Abstract

This research aims to realize human-centric technology that can provide safety and security through intelligence that is easily understood and harmonized with users. Then this paper proposes an anomalous sound detection (ASD) method that uses a combination of timbral feature-based metrics and short-term features, which is tailored to industrial machine faults to identify whether the sound emitted from a target machine is anomalous.

Daily maintenance of industrial machines is essential to ensure safe operation for efficient production and business management. Inspectors use their knowledge to detect anomalous situations by using their senses, especially hearing. They have excellent skills in discriminating differences in sounds using their “noticeable difference in hearing”. Due to a labor shortage, anomalous sound detection (ASD) is expected to support inspectors in identifying whether the sound emitted from a target machine is anomalous as automation and a remote solution.

Recent technical trends of ASD indicate advances in machine learning for discrimination, however acoustical features to capture characteristics of the anomaly of sound remain primitive measurements such as log-mel energies. This causes difficulties for users to understand the logic and to harmonize with ASD as a trustable technology in their fields.

We propose a timbre-feature-based ASD (TF-ASD) method that involves five sound quality metrics (SQMs), two short-term acoustic features, and a support vector machine (SVM) for classification. We develop two types of short-term features to estimate the change in the fluctuation of sound waves and pitch in terms of harmonics to improve the time resolution of the timbral analysis. This combination of SQMs and two dedicated short-term acoustical features is based on an investigation of timbral association with industrial machine malfunction from the viewpoint of “noticeable difference in hearing” that is the human ability to discriminate differences in sounds.

We evaluated the TF-ASD performance of our method in terms of SVM classification using the MIMII (Malfunctioning Industrial Machine Investigation and Inspection) dataset. The results indicate that the proposed method has excellent classification performance with an accuracy of 0.984 and an F-measure of 0.920 on average for emitted sounds of 16 machine types and models. This demonstrated that the combination of SQMs and our short-term features, which is derived from the “noticeable difference in hearing” is effective for ASD.

Furthermore, the timbre-based feature, which is a combination of SQMs and two short-term acoustical features, is verified on the classification capability for the abnormal sound of industrial machines using an anomalous score which estimates the rareness of probability of occurrence against the normal sound distribution. ROC-AUC (AUC) is used to measure the differentiation of the anomalous score of the abnormal sound from that of the normal sound, the further separated the anomalous scores each other, the closer the AUC value to 1.0. The result of an AUC of 0.856 shows the excellent discrimination ability of the timbre-based feature from the probability statistics.

In this paper, we derived a set of SQMs about an anomaly of the sounds emitted from industrial machines in terms of human noticeable differences in hearing and developed a timbre-based feature which is a combination of the SQMs and two original short-term acoustical features. With the timbre-based feature, human-centric ASD, which may be understandable and cooperative with users, is configured and demonstrates excellent classification performance.

Furthermore, by mutual analysis of the timbre-based feature value with human anomalous detection results, implicit knowledge of inspection for industrial machines can be digitized and be transferable assets in various industrial fields.

Keywords: anomalous sound detection, timbral feature, sound quality metrics, industrial machine faults, support vector machine.