ESA Discovery and Preparation – OSIP

Campaign on Remote Sensing of Plastic Marine Litter

Detection of Ocean Litter Plastics with Hyper-to-multispectral Infrared Neural Networks (DOLPHINN)

Executive Summary Report

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Acronyms

AVIRIS	Airborne Visible/Infrared Imaging Spectrometer
DOLPHINN	Detection of Ocean Litter Plastic with Hyperspectral-to-multispectral Infrared Neural Networks
ESA	European Space Agency
HSI	Hyperspectral imagery
JPSEmbed	Joint Plastic Spectral Embedding
MDA	MDA Systems Ltd.
MSI	Multispectral imagery
OSIP	Open Space Innovation Platform
SWIR	Short Wave Infra-Red

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1 Executive Summary

Successfully mitigating the damage caused by marine litter requires large-scale, accurate mapping of oceanborne plastics across the globe. Plastics commonly found as ocean litter have spectral absorption features in the Short-Wave InfraRed (SWIR). SWIR hyperspectral imaging (HSI) sensors can detect and monitor these plastics. Space-based monitoring of plastics is ideal for wide-area detection and monitoring but there is a lack of currently available spaceborne HSI sensors available for the task. While the bands of current spaceborne SWIR multispectral sensors contain some of the key spectral ranges for plastic detection, the wide bands cause entire absorption features to be captured in single bands, making it difficult to detect plastics reliably.

MDA's contribution to ESA's Discovery Campaign on Remote Sensing of Plastic Marine Litter is a feasibility study to establish the utility of artificial intelligence algorithms that learn to associate multispectral data with full hyperspectral absorption features, taking into account context that could confound the association, so that single multispectral images can be used to detect plastics more reliably. SWIR sensors already on orbit could then better contribute to marine litter detection.

Leveraging the latest advances in deep learning and applying these techniques to plastic detection our algorithmic framework creates a Joint Plastic Spectral Embedding (JPSEmbed) space between multispectral and hyperspectral pixels. This embedding space is optimized to prefer a representation that allows accurate detection of the presence of plastic in pixel.

Training this approach requires HSI and MSI collected simultaneously or near simultaneously. To overcome the lack of ideal data, we simulate data using real land target statistics to establish the preliminary feasibility of the approach. These plastic land targets along with the other man-made and natural materials serve as proxies for plastic debris on beaches, and the feasibility of the approach with these types of targets is foundational for the approach to be expanded to work with floating marine debris in future projects.

JPSEmbed trained using simulated AVIRIS/Sentinel-2 SWIR data with mixed pixels datasets show very promising performance, reaching F1 scores of over 90%, up to 16% better than the traditional multispectral-only Maximum Likelihood Estimator.

Qualitative assessments of real Sentinel-2 SWIR imagery with some known land plastics such as roofing and artificial turf, demonstrate the approach can detect land plastics, examples of which are shown in Figure 1 and Figure 2. We note instances with high false alarm rates with our baseline dataset. We demonstrate that re-incorporating materials falsely identified as plastic back into the training dataset can reduce the false alarm rate, also shown in the figures. We also demonstrate via simulation that adding visible-near infrared bands has the potential to significantly improve results and reduce false alarms.

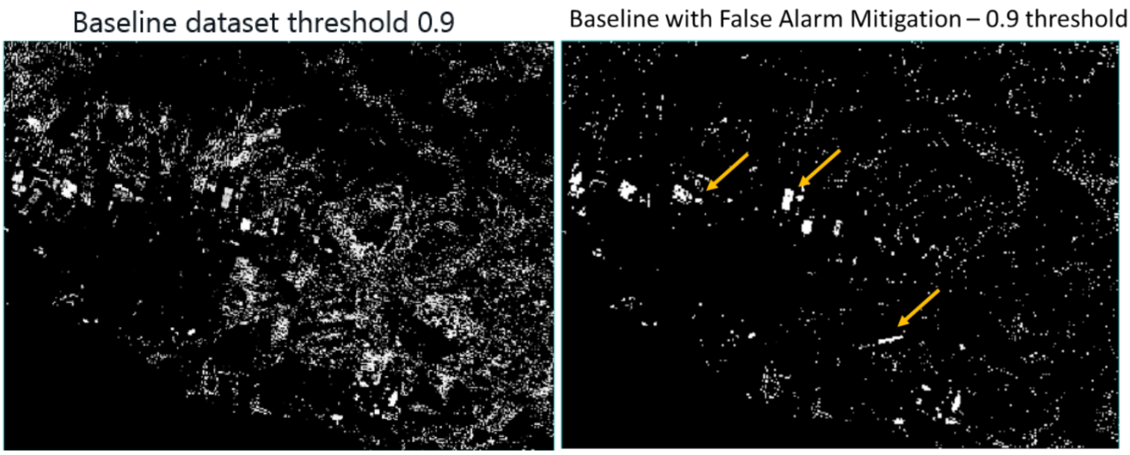

Figure 1 Comparison of the Baseline algorithm (left) index and False Alarm Mitigation (right) for a scene of Carpinteria, California with known plastic greenhouses indicated

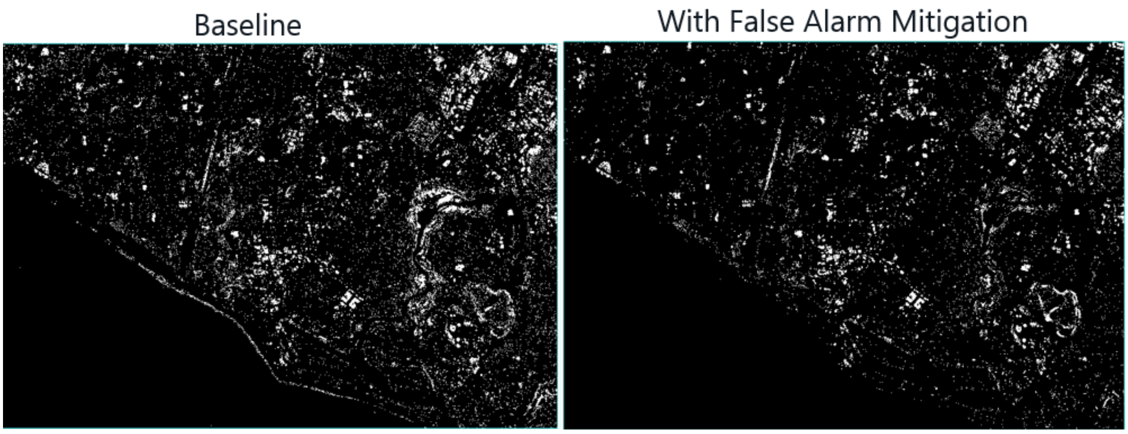

Figure 2 Comparison of the Baseline algorithm (left) index and False Alarm Mitigation (right) for a scene of Laguna Beach, California containing plastic roofs and artificial turf fields

The approach can be expanded to predict pixel plastic concentration and preliminary results suggest that the model predicts the plastic pixel fraction within a 20% error 72% of the time on average. As a comparison to previous qualitative results, Figure 3 shows the results of the concentration output, in which greenhouses and rooftops known to be plastic in the scene are assigned near pure-pixel values by the model.

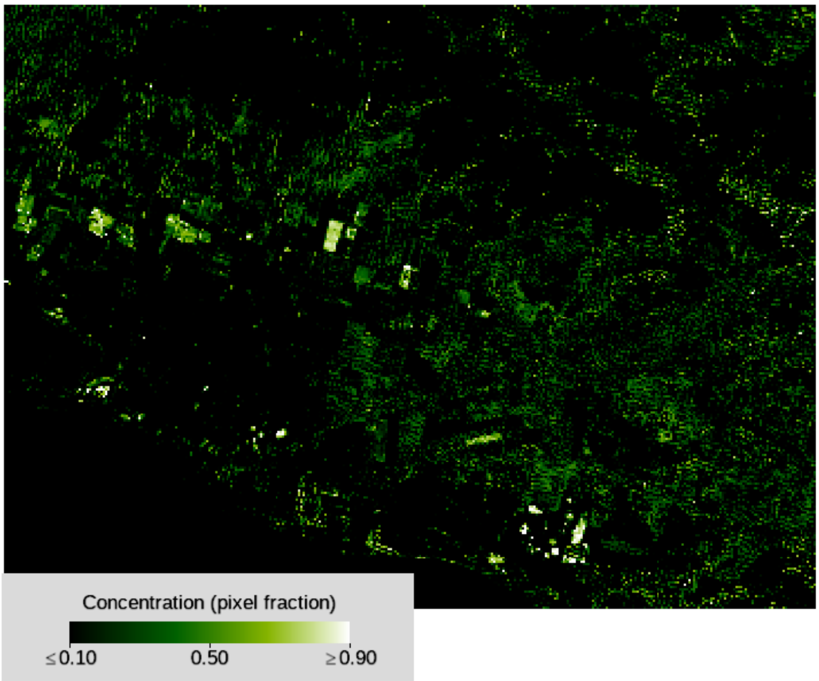

Figure 3   Pixel Concentration Results for Sentinel-2 SWIR Carpinteria Scene

Given the success of JPSEmbed in the assessment performed in this study, we are optimistic in the feasibility of the approach for land-based and shoreline plastics. Future work is needed to confirm the feasibility and refine the approach for operational-quality results and for transferring the approach to the open-water plastic detection. Future work should include incorporating real pixel pairs in training, testing on scenes with ground truth knowledge, and continuing to explore the training approaches that lead to best performance.