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Reformulated Neural Network (ReNN): a New Alternative for Data-driven Modelling in Hydrology and Water Resources Engineering

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Reformulated Neural Network (ReNN) has been recently developed as an efficient and more effective alternative to feedforward multi-layer perceptron (MLP) neural networks [Razavi, S., and Tolson, B. A. (2011). "A new formulation for feedforward neural networks." IEEE Transactions on Neural Networks, 22(10), 1588-1598, DOI: 1510.1109/TNN.2011.2163169]. This presentation initially aims to introduce the ReNN to the water resources community and then demonstrates ReNN applications to water resources related problems.
ReNN is essentially equivalent to a single-hidden-layer MLP neural network but defined on a new set of network variables which is more effective than the traditional set of network weights and biases. The main features of the new network variables are that they are geometrically interpretable and each variable has a distinct role in forming the network response. ReNN is more efficiently trained as it has a less complex error response surface. In addition to the ReNN training efficiency, the interpretability of the ReNN variables enables the users to monitor and understand the internal behaviour of the network while training. Regularization in the ReNN response can be also directly measured and controlled. This feature improves the generalization ability of the network.
The appeal of the ReNN is demonstrated with two ReNN applications to water resources engineering problems. In the first application, the ReNN is used to model the rainfall-runoff relationships in multiple watersheds in the Great Lakes basin located in northeastern North America. Modelling inflows to the Great Lakes are of great importance to the management of the Great Lakes system. Due to the lack of some detailed physical data about existing control structures in many subwatersheds of this huge basin, the data-driven approach to modelling such as the ReNN are required to replace predictions from a physically-based rainfall runoff model. Unlike traditional MLPs, the ReNN does not necessarily require an independent set of data for validation as the ReNN has the capability to control and verify the network degree of regularization. As such, the ReNN can be very beneficial in this case study as the data available in this case study is limited. In the second application, ReNN is fitted on the response function of the SWAT hydrologic model to act as a fast-to-run response surface surrogate (i.e. metamodel) of the original computationally intensive SWAT model. Besides the training efficiency gains, the ReNN applications demonstrate how the ReNN interpretability could help users develop more reliable networks which perform predictably better in terms of generalization.