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Machine learning methods for flood prediction: A review of methods, their strengths and limitations

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Abstract: Floods are among the most damaging natural disasters in the world. They are also hard to predict numerically and require models with high complexity. Hydrodynamic models have been in use in the last several decades for flood prediction and inundation modelling. While hydrodynamic models are highly effective tools for estimating detailed and accurate flood information (e.g. flooded area, water height, flow velocity, timing of flood peak), they typically require extensive configuration and calibration before simulating future floods. Moreover, hydrodynamic modelling is computationally expensive, limiting the capability of these tools for near real-time flood predictions. In recent years with technological advancement, machine learning (also called data-driven) methods contributed highly to the advancement of prediction systems providing better performance and cost-effective solutions.

Among data-driven methods, traditional machine learning (ML) approaches are widely used for inundation predictions and recently deep learning (DL) approaches have gained more attention across the research community. We reviewed recently published literature on ML and DL application for flood modelling for various hydrologic and catchment characteristics (Karim et al, 2023). Our literature review showed that DL models produce better accuracy compared to traditional approaches. Unlike physically based hydrodynamic (HD) models, ML/DL models suffer from lack of using expert knowledge in modelling flood events. Apart from challenges in implementing a uniform modelling approach across river basins, lack of benchmark data to evaluate model performance is a limiting factor for developing efficient ML/DL models for flood inundation modelling. The main contribution of this paper is to demonstrate the state of the art of ML models in flood prediction and to give insight into the most suitable models.

In this paper, the literature where ML models were benchmarked through a qualitative analysis of robustness, accuracy, effectiveness, and speed are particularly investigated to provide an extensive overview on the various ML algorithms used in the field. The performance comparison of ML models presents an in-depth understanding of the different techniques within the framework of a comprehensive evaluation and discussion. As a result, this paper introduces the most promising prediction methods for both long-term and short-term floods. Furthermore, the major trends in improving the quality of the flood prediction models are investigated. Among them, hybridization, data decomposition, algorithm ensemble, and model optimization are reported as the most effective strategies for the improvement of ML methods. We reviewed physically based HD models used to generate flood inundation data for ML models and provided technical information about both ML and DL models and then reviewed papers that applied these models to predict flood events. Further, we discuss strengths and weaknesses of such data driven methods (e.g. ML, DL) to model flood events and describe challenges and missing technologies that can be explored by the community to boost speed and performance of flood prediction. Our recommendations can be used as a guideline for hydrologists as well as climate scientists in choosing appropriate Data driven methods for prediction tasks.

REFERENCES

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