

An Intelligent Threshold Selection Based Dictionary Learning with Structured Incoherence and Shared Features for QCM Sensor Data-Based Alcohol Recognition



Pubali De and Amitava Chatterjee

Abstract In the modern world, the use of alcohol is increasing day by day in a variety of products across different industries like medical and pharmaceutical, food and beverage, cosmetics and personal care, automotive industries, etc. As a consequence, it becomes significantly important to classify the presence of these alcohols to reduce their harmful effects in a very sophisticated way. Hence, the significance of the research in developing an intelligent system to recognize the presence of alcohol is drawing the researchers' attention in modern times. On the other hand, the development of dictionary learning (DL) based approach and sparse modeling has emerged as a precursor in the machine learning based research domain over the past few years. Numerous DL based sparse solutions have been successfully proposed for solving different signal processing and image processing problems in recent times. In some of our previous work, we have demonstrated how supervised and unsupervised DL based approaches can effectively be employed for solving different problems in the domain of ambient assisted living. Advancing the scope of our studies, in this work, we have shown how DL based approach can be successfully employed for effectively classifying different alcohol categories, based on sensory signals acquired from five Quartz Crystal Microbalance (QCM) sensors. In this work, we first investigate the effectiveness of one prominent category of supervised DL based approach, called dictionary learning with structured incoherence and shared atoms (DLSI) for an available benchmark alcohol dataset, in detail. To improve the performance of the DLSI approach further, we propose a modified version of DLSI by introducing an intelligent threshold selection strategy for handling the sharing features among all dictionaries in a novel manner, which is the most significant issue in maintaining incoherence.

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The performance evaluation establishes that our proposed novel threshold selection strategy based on a modified DLSI approach outperforms other recent competing approaches.

Keywords Dictionary learning (DL) • Modified DLSI • Alcohol recognition

1 Introduction

Recognition of types of alcohol is very important for different significant industries like food, Cosmetics, pharmaceutical, etc. Employing gas sensors in conjunction with pattern recognition methodology might be very useful for classifying different chemical compounds and detecting detrimental effects. Designing a low-cost, sophisticated sensor-based system coupled with machine learning techniques has become crucial and encourages automated classification. In this study, the benchmark alcohol data set was used for classification, and five different gas measurements were conducted using five QCM gas sensor sensors. Several studies have demonstrated the success of QCM sensors in classifying alcohol [1–3]. Neural networks are widely used successfully in pattern classification of sensory data acquired by QCM sensors [4–7]. Despite the success of the neural network based approach, overfitting is a common problem with neural networks, especially when the training data set is not representative of all potential situations. DL has become the most prominent approach nowadays due to its capability of adaptive representation of data. The conventional concept of dictionary learning relies on sparse representation where the dictionary has been chosen as pre-fixed. To address this limitation of using a pre-fixed dictionary, many sophisticated methods have been developed where the dictionary has been learned automatically from the training data, leading to a flexible and efficient representation of data [8, 9]. DL algorithms have found numerous challenging applications in real life, mostly in ambient assisted living (AAL) and home automation e.g. detection of human behavior [10], detection of human movement direction [11, 12], and intruder detection [13, 14]. This work intends to establish the suitability of employing DL based approach where both unsupervised and supervised learning settings have been adopted, for alcohol classification problems which have become most important in different industries like food, cosmetics, and pharmaceuticals. Here, motivated by the success of DL based approach reported in our earlier works [10–14], a new DL with structured incoherence (DLSI) [15] approach has been employed for alcohol classification and then, a modified version of the DLSI [15] algorithm has been proposed where a novel threshold selection strategy has been adopted to maintain incoherence among the dictionaries. A comprehensive performance comparison is carried out to establish the effectiveness of our proposed approach.

The rest of this article is structured as follows. Section 2 presents how alcohol data acquisition can be done successfully using QCM sensors. In Sect. 3, the methodology employed based on DLSI and the modification proposed regarding threshold

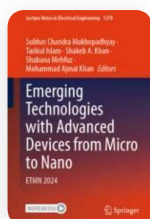
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In the modern world, the use of alcohol is increasing day by day in a variety of products across different industries like medical and pharmaceutical, food and beverage, cosmetics and personal care, automotive industries, etc. As a consequence, it becomes significantly important to classify the presence of these alcohols to reduce their harmful effects in a very sophisticated way. Hence, the significance of the research in developing an intelligent system to recognize the presence of alcohol is drawing the researchers' attention in modern times. On the other hand, the development of dictionary learning (DL) based approach and sparse modeling has emerged as a precursor in the machine learning based research domain over the past few years. Numerous DL based sparse solutions have been successfully proposed for solving different signal processing and image processing problems in recent times. In some of our previous work, we have demonstrated how supervised and unsupervised DL based approaches can effectively be employed for solving different problems in the domain of ambient assisted living. Advancing the scope of our studies, in this work, we have shown how DL based approach can be successfully employed for effectively classifying different alcohol categories, based on sensory signals acquired from five Quartz Crystal Microbalance (QCM) sensors. In this work, we first investigate the effectiveness of one prominent category of supervised DL based approach, called dictionary learning with structured incoherence and shared atoms (DLSI) for an available benchmark alcohol dataset, in detail. To improve the performance of the DLSI approach further, we propose a modified version of DLSI by introducing an intelligent threshold selection strategy for handling the sharing features among all dictionaries in a novel manner, which is the most significant issue in maintaining incoherence. The performance evaluation establishes that our proposed novel threshold selection strategy based on a modified DLSI approach outperforms other recent competing approaches.

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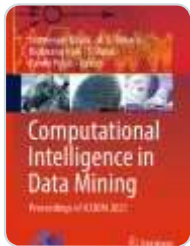
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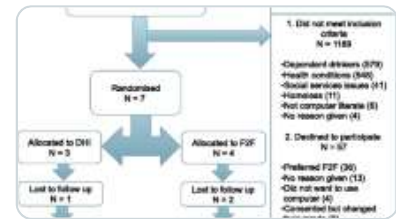
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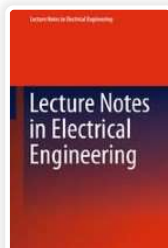
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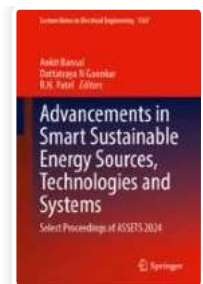
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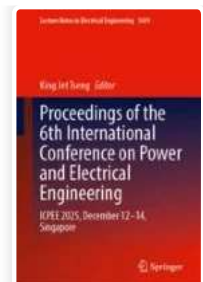
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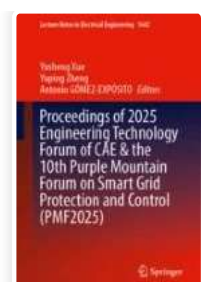
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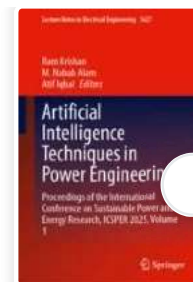
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