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Abstract

Classification in Early Fire Detection Using Transfer Learning Based on Multi-Sensor Nodes †

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Abstract: Multi-sensor data from a small laboratory setup was used to create a new feature space with linear discriminant analysis (LDA) to improve the classification of different fire materials. The LDA parameters were applied to a real room dataset to evaluate classification models. Data transformation using LDA improved the classification rate by up to 17% compared to principal component analysis (PCA) approaches used in previous studies.

Keywords: multi-sensor nodes; early fire detection; gas sensors; transfer learning; electronic nose; feature fusion; linear discriminant analysis (LDA); classification; public dataset

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1. Introduction

The advantages of multi-sensor approaches for early fire detection over traditional smoke detectors have been extensively discussed in the previous literature. Apart from the temporal aspect of early detection, distinguishing between various types of fire materials and events can offer additional information to first responders, e.g., the character and precise location of the fire source.

Prior research has demonstrated the efficacy of utilizing multi-sensor approaches to differentiate between various fire materials based on their distinct "smell prints". Nevertheless, these studies were restricted in their training and validation data, either confined to a single-room environment [1] or limited to a binary output (fire/no fire) when utilizing data from different room settings [2].

As generating fire data in real room environments can be prohibitively expensive, there is a pressing need to investigate how data from small-scale laboratory setups can be effectively transferred to real rooms. In this study, we employed LDA for supervised feature extraction from laboratory sensor data, using CO, H_2, VOC, and particulate matter (PM) as early fire indicators. Subsequently, we validated the classification models derived from these extracted features at different positions within a large-scale room using various distributed sensor nodes.

2. Materials and Methods

Multiple sensor nodes, each containing an SPS30, SVM40, CO/MF-1000, UST6xxx, SCD40, and a SGP40 sensor measuring CO_2, CO, H_2, PM, VOC, and air temperature, were used for data acquisition. A gassing cabinet served as the small-scale setup, where three sensor nodes were exposed to different fire loads of fuses, cable isolation, candle wax, and wood. In the large-scale setup, a non-ventilated fire test room with dimensions of $7 \times 10 \times 4$ m^3 was used, with the fire source located in the center of the room and nine distributed sensor nodes around the source.

The sensor data were processed as shown in Figure 1. The LDA as well as the scaler were fitted on the small-scale training dataset. The transformation parameters were used to transform both the training dataset and the large-scale dataset into the same feature space. Based on three LDA components derived from the training dataset, different classification models were trained and validated on different sensor node positions from the large-scale setup.

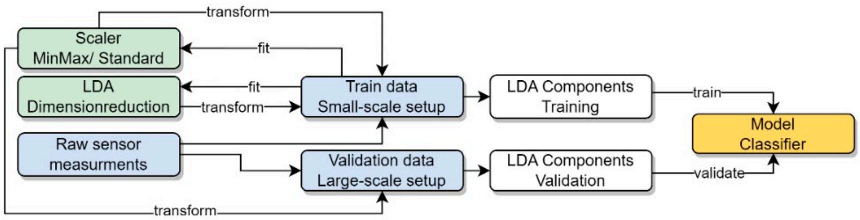

Figure 1. Data pipeline; blue: data sets, green: training data-based transformation parameters, white: derived transformation parameters for new feature space, yellow: classification model.

3. Discussion

Figure 2 shows the performance of a Support Vector Machine (SVM) classifier trained and validated as mentioned above.

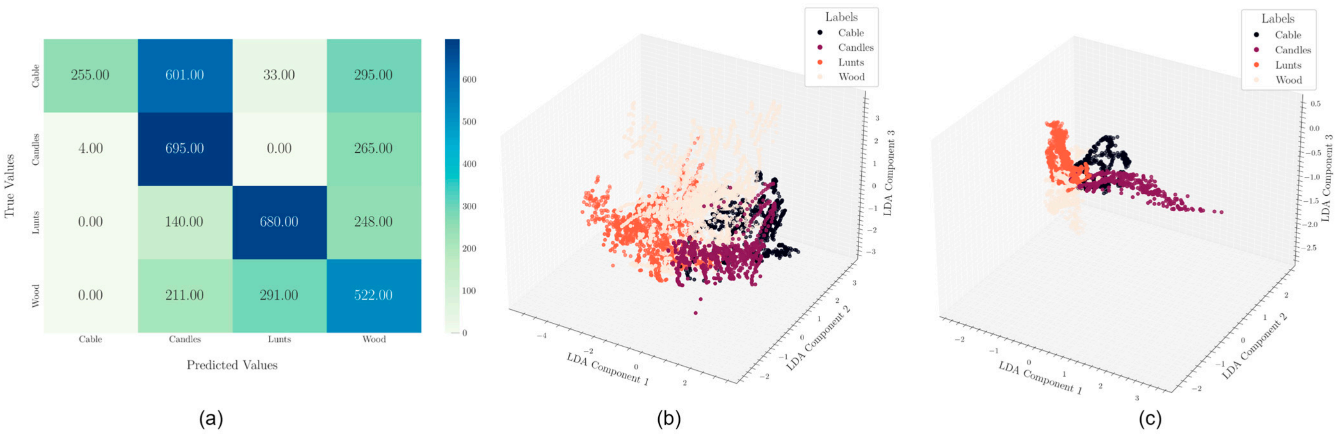

Figure 2. (**a**) Confusion matrix of SVM classifier distinguishing between 4 types of fire materials, (**b**) class separation of the training dataset using three LDA components, and (**c**) class separation of the validation data in the same feature space.

Despite the challenges of differentiating between different types of fires and transferring from the laboratory to a large-scale environment—a combination that has not been previously attempted—we were able to improve the classification rate by up to 17% compared to previous methods reported in the literature. A comprehensive evaluation of the input features, scaling methods, and sensor node positions used for validation will be presented at a future conference.

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References

1. Andrew, A.M.; Shakaff, A.Y.M.; Zakaria, A.; Gunasagaran, R.; Kanagaraj, E.; Saad, S.M. Early Stage Fire Source Classification in Building using Artificial Intelligence. In Proceedings of the 2018 IEEE Conference on Systems, Process and Control (ICSPC), Melaka, Malaysia, 14–15 December 2018; pp. 165–169. [CrossRef]
2. Solórzano, A.; Eichmann, J.; Fernández, L.; Ziems, B.; Jiménez-Soto, J.M.; Marco, S.; Fonollosa, J. Early fire detection based on gas sensor arrays: Multivariate calibration and validation. *Sens. Actuators B Chem.* **2022**, *352*, 130961. [CrossRef]