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Performance Evaluation of Different Thresholding Method for De-Noising of Vibration Signal Using Discrete Wavelet Transform

Mr. Arun Kumar*, Dr. Anup Mishra**
* (PhD scholar in Dr.C.V Raman Univ. Bilaspur, India)
** (Department of Electrical & Electronics Bhilai Institute of Technology Durg, India)

Abstract
De-noising of the raw vibration signal is essential requirement to improve the accuracy and efficiency of any fault diagnosis of method. In many cases the noise signal is even stronger than the actual signal, so it is important to have such system in which noise elimination can be done effectively, there are many time domain and frequency domain methods are already available, where use of wavelet as time-frequency domain method in the field of de-noising the vibration signal is relatively new, it gives multi resolution analysis in both is time-frequency domain. In this paper various conventional thresholding methods based on discrete wavelet transform are compared with adaptive thresholding method and Penalized thresholding method for the de-noising of vibration signal of rotating machine. Signal to noise ratio (SNR), root mean square error (RMSE) in between de-noised signal with original signal are used as an indicator for selecting the effective thesholding method.
Keyword: De-noising, DWT, SNR, RMSE

I.INTRODUCTION

In fault diagnosis of machine various parameters are being monitored in, like vibration, temperature, motor current, acoustic emission etc. In witch vibration signal plays important role in condition monitoring of the machine, it is used to detects different types of fault like gear fault, rotor fault, bearing fault, air gap eccentricity fault in rotating machine [1].When the machine is operated under the normal condition the vibration is small and constant however when fault is developed, some of the dynamic process in the machine will change and so as to the vibration pattern. Vibration signal carries dynamic information of machine so it is essential to make sure that signal should be free from noise. Vibration signal is recorded from machine but due to harmonics of fault frequency and the noise characteristic frequency and fault frequency is lost. Thus an efficient de-noising method is required before analyzing the signal for the characteristic and fault frequency retrieval. An availability of different thresholding technique and time-frequency representation capability of wavelet, enable it to separate the noise from the signal [2]. In present work section II gives a description of the DWT. Section III discuss about the de-nosing method using DWT. Detail of experimental set-up in section IV. Final discussion and conclusion is in section V and section VI

II.DISCRETE WAVELET TRANSFORMS (DWT)

A Fourier analysis consists in breaking up a signal in to a sign waves with different frequencies. Similarly a wavelet analysis is the breaking-up of a signal into shifted and scaled version of function called mother wavelet, where DWT is discrete in terms of sampling scaling and shifting parameters not in signal, quick way of obtaining a DWT is to use filter bank of low pass and high pass filter which is followed by down sampling to compute approximate and detail coefficient where approximate is low pass filtered and detail is high pass filter which is derived from mother wavelet, same process is continue with the approximate low frequency coefficient to increase the level of decomposition by breaking it up in approximate and detail part. The shape and the frequency response of these filter depends on the type and order of mother wavelet used in analysis [3][4][8].

A. Selection of mother wavelet

It is very essential to choose a suitable wavelet for the vibration signal, which provides the best correlation under the decomposition and de-nosing process, based on DWT. For this a number of wavelet are used to decompose the signal one by one and the variance of corresponding sub band coefficient are calculated and compared to select suitable wavelet as per the highest value of the variance.
A raw vibration signals are recorded from the surface of the machine under normal and fault condition, six

level of discrete wavelet transform is used to decompose the signal in approximate and details coefficient. Variance of all the approximate and detail coefficient are calculated there after sum and averaged. The decomposition process with calculating average variance is repeated for different wavelets [5]. Finally wavelet with highest value of variance of the detail coefficient is selected as most suitable wavelet for the analysis vibration signal. Average variance of different wavelet are listed in table 1. It is observed from the table.1 that 'Symlet-8' (sym8) is the most suitable wavelet, producing highest average variance of 4.0329. It is also observe from the experiment that reconstruction error of 3.19E-10 using same wavelet.

III.DWT based De-noising

Discrete wavelet transform perform automatic de-noising of signal, based on soft and hard thresholding algorithm, a hard thresholding method is based on 'keep or kill' method whereas soft thresholding is alternative to this[6][7], in which coefficients above the threshold value are shrunk and amount of shrinking is equal to threshold to keep input and output continuous, there are many threshold decision algorithm like Rigrouse Sure, Minmaxi, Huersure. These algorithms are used in wavelet based de-nosing method to remove the noise with respect to calculated threshold value. Present work made a comparison between all the conventional threshoding method of DWT using automatic denosing method with penalised and adaptive thresolding method. Signal to noise ratio (SNR) root mean square error (RMSE) and cross correlation are used to evaluate result of noise reduction, which is the measure of closeness of de-noised signal to the original signal

V.Experimental setup

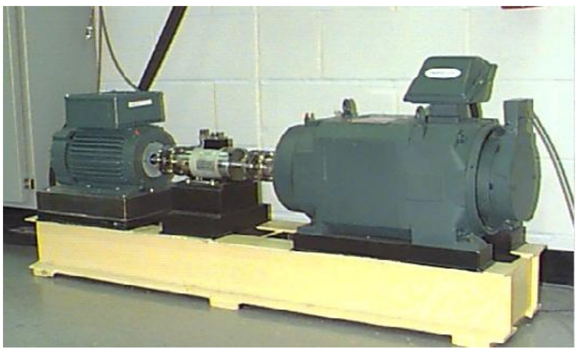

Figure .1 A test bench set-up

The test set up referred here and standard set of data is collected from the test setup prepared by vibration data center "case wastern reserve university" consists of a 2 hp motor (left) running at the speed of 1797rpm, a torque transducer/encoder (center), a dynamometer (right), and control electronics (not shown). The test bearings support the motor shaft. Vibration data was collected using accelerometers, which were attached to the housing with magnetic bases. Accelerometers were placed at the 12 o'clock position at both the drive end and fan end of the motor housing. During some experiments, an accelerometer was attached to the motor supporting base plate as well. Vibration signals were collected using a 16 channel DAT recorder, and were post processed in a Matlab environment. All data files are in Matlab (*.mat) format. Digital data was collected at 12,000 samples per second, Speed and horsepower data were collected using the torque transducer/encoder and were recorded by hand. The test bench set-up is shown in the figure.1.

IV.DISCUSSION

A Hard thresolding method based on "keep and kill" techniques is also implemented and tested to remove impusive noise from vibration signal as reported in[5]. It is observed from the result of implementation that the RMSE between original signal and noisy signal is 0.0543 and RMSE between original signal and de-noised signal is 0.0123, giving an improvement of 77%, but same method cannot make any considerable change in the indicators, because it is unable remove the white noise.

All wavelet based thresoding method along with peanalized thresholding method are compared with adaptive thresolding method in present work. Input SNR between original signal and noise signal is ***10DB*** and RMSE between original signal and noisy signal is ***0.3161***. the output SNR and RMSE is compared in table 2. The original signal and de-noised signal are shown in figure.2, figure.3 showing cross-correlation between original signal and de-noised signal for different thresholding method

VI.CONCLUSION

A suitable mother wavelet selection method for vibration signal analysis is implemented in present work. The DWT based different conventional thresholding methods are compared with the adaptive thresholding method. The indicator such as root mean square error (RMSE) and signal to noise ratio (SNR) are used to evaluate the result.

The result of comparison and their outcomes are listed in table II. In which a panelized thresholding method showing, highest noise reduction capability with highest SNR 6.45DB and lowest RMSE 0.1897.The percentage reduction in RMSE is 40%.

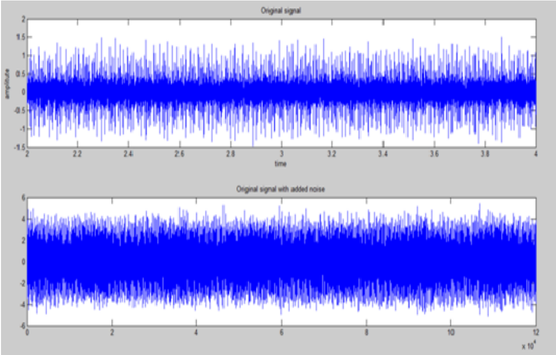
Figure 2. a) Original signal b) Signal with noise

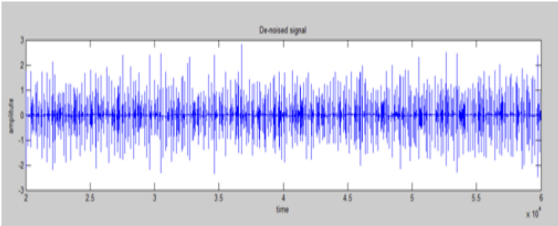
Figure 3.Denoised Signal with noise

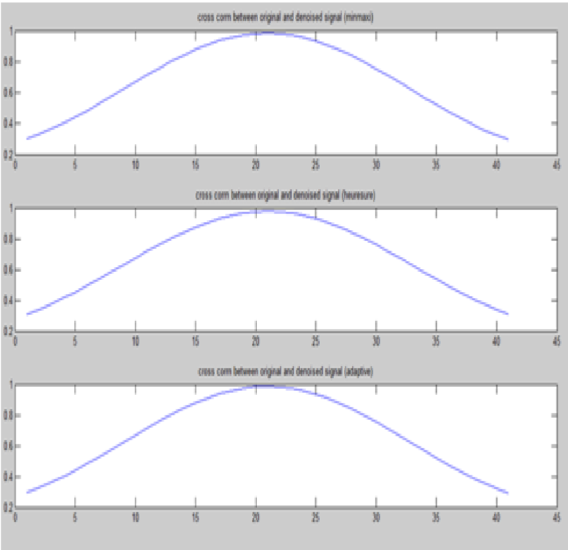
Figure 4. Crosscorrelation of denosed signal with original signal using (a)minmaxi (b) heuresure (c) panelized thresolding.

Table1. Average variance of detail coefficient

Wavelet	average varriance	Variance of the detail coefficient					
		D6	D5	D4	D3	D2	D1
Sym1	3.5073	5.1111	3.1159	1.9655	3.0257	0.8109	0.1311
Sym3	3.9335	7.0368	2.4551	1.3888	4.3446	0.5085	0.0211
Sym5	3.8872	7.0503	2.1942	1.1283	4.8002	0.3756	0.0106
Sym7	3.9127	7.2518	2.0679	1.0126	5.0118	0.3069	0.0073
Sym8	4.0329	7.7639	2.0301	0.979	5.0724	0.2859	0.0064
DB1	3.5073	5.1111	3.1159	1.9655	3.0257	0.8109	0.1311
DB4	3.9004	7.0381	2.2776	1.2354	4.62	0.4305	0.014
DB6	3.9413	7.3222	2.1214	1.0582	4.9278	0.3355	0.0087
DB8	3.9425	7.3946	2.0369	0.978	5.0739	0.2864	0.0064
DB44	4.0301	7.9693	1.8098	0.8928	5.2386	0.2146	0.0035
coif1	3.8744	6.6272	2.7148	1.6234	3.9154	0.6167	0.0403
coif3	4.0035	7.6023	2.0867	1.0362	4.9657	0.323	0.0081
coif4	4.0119	7.692	2.0118	0.9675	5.1001	0.276	0.006
coif5	4.005	7.6953	1.9724	0.9332	5.1686	0.2506	0.0049
bior2.2	3.5073	5.1111	3.1159	1.9655	3.0257	0.8109	0.1311
bior1.1	4.0015	10.759	6.9791	3.5648	4.7951	0.3898	0.017

Table 2. Comparison of the SNR and RMSE

(Input SNR 10DB and RMSE is 0.3161)

Threshold	Heuresure	Fix Thresholding	Minimaxi	Adaptive thresolding	Panelized thresolding
SNR	6.0802	5.2311	6.3132	5.9942	6.4505
RMSE	0.2259	0.2498	0.1956	0.2374	0.1897

Table 3. Comparison of cross correlation

Threshold	Minimaxi	Heuresure	Panelized thresolding
Cros-correlation	0.9767	0.9846	0.9854

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Mr. Arun Kumar, he received his B.E.degree in Electronics & Telecomm. From Pt. RSU Raipur, M.Tech in ETC from CSVTU Bhilai. Currently, he is a PhD scholar in Dr.C.V Raman Univ. Bilashpur and working as associate professor in the Department of ETC in Bhilai institute of Technology Durg India.

Dr. Anup Mishra, he received his B.E.degree in Electrical Engineering from Pt. RSU Raipur, M.Tech in ETC from Pt. RSU Raipur, Ph.D from BUB Bhopal, presently working as Professor & Head in department of EEE, in Bhilai institute of Technology, Durg, India.