Classification based Support Vector Machine on Frequency Domain and Wavelet Features in Signal Processing

[1] **Cheedaragadda Suryababu,**
Research Scholar, Veer Bahadur Singh Purvanchal University, Jaunpur-UP.
suryajessica@gmail.com
[2] **Dr. Vikrant Bhateja,**
Research Supervisor, Professor, VBS Purvanchal University, Jaunpur -UP
bhateja.vikrant@ieee.org
[3] **Dr. D. Subbarao,**
Professor, Dept. of ECE, Siddartha Institute of Engineering & Technology, Hyderabad
ecesiet.04@gmail.com

Abstract: -

Frequency domain based features and Wavelet features are extracted from the audio signals of the motorcycles. Frequency domain based classificationdeals with the spectrogram of the audio signals that explains the extraction of features, classification and the performance analysis of the proposed system.The key drawback of these features are more time consuming and therefore the time and frequency features are addressed separately. This makes the system not much efficient and produces very less classification accuracy. Wavelet Transform (WT) is a very efficient signal processing tool that estimates the signal in the time and frequency domain simultaneously by the transforming time domain signal into time and frequency domain. Here wavelet domain based features are extracted from the audio signals and the features are classified using the same SVM classifier. The performance of the wavelet domain based featuresare obtained separately and the performances are compared with time domain and frequency domain based features performances.

DOI Number: 10.48047/nq.2022.20.22.NQ10484 **NeuroQuantology2022;20(22): 4779-4785**

1. INTRODUCTION

The audio signals recorded from the motorcycles are preprocessed. After preprocessing, the features are extracted from the frequency constituents of the signal. These features are given as input to the Support Vector Machine (SVM) for further classification.The frequency based features of the audio signals are extracted by finding the spectrogram of the audio signal. The spectrogram of the audio signal represents the intensity or power of the audio signal with respect to the frequency present in the signal. The spectrogram varies for every different faults in motorcycle. From the spectrogram, the following features are extracted which are useful for the recognition of various faults in the motorcycles.The mean frequency of the audio spectrum is calculated as the sum of the product of the audio spectrogram intensity (in dB) and the frequency divided by the total sum of audio spectrogram intensity [30]. The median frequency is the frequency at which the audio spectrum is divided into two regions with equal amplitude. The MEDF is also defined as the half of the total power [26].

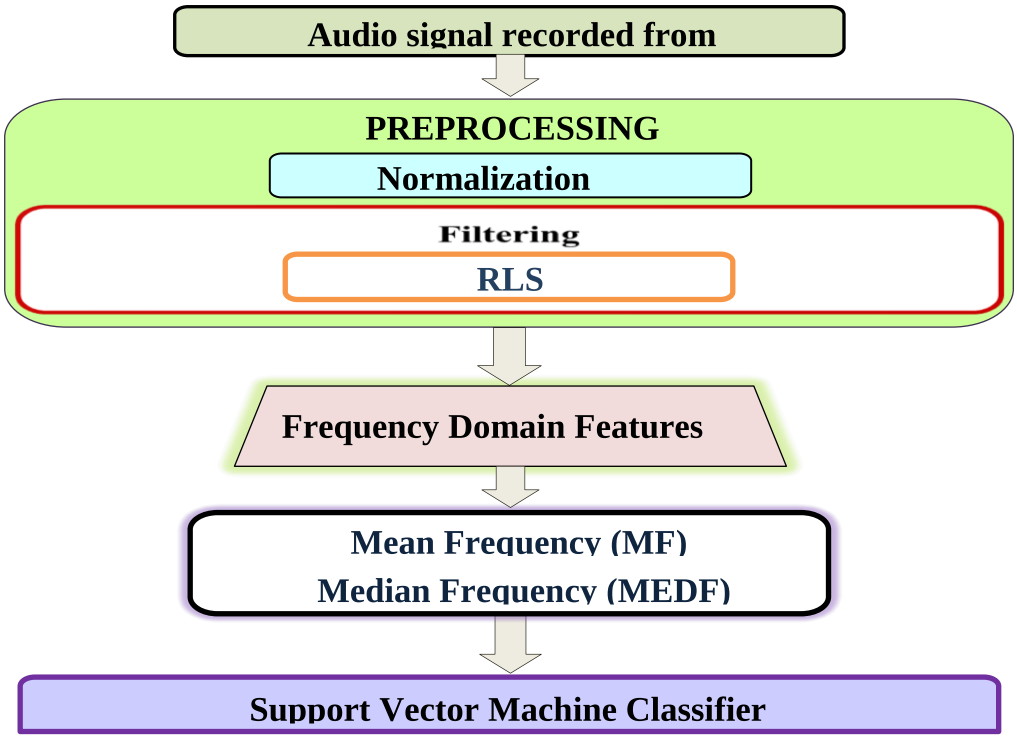

Fig 6.2 Block diagram for the frequency domain based features and SVM based classification

The Support Vector Machine (SVM) is one of the best classification machine learning algorithm. The SVM algorithm is also used to solve regression problems. The major application of SVM classifier is that it is used in classification related problems. Each input data element is presented as a point in the n-dimensional space (where n is the number of objects it has). The values of each element is represented in a specific coordinate. In SVM algorithm, the classification is done by identifying the hyper plane that separates the two classes of data elements [34]. This finest boundary or region is called as a hyper plane. This algorithm finds the closest point of the lines from both the classes. These points are called support vectors. The distance between the vectors and the hyper plane is called as margin. The objective of SVM is to maximize this margin. The optimum hyper plane chosen for the maximum margin.

The SVM normally performs linear classification. In addition to the linear classification, SVM uses kernel tricks to perform non-linear classification. During the non-linear classification the input data element is splitted into multidimensional feature spaces. When the data is not labeled, the supervised learning is not possible, and an untrained learning approach is needed that attempts to find a natural grouping of data by groups, and then match the new data to these formed groups. The support vector statistics is used for classifying the unmarked data elements in the support vector algorithm. This type of classification is used in many industrial applications [33]. The SVM can used in many audio signal classification and speech signal classification.

2. FREQUENCY DOMAIN BASED FEATURE VECTORS

The frequency domain based feature vectors is obtained as the combination of all the Mean Frequency (MF) and Median Frequency (MEDF) based extracted features.The experiments are carried out to extract the frequency domain based features for the SVM classifier. The features are extracted for both the datasets (DS1 & DS2). The SVM classifier is trained using the features and the faulty and normal conditions are classified during testing. The performance of frequency domain based classification approach is measured by using performance metrics.

2.1 Classification of Faults using SVM

The frequency spectrogram generated for all the audio signals are analyzed. The dataset DS1 consist of eight different classes. For each class, nearly 500 frequency spectrograms are generated and the feature values are extracted. For dataset DS2, it has six different classes. For each class nearly 60 frequency spectrums are generated and the feature values are also extracted. The Kernel type used in SVM is Radial Basis Function (RBF) with gamma value is 0.63, cost value is 12.4 and Nu value is 0.15. From the frequency spectrum, the frequency domain based features such as mean frequency values and median frequency values are extracted and given as the input to the SVM classifier. The Table 2.1 and Table 2.2 shows the classification accuracy of each fault for dataset DS1 and DS2.

	C1	C2	C3	C4	C5	C6	C7	C8
C1	**92**	1	1	0	3	1	1	1
C2	3	**83**	2	3	2	4	2	1
C3	2	1	**92**	0	1	0	3	1
C4	1	2	2	**90**	1	1	0	3
C5	1	2	2	3	**86**	2	1	3
C6	5	1	3	4	2	**78**	4	3
C7	0	4	2	2	3	4	**83**	2
C8	2	1	2	5	1	4	3	**82**

Table 2.1 Classification accuracy for DS1 with frequency domain based feature set with SVM classifier 4781

	H1	H2	H3	H4	H5	H6
H1	**88**	3	2	2	3	2
H2	4	**78**	5	3	4	6
H3	3	3	**86**	4	1	3
H4	3	3	4	**85**	3	2
H5	4	2	4	3	**82**	5
H6	4	5	5	3	4	**79**

Table 2.2 Classification accuracy for dataset DS2 with frequency domain based feature set and SVM classifier

Classifier	**Accuracy (%)**	**Specificity**	**Sensitivity**	**Precision**	**False Measure**	**F1-Score**
DataSet (DS1)						
Time domain based features with FFNN	83.37	0.8921	0.9012	0.9521	0.12	0.85
Frequency domain based features with SVM	**85.75**	**0.9045**	**0.9126**	**0.945**	**0.36**	**0.91**
DataSet (DS2)						
Time domain based features with FFNN	82.5	0.8723	0.8891	0.942	0.16	0.84
Frequency domain based features with SVM	**83.01**	**0.9144**	**0.9258**	**0.932**	**0.23**	**0.89**

The accuracy of the SVM during testing is given as the confusion matrix for dataset DS1 and dataset DS2 for the feature values. The diagonal elements show the truly classified output. Generally, for a high performance confusion matrix, the diagonal elements will have highest value. For dataset DS1, totally 8 classes are used to perform training and testing and for dataset DS2 6 classes are used.

Table 2.3 Performance results for different feature sets for both datasets

The maximum accuracy of 92% is achieved for motorcycle in normal condition (C1) and motorcycle with air screw problem for dataset DS1 in table 2.1. The motorcycle without fault (H1) achieves the maximum accuracy of 88% for dataset DS2 in table 2.2. The comparison of the accuracy results for the frequency and time domain based features with FFNN and SVM classifiers are shown in Table 2.3.

3. WAVELET DOMAIN BASED FEATURE VECTORS

Wavelet Transform (WT) is a very efficient signal processing tool that estimates the signal in the time and frequency domain simultaneously by the transforming time domain signal into time and frequency domain. Wavelet domain based features are extracted from the audio signals and the features are classified using the same SVM classifier. The performance of the wavelet domain based features are obtained separately and the performances are compared with time domain and frequency domain based features performances. In wavelet based feature extraction, the audio signal is decomposed in wavelet sub bands and the energy of the decomposed subbands are calculated as feature values. Here, Support Vector Machine (SVM) is used as a classifier to make decision based on the extracted wavelet domain features. Here, the extracted features are given as input to the classifier for training and the faults are classified during testing.The wavelet domain based feature vectors is obtained as the combination of all the energy based wavelet based extracted features.

The wavelet based features are to be extracted from the audio signal before classification. Before feature extraction choosing the appropriate mother wavelet adds more advantage recognition of faults. The common mother wavelet function used are Haar (db1), Daubechies (db), Coiflets (coif), and Symlets (sym) are used. The best mother wavelet is selected by calculating the accuracy for different mother wavelet features with SVM classifier. The accuracy of the recognition is tabulated in the Table 3.1.

SNO	**Feature Vector**	**Average Recognition Accuracy**
1	Haar	79.85%
2	Daubechies	81.45%
3	Coiflets	82.69%
4	Symlets	85.34%

Table 3.1 Average recognition accuracy using different mother wavelets

For the Table 7.1 it is very clear that, the Symlets (sym) mother wavelet produced better recognition accuracy compared to other mother wavelets. Therefore, the Symlets (sym) is choose to be the mother wavelet for the wavelet domain based feature extraction process. All the Wavelet Packet Transform (WPT) based energy features are extracted from the audio signals using Symlets (sym) and used for training and testing. The wavelet based features are trained and tested using SVM classifier. The features are extracted for both the datasets (DS1 and DS2).

3.1 Classification of Dataset DS1 and DS2 using SVM

The audio signal is decomposed in subbands and the energy values of each subbands are calculated from the audio signal of both the datasets using MATLAB. The wavelet energy values are more efficient and it can produce good percentage of accuracy [36]. The wavelet domain based the feature values (F3) are extracted and given as the input to SVM classifier. The algorithm of SVM is explained in the previous chapter. The extracted wavelet domain feature values are used to train and tested in SVM classifier. The Kernel type used in SVM is Radial Basis Function (RBF) with gamma value is 0.72, cost value is 9.4 and Nu value is 0.23. The classification accuracy for dataset DS1 and DS2 is shown in the form of confusion matrix in Table 3.2 and Table 3.3.

	C1	C2	C3	C4	C5	C6	C7	C8
C1	**93**	1	1	2	0	1	0	2
C2	1	**79**	4	1	3	5	4	3
C3	3	0	**86**	2	0	2	4	3
C4	1	3	4	**82**	1	3	2	4
C5	1	3	0	2	**89**	2	1	2
C6	0	2	1	2	0	**91**	3	1
C7	2	2	3	1	1	1	**88**	2
C8	1	1	2	0	1	0	2	**93**

Table 3.2 Classification accuracy for dataset DS1 with wavelet domain based feature set and SVM classifier

Table 3.3 Classification accuracy for dataset DS2 with wavelet domain based feature set and SVM classifier

	H1	H2	H3	H4	H5	H6
H1	**92**	1	2	2	2	1
H2	3	**80**	4	6	4	3
H3	2	2	**83**	3	3	5
H4	4	5	4	**86**	3	3
H5	1	3	3	2	**87**	4
H6	3	2	2	3	0	**90**

The confusion matrix gives the percentage of accuracy for each fault. The truly classified results are the diagonal elements. The Table 3.2 shows the classification accuracy of dataset DS1, the maximum accuracy of 93% is achieved for push rod problem (C8) and motorcycle without fault.

Method	**Accuracy (%)**	**Specificity**	**Sensitivity**	**Precision**	**False Measure**	**F1-Score**
Dataset DS1						
Time domain based features with FFNN	83.37	0.8921	0.9012	0.9521	0.12	0.85
Frequency domain based features with SVM	85.75	0.9045	0.9126	0.945	0.36	0.91
Wavelet packet based features with SVM	**87.62**	**0.9166**	**0.9216**	**0.9321**	**0.132**	**0.89**
Dataset DS2						

Time domain based features with FFNN	82.5	0.8723	0.8891	0.942	0.16	0.84
Frequency domain based features with SVM	83.12	0.9144	0.9258	0.932	0.23	0.89
Wavelet packet based features with SVM	**86.33**	**0.9275**	**0.9311**	**0.9213**	**0.235**	**0.87**

Table 3.4 Performance results for different feature sets of dataset DS1 & DS2

For dataset DS2 maximum accuracy is produced for motorcycle without fault (H1) is shown in Table 3.3. The average of diagonal element gives the total percentage of accuracy and it is tabulated in Table 3.4. The total percentage of accuracy for dataset DS1 is high compared to dataset DS2. The Table 3.4 shows the comparison results of time domain, frequency domain and wavelet domain based features with FFNN and SVM classifiers. The wavelet based features are very efficient compared to other features due to that an improved accuracy of 87.62% for dataset DS1 and 86.23% for dataset DS2. From the Table 3.4, it is also very clear that other performance metrics are also improved. This shows that SVM classifier is more efficient, compared to the FFNN.

4. CONCLUSION

The frequency domain based signal processing techniques are used for the fault analysis. The time domain audio signal is converted into audio spectrum (frequency domain) and the feature values are extracted. From the audio spectrum the mean frequency and median frequency feature values are obtained. These feature values are trained and tested using the Support Vector Machine (SVM) classifier. The performance measure shows an improved accuracy when compared to the time domain based features with FFNN classifier. The Wavelet Packet Transform (WPT) based signal processing techniques are used as the fault analysis method. In WPT based analysis, the audio signal is decomposed into low and high frequency bands called approximation and detail coefficients. They are extracted for each sub bands. The energy values of each sub bands are obtained and considered as the feature values. These feature values are trained and tested using the Support Vector Machine (SVM) classifier. The percentage of accuracy produced by wavelet domain based features shows very better accuracy of more than 86%, which is high compared to the previous methods.

REFERENCES

[1] Plaza E García&NúñezLópez, PJ 2018, "Application of the wavelet packet transform to vibration signals for surface roughness monitoring in CNC turning operations", Mechanical Systems and Signal Processing, pp. 902-919.

[2] PeymanKabiri& Hamid Ghaderi 2011, "Automobile independent fault detection based on acoustic emission using wavelet" In Singapore International NDT Conference & amp; Exposition.

[3] A. P, A. Sharma, S. B. M, P. Pavankumar, N. K. Darwante and D. G. V, "Performance Monitoring and Dynamic Scaling Algorithm for Queue Based Internet of Things," *2022 International Conference on Innovative Computing, Intelligent Communication and Smart Electrical Systems (ICSES)*, Chennai, India, 2022, pp. 1-7, doi: 10.1109/ICSES55317.2022.9914108.

[4] Wang &Xianghong 2015, "Acoustic emission detection for mass fractions of materials based on wavelet packet technology", Journal of Ultrasonics, pp. 27-32

[5] Rafiee, J, Rafiee, MA, Prause, N &Tse, PW 2009, "Application of Daubechies 44 in machine fault diagnostics", In IEEE 2nd

International Conference on Computer, Control and Communication, pp. 1-6.

[6] Xian, GM & Zeng, BQ 2009, “An Intelligent fault diagnosis method based on wavelet packer analysis and hybrid support vector machines”, Expert Systems with Applications, vol. 36, pp. 12131-12136

[7] Wu, Jian-Da, et al. "Faults classification of a scooter engine platform using wavelet transform and artificial neural network." *Proceedings of the International MultiConference of Engineers and Computer Scientists*. Vol. 1. 2019.

[8] Wu, J.D., Chang, E.C., Liao, S.Y., Kuo, J.M., Huang, C.K.: ‘Fault classification of a scooter engine platform using wavelet transform and artificial neural network’. Proc. Int. Multi Conf. Engineers and Computer Scientists, vol. 1, Hong Kong, 18–20 March 2009, pp. 58–63

[9] Zhenshan, L., Jianqun, W., Xuejun, R., Guozhong, Y.: ‘Traffic information extraction of vehicle acoustic signal based on wavelet packet analysis’. Proc. 29th Chinese Control Conf. (CCC), Beijing, China, 29–31 July 2010, pp. 5438–5440

[10] an, F. Chu, Fault diagnosis based on support vector machines with parameter optimization by artificial immunization algorithm, Mechanical Systems and Signal Processing 21 (2007) 1318–1330