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Detection of the Impulsive Noise and Vibration generated from Automotive Powertrain by using a Hidden Markov Model (HMM)

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In order to improve the quality of automobiles, it is necessary to detect and countermeasure abnormal noise and vibration from the powertrain in early development. In particular, there is need for detection technology for quasi-impulsive noise (Fig.1), exemplified by continuous impulsive noise such as “rattle" and “clunk" generated by the collision of gears and shafts, and isolated burst of sound energy "clanks".

In powertrain development, measurements are taken under various conditions in order to extract occurrences of abnormal noise, and an enourmos amount of data such as sound pressure and vibration is processed. During processing, an evaluator listens the this very large amount of data to detect abnormalities. However, this process has problems with inconsistency of detection accuracy due to differing levels of experience between evaluators, as well as psychoacoustic principles. Therefore, there is much expectation around the construction of a system that automatically detects the location of abnormal noise.

Many methods for abnormal noise detection, have been reported in the literature, such as identifying outliers based on a model of "normal" sound, or identifying abnormal sounds based on similarity with a (a large number of) labeled samples. However, preparing large datasets for these methods presents a challenge in practice, and they are often unable to identify novel abnormal noises that were not present in that data.

In this study, abnormal noise production was modeled using a Hidden Markov Model (HMM) trained on MFCC features extracted from a very small amount of data. By using an HMM, it is possible to capture the combination of time domain and frequency domain characteristics as surface level expressions of an unseen process that produces the target phenomenon. This representation is expected to be more robust when classifying novel phenomena.(Fig.2) After training, HMM states corresponding to abnormal noises were selected, thereby creating a binary classifier for use on new recordings.

Using the proposed method, it was possible to create a model that can identify abnormal noise of a different type after having trained on only about 40 s of training data, showing the effectiveness of the proposed noise detection algorithm. In addition, it was found that, in order to correctly detect unknown rattle noise, it is necessary to set the number of states/classes of the HMM to 16 or more. (Fig. 3) Furthermore, it became clear that using an F-score, the harmonic average of recall and precision, is effective as an evaluation metric for the choice of noise class.

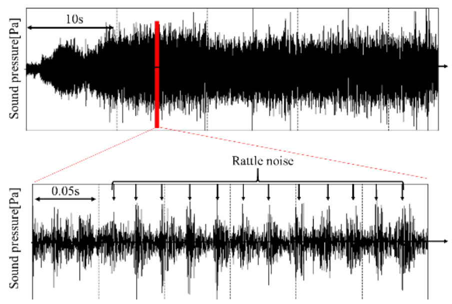

Fig.1 Example of quasi-steady impulsive noise (Rattle noise)

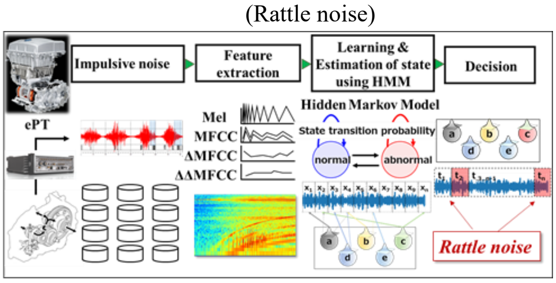

Fig.2 Outline of the detection process of rattle noise using a Hidden Markov Model

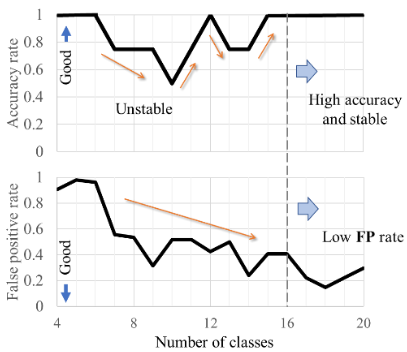

Fig.3 Accuracy and False Positive Rate by number of classes

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