Environmental Modeling & Assessment (2024) 29:425–426
https://doi.org/10.1007/s10666-024-09981-x

Foreword: Machine Learning in Environmental Modelling

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Published online: 16 May 2024
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From understanding climate patterns to optimizing agriculture and managing natural resources, environmental modelling plays a crucial role in quantifying and predicting the complex dynamics of our planet's ecosystems. Traditionally, these modelling efforts have relied heavily on physical process-based and statistical approaches derived from first principles and empirical observations. However, such methods often require extensive input of domain-specific knowledge from subject matter experts, which can constrain the pace of discovery and limit the ability to fully capture intricate environmental phenomena.

The rapid advancement of computing power and machine learning techniques has opened transformative possibilities for environmental modelling. Powerful machine learning algorithms like deep neural networks have demonstrated a remarkable ability to approximate and generalize from data, learning to represent highly complex systems without relying as heavily on prior knowledge from domain experts. Approaches such as convolutional neural networks and recurrent neural networks have proven particularly adept at modelling image data and time series data respectively, both crucial data modalities in environmental science.

While machine learning offers powerful tools, realizing their full potential requires carefully formulating environmental problems in mathematical terms and adapting these general techniques for optimal performance on domain-specific tasks. Bridging this gap between cutting-edge machine learning capability and the unique challenges of environmental modelling represents an ongoing area of active research. Creative machine learning frameworks tailored to environmental data are needed to push the boundaries of what can be modelled and predicted.

This special issue aims to contribute to this emerging nexus of machine learning and environmental modelling by showcasing novel approaches and diverse applications. After a rigorous peer-review process, 12 papers were carefully selected to exemplify the potential for machine learning to advance environmental modelling across diverse domains. The included papers focus on developing customized machine learning frameworks to tackle a range of environmental science tasks such as forecasting, optimization, and general prediction from real-world data.

- Environmental Monitoring and Prediction

Several works apply machine learning for monitoring environmental conditions and predicting future states across domains like greenhouse gas levels, urban air quality, wildfires, and lake surface area changes. In the paper "A seasonal-trend decomposition and single dendrite neuron-based predicting model for greenhouse time series", Li et al. proposed a hybrid model for greenhouse time series prediction. Luo et al. leveraged multivariate LSTMs for "Forecasting methane data using multivariate long short-term memory neural networks". He et al. introduced FD3, a novel deep learning framework for carbon emissions prediction in "A novel FD3 framework for carbon emissions prediction". Jiao et al. combined street view imagery and sensor data to "Evaluate air quality status in Chicago" using machine learning. Khalaf et al. compared deep learning, simulation, and cellular automata approaches for "Performance analysis of ConvLSTM, FlamMap, and CA algorithms to predict wildfire spread in Golestan National Park, NE Iran". He et al. also used time series clustering to study lake area dynamics in "Time series clustering and influencing factors analysis on Qinghai-Tibet Plateau lake area change".

- Agriculture, Land Use, and Natural Resource

In other papers, machine learning techniques are also applied to challenges in agriculture, land use, and natural resource management. Saini and Nagpal presented a hybrid particle swarm optimization and deep learning model for smart farming applications in "PSO-CNN-Bi-LSTM: A

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hybrid optimization-enabled deep learning model for smart farming". In "Machine learning for modeling soil organic carbon as affected by land cover change in the Nebraska Sandhills, USA", Li et al. leveraged machine learning to model soil organic carbon impacts. Ghasemi et al. fused UAV and satellite remote sensing data with machine learning to analyse tree decline in "Integrating UAV and freely available space-borne data to describe tree decline across semi-arid mountainous forests". Zhao et al. utilized clustering to investigate factors influencing energy consumption in "Factors influencing energy consumption from China's tourist attractions: A structural decomposition analysis with LMDI and K-means clustering". Kumar et al. developed neural network models for "Reference evapotranspiration modelling using artificial neural networks under scenarios of limited weather data: A case study in the Malwa region of Punjab".

- Environmental Contamination and Uncertainty

Quantifying and characterizing environmental contamination are another focus area, where Guridi et al. leveraged deep learning for "Uncertainty quantification of contaminated soil volume with deep neural networks and predictive models".

By disseminating these innovative works applying machine learning to monitor environmental health, optimize resource use, and quantify contamination, we hope to inspire further research that fuses machine learning with environmental science. Such interdisciplinary efforts can yield more accurate, scalable, and data-driven modelling of the multifaceted natural systems that sustain our planet.

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