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Abstract

Multispectral Integrated System with Discrete Light Sources for Material Classification †

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Abstract: This paper presents a compact and portable classification system that utilizes a discrete light source method combining near-infrared (NIR) reflectance spectroscopy with a Support Vector Machine (SVM) to identify and classify waste materials. The system operates by sequentially activating 10 light-emitting diodes (LEDs) of different wavelengths and measuring their reflectance using a photodetector. This system incorporates a DAQ card using the LabView program for data acquisition and system control. The proposed model achieved an identification accuracy of up to 98% using different input features and training batches. This efficient and cost-effective solution provides an innovative approach to waste management.

Keywords: NIR spectroscopy; material classification; support vector machine

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1. Introduction

Identifying raw materials such as plastic, glass, aluminum, and paper is an essential but challenging task in waste management. While optical spectroscopy is currently the most advanced method for material classification, its implementation can be challenging. Previous studies have utilized continuous reflection spectroscopy, but this approach can be time consuming and require expensive equipment. Near-infrared (NIR) spectroscopy, which uses wavelengths from 799 to 2500 nm, has emerged as a promising technique for material identification. However, the full reflectivity spectrum must be acquired. To address these limitations, our study proposes a low-cost system that uses multivariate analysis and a small number of LEDs to identify materials using only a few key spectral variables that contain the most useful information. By minimizing redundancy and unnecessary variables, this approach aims to improve the accuracy and efficiency of waste management.

2. Materials and Methods

Seven materials, including polypropylene (PP, white and transparent), polyethylene terephthalate (PET), recycled polymer (Acrylonitrile butadiene-AB), glass aluminum, and paper, were used in this experiment.

In this experiment, 10 LEDs were chosen to cover the NIR spectrum. LEDs were selected based on the overlap between their emission spectrum and the reflectance spectra of the different materials. Reflectance spectra were captured using a monochromator and smoothed using the Savitzky–Golay algorithm [1] prior to optimization. The setup includes a Portable system and a Control unit. The Portable system consists of a measurement head that holds a germanium (Ge) photodetector surrounded by the LEDs spaced uniformly at an optimal distance from the photodiode; an LED current driver; and a general purpose data acquisition unit (DAQ). The Control unit is a PC with the LabVIEW 2023 Q1 program installed that has a graphical interface to regulate light source emission intensity and collect readings from the photodetector by controlling the DAQ signal. The DAQ is linked to the light source through a current driver and collects readings from the photodetector via a trans-impedance amplifier with the appropriate gain. During the experiment, the samples were kept in a black box and exposed to each LED for a period of 600 microseconds.

3. Discussion

In this study, we collected 350 spectra from various positions on materials and developed a classification model using the SVM algorithm [2]. This study involved testing various classification tools, such as decision trees, neural networks etc., but it was found that SVM performed better than all the others. Therefore, we concluded that SVM was the most appropriate choice for the task at hand. Figure 1 shows a typical confusion matrix. Through cross-validation, the model achieved high accuracy rates of 98%. These promising results suggest that our classification method has significant potential for accurately identifying materials and could have important implications for the recycling industry.

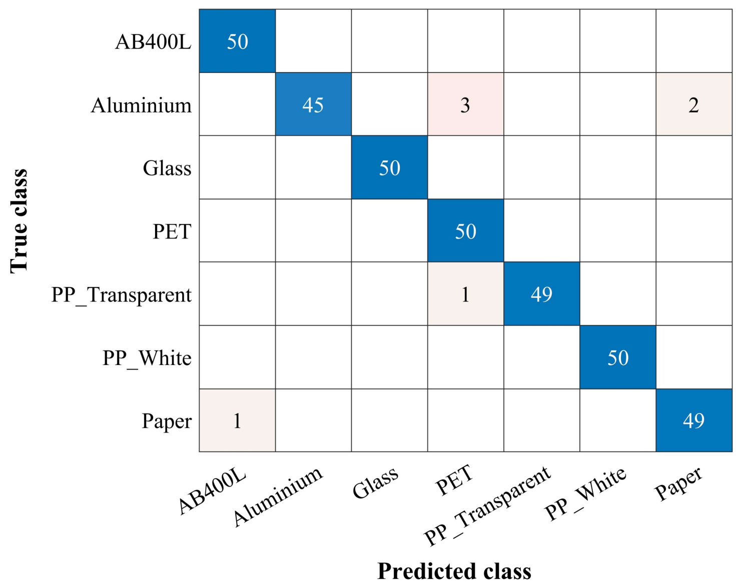

Figure 1. Confusion matrix of experimental model.

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References

1. Zheng, K.-Y.; Zhang, X.; Tong, P.-J.; Yao, Y.; Du, Y.-P. Pretreating near infrared spectra with fractional order Savitzky–Golay Differentiation (FOSGD). *Chin. Chem. Lett.* **2015**, *26*, 293–296. [CrossRef]
2. Cervantes, J.; Garcia-Lamont, F.; Rodríguez-Mazahua, L.; Lopez, A. A comprehensive survey on support Vector Machine Classification: Applications, challenges, and Trends. *Neurocomputing* **2020**, *408*, 189–215. [CrossRef]