Indian Journal of Fundamental and Applied Life Sciences ISSN: 2231– 6345 (Online)
An Open Access, Online International Journal Available at www.cibtech.org/sp.ed/jls/2015/01/jls.htm
2015 Vol. 5 (S1), pp. 1587-1592/Ghaedi et al.
Research Article

FAULT DIAGNOSIS OF INTERNAL COMBUSTION ENGINE USING DISCRETE WAVLET TRANSFORM AND IMPROVED CLASSIFICATION SYSTEM XCSR

***Azam Ghaedi[1], Ehsan Sadeghi Pour[2] and Farzad Hosseinzadeh[3]**
[1]*Department of Computer Engineering, Bandar Abbas Branch, Islamic Azad University, Bandar Abbas, Iran*
[2]*Sama Technical and Vocational Faculty, Islamic Azad University, Bandar Abbas, Iran*
[3]*Young Researchers and Elite Club, Bandar Abbas, Iran*
**Author for Correspondence*

ABSTRACT
Signal vibration processing is one of the most important methods for monitoring and fault diagnosis of mechanical systems. In this paper, using discrete wavelet transform and improved intelligent systems XCSR, we try to diagnose a deliberate non-combustion in the engine. In this respect, to select the best wavelet function, first, using the discrete wavelet function, the discretion of measured signals from the test machine is checked, then, we calculate the total energy of the Shannon entropy for all the measured signals on Dabocci wavelets, B orthogonal, coifelet. Then, selecting the db1 wavelet function and extracting Covariance and Crest factor, we use the average distance of the signal peaks, covariance crest factor related to discrete wavelet coefficients as the provision of training examples to train our system XCSR which results indicate fault diagnosis of non-combustion as to 93.3%.

Keywords: *Fault Diagnosis, Intelligent Systems XCS, Combustion Engine, Wavelet*

INTRODUCTION
Engineers from the perspective of control, status monitoring and troubleshooting purpose systems are dynamic systems and automated monitoring and diagnosis of faults and determine the date, location and size of the defect and are continuing to increase the availability. Monitoring of status, the lower the possible consequences of downtime and increase equipment life and reduce the cost of parts and repairs. Various methods for the detection and identification of errors and it has been suggested that the size of the protrusion grown over time and the ability of operators are alternative methods. Two different methods to detect faults and Signal Based Model Based there. Since the 1990s, the use of vibration analysis and analysis of vibrating pulses is an effective method for troubleshooting (Bernhard, 1988). They did the troubleshooting process. Chung Huang and his colleagues multivariate statistical analysis method for processing a momentary engine speed to locate events in the absence of combustion in internal combustion engines offered (Chongqing *et al.*, 2012). The distribution interference in terms of its distribution can be seen. As one of the most successful agents in the learning environment is the use of semi-observable lack of combustion in an internal combustion engine fault diagnosis is its ability to pay.

Wavelet
In 1909, Alfred Har wavelet was the first to refer to the corresponding Fourier transform, continuous wavelet function is a function of the sum of multiplication of that function in scale of the wavelet And shifts in the defined time interval. Thus, in general, can be written as:

$$\mathrm{C(scale,position)}=\int_{-\infty}^{+\infty} \mathrm{f(t)}\psi\mathrm{(scale, position)dt} \quad (1)$$

$$C(a,b)=\int_{-\infty}^{+\infty} f(t)\frac{1}{\sqrt{a}}\psi\left[\frac{t-b}{a}\right]dt \quad (2)$$

The result of the conversion of wavelet coefficients (c) are a function of the scale and multiplication of each of the coefficients of the wavelet scale and shift are. The contribution rate will be determined in the original signal. Overviews of the process in Figure 1 are:

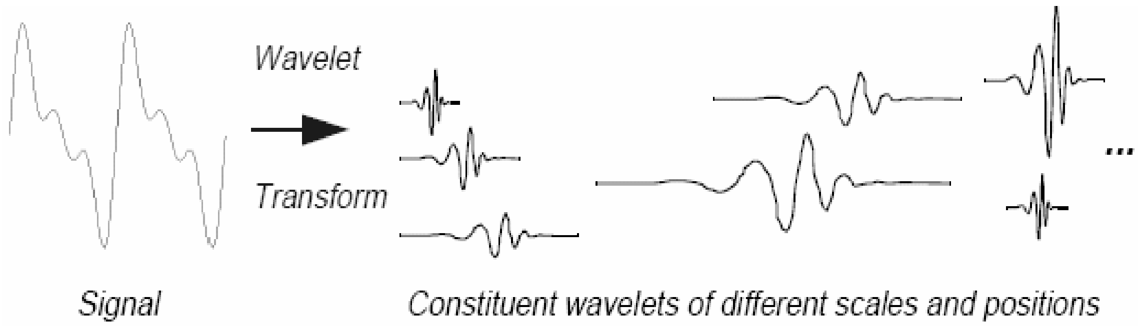

Figure 1: overview of the process of wavelet

Shift and scale wavelet used in the definition, as shown in Figure 2-4 defines. Shift simply means moving along the time axis and scale wavelet means of wavelet expansion along the time axis is Drop in wavelet domain to expand the scale of Figure 2 is to remain constant energy.

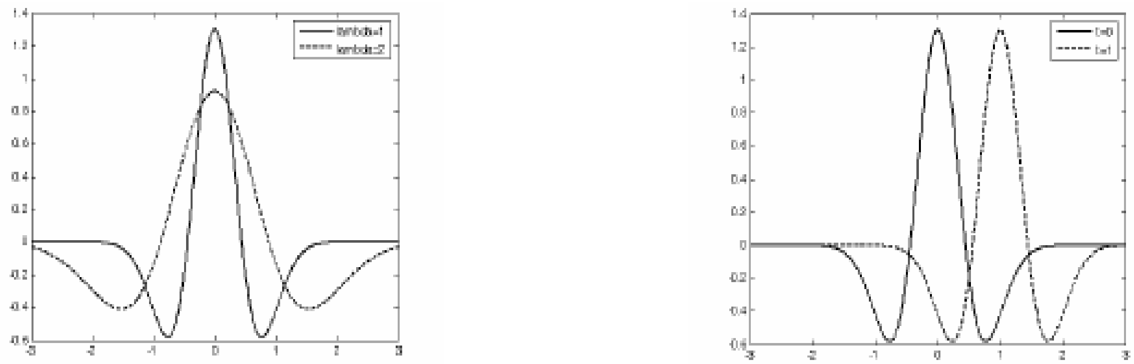

Figure 2: Shifts to the right and left of the scale of a wavelet

Note that the large-scale and small-scale waves of low frequencies to high frequencies St.hr as wavelet function is used the wavelet function is used as a mean of zero and a unit of energy. These concepts are expressed in equations 3 and 4 In addition to the transmitted signal to be reconstructed on the basis of wavelet basis Wavelet selected must also meet the acceptance criteria is that the relationship 5.

$$\int_{-\infty}^{+\infty} \psi(u)du = 0 \quad (3)$$

$$\int_{-\infty}^{+\infty} \psi^2(u)du = 1 \quad (4)$$

$$0 < \int \frac{|\psi(f)|^2}{f} df < \infty \quad (5)$$

In Equation 6, we have:

$$\psi(f) = \int_{-\infty}^{+\infty} \psi(u)e^{-2\pi fu}\, du \quad (6)$$

As of February it was the turn signal reconstruction The signal can also be transferred to the wavelet basis with respect to the return signal 7.

$$f(t) = \frac{1}{k_v} \int \int C(a,b) \frac{1}{\sqrt{a}} \psi \left[\frac{t-b}{a}\right] \frac{dadb}{a^2} \quad (7)$$

Signals that we 're most interested in their analysis, they are usually discrete As a result of the discrete wavelet transform is inevitable.

Discrete Wavelet Transform

Wavelet analysis is a powerful tool Transients can be converted using the data from the time domain transient signal in time - frequency domain will be mapped. The theory of discrete wavelet transforms

(DWT) (Equation 8) and comparison with the Fourier fully described. In this part of the theory of discrete wavelet transform and define a summary description of it is given. The Fourier transform of the signal is amplified by a trigonometric polynomial. However, the discrete wavelet transform, the signal using wavelet coefficients of intensive and extensive scale of the mother wavelet, is developed. This makes possible the analysis of transient signals locally and at the time it is possible by wavelet transform. The relationship used in discrete wavelet transform of a signal is as follows.

$$DWT(m,n) = \frac{1}{\sqrt{a_0^m}} \sum_k x(k) g(a_0^{-m} n - b_0^k) \qquad (8)$$

Given the high correlation with DWT, the original signal can be decomposed into two signals, namely the approximation and detail. Approximation consists of low-frequency signal and the original signal form. On the other details, including transient and harmonic frequency components of the original signal. This approximation is obtained by parsing can continue to the next level of detail and approximation. This is called multi-resolution signal decomposition known. Figure 3 shows how to analysis the frequency of the original signal levels. Frequency range, each detail of the original signal sampling rate depends on the discrete wavelet transform.

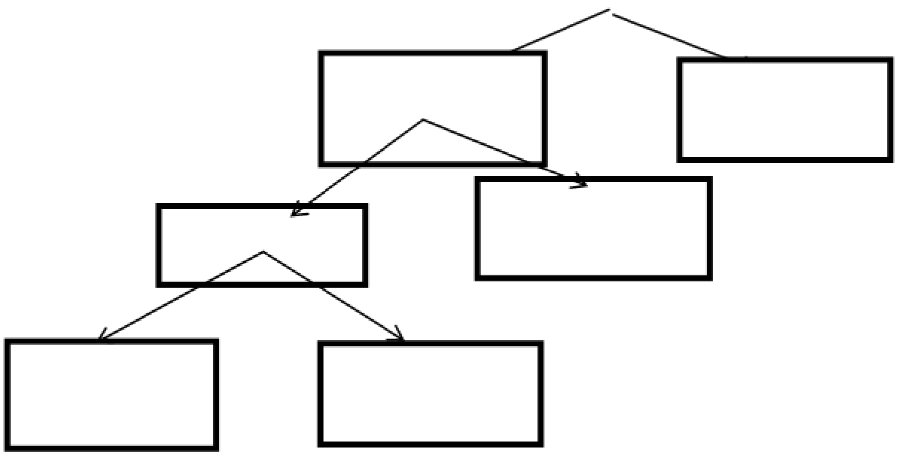

Figure 3: Structure of Discrete Wavelet Transform

Due to the special logarithmic discrete wavelet transform, in each frequency range, this conversion is called a level.
The maximum number of levels of wavelet analysis (j) according to the following equation is defined as:
$j = log_2^N$ Where N is the number of samples.
By choosing a0 = 12 and b0 = 1 in the above equation can be used as the mother wavelet low-pass filter with a surface low-pass filter l (n) and its dual as a high-pass filter h (n), discrete wavelet transform operation performed. Also, the top-down sampled by a factor of 2 (↓ 2) The output of low pass filter l (n), Wavelets for stage (stage) are then scaled and thus the operation **Dialation** is facilitated.

XCS

A wide variety of machine learning algorithms to learn to coach and mentor refers that the goal of data mining in the area, to avoid global search (exhaustive search) data and Time to search and replace these with clever ways to find the pattern (s) of the data, Category or modeling their behavior makes it easy.
In the past two decades, many methods have been proposed in the field of data mining that in which a variety of learning algorithms with coach (supervised), without coach (unsupervised) or reinforcement (reinforcement) for purposes such as pattern recognition and attribution is used. Among these methods are the most successful classifier systems (classifier systems) noted.
In general, classification systems include a set of rules format "If- then" that the law aims to provide a potential solution to the problem. This series of gradually applying a reinforcement learning mechanism has been assessed and at intervals specified by using a genetic algorithm is Updating. During this

evolution, the system learns the behavior and the application phase, the proper response to a query (query) are set by the user.
The first classification system in 1976 by the Dutch as a Learning Classifier System) LCS) was proposed. In this system, the value of the index called the "strength» (strength) was evaluated. The strength of a law suit with the correct answer to the training examples in terms of reinforcement learning framework rose at a certain time interval, an evolutionary search algorithm (generally GA) and remove the responsibility of the new rules inefficient responsibility were. At the end of training, the ability to set rules relative to that in the face of new questions, provide acceptable solutions. LCS yet successful performance depends on the values chosen for the control parameters which depend mainly on the experience of the system designer.
Since the creation of LCS, other types of classification systems have been proposed of which can be extended classifier system (Extended Classifier Systems: XCS) noted. Until the introduction of XCS in 1995, the ability of the system to obtain the proper response was very limited. However, since these systems are gradually became more accurate and intelligent agents and now it is believed that XCS and its improved versions are able to solve complex questions without having to adjust the parameters. With the introduction of the classification system with continuous variables (XCSR), some inherent weaknesses binary classification systems (binary), including failure to report within the specified variable values are largely fixed. Today, these systems are operating as one of the most successful learning (Learning Agents) for solving problems of data mining in half observable environments known. Today, these systems are operating as one of the most successful learning (Learning Agents) for solving problems of data mining in half observable environments known. This means that the chances of the new rules to eliminate the lack of and participation in the production process, directly depends on the training to how to answer and Set realistic chance requires the use of a large number of training data. Since the real issues, the number of training data is limited, and increasing the number of data is simply not possible, such applications usually use XCSR in terms of computational time and cost is not justified. In this paper a new method to improve performance and increase the convergence rate XCSR with limited training data is provided by which the internal combustion engine fault diagnosis explains.

MATERIALS AND METHODS

In the proposed method, first set (limited) training data are used to modify the characteristics of the legislation (such as " prediction"، "prediction error" and " Suitability") is used. This is done using the following relations:
Update prediction and prediction error
If $exp_i < 1/\beta$ then $P_i = P_i + (R-P_i) / exp_i$, $\varepsilon_i = \varepsilon_i + (|R-P_i| - \varepsilon_i) / exp_i$
If $exp_i \geq 1/\beta$ then $P_i = P_i + \beta (R-P_i)$, $\varepsilon_i = \varepsilon_i + \beta (|R-P_i| - \varepsilon_i)$
Update Suitability
If $\varepsilon_i < \varepsilon_0$ then $k_i = 1$
If $\varepsilon_i \geq \varepsilon_0$ then $k_i = \beta (\varepsilon_i/\varepsilon_0) - \gamma$
$F_i = f_i + \beta [(k_i/\sum k_j) - f_i$
In this relationship, β learning rate, γ be the accuracy, ε prediction error, exp experience in law, P prediction rule, R reward from the environment, k f precision and elegance of it. Subscript i indicates the number of rules in the rule set.
The next step is to expand the variety of data sets, using the "random selection remains" the fields that display the data if there are many couples as parents are choosing And the provision of new data using the same pass over the middle of the field, is applied parents. In this way, if any of the variables obtained from the following equation:
$a_i = \alpha(a_{iF}) + (1-\alpha)(a_{iM})$
Where ai if i is the value of the new data, aiF conditional variable i in the first parent (father), aiM conditional variable i in the second parent (mother), and α is the coefficient of parental involvement in adaptive (adaptive) is determined. The performance of new data using a nonlinear mapping from the

space variables, conditional on performance space that has been created using data generated (ShariatPanahi and Moshtaghi, 2012).

The Method of Work

The study is designed to evaluate the operation of the internal combustion engine vibrations and Peugeot 206 from B & K is a knock sensor and software. Engine vibration signals of interest are presented in 16 states. To select the first discrete wavelet function of the measured signal from the test apparatus, using discrete wavelet function check then The total energy of the Shannon entropy for all measured signals on wavelets Dabocci wavelets function, B orthogonal, coifelet was calculated that db1 wavelet function has the maximum energy of the Shannon entropy is ranked among the chosen wavelets. Selected based on the number of discrete wavelet function of wavelet coefficients were calculated for all signals Since the volume of data provided by the discrete wavelet coefficients are very high data processing for intelligent systems applied to classification is very time XCSR. Therefore, the various parameters used to obtain the feature vector extraction. At this Krtvsys parameters, the average distance of the signal peak, crest factor covariance and the discrete wavelet coefficients As the provision of training examples for training systems and the use XCSR THEN it is considered one of the 16 states. For each of the 16 states in 35 signal is measured by the number 20, the signal for the education system and 15 signals for testing, we consider that a total of 560 recorded signal 320 signals for training intended and 240 signal also to consider testing. The results of this experiment are shown in Table 1.

Table 1: Detection of non-combustible

	XCSR	**IMPROVED XCSR**
Detection of non-combustion in the cylinder 1	%93.3	%100
Detection of non-combustion in the cylinder 2	%80	%100
Detection of non-combustion in the cylinder 3	%86.6	%100
Detection of non-combustion in the cylinder 4	%86.6	%100
Detection of non-combustion Detection of non-combustion in the cylinder 1,2	%73.3	%100
Detection of non-combustion in the cylinder 1,3	%73.3	%93.3
Detection of non-combustion in the cylinder 1,4	%80	%93.3
Detection of non-combustion in the cylinder 2,3	%86.6	%93.3
Detection of non-combustion in the cylinder 2,4	%73.3	%93.3
Detection of non-combustion in the cylinder 3,4	%80	%93.3
Detection of non-combustion in the cylinder 1,2,3	%73.3	%93.3
Detection of non-combustion in the cylinder 1,2,4	%73.3	%93.3
Detection of non-combustion in the cylinder 1,3,4	%66.6	%86.6
Detection of non-combustion in the cylinder 2,3,4	%66.6	%86.6
Detection of non-combustion in the cylinder 1,2,3	%66.6	%93.3
Safe mode	%80	%100

CONCLUSIONS

This paper aims to identify the lack of combustion in the cylinder of the engine using the vibration signal is First, to the disadvantage of lack of combustion in the cylinder of the vibration signals measured Were measured. Then discrete wavelet transform for signal preprocessing and feature extraction, we use vector Shannon entropy as a function of energy and help db1 wavelet function optimally. The average distance of the signal peak, crest factor covariance and the discrete wavelet coefficients as the condition Training examples are used to train the system XCSR We use. Output system 16 shows the classification with 93.3% efficiency.

REFERENCES

David Bernhard (1988). Anonymous, Vibration Technology 1,IRD, Mechanalysis.

Chongqing H, Aihua Li, Xing and Yang Zhao (2012). Multivariate statistical analysis strategy for multiple misfire detection in the internal combustion engines. *Journal Mechanical Systems and Signal Processing* 694-703.

Shirazi FA and Mahjoob MJ (2007). Application of Discrete Wavelet Transform (DWT) in Combustion Failure Detection of IC Engines. *Proceedings of the 5th International Symposium on image and Signal Processing and Analysis.*

ShariatPanahi M and MoshtaghiYazdani N (2012). An Improved XCSR Classifier System for Data Mining with Limited Training Samples. *Global Journal of Science, Engineering and Technology* (2) 52-57.

