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Abstract of Doctoral Dissertation

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Title of Doctoral Dissertation

Development of a classification method for marine debris using spectral information
（スペクトル情報を用いた海洋ごみの分類手法の開発）

Marine plastic pollution poses a growing threat to aquatic ecosystems and coastal environments, yet current monitoring methods remain limited in spatial coverage and temporal frequency. This study presents a comprehensive approach for distinguishing plastics from natural materials—particularly wood—by integrating hyperspectral laboratory data, satellite-based multispectral imagery (Sentinel-2), and machine learning classification techniques. The goal is to develop a robust and scalable methodology for plastic detection in coastal regions.

In the first phase of the study, a spectral library was constructed using laboratory reflectance measurements of plastic materials (HDPE, LDPE, PET, PS, PP, Nylon, fishing nets) and wood samples. Key absorption features distinguishing plastic and wood were identified in the near-infrared range, particularly around 880 nm and 1500 nm. A band normalization strategy, using 798 nm as the reference point, significantly enhanced the spectral separation between materials. Feature engineering through Mahalanobis distance analysis selected optimal bands (754, 788, and 826 nm), which were used to train four machine learning classifiers: Support Vector Machine (SVM), Random Forest (RF), K-Nearest Neighbors (KNN), and Neural Network (NN). Grid search optimization yielded high performance, with KNN achieving the best F1-score of 0.98.

The study further applied these findings to Sentinel-2 satellite imagery by convolving laboratory spectra to Sentinel bands. Band 5 was used for normalization, and the Normalized Difference Spectral Index (NDSI) between Band 4 and Band 8A was found to provide maximum class separation. Validation was performed using artificial plastic and wood targets created under the Plastic Litter Project in Europe (e.g., Greece, Cyprus, Lebanon). Linear spectral unmixing simulations estimated plastic-to-wood pixel ratios, which were then compared to real-world targets. Land masking using Band 12 enabled accurate focus on coastal pixels, and estimated plastic content aligned closely with ground-truth references.

This study successfully demonstrates that integrating spectral analysis with multispectral remote sensing and machine learning offers a viable solution for large-scale, low-cost detection of marine plastics using the custom design camera which is less than 1000 nanometer. It contributes to remote sensing applications in environmental monitoring and lays the groundwork for future real-time detection systems and operational support tools for plastic pollution management.