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Efficient Distribution of Water using Machine Learning Techniques

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Abstract- Every country despite of having proper water distribution database is not utilizing it for the common good. Various water distribution corporations possess valuable data that if used in the proper methodologies can not only reduce human labor and increase efficiency but also be cost effective. Artificial Neural Networks (ANNs) have been brought into the scenario to accomplish the above maintained task. It has been found that there's plenty of scope of applying Machine Learning techniques in efficient water distribution. Delay in implementation of such methodologies are due to lack of in-depth knowledge about the techniques and lack of visualization. Continuous research has been going on in this field where different kinds of ANNs has been used for prediction of water flow in a WDS (Water Distribution System). Such readings can be further used to build an efficient WDS that will efficiently distribute water in every household. Time stamp prediction models are generally preferred for such approach as comparison of previous and current scenario is necessary for better future prediction.

Index Terms – ANN, machine learning, efficient water distribution, ultrasonic sensors, time stamp prediction, Doppler effect flow meter

1. INTRODUCTION

With increase in population in every major city in the world, the need for water for daily consumption has also increased. But due to constant water supply sources, the water distribution units are finding it difficult to efficiently distribute water i.e. distribute equal quantity of water. To cope up with this problem these water distribution authorities have allocated specific time slots to specific localities. As a result some place get hardly any water whereas the other area is getting plenty of water at a given time stamp. This system maybe providing water to the population but it is not efficient and a lot of water is wasted as well. To improve on this system, this paper proposes a system to efficiently distribute equal quantities of water at every time stamp and as per the requirements of the households. To develop on the existing system we need a to predict a better water distribution network. This network can be predicted only after a detailed case study of the topography of an area. This paper proposes the use of RNNs (Recurrence Neural Networks) for the prediction of a better WDS. These RNNs will help us to analyze datasets of a previous time stamp and datasets of current time stamps. A mathematical comparison will be done by the neural network using the BPT (Back Propagation Technique). We will also be discussing about the implementation of ultrasonic sensors such as Doppler Effect Flow Meter. These sensors will provide us with real-time data about the rate of flow of water and volume of water flowing. The development of an autonomous system will also be discussed that will allow us to divert the flow of water from one area to another.

2. CASE STUDY

Intensive case study was done to gather information about the water requirements of various households of a locality. The dataset gathered was for over a time period of 6 years. The dataset consists of water usage of both Domestic as well as Social. While doing the case study it was also kept in notice that the source of water supply has constant quantity of water. The second set of dataset that was gathered was that of the Doppler Effect Flow Meter.

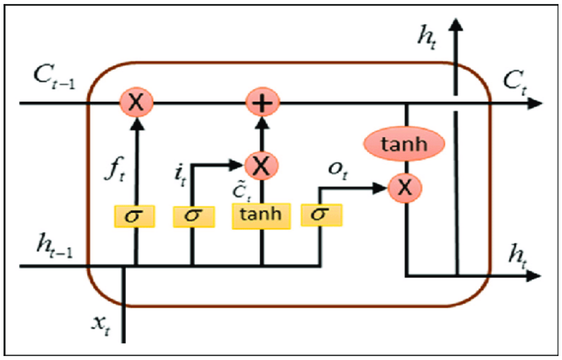
Nom. flow q_n [m³/h]	Nom. diameter [mm]	Meter factor [1] [imp./l]	Dynamic range $q_i:q_n$	$q_s:q_n$	Flow @125 Hz [2] (m³/h)	$\Delta p@q_n$ [bar]	Min. cut off [l/h]
0.6	DN15 & DN20	300	1:50 & 1:100	2:1	1.5	0.04	2
1.5	DN15 & DN20	100	1:50 & 1:100	2:1	4.5	0.22	3
2.5	DN20	60	1:50 & 1:100	2:1	7.5	0.03	5
3.5	DN25	50	1:50 & 1:100	2:1	9	0.07	7
6	DN25	25	1:50 & 1:100	2:1	18	0.2	12
10	DN40	15	1:50 & 1:100	2:1	30	0.06	20
15	DN50	10	1:50 & 1:100	2:1	45	0.14	30
25	DN65	6	1:50 & 1:100	2:1	75	0.06	50
40	DN80	5	1:50 & 1:100	2:1	90	0.05	80
60	DN100	2.5	1:50 & 1:100	2:1	180	0.03	120
100	DN100	1.5	1:50 & 1:100	2:1	300	0.07	200
100	DN125	1.5	1:50 & 1:100	2:1	300	0.1	200

Table 1 Dataset for Case Study

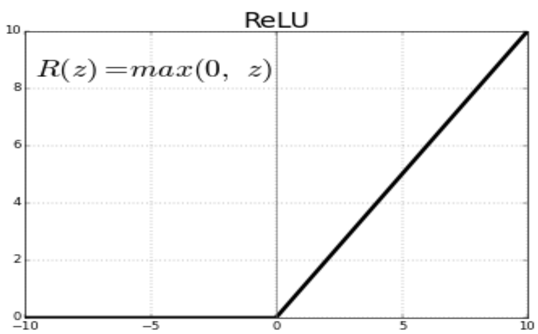
The above dataset shows the flow rate and the diameter of the pipeline, from which the volume of water flow can be calculated.

3. PORPOSED MODELLING

The methodology used in this paper is the LSTM network (Long Short term Memory). This network is a subset of RNN. LSTM was selected as the ideal approach because it can hold previous data for a long time. As a result when the feedback is sent and calculated a more accurate result is observed. Moreover LSTM lets us use the leaky ReLU (Rectified Linear Units) activation function. The leaky ReLU activation function prevents leakage of prediction margins. The general structure of an LSTM is given below.

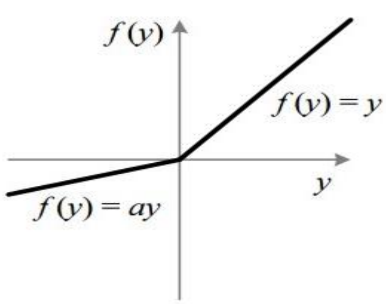


This is a generalized LSTM network which is using the tanh activation function.



This a graphica representation of a normal ReLU function. It can be seen that suddenly all the negative values are forced to become 0. This problem is kown as the dying problem of ReLU. Since all the negative values are forced to diverge to 0 we might not get a proper best fit line. The range of a ReLU activation function is 0 to infinity. Thus ReLU is a proper activation function for large values.

The LSTM network is selected over RNN network due to its advantge over vanishing gradient. In RNN networks due to repeatative multiplication of small numbers it takes a considerable amount of time to train. Whereas, in LSTM addidtive relationship between gradients is observed.



The above figure is of a leaky ReLU. Here, the negative values are considered as they are and we can obtain a proper best fit line. The value of a is usually 0.01.

4. RESULTS AND DISCUSSIONS

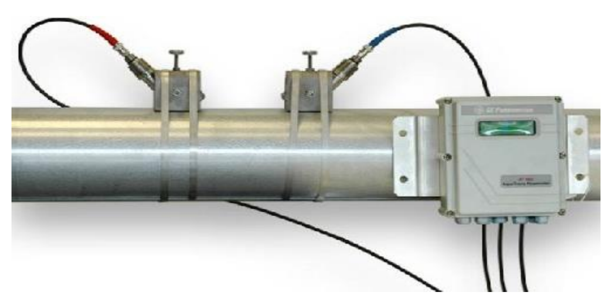
The above suggested LSTM network takes input at time stamps t-1 and t. The output of these two time stamps are y(t-1) and y(t) respectively. Both the time stamps will hold information of previous data. A comparison will be done using weights and biases. By changing the weights we can change the output for backpropagation. The results are backpropagated through different layers of the neural structure. Through numerous comparisons a prediction will be displayed that will be dependent on the parameters such as daily consumption of water usage, flow of water, excess water supply, scarcity of water supply, etc. The predicted output will inform us that how we need to distribute water among localitites i.e. how much water can be distributed to every household so that day to day chores of every house can be maintained properly. Since the data is being analysed it can also be used to detect which area is having shortage of water. We can use this information to divert some extra quantity of water from a neighbouring area to that particular area.

5. WATER FLOW SENSORS

To record real time water flow data we are using a Doppler Flow Meter. A pair of transcducers each having its own transmitter and reciever, are plsced on the pipe wall, one on the upstream and other on the downstream. The time for acoustic waves to travel from the upstream transducer to the downstream transducer is shorter than the time it requires for the same waves to travel from the downstream to the upstream. The larger the difference, the higher the flow velocity.

Features of the ultrasonic flowmeter used:

1. Design Pressure: 207 bars
2. Design Temperature: -180 Deg C to 260 Deg C
3. Sizes: 3 mm to 3000 mm
4. Fluids: clean gases, clean/corrosive liquids
5. Velocity range: 0.3 to 15 m/s
6. Range ability: 10:1 to 300:1
7. Upstream length/ Downstream straight length is 10/5
8. Bidirectional Flow measurement



6. OVERALL PHYSICAL ARCHITECTURE

The overall physical architecture stands till now is that of a deep learning technique known as LSTM that predicts the way water can be equally distributed among all households. The ultrasonic flow meteres will be attached to pipes that will give us real-time data. Through this data we will be able to learn that which area is having water scarcity. Once detected, water can be diverted from a nearby area by opening up valves that will be driven by motors.

7. CONCLUSION

We talked about the application of LSTM network in WDS. We also mentioned the application of leaky ReLU activation function in the neural network. The usage of ultrasonic flow meter will give us real time data that will increase the efficiency of the system. Since the entire system is based on observed data from the desired output is of great accuracy. It also reduces human effort and data is obtained at a very short notice. No major changes in the base foundation of th city pipelines is required as this process only focuses in distributing water through the existing pipelines. Excess of water loss can be reduced to a great extent as water will be delivered as per the needs of a household. This process is quite cost effective as the ultrasonic flow meters come at a very low cost.

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