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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)

This study aimed to address the critical environmental issue of plastic pollution in marine and coastal environments through the development of a remote sensing-based detection methodology using spectral data. The core focus was on differentiating plastics from natural materials such as wood by leveraging hyperspectral and multispectral data across laboratory and satellite platforms.

In the laboratory phase, reflectance spectra were collected for various plastic types (HDPE, LDPE, PET, PS, PP, Nylon, fishing net) and wood materials. The analysis identified key absorption and reflection features across the 700–1600 nm range. A clear spectral difference between plastic and wood was observed, especially in regions near 880 nm, 1150 nm, and 1500 nm. Normalization using a band at 798 nm enhanced the contrast between classes, allowing more robust comparison of spectral shapes. Machine learning models including SVM, Random Forest, KNN, and Neural Networks were trained on the selected bands (754, 788, and 826 nm) derived using Mahalanobis distance. Among them, KNN achieved the highest cross-validation F1-score of 0.98, demonstrating excellent classification performance even with a limited number of bands. Grid search optimization improved model accuracy and robustness, highlighting the importance of parameter tuning.

Following the successful classification in the lab setting, the same methodology was translated to multispectral satellite imagery (Sentinel-2). The lab spectra were convolved to Sentinel-2 bands, revealing that Band 5 (705 nm) served as the optimal normalization band. The Normalized Difference Spectral Index (NDSI) between Band 4 and Band 8A was identified as the most effective combination for distinguishing plastic from wood. This was consistent with results from spectral unmixing and linear mixture modeling. Validation with artificial targets from the Plastic Litter Project confirmed the effectiveness of the proposed approach. Sentinel-2 imagery from Mytilene (Greece), Limassol (Cyprus), and other field sites demonstrated the model's ability to estimate plastic coverage within mixed pixels. Wood targets were correctly identified as low-plastic-content areas (10–20%), while HDPE targets achieved high estimated plastic percentages (up to 80%). These results support the feasibility of monitoring marine debris using satellite-based reflectance data.

Overall, this work demonstrates that integrating laboratory-based spectral analysis with satellite observations, aided by machine learning and index-based approaches, provides a scalable method to detect and quantify plastic pollution. This pipeline can support large-scale environmental monitoring, particularly in remote or inaccessible coastal regions.