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Campaign on Remote Sensing of Plastic Marine Litter

ML-OPSI

Executive Summary Report

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Acronyms

BOA	Bottom Of Atmosphere
ESA	European Space Agency
E2E	End to End
ESTEC	European Space Research and Technology Centre
ML	Marine Litter
OSIP	Open Space Innovation Platform
RA	Reference Architecture
TOA	Top of Atmosphere
UAV	Unmanned Aerial Vehicle

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Executive Summary

The Project Marine Litter – Optical Processor Simulator (ML-OPSI) was funded by the Discovery Element of the ESA's Basic Activities. In this project, ARGANS acts as Prime Contractor, supported by AIRBUS, SHEC and a collaboration with University of Oldenburg, Germany, as well as University of Cadiz, Spain. The aim of the project was to design the components of a breadboard to enable the future development of a mission end-to-end (E2E) simulator, as well as support research of other aspects non-mission related, in this case the detection of litter pieces or patches, and assessment of litter pieces concentration. This challenge was supported by users and stakeholders, which provided different requirements and support the conceptualization of ML-OPSI.

ML-OPSI is a breadboard for EO scientists to create a *model* of the acquisition of an optical signal by a remote sensing sensor and use it to run *simulations* to characterise that signal under varying environmental conditions, such as sea state etc., to assess the optimal characteristics required for a sensor designed with an aim to detect marine litter. It is a modular, pluggable and extensible framework, promoting re-use and be adapted for different missions, sensors and scenarios.

Considering a *model* as a product, an abstraction or representation of a system that is simpler than the system it represents, while approximating most of the salient features of that system, and a *simulation* as the process of using a model to study the characteristics of the system, in this case detection of marine litter, by manipulating variables and by studying the properties of the model allowing an evaluation to optimise performance and make predictions about the real system.

ML-OPSI breadboard is based on a component-based architecture and the baseline architecture ML-OPSI conforms to that described in ARCHEO-E2E: A Reference Architecture for Earth Observation end-to-end Mission Performance Simulators (https://www.researchgate.net/publication/235699915_ARCHEO-E2E_A_Reference_Architecture_for_Earth_Observation_end-to-end_Mission_Performance_Simulators) (2012). This states that the purpose of the E2E is to help in the assessment of different system implementation options, the development of retrieval algorithms and the detailed design as well as the scientific preparation of the mission. Therefore, the simulator is composed of several modules providing all functionalities required to support runtime simulations, obtaining a consistent architecture and interface definition as well as a centralized and easy-to-control scenarios database. The basic design of the ML-OPSI is fundamentally built over several basic modules that take care of various aspects of the E2E simulation. Essentially composed of modules both of the Simulator and of the Model. The Simulator (OPSI) modules are responsible for the execution of the Model over varying initial conditions, these comprise the orchestrator, that controls the running of the processes, along with configuration management and the proposed GUI model-builder front end. Through a process of functional decomposition the top-level generic components identified have been refined to specify lower level modules, that are themselves components that can be modularised and the definition of inputs, outputs, parameters and interfaces of these components can be performed.

Following a well-defined functional decomposition of ML components, the top level modules are the Scenario Builder Module, the Scene Generator Module, Atmospheric Propagation, Instrument Detection, Retrieval and Performance Assessment

ML-OPSI is a proposed implementation of the Reference Architecture (RA) of ARCHEO-E2E, and the model identifies the Building Blocks considered necessary to provide the tailoring needed for a ML detection sensor.

In the spirit of promoting re-use an aim is inter-operability with the existing frameworks: BIBLOs and OpenSF, which are component-based systems that have been built for the purpose of EO Mission Performance Simulators. BIBLOS provides implementation for three of the six basic modules defined by the RA and ML-OPSI will re-use these. OpenSF can execute the BIBLOs modules and it provides a standardised set of E2E mission simulation capabilities including a GUI and orchestrator, which are the components of OPSI. From an implementation perspective then, the conclusion is that apart from creating representative images BOA with an extent greater that the target sensor Field of View and resolution finer than the subpixel grid used to simulate the CCD, there is nothing remaining to be done after the configuration and inclusion of the required BIBLOS modules in OpenSF. However, the ML components are not defined at the same level as the other top modules. Therefore, the demonstrator of ML-OPSI has focused on better understanding the signal when litter is present in the pixel through the integration of the model provided by Goddijn-Murphy et al., 2018[1]. Three modules have been implemented in the standalone demonstrator, which was built as a rapid prototype, where the modules not implemented during this iteration where considered through stubs/mocks to show the functionality of future ML-OPSI iterations. The three implemented modules are BOA rendering module, Litter Raft Module and the Ocean Colour Module and the outputs of the demonstrator are considered for different types of satellite data, such as Landsat 8 and Sentinel 2 (A and B). For the implementation of these three modules, a database considering measurements of different peer reviewed papers[2,3] (ML-OPSI database) was created. It integrates laboratory measurements for different types of litter (to be used by Litter Raft Module) and different types of water (Ocean Colour Module) which are combined following the model of Goddijn-Murphy et al. (2018) in the BOA Rendering Module. The Scenario Builder of the rapid prototype can be used in GUI and CLI modes and it depends on a series of configuration files that should be modified by the user to run the desired simulation (Figure). The user can specify the quantity and proportion of the chosen litter present in the pixel, as well as the types of litter, which are selected from the database and the different options are specified in the 'artificial_target_labels.txt' configuration file.

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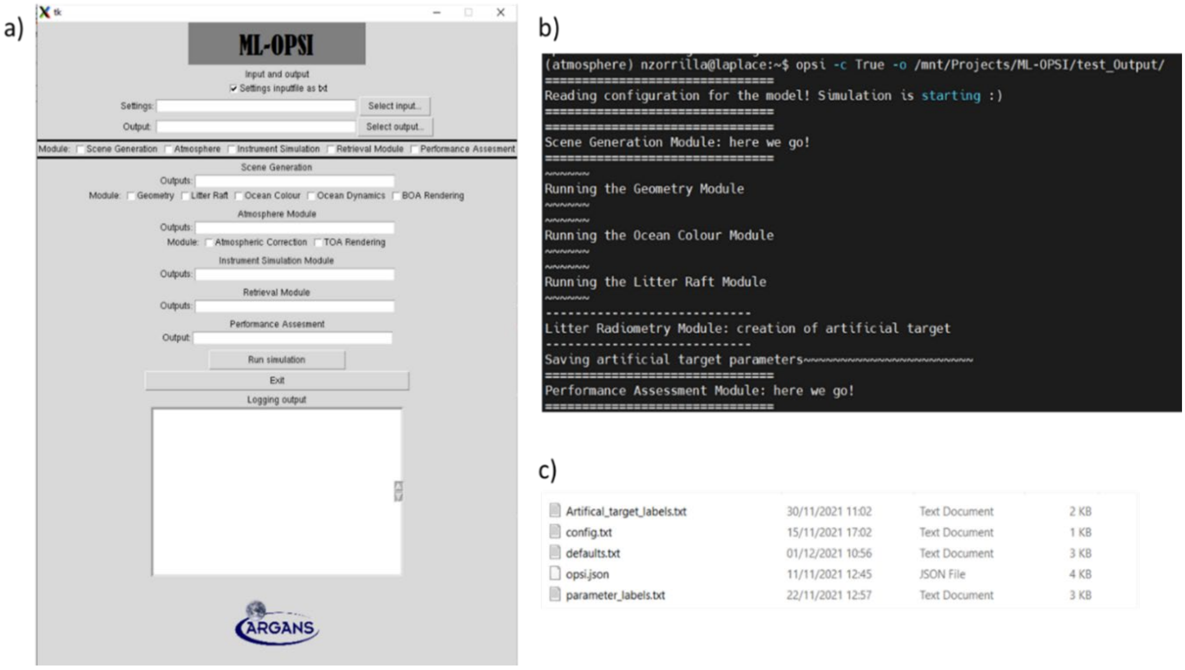
[1] Goddijn-Murphy, L., peter, S., van Sebille, E., James, N.A., Gibb, S. Concept of a hyperspectral remote sensing algorithm for floating marine macro plastics. Marine Pollution Bulletin 126, 255-262 (2018).

[2] Garaba, S., Arias, M., Corradi, P., Harmel, T., de Vries, R., Lebreton, L. Concentration, anisotropic and apparent colour effects on optical reflectance properties of virgin and ocean-harvested plastics. Journal of Hazardous Materials 406 (2021) https://doi.org/10.1016/j.jhazmat.2020.124290

[3] Knaeps, E. et al. Hyperspectral reflectance of marine plastics in the VIS to SWIR (2020). https://doi.org/10.4121/12896312.v2



```
(atmosphere) nzorrilla@laplace:~$ opsi -c True -o /mnt/Projects/ML-OPSI/test_Output/
================================
Reading configuration for the model! Simulation is starting :)
================================
================================
Scene Generation Module: here we go!
================================
~~~~~~~~
Running the Geometry Module
~~~~~~~~
~~~~~~~~
Running the Ocean Colour Module
~~~~~~~~
~~~~~~~~
Running the Litter Raft Module
~~~~~~~~
----------------------------
Litter Radiometry Module: creation of artificial target
----------------------------
Saving artificial target parameters~~~~~~~~~~~~~~~~~~~~~~~~~~
================================
Performance Assessment Module: here we go!
================================
```

Artifical_target_labels.txt	30/11/2021 11:02	Text Document	2 KB
config.txt	15/11/2021 17:02	Text Document	1 KB
defaults.txt	01/12/2021 10:56	Text Document	3 KB
opsi.json	11/11/2021 12:45	JSON File	4 KB
parameter_labels.txt	22/11/2021 12:57	Text Document	3 KB

Figure. Scenario Builder. GUI (a) and CLI (b) formats. Configuration files used by ML-OPSI (c).

In order to perform demonstration of creating representative images BOA with an extent greater that the target sensor Field of View and resolution finer than the subpixel grid used to simulate the CCD, a BOA-TOA proxy that goes into all the details is here presented as a rapid prototype solution due to the need of different input parameters, such as the instrument characteristics, which are unknown, among others. Two different approaches were followed: Cinema4D software, used for simulating the ocean surface when adding different types of plastic, and the acquisition of UAV imagery to be compared to concomitant satellite imagery. The first approach couldn't be further developed as it required a high-performance GPU and RAM, which hamper its further development. However, a scientific collaboration was achieved with Prof. Dr. Luis Barbero González at the University of Cadiz, Spain. The surveys were conducted as by change surveys-of-opportunity to support ML-OPSI as efforts to obtain matching imagery from drones and satellites during the project were fruitless. Thanks to the acquisition of such hyperspectral data in a concomitant day of a PRISMA pass-by, two different use case scenarios were proposed to prove that the modules of the simulator can support forward and backward simulations. The two use cases were completed:

- Use Case A: the steps followed and presented by this use case are: 1) use drone imagery as ground-truth BOA information (Scene Builder Generator Module); 2) sub-sample of image to PRISMA resolution (BOA Rendering Module); 3) *RTM from BOA to TOA (TOA Rendering Module)*; 4) Spectral matching between drone and PRISMA data (Instrument Module); 5) Measure of performance using Spectral Angle Measure (Performance Analysis Module).
- Use Case B: 1) use drone imagery as ground-truth BOA information (Scene Builder Generator Module); 2) sub-sample of image to PRISMA resolution (BOA Rendering Module); 3) *apply atmospheric correction to PRISMA data (Atmospheric Correction Module)*; 4) Spectral matching between drone and PRISMA data (Instrument Module); 5) Measure of performance using Spectral Angle Measure (Performance Analysis Module).

ML-OPSI, in the current iteration, consists of a fundamental basis of the complete development of an E2E simulator for ML observations. It is expected, after the integration of several engineering and scientific solutions that it will be capable of obtaining detail understanding of the contribution of marine litter to the signal, defining future instrument specifications and assisting in the development of retrieval algorithms capable of detecting, distinguishing and quantifying ML presence. The benefit of this work is not only technical, as it would facilitate lobbying of funding entities when it evolves into a fully functional simulator for both marketing and mission design purposes.