Intelligent Classification Enhancement using Siny-Hard Wavelet Thresholding

Ibraheem H. M. Al-Dosari[a], Viktor Sykhomlyn[b], and Alexander Selykov[c]

[1]*Al-Rafidain University College, computer communications engineering department, Baghdad, Iraq*
[2]*Vice-Rector forUkrainian State Employment Service Training Institute (USESTI), Ukraine*
[3]*Kyiv National University of Construction and Architecture, Povitriflotskyi ave., 31, 03037, Kyiv, Ukraine*

Abstract

Many signal transmission over communications system face an inherent noise attack the transmitted signal and cause the degradation in the signal quality at the receiver end. One of the popular techniques to overcome this noise attack is to make a prepossessing for the noisy signal before transmission over the channel. The aim of the work is to use Wavelet based signal denoising method for noise removal and enhance the intelligent classification results. In this work a new proposed wavelet thresholding method is formulated and implemented for signal enhancement. The proposed method is compared with classical method using different performance indices such as NMSE (normalized mean square error) and ESNR (enhancement in signal to noise ratio). The results for new proposed method shows outperforming 10% in ESNR and 5 % in NMSE when using symlet8 wavelet mother function with5 decomposing levels. The conducted results have confirmed the success for the new proposed wavelet thresholding method in signal denoising, this enhancement in processed signal will improve the signal quality at the receiving end and increasing signal to noise ratio enhancement for the overall communication system.

Keywords

Hardy-sine thresholding, wavelet, denoising, classification.

1. Introduction

In any existing measurement system in real life there is always an inherent noise emerge which is non-stationary in nature. It is necessary to suppress this unrequired noise using some of the effective denoising methods. Wavelet analysis can be recognized as a multi-resolution tool that is used for removing noise from the desired signal and hence denoising the non-stationary signal successfully.

Sometimes statistical computations are required to choose the suitable wavelet analysis for the denoising process, because there are many types of noise attacking the signal. So it is better to correlate the signal with the utilized wavelet in order to isolate most of the signal energy in the passband and filtering only the band where the expecting noise exists [1].

Wavelet denoising process can be summarized by some steps in the following sequence, initially transforming the noisy signal from time domain to the wavelet domain, where this mapping step will redistribute the energy of the noisy signal in a suitable manner that is distinguish easily between the wavelet coefficient that almost represent the signal part which is call approximation coefficient.

On the other hand, the wavelet coefficients that almost represent the noise part which is called the details coefficients. The second step for denoising procedure involved by

Emerging Technology Trends on the Smart Industry and the Internet of Things, January 19, 2022, Kyiv, Ukraine
EMAIL: ibraheemdoser77@gmail.com (I. H. M. Al-Dosari); suhomlin63@ukr.net (V. Sykhomlyn); selukov@3g.ua (A. Selyukov)
ORCID: 0000-0002-7362-7870 (I. H. M. Al-Dosari); 0000-0001-9558-1968 (V. Sykhomlyn); 0000-0001-7979-3434 (A. Selyukov)

thresholding process using suitable threshold to remove some part from the noise part amplitude fairly, finally, reconstruction are made for the thresholded details coefficients with the approximations coefficients to get a denoised signal with minimum error between the denoised and original signals [2].

Wavelets analysis has many applications in signal and image processing fields, denoising and compression processes play an important role in the wavelet analysis applications. Some of the recent researches try to propose new thresholding techniques for wavelet denoising in order to enhance the signal to noise ratio in the output of the wavelet de-noisier [3].

Some other researches try to optimize the threshold selection to reduce the noise effect; the suitable value of the threshold should be chosen in trade way between high and low values. The high selected threshold will permit some noise to be passed with the required signal and hence keeping the noise unresolved, while low value threshold will suppress some of the original signal and considers it as a noise part. Therefore choosing the threshold based on the noise power estimation is the successful way to balance between the two scenarios [4].

The object of study is the utilization for the artificial neural network in classification problem to diagnose the size of the leak in fluid pipeline system, the process involved an application for wavelet based denoising method to enhance the signal under study which is used as an input to the intelligent classifier.

The subject of study is the wavelet thresholding methods [5–11] and a comparison between traditional method and the new proposed method using some popular performance indices.

The purpose of the work is to improve the intelligent classification results for the overall system by enhancing the transmitted signal through the communications system using wavelet based denoising method with new proposed thresholding technique known as Siny-hard thresholding.

1. Problem Statement

For any communication system, a transmitted signal travels though medium and attacked by some inherent noise. So it is required to remove this noise and improve the signal quality in order to get good results when using this denoised signal. The denoised signal will be used for intelligent leak classification for a fluid pipeline system.

2. Review of the Literature

Some of the recent year's related work in developing the wavelet thresholding methods can be summarized as follows, a new adaptive thresholding method was proposed by researchers in order to enhance the denoising method as compared to the global thresholding method depending on the truth for noise degradation in the details coefficients for decomposition of wavelet transform [5]. In 2018 other researchers proposed a new thresholding function by modifying the classical soft and hard thresholding functions, in this proposal the researcher add two parameters for controlling the thresholding processes and make it more adaptive with the input signal [6]. Another researcher utilize the concept of logarithm in order to enhance the image by removing the noise corrupted it [7]. The process of image denoising based on logarithmic thresholding outperformed the classical thresholding by about 35% when augmented with proper threshold selection rule for many types of noise such as speckle, pepper, and Gaussian [8]. A mixed thresholding was proposed for denoising signal and image denoising using Matlab simulation tool with many performance indices such as signal to noise ratio enhancement and minimization mean square error [9].

The denoising process is augmented with hybrid threshold selection rule , such that better results was achieved for hard thresholding than traditional methods [10].

A modified thresholding called improved thresholding was proposed based on classification for low and high scale wavelet coefficients as two state mixed model for Gaussian distribution, also the new thresholding method utilized the combination for soft and hard thresholding and get more advantage against the traditional methods [11].

3. Material and Methods

In any comparison process it is nessacary to use some suitable performance measure to examine the new proposed method against the existing methods. In this work , the paper adopt some of the popular performance indices In order to evaluate the performance for the new proposed thresholding method, difference between signal to noise ratios at the input and output of the denoising process is one of the performance measure for the quality of the new proposed thresholding [12].

This performance index always calculated based on dB value, another performance measure is the mean square error with its different form such as average error or root mean square error. Table 1 shows some of the used performance measure in this work.

In order to get a good analysis results in the wavelet tool, it is better to choose the right wavelet mother function for decomposing the signal under denoising process [13].

Choosing for the suitable wavelet depends on many aspects such as entropy, cumulative energy concentrated in the wavelet approximations coefficients, or the maximum correlation between the signals under test with the wavelet mother function [14]. Table (2) demonstrated the correlation between the noisy signal and some proposed wavelet functions.

4. Experiments

In any communication system it is required to evaluate the signal transmission quality in order to ensure the reception for the data in the receiver end. So if the signal is attacked by some noise or disturbance in the transmission path, it is required to evaluate the signal degradation using some performance measure and try to enhance the signal quality based on signal to noise ration index, such that the an acceptable signal quality reached to the receiver with a good overall signal to noise ratio. [15-16]

In this work a new wavelet thresholding method is proposed as shown in figure (1) in order to enhance the performance for signal transmission in the communication system. The proposed method is considered as a modification for the traditional soft and hard thresholding methods after augmenting the later methods by a sinusoidal function in the passband region yielding a new hardy-sine and softy-sine thresholding functions.in addition to that, a two controlling parameters are inserted in the proposed function to control the amplitude and frequency for the ripples in the passband.

The proposed thresholding functions for the wavelet based denoising method are clarified by mathematical models known as siny-soft and siny-hard thresholding as follows:

a) Hard thresholding

$$Q_j = \begin{cases} W_j & |W_j| \geq \lambda \\ 0 & |W_j| < \lambda \end{cases} \quad (1)$$

b) Soft thresholding

$$Q_j = \begin{cases} [\text{sign}(W_j)(|W_j| - \lambda)] & |W_j| \geq \lambda \\ 0 & |W_j| < \lambda \end{cases} \quad (2)$$

c) Siny-Hardy thresholding

$$Q_j = \begin{cases} W_j + a\sin(b\pi W_j) & |W_j| > \lambda \\ 0 & |W_j| \leq \lambda \end{cases} \quad (3)$$

Where; Q_j Is an output signal from wavelet thresholding at level j

W_j Is an input signal to wavelet thresholding at level j, λ Is a threshold

5. Results

A pressure signal is generated from a sensor mounted on the water pipeline of 2" diameter and it is required to classify the artificial leak type among different values (0.25", 0.5", 0.75", or 1") which was made by artificial valve fixed on the pipeline.

So in order to improve the classification process a preprocessing is essential to enhance the signal quality and remove the inherent noise by sensor and other nearby devices using new proposed wavelet thresholding method as shown in figure (1).

The classification is implemented using neural network trained using Matlab simulation tool as shown in figure (2) , and the result for leak detection of size 0.25" is demonstrated at figure(3)

6. Discussion

Referring to Table 2 a cross correlation coefficient between some wavelet mother function and the noisy signal was computed in order to choose the suitable wavelet function for further analysis in decomposition and reconstruction processes. The results show that sym8 is the wavelet function with highest correlation coefficient as compared with other used functions.

So the denoising process used sym8 wavelet function with different decomposition level and the performance is evaluated using 4 performance indices as shown in Table 3.

As the NMSE, RMSE,and PDR decreased or in other statement as ESNR increased , this indicates the better performance for the denoising process, so table 3 shows the performance evaluation for denoising process for both hard and hardy-sine (or siny – hard) thresholding. From the appeared results it was clear that hardy-sine was almost better than hard thresholding and level 5 is the best decomposition level among the used levels and there is about 10% enhancement in the ESNR value for the hardy-sine over the traditional hard thresholding.

7. Conclusions

The scientific novelty of the obtained results is that the new proposed wavelet thresholding method is succeed in denosing the signal under study with performance better than the traditional method. The practical significance of obtained results is that the wavelet based new thresholding method is proposed and simulated using Matlab software. This trail can be extended for real time application using digital signal processer boards and filtering tasks.

Prospects for further research are to study the possibility for application of the new proposed wavelet thresholding method for other signals and image processing field

The results for the new proposed thresholding method emphases the possibility for further utilization of this new thresholding method for signal or image enhancement. Preprocessing the signal before transmission will improve the signal quality and remove most of the noise prior to transmit it via noisy medium. So even the intelligent classifier efficiency will be improved in conjugate with the signal improvement and hence minimizing the error rate caused by signal contamination through transmission phase. Cross correlation, pre-calculation for the best wavelet mother function and proper level leads to an ideal denoising strategy with almost accepted results.

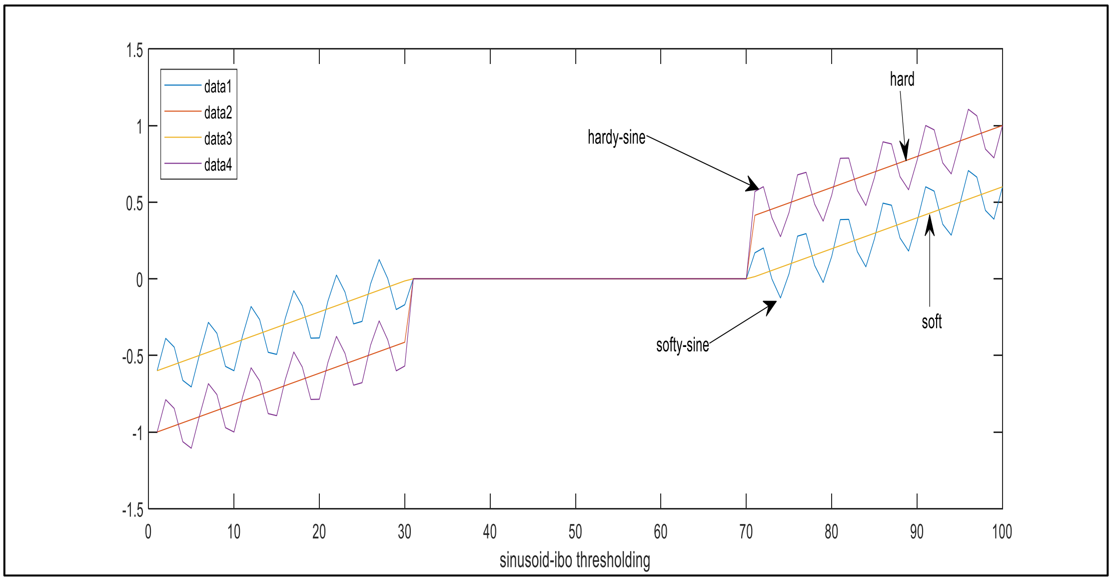

Figure 1: Proposed Siny-hard and softy-sine

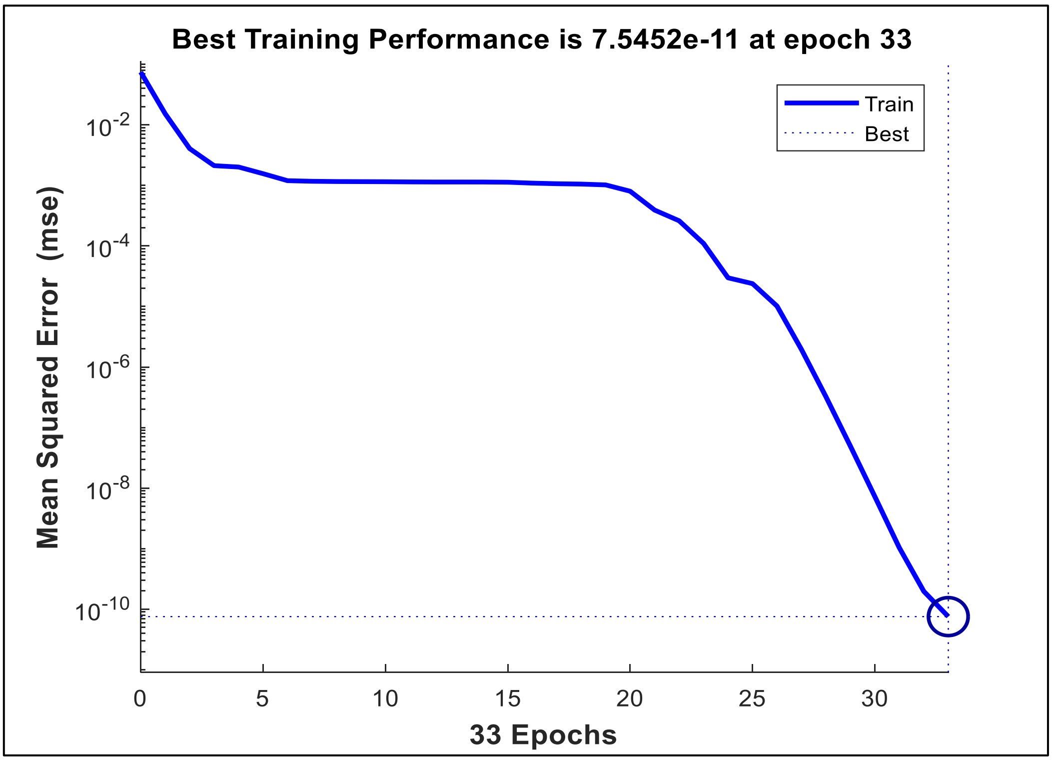

Figure 2: Training performance for the neural network explaining the MSE for each Epoch

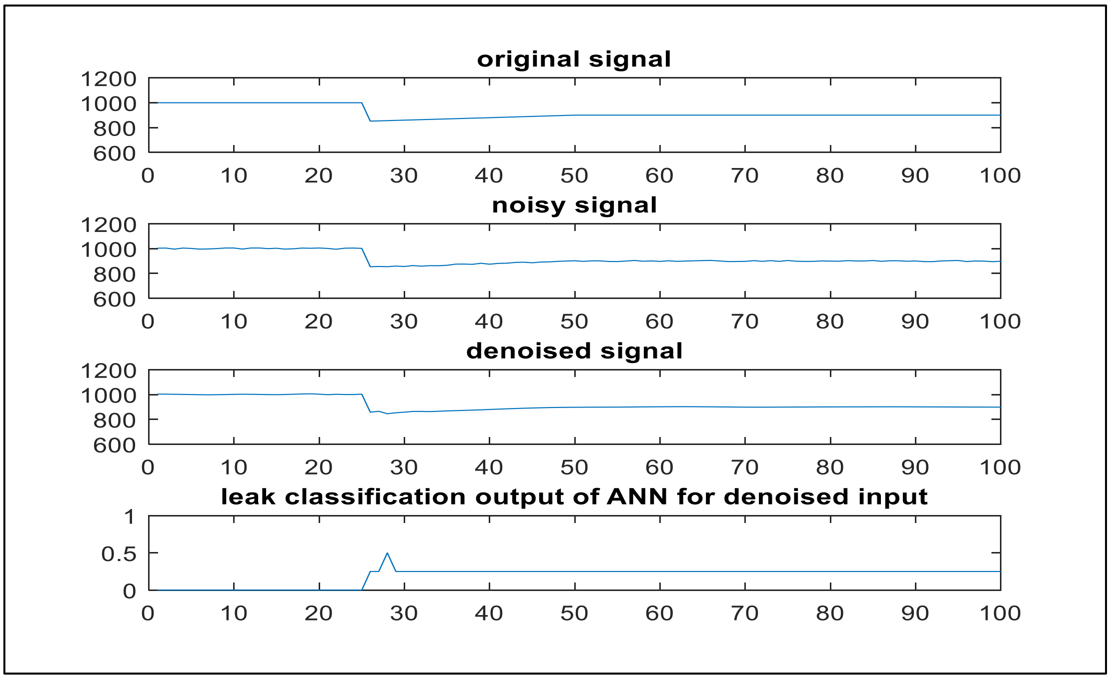

Figure 3: original, noisy, and denoised signals with classification result for the ANN output

Table 1
Different performance indices for evaluation of signal compression algorithm

Performance index	Formula
Signal to noise ratio	$10\ \log_{10}\left[\dfrac{\sum_{n=0}^{N-1} s^2(n)}{[s(n) - \tilde{s}(n)]^2}\right]$
Normalized Mean square error	$\dfrac{1}{N}\sum_{n=0}^{N-1}[s(n) - \tilde{s}(n)]^2$
Root mean square error	$\sqrt{\dfrac{1}{2N}\sum_{n=0}^{N-1}[s(n) - \tilde{s}(n)]^2}$
Percentage root mean square difference	$\sqrt{\dfrac{\sum_{n=0}^{N-1}[s(n) - \tilde{s}(n)]^2}{\sum_{n=0}^{N-1}[s(n)]^2}} * 100\%$

Table 2
Cross correlation results between signal and wavelets functions

wavelet scaling function	cross correlation
biorthogonal 6.8	7.0701
symlet 8	53.5657
Coiflet 2	25.4343
discrete Meyer	13.9638
reverse biorthogonal 4.4	18.9874

Table 3
Results for signal denoising using hard and hardy-sine thresholdings

decomposition level		1	2	3	4	5	6	7
Hard Thresholding	NMSE	0.1341	0.0719	0.0386	0.0264	0.0221	0.0239	0.2175
	RMSE	0.2589	0.1896	0.139	0.1149	0.105	0.1093	0.3298
	ESNR	2.6964	5.4046	8.1015	9.7555	10.5345	10.1856	0.5966
	PDR	0.1187	0.0869	0.0637	0.0527	0.0481	0.0501	0.1512
decomposition level		1	2	3	4	5	6	7
Hardy-sine Thresholding	NMSE	0.1331	0.0709	0.0376	0.0254	0.0211	0.0229	0.2165
	RMSE	0.2579	0.1886	0.138	0.1139	0.104	0.1083	0.3288
	ESNR	2.7964	5.5046	8.5015	10.1555	11.5845	11.2156	1.6066
	PDR	0.1177	0.0859	0.0627	0.0517	0.0471	0.0491	0.1502

8. Acknowledgements

The work is supported by the computer communication engineering department at Al-Rafidain University College represented by its dean Prof. Dr. Mahmood J. Abu-Alshaeer. So I would like to express my sincere appreciation to Prof. Dr. Mahmood J. Abu-Alshaeer for his help, support, and encouragement during all the periods of my employment.

9. References

[1] L.Hui, W. Weida, X. Changle, H. Lijin, N. Haizhao(2018)."A de-noising method using the improved wavelet threshold function based on noise variance estimation "Mechanical Systems and Signal Processing 99 (2018) 30-37.

[2] Akkar H., Hadi W., Al-Dosari I., "Implementation of Back-Propagation Neural Network for Leakage Estimation in Oil Pipelines", International Journal of Scientific & Engineering Research (IJSER), Vol.9, Issue 7, July 2018.

[3] Wibowo, A., Setianto D., Wisnu, W. P., Jatmiko, W. "Optimization of backpropagation using Nguyen-Windrow and stimulus-sampling for breast cancer classification and feature selection". Journal of Engineering Science and Technology. 2019, 14(6), p. 3437-3456. ISSN 1823-4690.

[4] Akkar H., Jasim F. (2018). "Intelligent Training Algorithm for Artificial Neural Network EEG Classifications", International Journal of Intelligent Systems and Applications 10 (5), pp. 33-40.

[5] Dr. V.V.K.D.V.Prasad, "A New Wavelet Packet Based Method for Denoising of Biological Signals", International Journal of Research in Computer and Communication Technology, Vol.2, Issue.10, pp.1056-1062, (2013).

[6] Xiaobin Xu. 'Single pulse threshold detection method with lifting wavelet de-noising based on modified particle swarm optimization', Infrared Physics & Technology vol. 88, no. (1), pp. 174–183, (2018)

[7] Hayat Ullah Muhammad Amir, Ihsan Ul Haq, Shafqat Ullah Khan, M. K. A. Rahim. 'Wavelet Based De-noising Using Logarithmic Shrinkage Function', Wireless Pers Commun, vol. 98, pp.1473–1488, (2018).

[8] Khan, S. U., Rahim, M. K. A., Qureshi, I. M., & Murad, N. A.,"Detection of faulty sensors in linear arrays using hybrid differential evolution based compressed. Sensing technique". International Journal of Electrical and Computer Engineering (IJECE), vol.7, no. (2), pp. 961–966, (2017).

[9] Hari Om, Mantosh Biswas, "An Improved Image Denoising Method Based on Wavelet Thresholding", Journal of Signal and Information Processing, vol. 3, pp. 109-116, 2012.

[10] Manjit Kaur, "Image de-noising using wavelet transform", International Journal Of Engineering And Computer Science vol. 2, No. 10 , pp. 2932-2935, (2013).

[11] Fucheng. You, Ying. Zhang, "Research of an improved wavelet threshold de-noising method for transformer partial discharge signal", J. Multimedia vol.8, no.1, pp. 56–63 (2013).

[12] Akkar H., Jasim F. (2018). "Intelligent Training Algorithm for Artificial Neural Network EEG Classifications", International Journal of Intelligent Systems and Applications 10 (5), 33-40.
[13] Rashid, S., Qaisar S., SAEED H., FELEMBAN, E. Performance analysis of leak detection algorithm in long range pipeline networks using transform analysis. In: IEEE Conference on Systems, Process and Control ICSPC ’13: proceedings. IEEE. 2013. p. 10-15.
[14] Akkar, H., AL-Samarrie, A., Saeed, A. Simulation design of back propagation neural system of sensor network trained by particle swarm optimization. International Journal of Scientific and Engineering Research. 2016, 7(4), p. 576-582. ISSN 2229-5518.
[15] S. Rashid, S. Qaisar, H. Saeed, and E. Felemban, “Performance analysis of leak detection algorithm in long range pipeline networks using transform analysis,” in Proceedings of the IEEE Conference on Systems, Process and Control (ICSPC ’13), pp. 10–15, 2013.
[16] Qasim Nameer, Mohsim Aram ,Rafeeq Ranjdr, Pyliavskyi Vladimir. (2019). New Approach to the Construction of Multimedia Test Signals. International Journal of Advanced Trends in Computer Science and Engineering. 8. 3423-3429.