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Physics-Informed AI-based Modelling for Flood Early Warning Systems

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Today, the vast majority of early warning systems (EWS) are introduced in which advanced deep learning, recurrent neural network or ensemble-based data mining techniques are applied to provide more accurate and reliable flood forecasting [1]. This trend have been gained more trends mainly due to recent advances in computational capabilities, technological enhancement, and data science-based modelling have empowered these data-driven models [2]. A novel addition in this community is the physics-informed neural network models (PINN), integrating physical principles and constraints into architecture of data driven models. This hybrid approach is particularly beneficial in scenarios where prior knowledge of underlying physics such as nature of rainfall occurrence or catchments hydraulic characteristics are limited [3].

In the present study, PINN-based ensemble multi-class data mining model, inspired by [4] is introduced for forecasting water level classes ranging from no risk to high risk in the context of urban drainage systems (UDS). To keep simplicity, this model is developed with only two datasets: rainfall and UDS water levels. In addition to conventional inputs such as rainfall intensity, duration, session, and soil moisture, two physics-informed rainfall inputs - namely, the potential future return period (RP) of current rainfall and the current return period class - are incorporated. Additionally, two physics-informed catchment water level inputs - specifically, the water level class at the current timestep and the duration of the current class - are integrated into the model framework. The introduction of these new parameters aims to offer valuable insights into system dynamics, enhancing the model's ability to comprehend both short-term and long-term memory patterns.

The results, assessed using the method outlined in [2], indicate a substantial improvement in hit rates - from 67% to 88% - compared to a benchmark model. Notably, time lags in the correct detection of water level classes, are halved on average, reducing from 2-timstep intervals. More specifically, the rate of event underestimation decreases from 7% to 2%, showcasing that the new method has the potential to reduce false alarms in EWS. It is essential to note that the application of PINN is currently limited to using only physics-informed input data. However, a promising avenue for future exploration involves extending this approach to adjusting hyperparameters of data-driven models with physics equations. This adaptation is recommended for future directions in research and application.

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