國 立 清 華 大 學

碩 士 論 文

基於監督式和非監督式學習之
微型化異音檢測系統

Compact anomalous sound detection system based on supervised and unsupervised learning

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摘要

異常聲音檢測 (Anomaly sound detection, ASD) 對於機器狀態監測、故障診斷非常有用。透過深度學習應用於異音檢測已受到研究界的關注。然而，缺乏異常聲音數據對監督式和非監督式學習都帶來了挑戰。在本論文中，我們致力開發了一個小型的異音檢測系統，利用環形陣列式微機電 (Microelectromechanical Systems, MEMS) 麥克風和樹莓派搭建，具有經濟性和便攜性。我們提出的模型結合卷積神經網路 (Convolutional Neural Networks, CNN) 與全連接網路 (Fully-connected Neural Networks, FNN)，應用於兩種不同的情境。第一種應用情境中為多分類監督式的異音檢測，由於有限的異常音檔導致呈現數據不平衡狀態。因此，我們提出資料重組方法，透過不同比例拼接不同機器狀態的時域片段進而生成新的訓練資料，之後依其比例進行標記並使用交叉熵為損失函數訓練模型。實驗結果顯示，在不平衡率 (Imbalance rate) 為 154 時其準確率 (Accuracy) 可達到最高的 92.15%，而且在比較不同的不平衡率下，皆能超過其他過採樣方法。第二種應用情境為非監督式的異音檢測，只有正常音檔可獲得下，我們提出的異常值分類器使用麥克風陣列的位置和轉動機具的轉速作為分類目標。模型預測每個目標的概率並接著計算異常分數以區分正常和異常狀態。實驗結果顯示我們的檢測系統具有優異的檢測性能，平均接收者操作特徵曲線下面積 (Area under the curve, AUC) 為 98.2%、部分接收者操作特徵曲線下面積 (Partial area under the curve, pAUC) 為 93.7%，且明顯優於其他非監督式方法。

關鍵字— 異常聲音檢測、機器狀態監測、深度學習

ABSTRACT

Anomaly sound detection (ASD) is useful for machine condition monitoring and fault diagnosis. Deep learning-based approaches have received research attention for ASD. However, the lack of anomalous sound data is a challenge for both usupervised and unsupervised learning. In this thesis, a compact ASD system was developed, using a circular microelectromechanical systems (MEMS) microphone array and a Raspberry Pi® processor, with great affordability and portability. The proposed model combines Convolutional Neural Networks (CNN) and Fully-connected Neural Networks (FNN) to address two application scenarios. In the first scenario of multi-class supervised ASD, the problem of imbalanced dataset arises due to limited anomalous sound data. To overcome this, the proposed data reassembly method generates new training data by concatenating the time-domain segments from different machine states in preselected proportions before labeling them for training with cross-entropy loss. Experimental results have shown that the proposed system achieves the highest accuracy of 92.15% for an imbalance rate of 154, and consistently outperforms other oversampling methods across different imbalance rates. In the second scenario, unsupervised ASD, where only normal sound data is available, the proposed outlier classifier uses the array position and the rotational speed of a rotor kit as the classification targets. The model predicts the probability of each target and calculates an anomaly score to distinguish the anomalous conditions from the normal ones. Experimental results have shown that the proposed system has excellent detection performance, with an average area under the curve (AUC) of 98.2% and partial area under the curve (pAUC) of 93.7%, which significantly outperforms other unsupervised methods.

Index Terms— Anomalous sound detection, machine condition monitoring, deep learning