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| *Predictive modelling of sea debris around Maltese coastal waters* |
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Abstract

The accumulation of sea surface debris around the coastal waters of Malta, presents numerous ecological and environmental challenges that negatively affect both marine ecosystems and human activities. This is exacerbated by the absence of an effective system that can predict their movement, making it more challenging to address and mitigate this issue effectively.

The primary objective of this project was to develop a system that can predict dispersion patterns of sea surface debris around Malta’s coast. To achieve this, we developed a comprehensive machine learning and physics-based pipeline. This pipeline uses historical sea surface current data to predict future conditions, while also having the ability to visualise the movement of debris.

Central to this system is the integration of LSTM and GRU models, trained to predict the next 24 hours of sea currents within a specific area. These predictions were subsequently utilised by the Lagrangian model to visualise the movement of surface debris, offering insights into future dispersion patterns.

A comparative evaluation was conducted for both models, examining the accuracy of their predictions and the quality of the simulations generated by the Lagrangian model, based on these predictions. The results indicated that the LSTM model outperformed the GRU model. This was evidenced by the LSTM's enhanced precision in forecasting the movements of sea surface currents, thereby providing a more reliable basis for the subsequent simulation of debris dispersal patterns.

Overall, this project offers a novel approach to addressing the challenge of seasurface debris around Malta. By harnessing the power of machine learning in tandem with a physics based Lagrangian model, we have established a framework that not only predicts sea surface currents with notable accuracy, but also visualises the movement of surfacemarine debris, allowing us to make more informed decisions about our environment and our effect on it.

Acknowledgements

I would like to extend my deepest gratitude to several individuals whose support and guidance were invaluable in the completion of this project.

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List of Abbreviations

FYP Final year project (Style: Abbreviations)

LSTM

GRU

Note that the List of Abbreviations should be sorted on the acronym list.

# Introduction

This project is an integration of machine learning techniques with a physics based Lagrangian model [1] to address the environmental issues of sea debris. At the core of this project is a pipeline that harnesses historical data to forecast future conditions, specifically predicting the next 24 hours of sea surface currents. These predictions serve as inputs for a Lagrangian model [1], enabling it to simulate the movement of surface marine debris. Finally, a comparative evaluation of both LSTM and GRU models is conducted, focusing on their predictive accuracy and the quality of the visualizations. This project introduces an approach of merging machine learning with a physics-based model, offering valuable insights to marine conservation efforts and improving decision-making for managing marine debris around the Maltese Islands.

## Problem Definition

Sea surface debris around the coastal waters of Malta presents a significant environmental challenge. Predominantly composed of plastics, which constitute 82% of all man-made floating items encountered in the Mediterranean sea [2], this debris endangers marine life, disrupts ecological balances, and undermines the ecological integrity of coastal areas [3]. This problem is further aggravated by the lack of an effective system that can predict and forecast the movement of this surface debris, since as of writing, there exists no system that adequately addresses this challenge specifically for the coastal areas around Malta. This further underscores the need for a system that can accurately predict and visualise the dispersion patterns of sea surface debris.

## Motivation

The geological characteristics of the Mediterranean sea makes it difficult for surface debris to escape the area naturally, leading to the accumulation of sea surface debris [4]. The current absence of a predictive system tailored to the coastal regions of Malta impedes effective interventions to mitigate environmental harm. This gap opens an opportunity for the implementation of a system that through the application of Machine Learning and physics-based modelling, aims to address an urgent ecological issue, which is widely recognised as a global crisis [5]. By fulfilling this need, the project aims to provide accurate predictions that can guide effective cleanup operations and inform strategies for long-term marine conservation around the surrounding waters of Malta.

## Aims and Objectives

The aim of this project is to create a system enhanced with Machine Learning for simulating and predicting the movement of marine debris in the coastal waters of Malta, thereby supporting marine conservation efforts. To achieve this aim, the following objectives have been identified:

1. Data integration: To preprocess and integrate the sea surface currents datasets ensuring compatibility and consistency for input into both models.
2. Lagrangian model development: To utilize develop a Lagrangian physics-based model for simulating the movement of surface marine debris, employing historical data to ensure accurate simulations.
3. AI models development: To develop and fine-tune both LSTM and GRU models for the prediction of future sea surface currents. These models will serve as a crucial component of the forecasting system, leveraging their respective strengths in time series data processing to ensure robust and accurate predictions.
4. Integrating the AI models with the Lagrangian model: To integrate the model’s predictions into the Lagrangian model. This integration aims to create future simulations and visualisations of marine debris movement, enhancing the project’s predictive capabilities for marine conservation.
5. Comparison of AI models: To conduct a comparative evaluation of both LSTM and GRU models, focusing on their predictive accuracy and the quality of the final visualizations.

## Proposed Solution

This project aims to develop an integrated pipeline for predicting and simulating the movement of marine debris around Malta's coastal waters. The process begins with the preprocessing of the sea surface currents datasets that will be used as input for the subsequent modelling stages. A Lagrangian model will be developed to visualise the debris movement. This approach is designed to clarify both the expected input from the AI models and the expected nature of the ensuing visualizations. The core of the solution involves developing and fine-tuning two types of machine learning models: LSTM and GRU. These models will undergo extensive testing to determine the optimal architecture and hyperparameters, aiming to accurately predict sea surface currents for a future 24-hour period.

Upon establishing the predictive models, the pipeline integrates these predictions into the Lagrangian model, transforming the predicted data into dynamic visualisations of future debris movement. The project culminates in a comparative analysis of the LSTM and GRU models, evaluating their effectiveness through various metrics, including their predictive accuracy and the quality of the generated visualisations. By analysing the results and visualisations, this project aims to provide actionable insights for effective cleanup operations and strategies for long-term marine conservation around the coastal waters of Malta.

## Summary of Results

*To force Word to automatically update the cross-referencing, select the entire document by pressing CTRL-A on your keyboard, followed by F9.*

## Document Structure

The remainder of this document is organised into the following chapters:

**Background:** Here, the foundational elements of the project are discussed. This chapter includes a thorough overview of the utilized datasets, an explanation of the Lagrangian model's principles and capabilities, and an insight into the Machine Learning models.

**Literature Review:** In the literature review, we will delve into existing research and findings relevant to marine debris, the use of Lagrangian models, and the application of different AI models in environmental forecasting, establishing the scientific grounding for the project’s methodologies.

**Methodology:** This section details the processes undertaken in implementing the FYP. It includes the steps involved in data integration, the development and integration of the Lagrangian and AI models, and the comparative evaluation of the AI models.

**Evaluation:** A comprehensive outline of the strategies employed to test and evaluate the effectiveness and reliability of the implementation is presented in this section. This will be followed by the presentation and discussion of the results.

**Conclusion:** This FYP is concluded by summarizing conducted work, revisiting the aims and objectives, acknowledging any encountered limitations, highlighting obtained results, and finally suggesting any proposals for future work.

# Background and Literature Review

## Writing this Chapter

*The purpose of the background section is to provide the reader with information that they cannot be expected to know but which they will need to fully understand and appreciate the rest of the project.*

*This section may describe such things as:*

*· the wider context of the project.*

*· the anticipated benefits of the system.*

*· the likely users of the system.*

*· any theory associated with the project.*

*· the software/hardware development method(s) used.*

*· any special diagramming conventions used.*

*· existing software (or hardware) that is relevant to the system.*

*· etc.*

*Since projects will likely include different kinds of theory, programming language choices, compilers, software/hardware components, APIs, development boards, IC technologies, one cannot always assume that the reader will be familiar with the details of all of them. The student should therefore explain concepts and use references to guide the reader.*

*The literature review component of the report should include:*

*· A study in the area of interested, highlighting the strengths and weaknesses of existing methods.*

*· A review of the state-of-the-art published material in the area.*

*· A critical analysis of exiting material and methods.*

*An explanation showing why the literature chosen to review is relevant to the FYP.*

# Methodology

# Evaluation

## Writing the Evaluation Chapter

*The evaluation component of an FYP is critical.*

* *One has to make sure and explain why all tests used to evaluate the system are relevant, using evidence from the literature about similar systems, and justifying any deviations from standard approaches.*
* *Demonstration that system works as intended (or not, as the case may be).*
* *Include comprehensible summaries of the results of all critical tests that have been made.*
* *The student must also critically evaluate the system in the light of these tests results, describing its strengths and weaknesses.*
* *Ideas for improving it can be carried over into the Future Work section.*
* *Comparison of practical with theoretical results and their interpretation.*
* *Comparison with published work when available.*

# Conclusion

## Writing the Conclusions Chapter

*The Conclusions section should be a summary of the project and a restatement of its main results, i.e. what has been learnt and what it has achieved. An effective set of conclusions should not introduce new material. Instead, it should draw out, summarise, combine, and reiterate the main points that have been made in the body of the report and present opinions based on them.*

## Writing the Future Work Chapter

*Whether by the end of the project all the original aims and objectives have been completed or not, there is always scope for future work. Also, the ideas will have evolved during the project beyond the original target. The Future Work section is for expressing these ideas.*

References

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