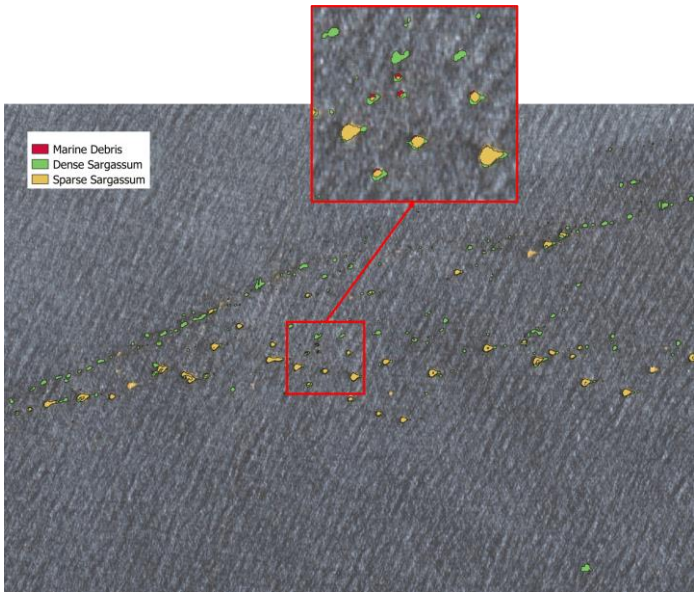

SPOTTED Spatio-temPoral fusiOn and arTificial inTelligence for dEbris Detection

Executive Summary

Study

DISCOVERY IDEAS OPEN CHANNEL STUDIES

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Activity summary:
The SPOTTED project addresses the critical issue of marine debris, particularly plastic pollution, by enhancing detection and monitoring capabilities. Utilizing advanced spatio-temporal fusion (STF) techniques and Artificial Intelligence (AI) with high-resolution satellite imagery from Sentinel-2 (S2) and PlanetScope (PS), the project aims to refine S2 data and develop AI algorithms for identifying landfills and floating debris. Key findings demonstrate improved accuracy in detecting smaller debris, offering significant potential for better management and cleanup efforts in marine environments.

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Document History

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1. Introduction

1.1. Purpose and scope

This document constitutes the Executive Summary Report for SPOTTED and is integral to the project's deliverables. It concisely summarises the project's findings, in a way suitable for non-experts in the field.

1.2. Acronyms and Abbreviation

Acronyms	
AI	Artificial Intelligence
cGANs	Conditional Generative Adversarial Networks
CNMF	Coupled Nonnegative Matrix Factorization
EO	Earth Observation
DL	Deep Learning
ML	Machine Learning
PS	PlanetScope
ResAttUNet	Residual Attention U-Net
S2	Sentinel-2
STF	Spatio-Temporal Fusion

2. Executive Summary

2.1. Introduction

Marine debris is a growing environmental crisis, with plastic pollution posing a major threat to our oceans and marine life. Monitoring the presence, location, and type of debris is crucial for effective management and cleanup efforts. Traditional satellite imagery methods often lack the necessary detail and resolution to detect marine debris, particularly smaller objects, accurately.

The SPOTTED project aims to enhance the detection and monitoring of marine debris using advanced spatio-temporal fusion (STF) techniques and Artificial Intelligence (AI) with high-resolution satellite imagery, particularly Sentinel-2 (S2) and PlanetScope (PS) data. The project focuses on two main objectives: refining S2 data through STF techniques and developing AI algorithms for identifying landfills and floating debris.

This Executive Summary explains the project's objectives, methodology, key findings, and potential applications.

2.2. Data procurement

Open databases such as MARIDA and GlobalPlasticWatch were utilized to gather the necessary data. This data included high-resolution satellite imagery from PlanetScope and Sentinel-2, focusing on areas known for debris accumulation and landfills near waterways. Selected areas for the study included regions prone to floating debris and landfills near waterways, providing a comprehensive dataset for training and validating the AI models. Satellite data underwent pre-processing steps to ensure consistency and quality.

2.3. Spatio-Temporal Fusion (STF) Algorithm

Standard satellite imagery often lacks the high resolution needed to distinguish small debris objects. To address this limitation, the SPOTTED project employed STF techniques to combine high-resolution images from PlanetScope with the broader spectral coverage of Sentinel-2 data. It creates a more detailed and informative picture of the target area by providing fused PlanetScope (PS)/Sentinel 2 (S2) data on a daily basis.

The STF methodology utilized Conditional Generative Adversarial Networks (cGANs) generate daily high-resolution fused PS/S2 images using PlanetScope data as input. For training the cGANs, spatial-spectral fusion was performed using CNMF and HySure algorithms. Despite some spatial noise, experimental results showed that cGANs employing instance normalization outperformed those employing batch normalization in most quality metrics.

2.4. Landfill Monitoring

Landfills are often sources of marine debris, as plastic waste can escape through wind, rain, or improper management. Therefore, identifying and monitoring landfills is crucial for tackling debris pollution.

The landfill monitoring module focused on training AI models to identify and classify landfills. Using a combination of deep learning (DL) and machine learning (ML) approaches, the study found that standard ML models such as random forest,

XGBoost and LGBM, trained with data generated by cGANs employing instance normalization performed better than those trained with data generated by cGANs employing batch normalization. Random Forest models demonstrated the highest accuracy, although further data is needed for more precise monitoring. On the other hand, the YOLO approach, a deep learning method, seems more accurate than the standard ML algorithms due to its use of shape information for segmenting and tracking landfills.

2.5. Floating Matter Detection

The project also investigated the use of AI for directly detecting floating debris objects in satellite imagery. Pre-trained deep learning models, specifically the ResAttUNet architecture, were adapted to higher-resolution STF data for floating debris detection. The qualitative analysis indicated that these models successfully and more accurately detected small plastic accumulations using higher-resolution STF data instead of Sentinel-2 data. Further validation with ground truth data is necessary to enhance detection capabilities.

2.6. Key Findings

The SPOTTED project yielded several key findings that demonstrate the significant potential of combining STF techniques and AI for improved marine debris detection and monitoring:

1. Spatio-Temporal Fusion
    a. STF techniques significantly improved the spatial, spectral and temporal resolution of satellite images.
    b. cGANs with instance normalization provided better spectral accuracy, essential for detecting marine debris and landfills.
2. ML algorithms for Landfill Detection
    a. YOLO model showed the highest recall and precision in identifying landfill areas.
    b. Daily high-resolution images from PlanetScope enhanced monitoring capabilities, though more data is required for thorough validation.
3. Floating Matter Detection
    a. ResAttUNet models successfully detected marine debris with an accuracy of approximately 75%.
    b. Enhanced spatial resolution from STF images allowed the detection of smaller debris accumulations not visible in Sentinel-2 data.

2.7. Conclusion

The SPOTTED project demonstrated the potential of STF techniques and AI models in improving the detection and monitoring of marine debris and landfills. The ability to fuse high-resolution satellite images and apply advanced AI algorithms opens new possibilities for environmental monitoring. However, further data collection and validation are necessary to fully realize these capabilities.

The project highlights the importance of continuous development in remote sensing technologies and AI to address environmental challenges effectively. Future work should focus on enhancing the accuracy of detection models and expanding the dataset to include diverse environmental conditions.