematical framework of wavelets, e.g., the
fact that:

- The associated system forms an affine system,
- The transform can be regarded as matrix coefficients of a unitary representation of a special group,
- There is an MRA-structure associated with the systems.

The shearlets satisfy all these properties in addition to showing optimal behavior with respect to the detection of directional information. Shearlet transform

4. Proposed Method

First, according to the equation 1, noise is added to the image.

$$\begin{aligned} Sigma &= K \\ x\_noisy &= originalimage + sigma. * randn(L, L), \end{aligned} \tag{4.1}$$

Where,
L is the original image size. Then the proposed method are applied to the noisy image [15].

4.1. Construction of the hybrid filter

Genetic Algorithm obtains the optimal model of hybrid filter. These models can be coded in form of a chromosome's genes. Figure 2 shows coding of combination of the one-level of the shearlet filter that is divided into eight directions and the low-frequency image. Each gene is marked in the form of two values. These values equal 0 or 1. Number 1 in each gene suggests the implementation of the adaptive Wiener filter.

Low frequency	High Frequency							
1	0	1	1	0	0	0	0	1

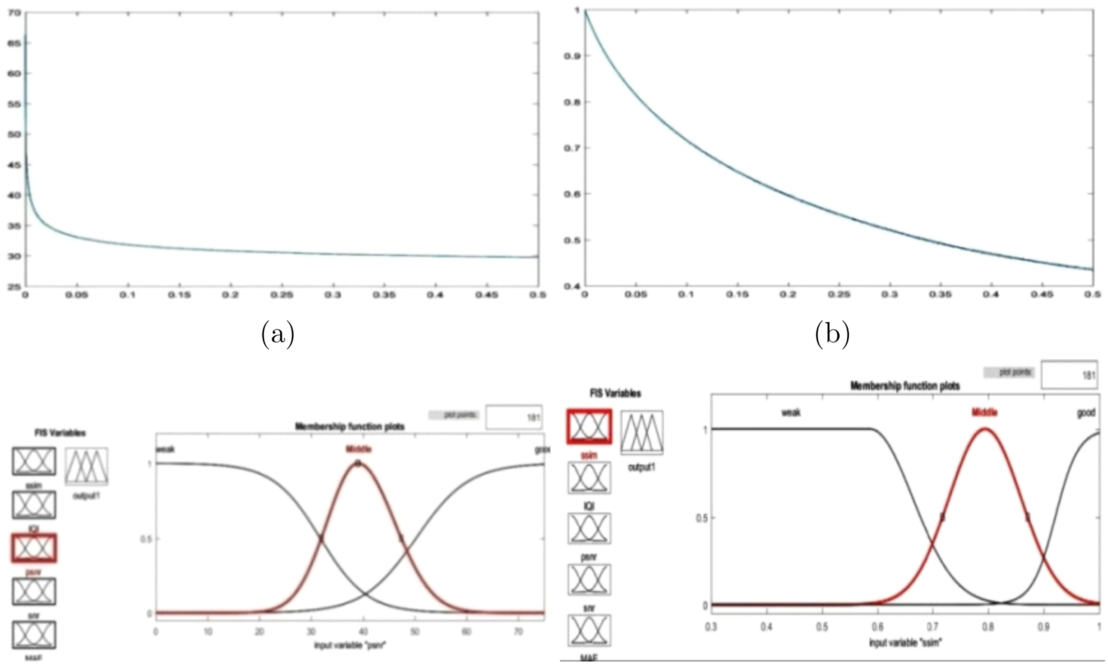
Figure 2: combination of WF and FBF

4.2. Measurement of Performance

The image quality after the enhancement is measured through comparing with the noise-free image using some metrics like PSNR, SNR, SSIM, IQI and MAE. **PSNR** is an engineering term for the ratio between the maximum possible power of a signal and the power of corrupting noise that affects the fidelity of its representation. Next, **SNR** or ***S/N*** is a measure used in science and engineering that compares the level of a desired signal to the level of background noise and **SSIM** is a procedure for predicting the perceived digital television quality and cinematic pictures, also other kinds of digital images. In addition, **IQI**is considered as the fourth parameter for judging the quality of denoised images and finally, **MAE** is a quantity used to measure how close forecasts or predictions are to the eventual outcomes [16].

4.3. Fuzzy Evaluation

Some numbers of different hybrid filter attributes may be applied for evaluation, but people's cognitive processing power, as well as the number of independent attributes which can be processed, usually are faced with restrictions [7]. In addition, there is no linear relationship between the values of an attribute and noise intensity. Therefore, architecture intuitive evaluation is difficult. For example, significant changes of PNSR and SSIM in the middle and the begining of the range occur (Figure 3(a), 3(b)) which are well modelled by fuzzy membership functions(Figure 3(c), 3(d)). In addition, because of the difficult nature of the boundaries between evaluation regions, MBF evaluation are ideally suited to fuzzy logic approaches. Other advantages of the Fuzzy Inference System can be automatic evaluation, integrated evaluation of hybrid filters, and Facilitating of MBF evaluation by a large number of attributes.



(a) (b)

(c) (d)

Figure 3: a)The impact of increased noise on the amount of PNSR,b) The impact of increased noise on the amount of SSIM, c) PSNR value membership functions, d) SSIM value membership functions.

After the measurement of performance attributes, the results are sent to the fuzzy deduction system. Each of the attributes is normalized to a range of weak, middle and good, but each could have individualized gradations (Figure 3(c), 3(d)). Now, we need an evaluation through combination the individual attribute values. Fuzzy evaluation allows for multiple evaluation. Next, a FIS is used to combine performance attribute values by fuzzy rules set. Figure 4 shows the output of MATLAB FLT with constant amount IQI and MAE.

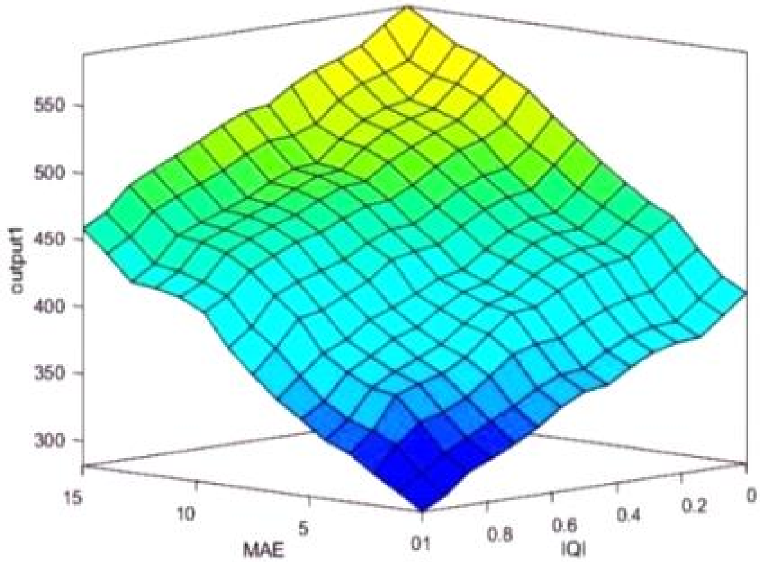


Figure 4: output of MATLAB Fuzzy Logic Toolbox with constant amount PSNR and MAE.

4.4. System behavior modeling

In the second section, we optimize the hybrid filter. The hybrid filter optimization is performed on more of 600 images. To find the optimal hybrid model for each noise intensity, we optimize a wide range of different hybrid models by GA algorithm. First, we add noise to each original image. Then, denoising models are optimized. Table 1 shows the optimum hybrid models of first image with different noise intensity.

Table 1: Information extracted from an image

NO. models	Models									Image Features			
1	0	0	0	0	0	0	0	0	0	73.23512	73.23188	221.9986	252.434
1	0	0	0	0	0	0	0	0	0	94.56912	94.52499	231.5713	269.5536
13	0	1	1	1	1	0	0	0	1	138.431	145.1273	242.3071	285.9346
27	0	1	1	1	1	1	0	0	1	179.0605	192.8853	254.4315	298.7961
31	0	1	1	1	1	1	1	1	1	217.9317	234.4807	268.3946	309.9476
31	0	1	1	1	1	1	1	1	1	247.3294	262.7629	280.9025	321.1861
31	0	1	1	1	1	1	1	1	1	273.7118	286.3718	292.4186	331.9033
31	0	1	1	1	1	1	1	1	1	296.3745	305.6926	304.6429	342.2401
32	0	0	0	1	1	1	1	1	1	313.6322	320.4282	315.0565	352.895
32	0	0	0	1	1	1	1	1	1	328.6494	334.3861	325.7114	362.9842
34	0	0	0	0	1	1	1	1	0	343.5024	348.3479	336.3706	374.4667
34	0	0	0	0	1	1	1	1	0	356.7247	361.1975	346.5574	384.1607
38	0	0	0	0	0	1	1	1	0	370.6292	374.7596	357.4858	394.7484
38	0	0	0	0	0	1	1	1	0	382.4421	385.1917	368.5422	404.1885
38	0	0	0	0	0	1	1	1	0	393.9507	396.4582	377.6898	412.688
38	0	0	0	0	0	1	1	1	0	403.8305	405.5693	387.5306	420.998
58	0	0	0	0	0	0	1	1	0	413.4252	414.8746	396.6864	427.7693
58	0	0	0	0	0	0	1	1	0	422.1509	422.8795	405.0072	433.4244
64	0	0	0	0	0	0	1	0	0	429.8791	430.239	414.4599	439.0871
67	1	0	0	0	0	0	0	0	0	434.319	437.2969	421.9717	444.5566
67	1	0	0	0	0	0	0	0	0	436.7374	443.3404	429.7195	449.414
67	1	0	0	0	0	0	0	0	0	438.209	449.7067	436.453	453.2216
67	1	0	0	0	0	0	0	0	0	440.3993	453.1851	442.6871	456.5984
67	1	0	0	0	0	0	0	0	0	443.0054	457.3442	448.6034	459.4742
67	1	0	0	0	0	0	0	0	0	444.4561	461.1143	453.1593	462.9405
67	1	0	0	0	0	0	0	0	0	445.9239	466.3194	456.4238	466.1767
67	1	0	0	0	0	0	0	0	0	448.124	470.7625	460.0043	471.5518
67	1	0	0	0	0	0	0	0	0	450.6871	477.5337	464.0744	476.9366

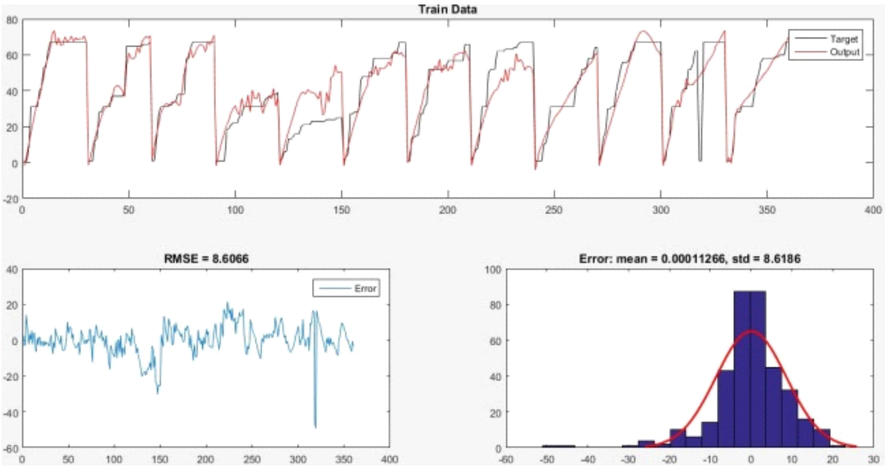


Figure 5: ANFIS train data with input features and output optimum model

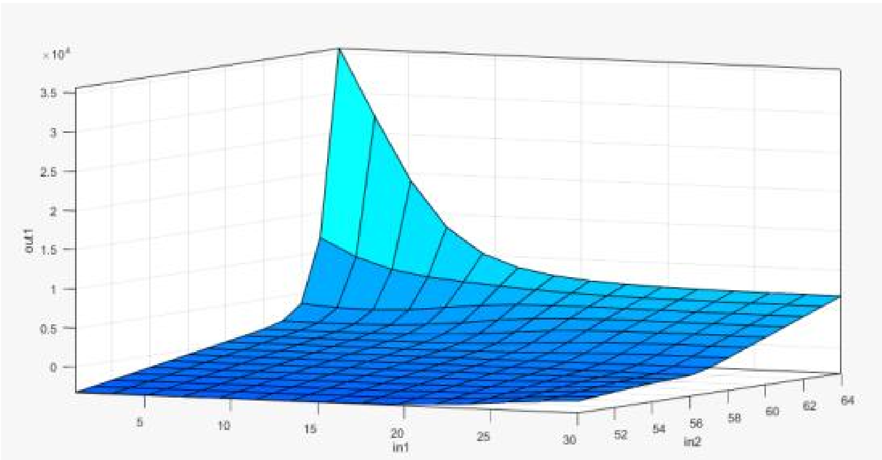


Figure 6: a. ANFIS fuzzy system.

4.5. Feature Extraction and Learning system behavior

The GLCM is a method for extracting features of the second order. It requires many matrices which provide accuracy for the image estimation. It also represents the specified spatial relationship between pixels [17]. We use four features. The first feature is the noise variance. The noise variance is obtained from the wavelet coefficients of highest frequency in the wavelet domain [3]. The other three features (Sum average, Sum variance, Sum entropy) can be derived from the GLCM [17]. Next, for independence of the hybrid filter from the original image in GA optimization, the ANFIS software models the behavior of the optimal hybrid models. The images' features and the hybrid optimal models are sent to ANFIS. As a train ANFIS, 800 images are studied. But, in these training images, sixty seven models are found. Figure 5 shows the ANFIS train data with input features and output optimum hybrid models. Each model is characterized by a number from one to sixty seven. After the ANFIS training, features of the sample image with thirty different noises are sent to the ANFIS. Next, ANFIS proposes estimated models as output.

By help of training input data, the ANFIS makes fuzzy and neural network systems (Figure 6).

Next, the features of a sample image with 41 different noises are sent to ANFIS (Figure 7). Then we consider 41output models.

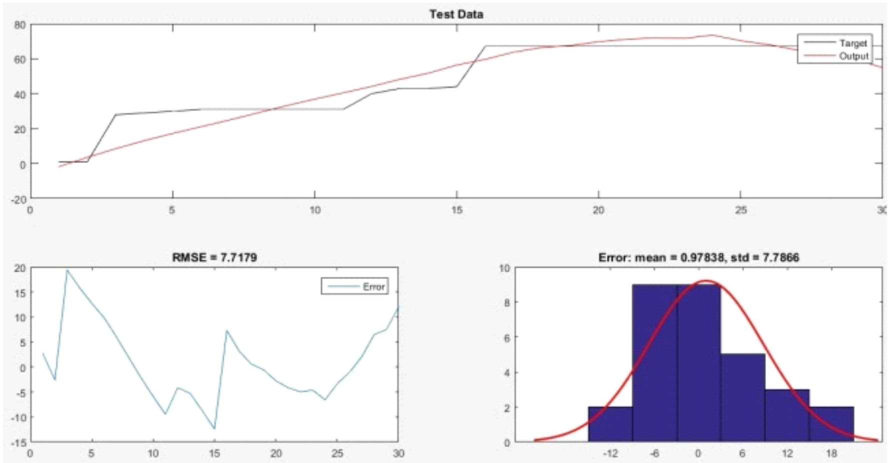


Figure 7: ANFIS test data with input features and output optimum model of sample image.

5. Simulation

In this section we show a comparison among proposed method, hybrid model adaptive wiener filter, Sherlet Filter , FBF, , TV-L1, Median, wavelet filter.

In the first step, hybrid filter and component are compared. As shows in Figure 8(a), the costs of the hybrid filter are a little more than the costs of components.

In the second step, the proposed method, TV_L1, FBF , median filter are compared. Figure 8(b), shows that the proposed method have the lowest cost of denoising. In the next step, proposed method, wavelet in tow level and wavelet in four level are compared. As shows Figure 8(c), In this comparison proposed method has the best performance, then the wavelet filter in four level have a good performance.

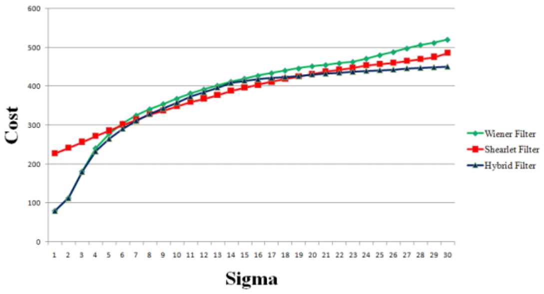
In the final step, The time complexity is calculated (Table 2)

Table 2: Comparison of runtime

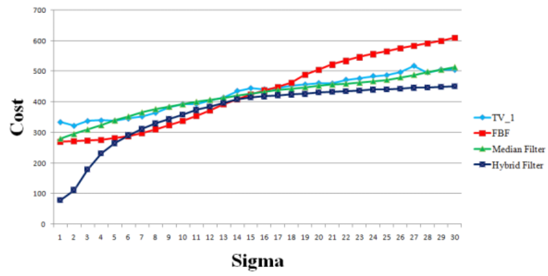
Filter	Seconds
shearlet	0.03
FBF	0.49
proposed method	0.044
Wavelet	0.22
Wiener	0.05
Median	0.05

6. Conclusion

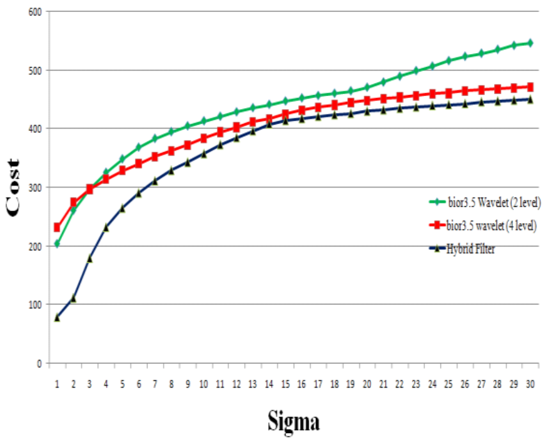
This paper studies denoising of the digital images under unstable noise. The hybrid filter is capable of adapting the denoising models according to input image features. In addition, for an integrated evaluation, automated evaluation and defect fixes intuitive evaluation the fuzzy evaluation system has been used to evaluate the denoising models. All of 800 images only use sixty seven models for noise canceling which are modeled by ANFIS. Then, for the sample images and its features, the optimal hybrid models are estimated by ANFIS. Next, image noise is eliminated by help of



(a)



(b)



(c)

Figure 8: The cost comparison of denoising methods among, a. Hybrid filter with its components, b. Hybrid filter, TV_L1, FBF and , Median filter c. Hybrid filter, wavelet filter in 2 and 4 level.

the hybrid model.The proposed method in terms of qualitative and run time is evaluated. The qualitative comparison shows that the proposed method has better performance than wavelet, FBF, TV-L1, Median and Shelolet filter. Finally, comparison runtime shows the proposed method has the appropriate run time for real-time applications.

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