

DEEP LEARNING FRAMEWORK TO USE COMPLEX MODELS IN OPERATIONAL FORECAST SYSTEMS

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INTRODUCTION

The C2IMPRESS project (Co-creative improved understanding and awareness of multi-hazard risks for disaster-resilient society, www.c2impress.com) is funded by the European Union through the Horizon Europe Programme. It aims to develop an innovative set of products that contribute to a more resilient society in the face of risks due to extreme weather events under different climate change scenarios.

There are four case study areas, Egaleo (Greece), Mallorca (Balearic Islands, Spain), Ordu (Turkey) and Centro Region (Portugal). In each of those study areas, different hazards will be studied, e.g., heat waves, wildfires, river floods, wave overtopping, and coastal floods. In the Portuguese study area (Centro Region), several hazards will be studied, within five different sub-areas. One of the sub-areas is Figueira da Foz harbour and adjacent beaches, where the focus will be on predicting wave overtopping, river and coastal flooding, and ship mooring and manoeuvring, and on developing an Early Warning System to forecast these hazards. This communication presents the development of the framework to forecast the wave overtopping over the Figueira da Foz port structures and adjacent beach fronts such as Praia do Cabedelo. The framework will use a suite of models, SWAN (SWAN team, 2006) and SWASH (SWASH team, 2023) to simulate wave overtopping and its impacts on pedestrians and vehicles. As SWASH is a time-consuming model, an Artificial Neural Network will be used to enable the delivery of operational warnings in due time.

STUDY AREA

The Figueira da Foz harbour is located on the west coast of Mainland Portugal (Figure 1).

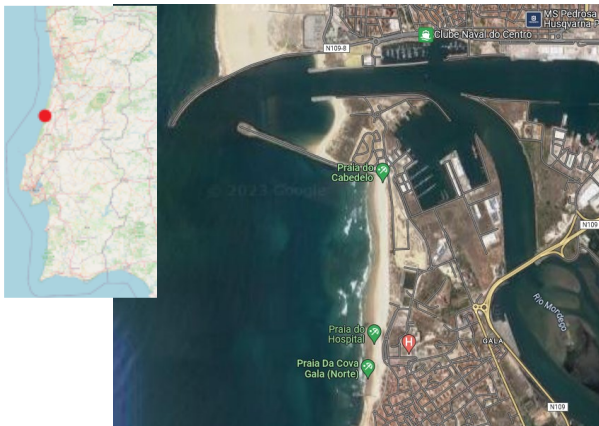


Figure 1 - Location of Figueira da Foz harbour. Source: GoogleEarth™

With around 900 metres of quay available for handling the most diverse types of cargo and accessible to ships up to 120 metres in length and 6.5 metres in draught, the Port of Figueira da Foz has a vast area of embankment. General breakbulk and bulk cargo occupies a prominent place in the port, which offers excellent conditions for the import and export industries of the Centre Region. The Figueira da Foz harbour is protected by two breakwaters, North and South, and there are also two jetties at the river Mondego mouth (Figure 1 and Figure 2). The breakwaters and the jetties have intense pedestrian use, and in some areas, there can even be vehicles. The harbour entrance has some accretion problems, and the bathymetric conditions can vary significantly.



Figure 2 - Figueira da Foz harbour. North and South breakwaters and jetties of the river Mondego mouth. Source: APFF (<https://portofigueiradafoz.pt/>)

NUMERICAL FRAMEWORK

The forecast of the wave overtopping and its impacts on pedestrians and vehicles involves the following phases:

- 1) Define all the representative range of oceanic boundary conditions that can occur in the study area;
- 2) Propagate those representative oceanic boundary conditions to nearshore using the SWAN model;
- 3) Study bathymetric changes near the harbour entrance, to define typical bathymetric configurations and the period of the year at which each one of them occurs;
- 4) Estimate the wave overtopping with the SWASH model (2D version) using the nearshore wave characteristics given by the SWAN model as an input, for different bathymetric conditions;
- 5) Train an Artificial Neural Network (ANN) with the extensive set of pre-run SWASH simulations;
- 6) Categorize the overtopping impacts on pedestrians and vehicles according to the conceptual description provided by Garzon et al. (2023).

Phases 1 and 2 are already at their final stage. Phase 4 is under development and requires a pre-calibration of the

SWASH model regarding the friction of the armour layer. Manz et al. (2022) have applied the SWASH model (in its 1D version) to simulate overtopping at two different profiles (antifer and tetrapods) of a breakwater and calibrated the Manning coefficient to represent the friction of the armour layer. Then, for operational purposes, four expressions to calculate the Manning coefficient were developed based on: the relative crest freeboard, the wave steepness, the incident wave angle and the type of armour layer. The expressions showed small errors between the calculated and calibrated Manning coefficients and highlighted the importance of the incident wave angle to obtain an accurate calibration. Despite an underestimation of the overtopping discharge in some cases, the SWASH model was found to provide overall good results.

In the present study, after the pre-calibration of the SWASH model using historical storm data and their impacts, an extensive modelling effort will be carried out, ensuring that the representative range of oceanic boundary conditions is simulated.

OPERATIONAL FORECAST SYSTEM

To be able to rapidly forecast the wave overtopping risk, the extensive set of pre-run SWASH simulations will be used to train an Artificial Neural Network (ANN) and deliver the risk forecasts instantly. For the development of the ANN, Keras open-source neural network library, written in Python, will be used. The output of the ANN will make it possible to use a time-consuming model such as SWASH, which would take several hours to run, in an Early Warning System (EWS) to deliver forecasts of wave overtopping risks. Due to the changes in the bathymetric configuration, the ANN will also have as input the temporal distribution of the typical bathymetric configurations defined in phase 3 of the numerical framework implementation.

The ANN will be introduced into the existing HIDRALERTA EWS (Fortes et al., 2020). HIDRALERTA is running in a real-time mode and is responsible for acquiring wave and wind boundary conditions and for propagating the waves from offshore to nearshore. With the nearshore wave input, the ANN will provide the level of impact due to overtopping, allowing for an almost instantaneous forecast for the next 72 hours (or more up to 240 hours). The EWS will be validated with qualitative records of overtopping events and their impacts. For this, a video-monitoring system will be placed near the root of the North breakwater, to allow for a better validation of the EWS.

CONCLUSIONS

The numerical framework consisting of SWAN+SWASH simulations, together with the ANN, allows for the operational forecast of wave overtopping and its impacts using a complex and time-consuming model, such as SWASH 2D. The methodology developed for Figueira da Foz harbour can be used to develop EWSs for other areas. This is the first stage of the development of an EWS for Figueira da Foz that accounts for wave overtopping, coastal flooding, river flooding and ship mooring and manoeuvring. The methodology developed here, and the lessons learned from its application will serve as a basis for the development of the following stages of the broader EWS. This latter one will be ultimately made available to different stakeholders. The

content of the displayed information as well as the design of the means of distributing that information, will be defined in co-creation with the local stakeholders, and serve as a tool to reduce the impact of extreme events in the community.

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