Investigating Audio Classification For Engine Fuels Using Machine Learning

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1 Introduction

Vehicle Engines utilize specific fuels to convert chemical energy into mechanical energy and the selection of these fuels within transportation systems have impact on our environment. Intelligent Transport Systems (ITS) use tracking methods including video recognition, to collect data for improving or controlling the safety, revenue, identification and efficiency of transportation networks. Audio based recognition methods already provide an efficient solution for engine diagnostics. This paper is a proof of concept to integrate fuel diagnostics for M1 classification cars to better aid environmental data collection in Low-Emission Zones and fuel detection for automatic fuelling systems. In this work, machine learning research was applied to the construction of audio features - used to train and test the model - . Keras convolutional neural network was proposed and designed as an effective classification learning process for the project. Raw audio data of petrol and diesel cars were transformed into MFCC cepstrum features, selected after testing against alternative spectrogram features. MFCC cepstra yielded a training accuracy of 76.1%, further validated against the testing dataset with an accuracy of 77.5%. The proposed model is demonstrated to be effective at differentiating petrol and diesel waveforms through a small relative training size and suitable guidance to the collection of appropriate dataset is achieved. This report provides context for the deployment to an embedded edge device, which utilizes the engine sound identification for fuel prediction of petrol and diesel cars.

2 Aims

The aim of this report is to utilize suitable machine learning architecture & to evaluate features for building an edge deployed machine learning model which can efficiently separate a diesel engine sound from a petrol engine.

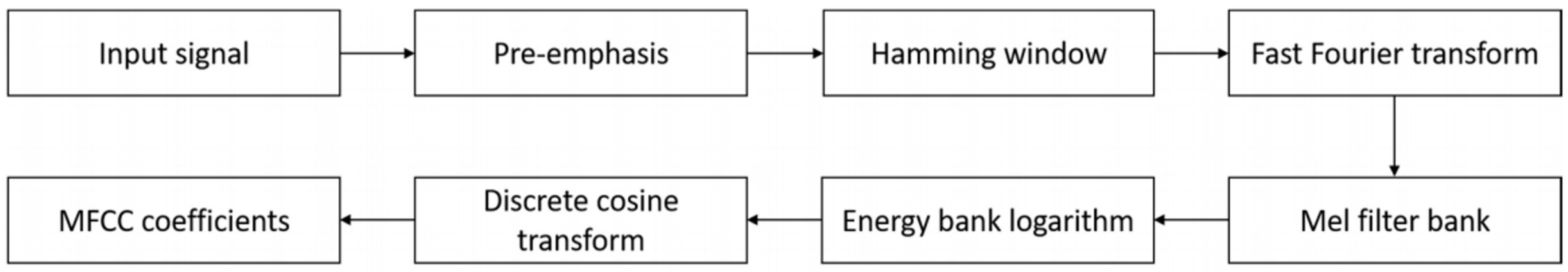
The scope includes the capture of audio from stationary, idling, M1 (License classification) stock-built cars and aims to evaluate the requirements for the collection of training/validation datasets that can generate a high accuracy machine learning model

3 Dataset

Using guidance from related machine learning studies, training and validation datasets where collected using audio samples of selected cars. Consideration was taken to understand hidden variables that negatively impact classification with selection of cars/enviroment and signal preprocessing techniques. Using a portable Zoom Handy recorder, a total of 13 cars made up the dataset of 52 - 10 second - samples implemented for training and testing of the proposed model. Collecting engine samples from 4 orientations was proposed to enable the system to be deployed in a variety of positions around the car with similair accuracy.

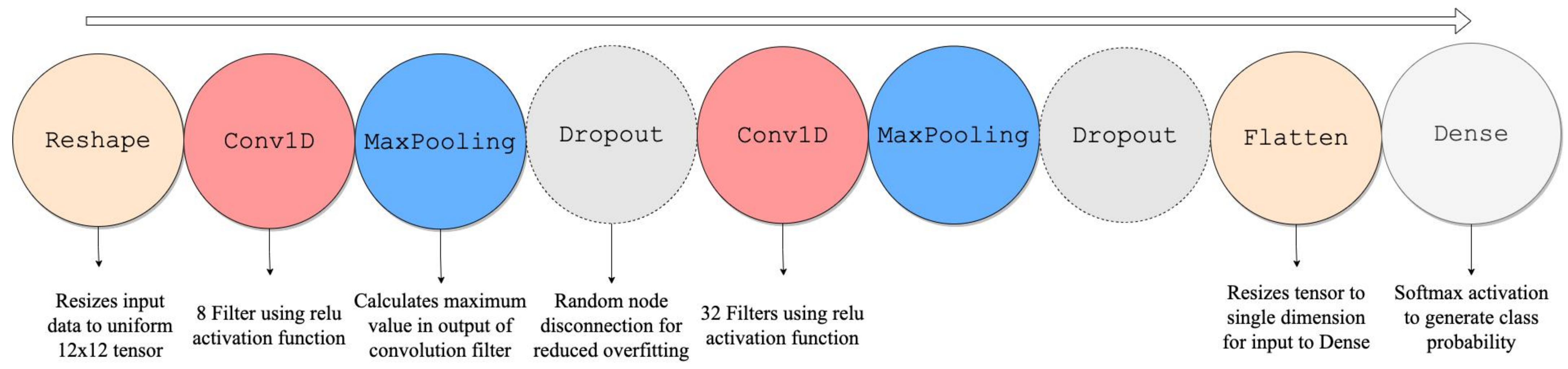
4 Feature Extraction

Feature extraction and appropriate datasets represent important stages for high accuracy models. Testing a hypothesis of applying spectogram features to image classification models, for the recognition of petrol and diesel engines was tested using three seperate spectrogram features. Windowing functions where applied to the 10 second samples to split into 1 second segments, generating 440 samples for testing and 80 for validation. Utilizing Fast Fourier Transforms to time-domain signals, enabled the construction of spectrogram features. This was expanded in alternative features by applying Mel-Frequency filter bands - applying psycological frequency modelling - to derive Mel-Frequency Energy (MFE) features. This was further processed using a Discrete Cosine Transformation (DCT) to compute Mel-Frequency Cepstral Coefficients (MFCCs), used as the final tested feature. MFCC features have shown great accuracy with voice recognition tasks (Babu.N & Mohan. B, 2014), but there application for engine fault diagnostics has only been demonstrated in a study using limited sample size and is such affected by unreliable data (Kemalkar & Bairagi , 2016).



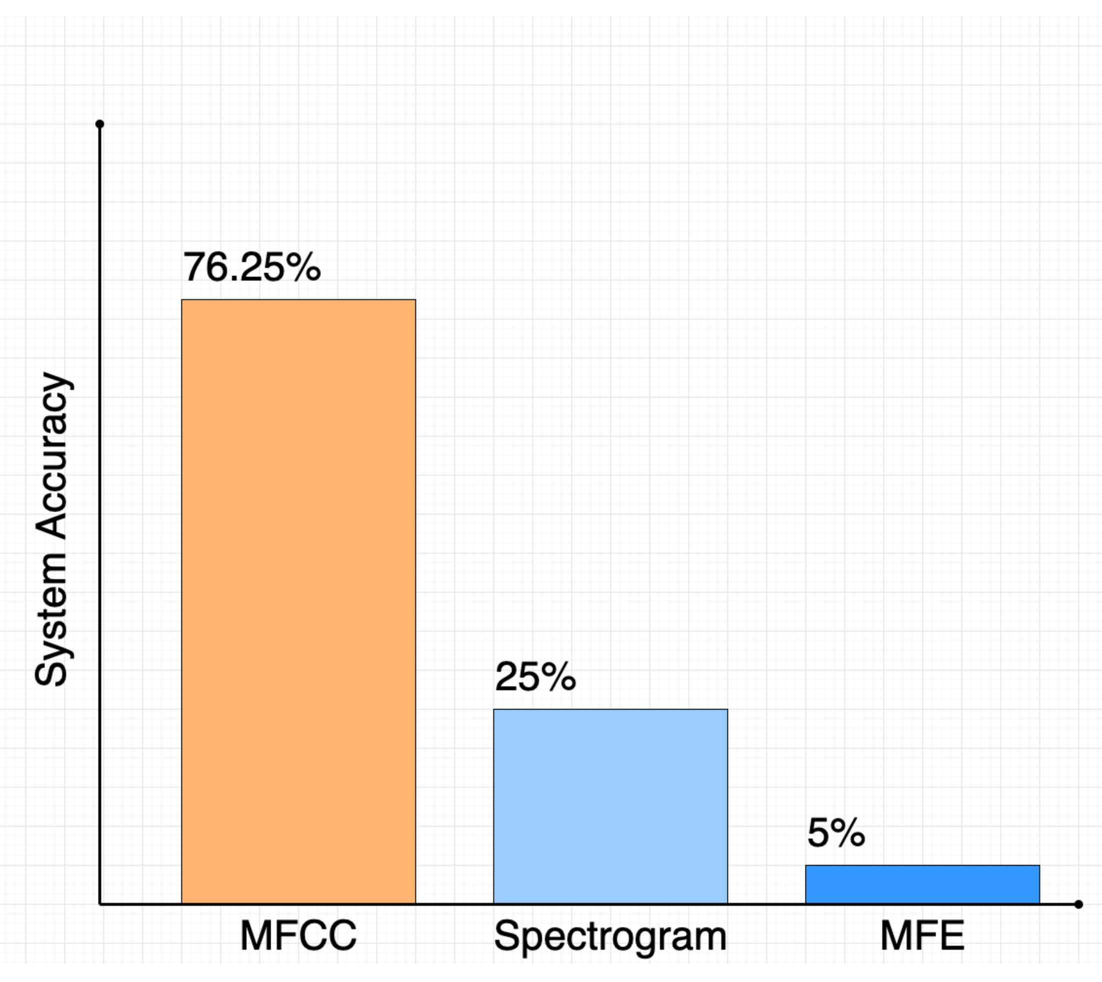
5 Model Design

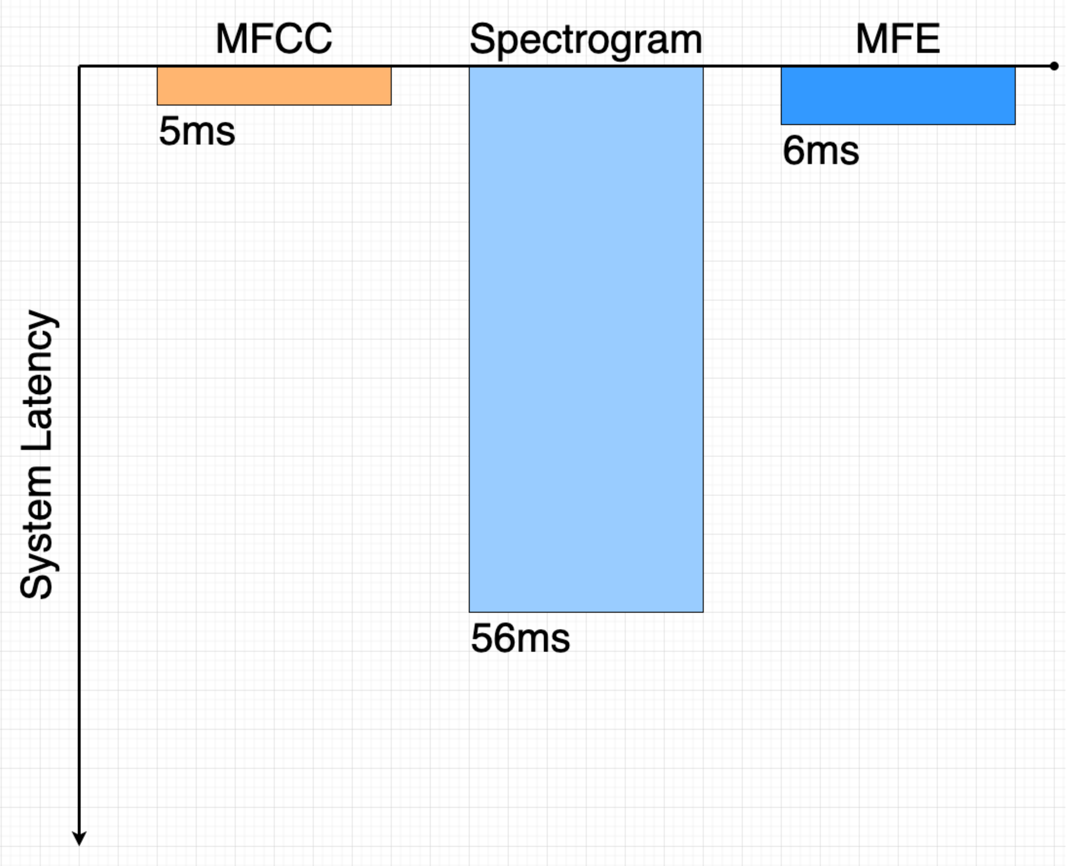
Keras convolutional neural network - a model design proposed for image classification - was proposed to classify spectrogram features, a technique that has been applied with 73% accuracy for general audio classification (Khamparia, et al., 2019). Architecture of Layer functions is shown below, using consideration of related studies. Optimized hyperparameters have been adjusted using cloud-powered Edge Impulse Studio. Application of data augmentation methods where applied to further extend the resilience of the model to noise and frequency deviations. Deployment to edge microcontroller processors for consideration of intergration with Intelligent Transportation Systems or automatic fueling systems (Halim, et al., 2019).



6 Results

Use of MFCC features resulted in highest accuracy of the proposed model with 76.1% on the training data, validated against the test data with 77.5% accuracy. Comparatively spectrogram features (33.75%) and MFE features (2.5%) classified poorly using the validation set. The computational performance of the alternative feature models on the proposed embedded edge micocontroller resulted in a RAM requirement of 10.8Kb for MFE/MFCC interations and 25.5Kb for the spectrogram feature extraction. Selection of feature extaction impacted efficiency of the model, the system latency for real-world classifications is shown below (right). The accuacy of the deployed Raspberry Pi engine classifier, is comparatively shown below (left) with feature extraction method.

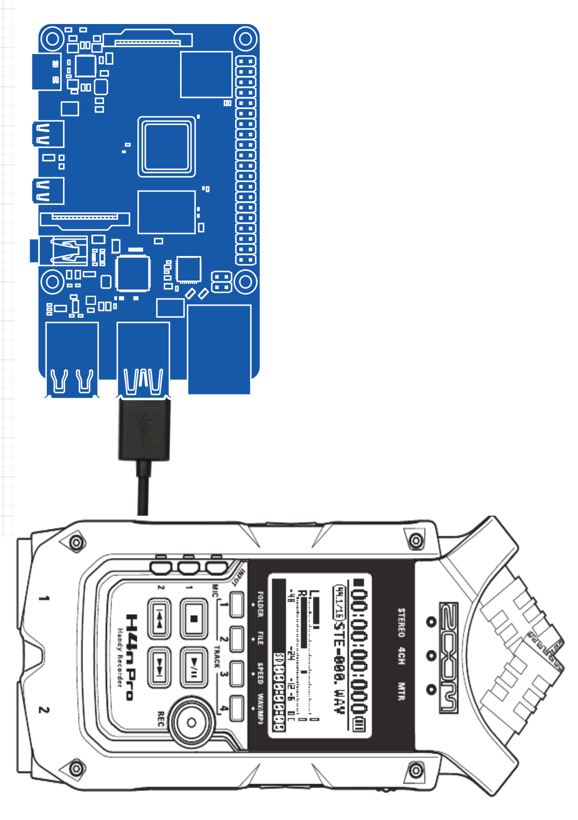


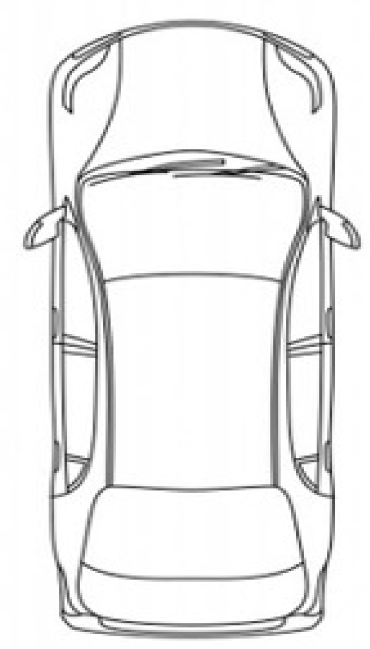


7 Conclusions

The findings of this report highlighted the suitability for Convolutional Neural Networks models - commonly used for image classification - to be applied to engine fuel clasification with the use of MFCC extraction of audio data. Its resiliency has been demonstrated with a 1.4% increase in validation accuracy over training accuracy, outlining less effects of over fitting that plagged results of similair studies (Kemalkar & Bairagi , 2016).

Considerations for embedding the system into a low-power microcontroller (Raspberry Pi)have been applied too allow for economical intergation into enviromental monitoring, automatic fueling and Intelligent Transport systems. The accuracy demonstrated in this report are subject to the size of it's dataset, and for commerical development, applying the proposed model should be used in conjunction with a larger dataset for improved accuracy





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