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AI in Civil Engineering: practical cases

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Graphical Abstract

Abstract.

This work focuses on port management and the hydrodynamic impact that waves, tides and wind have on moored cargo ships and port infrastructures. We present two examples where Artificial Intelligence (AI) was applied to port management tasks: monitoring the movement of a moored vessel and monitoring wave overtopping events. We have recorded ship movements during two years utilizing a technique developed in a previous work of the group, and designed, trained and tested a deep neural network that classifies the movement of cargo ships given the sea state, weather conditions and ship dimensions. Using the model with forecast data for the weather conditions and sea state, we can predict when a ship is going to exceed the recommended movement. Wave overtopping is a dangerous phenomenon. We recorded three years of overtopping phenomena and created a database with overtopping events, sea state and weather conditions. This data is being used to create an overtopping predictor based on neural networks. Using the predictor with forecast data for the weather conditions and sea state, we will be able to predict when an overtopping event is going to take place.

Introduction

Spain has an 8000 km coastline, making it the European Union country with the longest coastline. It is also the closest European country to the axis of one of the world's major maritime routes. Its geographical location positions it as a strategic element in international shipping and a logistics platform in southern Europe [1]. There are several weather and sea conditions that can affect the regular activities in a port. Our work focuses on monitoring and trying to predict two of the most disruptive events: moored vessel movements and wave overtopping. All data was gathered in the outer port of *Punta Langosteira*, located in *A Coruña*, north-west of Spain.

Monitoring the movement of a moored vessel is a costly, and not always feasible, operation. There are several variables that influence the movement of a vessel, such as the vessel type, the mooring system, the configuration of cargo, etc. However, the relationship between all of them is not entirely known, due to the complexity of their interactions.

With our work we try to create a system that predicts how a moored vessel is going to behave, helping to decide when to stop the ship operations more precisely, thus minimizing the economic impact the hydrodynamic phenomena have due to cargo ship being unable to operate.

Wave overtopping is the event that takes place when waves meet a submerged reef or structure. It also happens when waves meet an emerged reef or structure lower than the approximate wave height. The later case is the one that affects a port's breakwater and the one we want to measure. During an overtopping, two processes, important to the coastal processes, take place: wave transmission and the passing of water over the structure. We studied the passing of water over the structure.

When an overtopping occurs in a commercial port environment, the best case scenario will be the disruption of activities and even this best case scenario has a negative financial repercussion. With our work we try to avoid the disruption of said activities and the financial repercussion it entails.

Materials and Methods

In order to obtain the movement of a vessel, we took the approach of measuring the movement and variables that influence it in a real moored vessel (instead of numerical modeling). This approach is laborious and time demanding, but can produce precise results. The exact methodology used to measure the ships movement, in its six degrees of freedom (3 axial movements and 3 rotations), is described in [2], where 3 complementary and fully synchronized measurement systems are used: an IMU, two laser distance meters and two cameras. This method provides us with six variables denoting the six degrees of freedom of the vessel movement. We also use the variables: significant wave height H_s, peak wave period T_p, mean wave direction θ_m (all provided by a buoy), wind speed W_s and wind direction W_d (both provided by a weather station) and sea level H_0 (provided by a gauge). Using the data collected during two years, we created a neural network that allows us to predict the vessel movement, in terms of operational limits used in the Spanish Port System (ROM [3]). Using a prediction for the weather and sea state variables as input to the neural network, we can predict the behavior of a moored vessel several days in advance. This neural network is being evaluated in a real environment in order to measure its performance.

Currently there is no system available (without incurring in huge costs) to determine if an overtopping event has occurred. In order to monitor the overtopping events, we installed a system of 5 cameras located on different locations in the port, covering the areas of the breakwater where an overtopping could happen. One camera was located between 1-2 km from the port, providing a panorama of the port, thus facilitating the location of overtopping events. Another camera was located in the port's breakwater head. This turned out to be the most active part of the breakwater, regarding overtopping events. The remaining three cameras were located to cover another view of the port's breakwater head, the central area of the breakwater and an area to the right of the central area, covering, a priori, highly active, medium and low overtopping areas. The events were recorded from November of 2015 until March of 2017. The overtopping identification process consisted in watching all the videos, identifying the overtopping events and classifying them. The classification consist on: the visual measurement of the overtopping length, the location within the breakwater where it occurred and the exact time of occurrence. With this data and the previously mentioned variables H_s, T_p, θ_m, W_s, W_d and H_0 we created a dataset that is being used to train a deep neural network to predict overtopping events several days in advance using a forecast for the weather condition and sea state (that provide predictions for , T_p, θ_m, W_s, W_d and H_0).

Conclusions

The deep neural network models developed (or being developed) in this work have shown to be a good alternative to conventional models (physical and numerical), having the advantage that it does not need as many elaborate data as conventional models do. Using these models, port operators can decide whether to anchor the ship better in order to reduce its movements or to wait to start the (un)loading operations and also decide to forbid the access to a breakwater section because an overtopping event is predicted to happen there. These actions could reduce the economic loss and physical damage during operations.

References

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