Artificial Intelligence Based Green Technology Retrofit for Misfire Detection in Old Engines

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ABSTRACT

The core theme of the paper is misfire detection using random forest algorithm and decision tree based machine learning models for emission minimization in gasoline passenger vehicles. The engine block vibration signals are used for misfire detection. The signal is a combination of all vibration emissions of various engine components and also contains the vibration signature due to misfire. The quantum of information available at a given instant is enormous and hence suitable techniques are adopted to reduce the computational load due to redundant information. The random forest algorithm based model and the decision tree model are found to have a consistent high classification accuracy of around 89.7% and 89.3% respectively. From the results obtained the authors conclude that the combination of statistical features and random forest algorithm is suitable for detection of misfire in spark ignition engines and hence contributing to emission minimization in vehicles.

Keywords: Emission Control, Engine Condition Monitoring, Green Technology, IC Engine, Misfire, Rule Based Models, Signal Processing

INTRODUCTION

The rapidly growing economy of the developing nations has resulted in the explosive growth of automobiles. This has brought along insurmountable environmental challenges, major contributor being pollution due to uncontrolled tail pipe emissions of the internal combustion (IC) engines. The focus on green technologies for sustenance has diverted the attention on combating vehicular pollution using a combination of technology and online monitoring systems but the older vehicles which did not evolve out of sophistication are potentially large in number in the developing economies, where the average service life of the automobile is 15 to 20 years. The retrofit engine diagnostic system of the vehicle should be designed to monitor misfire continuously because even with a small number of misfiring cycles, engine performance degrades, hydrocarbon emissions increase, and drivability will suffer (Lee & Rizzoni, 1995). The misfire also results in a large quantity of unburned fuel being sent through the catalytic converter, which causes a reduction in its service life due to high temperature exposures (Klenk, Moser, Mueller, & Wimmer, 1995).

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1993). Engine misfire is defined as, “lack of combustion in the cylinder due to absence of spark, poor fuel metering, poor compression, or any other cause” (California Air Resources Board, 1991). Misfire detection in an internal combustion engine is very crucial to maintain optimum performance throughout its service life and to reduce emissions.

**LITERATURE REVIEW**

There are diverse techniques available for misfire detection each having a specific advantage but the main challenge is the non availability of a retrofit for engines that do not have sophisticated controls and embedded sensors for monitoring vehicle performance. The various possible techniques with a detailed analysis are performed to design and develop the best possible artificial intelligence model.

Extensive studies have been done using measurement of instantaneous crank angle speed (Tinaut, Andres, Laget, & Jose, 2007) and diverse other techniques have been developed on similar lines to predict misfire (Lee & Rizzoni, 1995). These methods call for a high resolution crank angle encoder and associated infrastructure capable of identifying minor changes in angular velocity due to misfire. The application of these techniques becomes more challenging due to continuously varying operating conditions involving random variation in acceleration coupled with the effect of flywheel, which tries to smoothen out minor variations in angular velocity at higher speeds. Fluctuating torque experienced by the crankshaft through the drive train poses additional hurdles in decoding the misfire signals. In-cylinder pressure monitoring is very reliable and accurate as individual cylinder instantaneous mean effective pressure could be calculated in real time. However, the cost of fitting each cylinder with a pressure transducer is prohibitively high. This initiated the quest for identifying a low cost model capable of competing with the existing solutions.

The use of Harr and Daubechies wavelets for signal processing by approximation (Yajnik & Mohan.S, 2009) is a workable idea but the use of signal approximation techniques could lead to loss of information, hampering the possibility of growing this model in to a full vehicle monitoring system. The implementation of wavelet based clustering techniques (Palanisamy & Selvan, 2009) for handling high dimension data is encouraging. The use of pattern recognition techniques including wavelets for structural health monitoring reported by Navarro and Mejia (2010) can be reliably extended for misfire detection. A detailed work is reported by Jinseok (Chang, Kim, & Min, 2002) using a combination of engine block vibration and wavelet transform to detect engine misfire and knock in a spark ignition engine. The use of engine block vibration is encouraging since it requires minimum instrumentation. The use of wavelets in all the above mentioned work has one common challenge; the increased computational complexity due to the additional load induced into the model by the wavelets.

Misfire detection using SVM reported by Devasenapati, Ramachandran, and Sugumaran (2010) demonstrates good classification efficiency. The use of support vector machines (SVM) for pattern recognition when compared to neural network, method of least squares or linear discriminant analysis produces less misclassification rate hence are more suitable for real time applications (Kalyani & Swarup, 2010). In spite of the good performance of SVM, the main concern is the computational complexity of SVM, which could pose a serious challenge for implementation in an online model. SVM is computationally intensive and consumes more processing power. The use of multivariate statistical analysis (Hu, Li, & Zhao, 2011) by processing the instantaneous engine speed signal for locating multiple misfire events in internal combustion engines is encouraging but the noise induced due to the torsional vibration of the engine will pose additional operational challenges (Tameem, David, & Sanjeev, 2010). The use of Kalman filter for misfire detection (Mohammad Kazem, Ali, Ali, & Ahmad, 2011) is saddled with the loss of information due to the inherent linearising
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