Water Quality Prediction Using LSTM-RNN: A Review

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Water Quality Introduction

Problem Statement

- According to the Water Quality Index (WQI), a good water quality involves the factor of pH, turbidity, dissolved oxygen, biochemical oxygen demand, chemical oxygen demand, solids, temperature and more (Cantor, 2019).
- Weather and the environment can be a plausible influence in the water condition readings (Wei et al., 2019).
- The close-chain system for the parameters related closely to the difficulty of predicting the changes.
- The nonlinear behavioural characteristics to the results obtained and make it dynamic and challenging to explain (Pasini, 2015).
- Main focus: To implement of robust river water quality prediction using historical samples and readings techniques to control the problem

Research Question

- How well does the LSTM-RNN performs when implemented for water quality prediction?

Artificial Neural Network Review

Literature Review

- Artificial Neural Network (ANN) - replication of how data is processed in the neural system of the brain.
- The ANN processes the nonlinear relationship between inputs and outputs, parallel to the human brain at all times.
- The system is capable of learning how to produce output data that is not only subject to input data provided (Sulaiman et al., 2019).
- With the ability to learn by example, the ANN system can obtain data based on current events or real-time events (Abiodun et al., 2018).

Feedforward Neural Network on Water Quality Prediction

PROS

- Feedforward architecture is the simplest way of processing data.
- Water quality measurement parameters such as the pH, temperature , dissolved oxygen, and many more may be input in the assessment of water quality
- Multilevel FFNN can learn faster with reduced output and requires fewer weights

CONS

- FFNN is lack of time dynamics and only processing signals in one direction.
- Multilevel FFNN will increase the number of learning cycles and required a high level of training accuracy.
- The network will be too sensitive to weight changes and cause convergence problems.

Recurrent Neural Network

PROS

- Often reflect on the past, and its decision-making depends on what has been learned from the past.
- Each output signal from the perceptron is fed back to the hidden layer of the perceptron.
- The system not only takes into account the new input but also remembers the value of the last element.
- Has been designed to be capable of handling long-term dependencies.

CONS

- In reality, RNN could not learn them very well even though the parameter was carefully selected by humans (vanishing gradient).
- The RNN upgrades the weight using the gradient algorithms which grow smaller when the network progresses down to the lower layer.
- The gradient remains constant and will learn nothing and affects the output of the network.

Recurrent Neural Network on Water Prediction

NARX

- NARX is also part of the RNN architecture family.
- NARX is a combination of an ANN and a self-regressive model with an exogenous (ARX) input, which is a statistical technique for time series analysis and modeling.
- NARX is an RNN type that modeled the process based on the lagged input-output variable.
- The input of NARX is fed by several delay units and the output is returned to the hidden layer through the delay units.

LSTM

- Capable of learning long-term dependencies that have been a problem with the basic RNN.
- Has the advantages of remembering information for a longer period of time
- Prevents back-propagated bugs from vanishing or exploding.
- Advantages of robustness when dealing with nonlinearity and large data that are suitable for time series prediction
- The long-term memory capability of the LSTM is suitable for processing, classifying, and making predictions based on time series data

Water Quality Prediction Using LSTM-RNN

Methods

- The LSTM is useful in handling large inputs of water quality prediction, which must be flexible due to changes in the flow of water, weather, and others (Alsumaiei, 2020).
- It also improves the capabilities of the conventional approach to the reliability and assessment of the water parameter.
- This is a tremendous advantage in resolving the poor adaptability and low efficiency of the traditional model (Y. Chen et al., 2019).
- Therefore, the use of LSTM is expected to provide an alternative to the water quality prediction method.

Water Quality Prediction Using LSTM-RNN

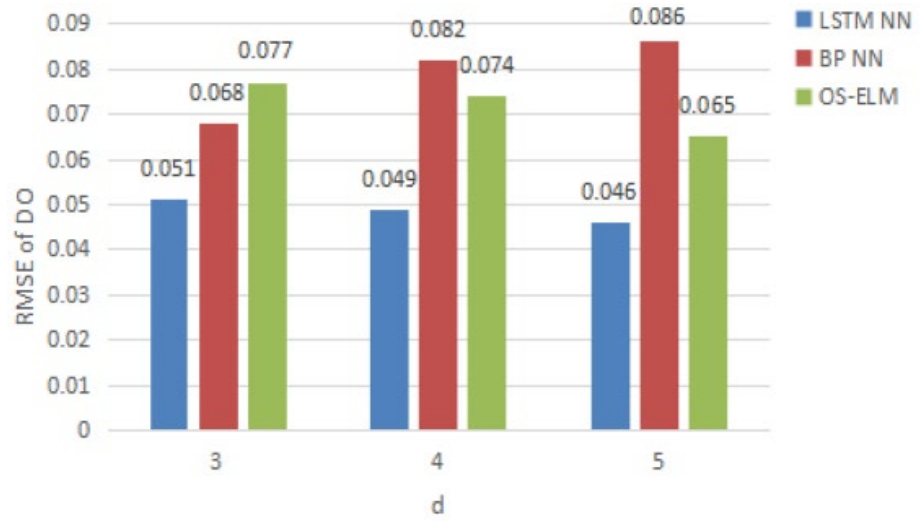
Zhuhua Hu et al. (Hu et al., 2019). Data were collected from the Mariculture Center in Xincun Town, Hainan Province, China.

Training Times	MAE				RMSE				MAPE			
	Temperature		pH		Temperature (°C)		pH		Temperature		pH	
	LSTM	RNN	LSTM	RNN	LSTM	RNN	LSTM	RNN	LSTM	RNN	LSTM	RNN
500	0.0421	0.0439	0.0042	0.0325	0.0519	0.5340	0.6236	1.0875	0.085	0.078	0.0092	0.0102
1000	0.0312	0.0424	0.0035	0.0052	0.0457	0.1451	0.3108	0.3254	0.052	0.065	0.0068	0.0073

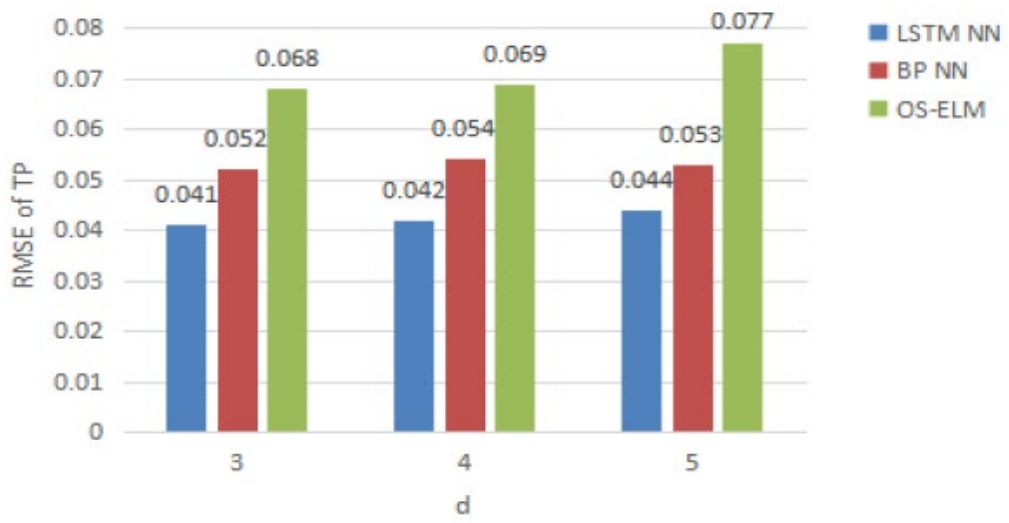
Records of MAE, RMSE, and MAPE for predicting pH and water temperature

Water Quality Prediction Using LSTM-RNN

Yuanyuan Wang et al. (Wang et al., 2017). Data were collected from Taihu Lake in China



(a)

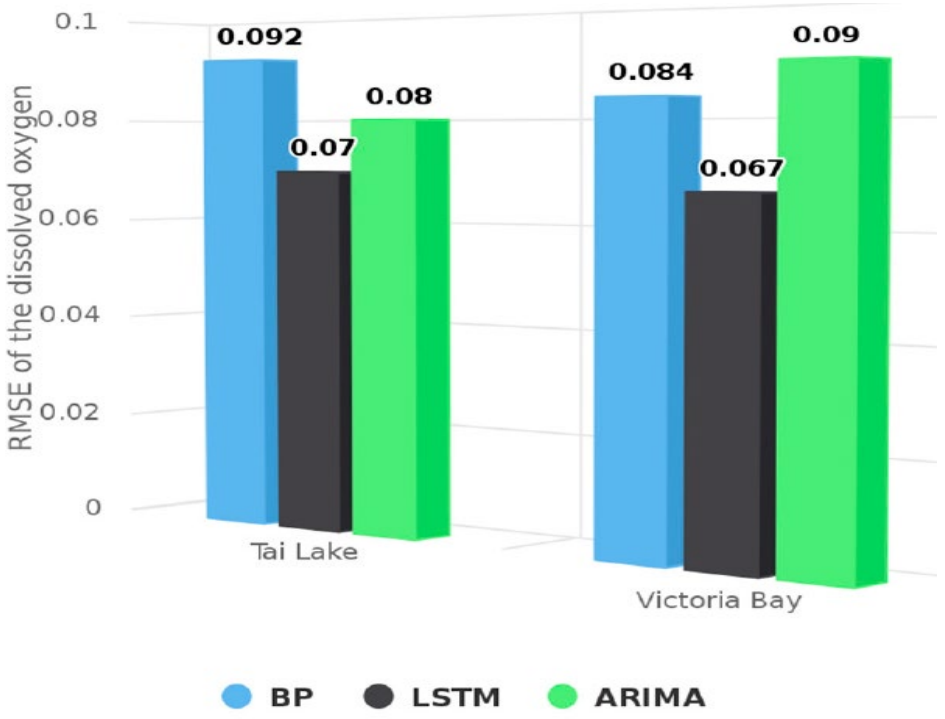


(b)

RMSE using three different time steps for (a) Dissolved Oxygen and (b) Total Phosphorus

Water Quality Prediction Using LSTM-RNN

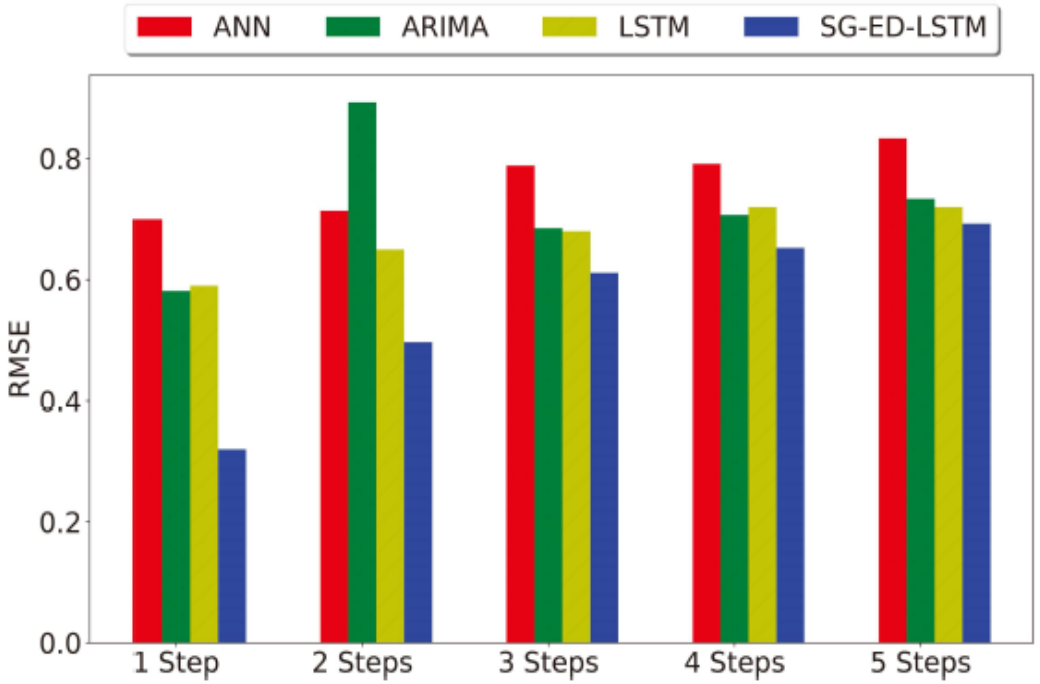
Jian Zhou et al. (Zhou et al., 2018). The data were collected from Tai Lake and Victoria Bay in China



Water quality prediction results of Tai Lake and Victoria Bay

Water Quality Prediction Using LSTM-RNN

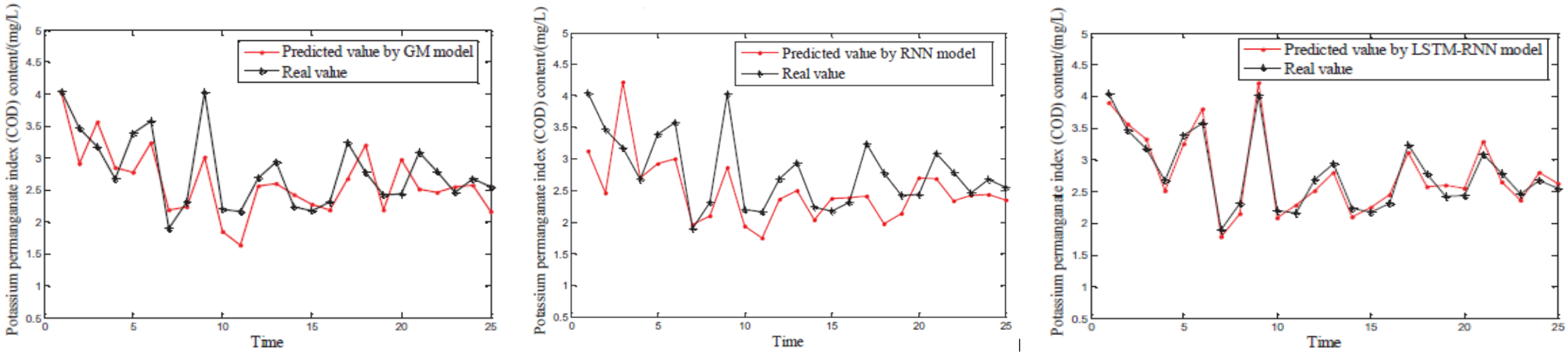
Quanxi Dong et al. (Dong et al., 2019). The data were collected from Gubeikou water area, Beijing



Total RMSE of the SG-ED-LSTM model and other models with the step size from 1 to 5

Water Quality Prediction Using LSTM-RNN

Qiangqiang Ye et al. (Ye et al., 2019). The data were collected from Shanghai River, China



The result of COD for (a) predicted using GM model (b) predicted using RNN model (c) predicted using RNN-LSTM model

Water Quality Prediction Using LSTM-RNN

Model	RMSE	MAPE
GM model	3.089	2.278
RNN model	3.758	2.159
LSTM-RNN model	1.174	0.594

Performance index for the prediction results (Ye et al., 2019)

Conclusion

- ANN is found to be useful in using a nonlinear quantity of water parameters to predict the water quality in resolving the water quality prediction problem.

- Can be concluded that basically all ANN architectures can be used to predict water quality with varying levels of efficiency and performance, including time taken.

- The LSTM-RNN based model proved to have the best performance and accuracy in the time series for predicting water quality.

THANK YOU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