Application of deep learning methods for urban water demand forecast modelling

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Water demand predictions forms an integral part of sustainable management practices for water supply systems. Demand prediction models aids in water system maintenance, expansions, daily operational planning and in the development of an efficient decision support system based on predictive analytics. In recent years, it has also found wide application in real-time control and operation of water systems as well. However, short term water demand forecasting is a challenging problem owing to the frequent variations present in the urban water demand patterns. There are numerous methods available in literature that deals with water demand forecasting. These methods can be roughly classified into statistical and machine learning methods. The application of deep learning methods for forecasting water demands is an upcoming research area that has found immense traction due to its ability to provide accurate and scalable models. But there are only a few works which compare and review these methods when applied to a water demand dataset. Hence, the main objective of this work is the application of different commonly used deep learning methods for development of a short-term water demand forecast model for a real-world dataset. The algorithms studied in this work are (i) Multi-Layer Perceptron (MLP) (ii) Gated Recurrent Unit (GRU) (iii) Long Short-Term Memory (LSTM) (iv) Convolutional Neural Networks (CNN) and (v) the hybrid algorithm CNN-LSTM. Optimal supervised learning framework required for forecasting the one day ahead water demand for the study area is also identified. The dataset used in this study is from Hillsborough County, Florida, US. The water demand data was available for a duration of 10 months and the data frequency is about once per hour. These algorithms were evaluated based on the (1) Mean Absolute Percentage Error (MAPE) and (ii) Root Mean Squared Error (RMSE) values. Visual comparison of the predicted and true demand plots was also employed to check the prediction accuracy. It was observed that, the RMSE and MAPE values were minimal for the supervised learning framework that used the previous 24-hour data as input. Also, with respect to the forecast accuracy, CNN-LSTM performed better than the other methods for demand forecast, followed by MLP. MAPE values for the developed deep learning models ranged from 5% to 25%. The quantity, frequency and quality of data was also found to have substantial impact on the accuracy of the forecast models developed. In the CNN-LSTM based forecast model, the CNN component was found to effectively extract the inherent characteristics of historical water consumption data such as the trend and seasonality, while the LSTM part was able to reflect on the long-term historical process and future trend. Thus, its water demand prediction accuracy was improved compared to the other methods such as GRU, MLP, CNN and LSTM.