The MARI-Sense Project: Employing Artificial Neural Networks for Sustainable Coastal Environmental Management

Abstract

The Maritime Cognitive Decision Support System (MARI-Sense) Project aims to develop intelligent systems, able to provide informative insights into the complicated mechanisms related to marine processes and maritime applications; such as transport and shipping, coastal tourism, search and rescue, and maritime spatial planning. The Project is co-financed by the European Regional Development Fund and the Republic of Cyprus through the Research and Innovation Foundation (INTEGRATED/0918/0032), for the period between 01/01/2020 - 31/12/2022. One of the main objectives of the MARI-Sense Project is to promote Sustainable Blue Growth through Environmental Sustainability. Towards this end, environmental data are collected from monitoring surveys carried out to assess water quality and condition of the marine environment. The analysis of such datasets through a properly structured modelling procedure can provide both scientists and managerial competent authorities valuable information, and to assist in finding solutions to environmental challenges. Data-driven models, especially Artificial Neural Networks (ANNs), have been proved ideal for modelling environmental problems, such as eutrophication, which is responsible for the degradation of the water quality. The ANNs ability to model complex and nonlinear processes and the fact that it does not make any assumptions regarding the underlying distribution of the data or the relationships between input and output variables, makes them suitable for modelling ecological/environmental phenomena, which can be characterized by complex dynamics and nonlinear relationships. For the needs of the MARI-Sense Project, Feedforward ANNs (supervised models) were developed, aiming to simulate the Chlorophyll-a parameter, which serves as a proxy for eutrophication. A dataset (n = 681 samples) of surface coastal water quality parameters including sea water surface temperature, nitrogen species (NH4+, NO2-, NO3-), phosphorus (PO43-), pH, salinity, electrical conductivity and dissolved oxygen, served as the model's inputs, while the surface Chlorophyll-a was the modelled output. The monitoring period was between the years 2000-2014. An ANN with a 9-8-1 topology was developed for the needs of this modelling study, while the k-fold cross validation technique was used for model validation purposes. The created ANN model managed to simulate the Chlorophyll-a levels very well (RMSE=0.25 and R=0.85, for the testing set). Additionally, sensitivity analysis of the input parameters was performed for the ANN model. The sensitivity analysis revealed the negative impact of global warming on eutrophication, since a small increase (+ 8%) in water temperature resulted in a large increase in algal production (over 123%). Furthermore, the sensitivity analysis confirmed that nutrients' increased levels could be associated with elevated Chlorophyll-a values and vice versa. This finding allows us to create management scenarios and extract threshold values for the nutrients. Finally, the created ANN not only managed to successfully predict the Chlorophyll-a levels but also proved to be a useful tool for examining the effect of the parameters on the Chlorophyll-a production mechanism.

Keywords

Artificial Neural Network; sensitivity analysis; chlorophyll-a

Authors

Ekaterini Hadjisolomou
CMMI, Cyprus
Department of Electrical Engineering, Computer Engineering and Informatics, Cyprus University of Technology, Cyprus
katerina.hadjisolomou@cmmi.blue

Konstantinos Antoniadis
Department of Fisheries and Marine Research, Ministry of Agriculture, Rural Development and the Environment, Cyprus
kantoniadis@dfmr.moa.gov.cy

Ioannis Thasitis
Department of Fisheries and Marine Research, Ministry of Agriculture, Rural Development and the Environment, Cyprus
IThasitis@dfmr.moa.gov.cy

Maria Rousou
Department of Fisheries and Marine Research, Ministry of Agriculture, Rural Development and the Environment, Cyprus
MRousou@dfmr.moa.gov.cy

Lavrentios Vasiliades
Department of Fisheries and Marine Research, Ministry of Agriculture, Rural Development and the Environment, Cyprus
lvasiliades@dfmr.moa.gov.cy

Rana Abu-Alhaija
Cyprus SubSea Consulting and Services (CSCS) Ltd, Cyprus
rana.a@cyprus-subsea.com

Herodotos Herodotou
Department of Electrical Engineering, Computer Engineering and Informatics, Cyprus University of Technology, Cyprus
herodotos.herodotou@cut.ac.cy

Michalis Michaelides
Department of Electrical Engineering, Computer Engineering and Informatics, Cyprus University of Technology, Cyprus
michalis.michaelides@cut.ac.cy

Ioannis Kyriakides
CMMI, Cyprus
Department of Engineering, University of Nicosia, Cyprus
ioannis.kyriakides@cmmi.blue