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ACOUSTIC BASED CAR ENGINE FAULT IDENTIFICATION AND ANALYSIS FOR PERFORMANCE

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Abstract

An acoustic-based automotive engine problem diagnostic system on the Android platform is the focus of this research project, which intends to design and build the system. The software is presented in an Android-like format. programme that is capable of running on any mobile device that utilises the Android operating system. In order to do an analysis of the sounds generated by the automobile engine, an Android-powered smart phone is used. Simply positioning the smart phone around one foot away from the engine assembly is all that is required to complete this step. The study of the drive belt and the detection of the need for a tune-up based on the valve clearance are both included in the fault diagnostic process. An individual analysis is performed on each defect, and a sample of the engine's acoustics is gathered for each fault that is indicated. The noises that are gathered are put through a signal processing technique that employs Fourier transforms and spectrum power densities. This allows the system to come up with a diagnostic result and then suggest some potential fixes. The algorithm is based on the correlation coefficient of the spectral power densities (SPD) of the audio signals (test and reference engine sounds), which are fed into a fuzzy logic inference system for classification. These spectral power densities were collected using two distinct clustering techniques (spectral power sum and spectral power hop). These techniques were used to collect the data. In order to detect faults, fault signatures were created and utilised as a reference throughout the process. According to the findings, the system was successful in identifying engine problems with the target model as well as with other makes and models of automobiles.

Keywords:- FFT, fuzzy logic, spectral power, performance, acoustics

INTRODUCTION

Usually, a change in sound is the first sign that there is a problem that will eventually lead to a breakdown. When the engine of a vehicle is not in good running condition, there is an increased risk of danger for the people who are travelling in the vehicle. The majority of the noises that are made by automobiles are generated by the engine. A vehicle's drivetrain, particularly its engine, is one of its most crucial components. Monitoring the engine on a consistent basis is necessary in order to keep it in good running condition. A sudden impulse or even a continuous auditory activity that is different from the engine's typical pattern of behaviour can be an indication that the engine is not performing up to its potential.The majority of people who own cars are not knowledgeable on how to properly diagnose issues with their vehicles' engines. The standard dashboard display of a car is typically used to provide the driver with an early warning sign in the event that there is a potential issue with the vehicle's engine. This is one of the safety steps that are taken. Problems such as engine vibrations, timing-belt and drive-belt issues, and the like may not always be obvious from the information displayed on the dashboard. When an engine problem develops worse, the owner of the car will take it to a centre that specialises in automobiles, only to find out that the damage will cost him considerably more than it would have if it had been recognised and dealt with sooner and in the appropriate manner. [1] developed algorithms for the recognition of particular engine sounds, while [2] developed a mobile-based application for detecting engine defects that runs in Windows. Both of these were done in conjunction with [3]. [3] made the suggestion that an on-board diagnostic system (OBD) based on microcontrollers may be used to diagnosis engines that do not yet have OBD installed. A summary of the various types of work that have been done in the field of problem detection and diagnostics for automobile engines was provided by in the form of a survey on diagnostic procedures for automotive engines [4]. Despite this, there are still uncharted territories, most notably in the data processing method that is applied and the procedures that are followed to carry out engine diagnostics. Recent years have seen an increase in the proportion of mobile devices that are powered by the Android operating system [5]. The number of software programmes that are available to suit the expectations for these devices to have the best possible usability is growing. For the purpose of this investigation, an Android application (often known as a "app") that runs algorithms that can recognise car engine conditions was developed. It contains a graphical user interface (GUI) that can capture engine sounds, then process those sounds, and then give diagnostic results based on those sounds.

DATA COLLECTION, PROCESSING AND ANALYSIS

The research looked at three significant diagnostic occurrences. Every competition has its own method for the procedure of data collection. a) Engine Start Analyzer (ESA) In this test, the data collecting approach consisted of recording the sound of an engine as it started up. The processing begins with the collection and organization of reference sounds. The recording was made at a variety of times and under a few distinct environments. b) Drive Belt Analyzer (DBA) The data collecting procedure for this test was performed at various times and settings by recording the sound of an engine that was either idle or operating at a speed of approximately one thousand revolutions per minute.b) Tune-up Detector (TUD) Recording the sound of an engine while it was operating in an idle state served as the technique of data collection for this particular test.The researcher started by selecting a reference sound and recording it, then continued by recording another reference sound to use as a fault reference. To reiterate, the recording was created at a wide range of times and under a variety of circumstances.

Data Conversion

The byte data type is used for the raw audio file that is stored on the SD card. The length of the bytes that make up the audio data is 4096. The byte data type is an 8-bit signed integer that works with two's complement. Its highest possible value is 127, while its lowest possible value is -128. (inclusive). When dealing with huge arrays, where the amount of memory saved is truly something that matters [7], the byte data type might be helpful for saving space. It is impractical to do mathematical operations using bytes, particularly if the results are to be stated in terms of numerical values that are most frequently utilised in programming, such as integers, floats, or doubles. It is necessary to transform the byte data to another data type before attempting to modify it. In this instance, the float data type was selected as the best option. The procedure begins by converting the byte into the short format, and then it moves on to the float format. The short data type is an integer with two's complement sign and 16 bits of data. Its highest possible number is 32,767 and its lowest possible value is -32,768. (inclusive).

Windowing is a technique that is used to shape the time portion of the measurement data in order to minimise edge effects that result in spectral leakage in the FFT spectrum. Windowing is a technique that is used to shape the time portion of the measurement data. When Window Functions are utilised appropriately, the spectral resolution of the result obtained in the frequency domain will improve [8].

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The audio data that has been transformed must first go through the windowing process before being allowed to enter the FFT block. In this particular instance, the Hamming window function was put to good use. The formula for calculating the Hamming window is as follows: w(k) = 0.54 .04cos(2k N). (1) Before applying the FFT, the resulting vector is multiplied, element by element, with the sample signal vector [9]. d) The Fast Fourier Transform Algorithm, The complex FFT, which is one of the Fast Fourier Transform methods, was implemented in the study. This method can be found in the Float FFT 1D class, which is part of the transforms library by [10]. This class is responsible for computing the 1D Discrete Fourier Transform (DFT) of real and complex data using single precision. There is no set limit on the amount of data that can be stored. A 1D forward DFT of a complex data set can be computed using the complex Forward method. The real and imaginary components of a complex number are each represented as separate float values when the number is saved using this method. The width of the input array needs to be greater than or equal to its length, and it needs to be at least that wide. In terms of the system, the values that were stored in complex form were subjected to a variety of transformations before the magnitude of the FFT coefficients could be computed. Because the area in the array that was designated for the complex values has been cleared out, the length of the data has been cut down from 2048 to 1024.

Calculations of the Spectral Power Density (SPD), followed by Normalization

The frequency response of a signal, whether it is random or periodic, is referred to as its spectral power density (SPD). It provides information regarding the location of the average power distribution as a function of frequency. The SPD is deterministic, and in the case of certain random signal types, it is not reliant on time.Calculating the signal-to-noise ratio (SNR) is extremely helpful for characterisation of signals. It is possible to group the SPD array of the information into a number of segments, and the SPD can be determined in each of those segments individually [11].The normalising process was carried out so that the computation of the SPD value may be standardised. The procedure is similar to that of standardising the values of the SPD to a range of values, which, for the sake of this study, is set from 0 to 1.

DATA CLUSTERING FOR THE SPD

Using this particular approach of clustering, the probable SPDs of the audio signal are determined for each cluster. Clusters with the same distance between them were created for the initial implementation. The sound processing digital signal processor (SPD) array was cut up into 64 clusters, and each cluster contained 16 data points. The total SPD as well as the pattern that the SPDs follow was considered while analysing each cluster's SPD in terms of its individual component. The total SPD for each cluster is equal to the sum of the 16 SPDs that are contained within that cluster. Additionally, the behaviour of the SPDs, also known as the "SPD hop pattern," was investigated by computing the standard deviation of the 16 data points that are contained within that cluster. Figure 1 shows power spectrum estimate of car acoustic signals

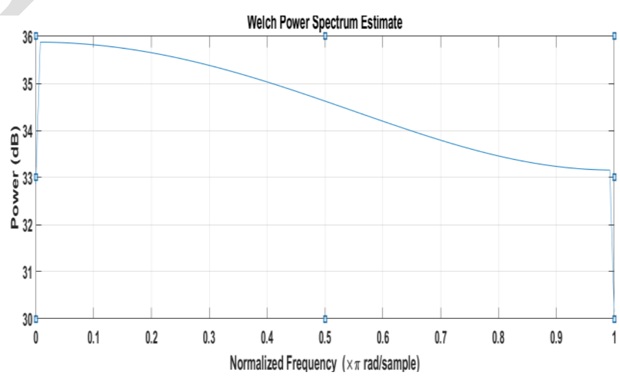

Figure 1 power spectrum estimate of car acoustic signals

Clustered SPD Sum Analysis is the next step.Calculating the total SPD for each cluster is the first step in carrying out the clustered SPD sum analysis. This results in the production of a new array that contains 64 SPD sums by the procedure. The SPD sums are calculated for both the sounds of the test audio and the sounds of the reference audio. In order to determine the correlation coefficient between the two signals, the SPD sum array of each signal was taken into consideration. Calculating the standard deviation of the SPDs that are contained within a cluster is how the clustered SPD hop analysis is carried out. A set of data's dispersion from its mean can be measured using a statistic known as the standard deviation. The variation tends to be bigger when the data are more widely scattered. A greater variance is indicative of the data points' level of volatility. This indicates that there is some degree of unpredictability or volatility associated with the data that were assessed. This is accomplished using a Java function that generates a new array that is made up of 64 SPD standard deviations. The standard deviations of the PSD are calculated for both the sounds of the test audio and the sounds of the reference audio. The subsequent steps involve calculating the correlation coefficient in addition to the NRMSE.

THE DECISION-MAKING PROCESS

The application of fuzzy logic within the Android platform underpins the capability of the system to make decisions. The fuzzy logic is made up of membership functions and rules, and these are the guidelines that are utilised for drawing conclusions based on a certain defuzzification method (centroid). The implementation of fuzzy logic in Matlab® served as inspiration for the fuzzy logic that was included in the system. A comparison is made between the audio signal collected from the engine and a reference audio file obtained from the engine. The signal processing block is simultaneously traversed by both of the audio files. The results of applying the decision rules are used as the basis for making a diagnosis of the system. The crisp value is used to determine which fault the coefficients that were acquired through correlation belong to. Figure 2 shows Fuzzy based performance analysis of vehicles

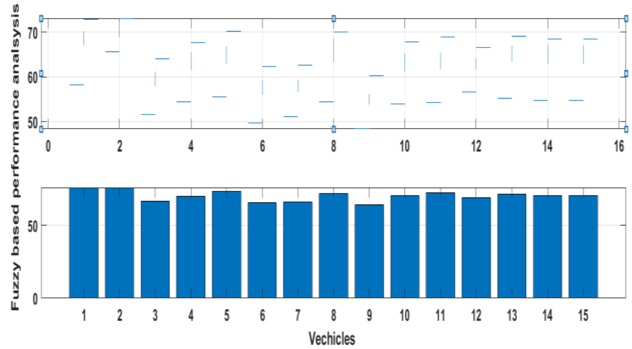

Figure 2 Fuzzy based performance analysis of vehicles

The system was evaluated using the sounds of thirty-five (35) different automobile engines, in accordance with the system's test categories. Initial recording sessions took conducted in a variety of settings, each with their own distinct environmental conditions. The recorded noises were then processed so that they could be utilised for testing the system. The next section presents the performance results obtained from the application that was developed. Figure 3 shows performance of vehicles abased on sample car acoustics signals

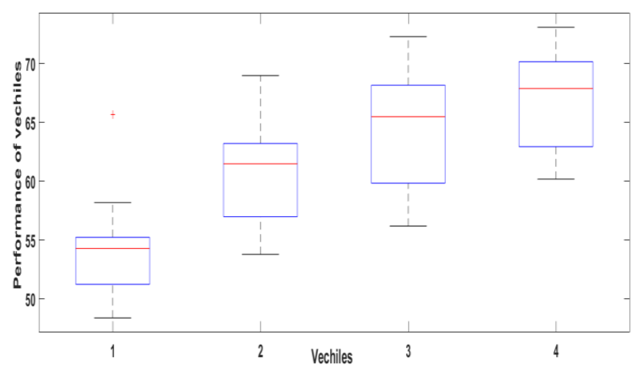

Figure 3 performance of vehicles abased on sample car acoustics signals

The sound samples used as a point of reference were collected from Honda Civic automobiles manufactured between the years 1996 and 2000.

CONCLUSION

An acoustic-based automotive engine problem diagnostic system was successfully designed and implemented by this study, and it was powered by the Android platform. The correlation coefficients that were acquired from the two different clustering methods of the spectrum's power density were used in an algorithm that was developed in order to perform an analysis of the sound that was emanating from the engine of the automobile. The application of fuzzy logic in the Android platform worked effectively, as evidenced by the fact that the findings demonstrate a perfect correspondence between the crisp values produced from the Android platform and the crisp values received from the fuzzy logic toolbox in Matlab®. The functionality of the system can be controlled through the use of a graphical user interface that was built. The graphical user interface includes button controls and display menus for the purpose of result visualisation. The diagnosis of the automobile engine was carried out at a range of different rates of recognition. As a result, the recognition rate is satisfactory to a sufficient degree in the vast majority of the automobile types investigated in this study. The system was validated by first putting it through its paces on the reference automobiles, and then moving on to test it on other makes and models of automobiles to determine whether or not its application was viable.

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