Measurement 50 (2014) 370–380

Contents lists available at ScienceDirect

Measurement

journal homepage: www.elsevier.com/locate/measurement

Misfire detection in an IC engine using vibration signal and decision tree algorithms

Abhishek Sharma [a,*], V. Sugumaran [b], S. Babu Devasenapati [c]

[a] SELECT, VIT University, Chennai Campus, Vandalur-kelambakam road, Chennai 600127, India
[b] SMBS, VIT University, Chennai Campus, Vandalur-kelambakam road, Chennai 600127, India
[c] Sri Subramanya College of Engineering and Technology, Palani 624615, India

ARTICLE INFO

Article history:
Received 16 September 2013
Received in revised form 25 November 2013
Accepted 10 January 2014
Available online 18 January 2014

Keywords:
IC engine
Classification accuracy
Misfire
Decision trees
Linear model tree
Functional tree
Statistical features

ABSTRACT

Misfire in an IC engine continues to be a problem producing consequences like reduced fuel efficiency, increased power loss and emissions containing heavy concentration of uncombusted hydrocarbons. Misfiring creates a unique vibration pattern attributed to a particular cylinder. Useful features can be extracted from these patterns and can be analyzed to detect misfire. Statistical features of these vibration signals are extracted. Out of these, useful features were identified using the J48 decision tree algorithm and selected features are used with various decision trees. Classification accuracies from J48 algorithm, Best first tree algorithm, random forest tree algorithm, functional tree algorithm and linear model tree algorithm are compared and the best algorithm for such a system is suggested.

© 2014 Elsevier Ltd. All rights reserved.

1. Introduction

Misfire is a common engine fault that occurs in an IC engine. This problem arises in a cylinder of an IC engine due to faulty spark plug, cracked distributor cap, blown head gasket, too high temperature resulting in engine pinging, lean fuel/air mixture, lack of compression or even exhaust gas recirculation issues like the valve sticking closed or open causing too much flow. It can reduce the engine output by 25%. Other problems associated with this condition are loss of fuel economy and pollution caused due to higher concentration of unspent hydrocarbons present in the exhaust gases. Due to these problems, it is necessary to counter the problem of misfire to reduce pollution and to increase the fuel efficiency. Engine misfires can be very difficult to diagnose. In recent history, researchers have applied various methodologies to detect misfire. A few eminent techniques used for detection of misfire were developed on the acceleration signal [1–3] of the engine head or torsional vibration signal of the crankshaft [4,5]. Some techniques have already been applied in this field using features such as crankshaft speed [6], instantaneous angular velocity [7], cylinder deviation torque [8], instantaneous exhaust manifold pressure [9], instantaneous crank angle speed [10–14]and several other techniques. Chang et al. [15] have devised detection of misfire in SI engines by wavelet transform of engine block vibration signals. Wong and Wong [16] have also adopted an approach of engine ignition signal diagnosis with Wavelet Packet Transform and Multi-class Least Squares Support Vector Machines. An approach for misfire detection of a turbocharged diesel engine through neural network was proposed by Liu et al. [17]. Another avenue in this field is the approach by machine learning that have been adopted in many works. Sugumaran et al. have used J48 algorithm under the decision trees

* Corresponding author. Tel.: +91 8963006436.
E-mail addresses: abhiresearch91@gmail.com (A. Sharma), v_sugu@yahoo.com (V. Sugumaran), babudeva@yahoo.com (S. Babu Devasenapati).

http://dx.doi.org/10.1016/j.measurement.2014.01.018
0263-2241/© 2014 Elsevier Ltd. All rights reserved.

[18] and support vector machine [19]. Apart from misfire detection, Sugumaran and Ramachandrana have used support vector machine and proximal support vector machine [20] and decision tree [21] for fault detection in roller bearings. Piotr and Jerzy [22] have applied nonlinear methods modelled using vibro-acoustic measurements at engine exhaust for detecting misfires in engines. Various fault diagnosis for centrifugal pump has also been carried out by implementing algorithms such as decision tree [23,24], Naïve Bayes and Bayes net [25], rough set [26], support vector machine and proximal support vector machine [27]. Kirk et al. [28] have carried out computer image analysis of wear debris for machine condition monitoring and fault diagnosis. Such a system requires a good image input and high processor requirements. Thus, they increase the cost and computational infrastructure. Matter-element model for misfire detection [29] has also been presented for misfire diagnosis of gasoline engine. The disadvantage here is that the technique depends mainly on the knowledge of an expert and does not use a machine learning model based on an algorithm using features from the data. These require sophisticated instruments to extract the features and can be difficult to implement in varying conditions.

There are various approaches for processing the signals to give the output for a fault diagnosis system including temporal data, optimal disturbance de-coupling, model-based reasoning, heuristic reasoning, machine learning, etc. [30–33]. Machine learning approach is more preferable, as computational resources are relatively easily available, they possess greater accuracy and they are reliable, also a system using this approach can be trained for continuously changing engine conditions. The use of engine vibration data is supported as produces results with considerable accuracy. Here the data acquisition system measures the vibration signal by using an accelerometer. Then from the signal, statistical features were extracted and the most contributing ones were selected. Decision trees are well known for the same attributes, they are a family of well-developed machine learning algorithms. The main advantage with decision tree algorithms is that the set of classification rules obtained can be easily implemented as fuzzy logic in many systems.

In the present study vibration signals are utilized for the fault diagnosis of an IC engine. The machine learning approach is used. Various decision tree algorithms, such as, J48, best first tree (BFT), functional tree (FT), linear model tree (LMT) tree and random forest algorithms are used for the same. The classification accuracies for different algorithms are compared and presented. Further, feature selection and effects of number of features is studied for the most efficient classifier and observations are presented. The optimum classifier is then selected among these and results are displayed.

2. Experimental setup

The experimental setup comprises mainly of the spark ignition IC engine with provisions made in order to manually cause misfire in a particular cylinder and the data acquisition system. An accelerometer is attached on the engine which measures the vibration signals. The acquired signal is then passed through an analog to digital converter to collect the required data from which features are extracted. Fig. 1 shows the basic flow of the steps involved in the whole process.

2.1. IC engine

The IC engine used for the experiment is a 10 hp rated four stroke vertical four cylinder petrol engine. It has the provisions to simulate the misfire by cutting the electric supply to individual spark plugs. The engine accelerator is firmly attached at the desired position via screw and nut mechanism. A tachometer is included in the system to measure the speed (see Fig. 2).

The specifications of the engine are provided in Table 1.

2.2. Data acquisition system

To measure the vibration signals, accelerometers were used. They can detect both small and large vibrations. Magnitude of output voltage is directly proportional to the intensity of vibration signals. The apparatus is designed in such a way that accelerometer records the data from all the cylinders. Thus the accelerometer is fixed at the centre of the engine block. The signal from the accelerometer is

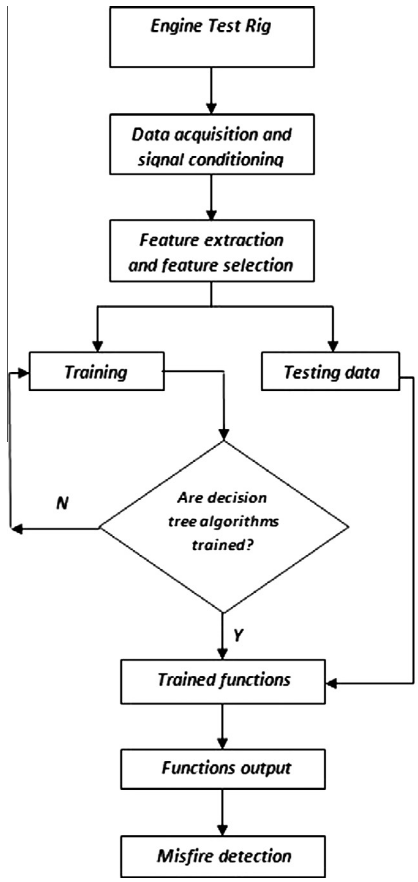

Fig. 1. Flowchart for engine misfire detection.

Download English Version:

https://daneshyari.com/en/article/730289

Download Persian Version:

https://daneshyari.com/article/730289

Daneshyari.com