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# Deep Neural Network Enhanced Early Warning System for Ports Operations

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ABSTRACT

Downtime of port terminals results in large economic losses and has a major impact on the overall competitiveness of ports. Early Warning Systems (EWS) are an effective tool to reduce ports' vulnerability by increasing their preparedness and planning capacity to either avoid or efficiently respond to emergency situations.

The SAFEPORT EWS predicts met-ocean variables and their impact on ships (navigating, docking or moored) and port operations daily, Pinheiro et al. (2020), and provides alerts for emergencies and operational constraints. It is currently implemented in six ports, namely: Praia da Vitória, São Roque do Pico and Madalena do Pico, in the Azores archipelago, and Sines, Aveiro and Figueira da Foz, on the west coast of Portugal.

All information provided by this EWS is available in a dedicated website and mobile application. In addition, an alert bulletin is sent by e-mail to interested parties. This provides port stakeholders with a decision support tool for timely implementation of mitigation measures to prevent accidents and economic losses.

This system is now being enhanced with artificial neural network tools to obtain more accurate results from numerical wave propagation models and to allow the use of complex and time-consuming numerical models in an operational framework. As with any EWS, its usefulness depends heavily on its reliability, accuracy, and consistency. Two types of ANN have therefore been developed.

## 1. The Early Warning system

The SAFEPORT EWS follows a series of EWS from the HIDRALERTA platform, which includes three Azorean ports: Praia da Vitória, S. Roque do Pico and Madalena do Pico, (Poseiro, 2019 & Pinheiro et al., 2020), five other ports on the west coast mainland: Sines, Aveiro, Figueira da Foz, Ericeira and Peniche, and three coastal areas: Costa da Caparica, Faro and Quarteira. All the EWS of HIDRALERTA include coastal flooding and/or wave overtopping of coastal structures. Some of the ports in Hidralerta have implemented the SAFEPORT Port Navigation and Operations Alert System for certain vessels.

The system uses available forecasts of regional offshore wind and wave characteristics, together with astronomical tidal data, as inputs to a series of numerical models. These numerical models provide estimates of wave and wind characteristics at all scales, from regional, simulated with multiple nested grids using the SWAN model (Booij et al., 1996), to local, using a non-linear Boussinesq-type model or a linear mild-slope model. The EWS uses DREAMS and BOUSS-WMH to transfer the wave characteristics from the harbour entrance area to the harbour interior. The numerical model DREAMS (Fortes, 2002) is a linear finite element model based on the mild slope equation to simulate the propagation of monochromatic waves. The BOUSS-WHM model, (Pinheiro et al., 2011) is a nonlinear finite element model based on the extended Boussinesq equations derived by Nwogu (1993), capable of simulating the propagation of regular and irregular waves.

Finally, the ship's response to these wave and wind forcings is computed using a 3D panel method hydrodynamic model (Korsemeyer et al. 1988) and a motion equation solver.

Predicted hourly movements and mooring forces are compared with pre-set thresholds. An assessment of the probability of these values being exceeded gives a hazard level. The risk levels depend on the Maximum Breaking Load (MBL) of the mooring lines (OCIMF, 1992). Finally, on the basis of the predicted risk level, emergency situations and the safety of port operations can be foreseen in advance (72 hours) and appropriate warnings are issued.

## 2. Artificial Neural Networks

Two types of ANN were developed for the system. The first type of ANN uses available measured data to train the ANN and then calibrate/correct the numerical results to achieve more accurate predictions.
Three neural networks were trained to evaluate the possibility of improving the accuracy of the forecasts. The Keras open source neural network library, was used to develop the NNs.
Input layer data consists of a 40-year database of offshore wave parameters (Hs, Tz and θ) and wind data (speed and θ), Figure 1. Training data consists of 20-year measured wave characteristics from the Sines 1D wave buoy.
Output layers (one for each NN) consist of the wave parameter at the buoy, Hs, Tz and θ. To train the network 80% of the data was used and 20% was used to test it. The cost function is the mean squared error, mse, of the entire training set. The rectified linear unit (ReLU) activation function is used to introduce non-linearity to the network. The trained networks provided more accurate estimates for all variables and thus can be used to improve the reliability of the EWS.

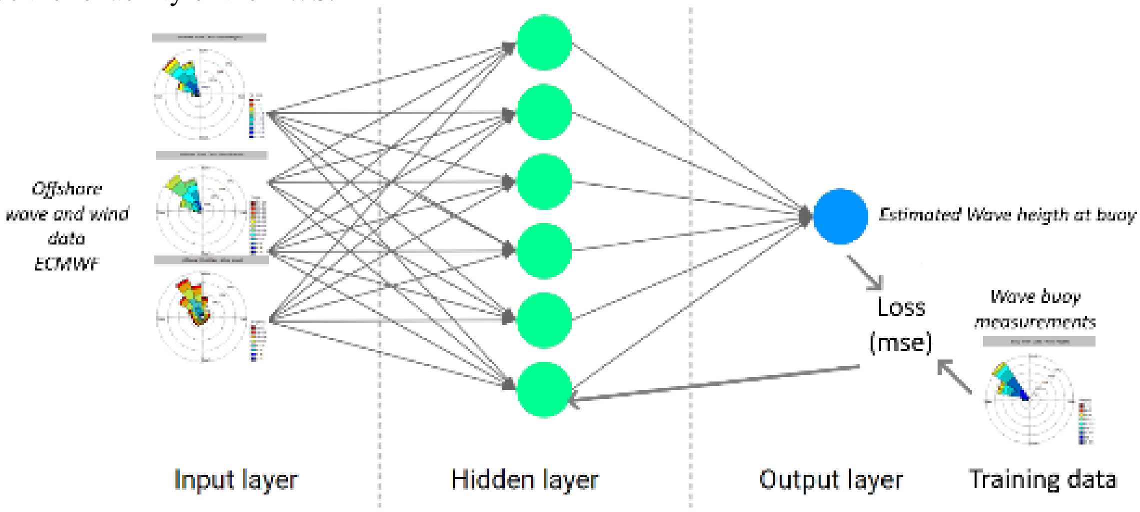


**Fig. 1.** Structure of the Neural Network for the wave height estimation/forecast at the Sines Buoy.

The second type of ANN uses an extensive set of pre-run complex numerical simulations using a Boussinesq-type numerical model for the wave propagation inside the sheltered area of the harbour to train the ANNs. The output of this ANN enables the system to get the same complex hydrodynamic fluid flow in shallow waters sheltered areas and around the 3D ship hull simulations results in the most time effective manner.
Results are extracted at any number of points along the ship's navigation channels, berths and moorings.
Another ANN is trained to reproduce the ship's response to wave and wind forcings using a 3D panel method hydrodynamic model (Korsemeyer et al. 1988) and a motion equation solver. Each specific ship hull and mooring arrangement will be replaced by a specific ANN.

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