MIDDLE POMERANIAN SCIENTIFIC SOCIETY OF THE ENVIRONMENT PROTECTION

Rocznik Ochrona Środowiska

Volume 22. Year 2020 ISSN 1506-218X 117-129

Internet of Things (IoT) and Artificial Neural Networks Towards Water Pollution Forecasting

Thaer Ibrahim[1,2], Alok Mishra[2,3]*

[1]Iraqi Federal Board of Supreme Audit, Baghdad, Iraq

[2]Atilim University, Ankara, Turkey

[3]Molde University College-Specialized University in Logistics, Norway

[*]corresponding author's e-mail: alok.mishra@atilim.edu.tr; alok.mishra@himolde.no

1. Introduction

The Tigris river originates from the Taurus mountains, the southeastern region of Anatolia in Turkey and passes through Syria 50 km from the outskirts of the city of Qamishli. The river contains a wide range of tributaries scattered in the lands of Turkey, Syria and Iraq, the most important of which are the Khabur, the Great Zab, the Small Zab, Al-Ethaim and Diyala. These tributaries contribute about two thirds of the river's total water volume. The other third comes from Turkey and takes the last tributary in the Tigris, the Diyala River south of Baghdad in a short distance. The Tigris branches further into two in the city of Kut, called Nahrgraf and Dujaila, respectively. The Tigris River meets the Euphrates River at Qurna in the south of Iraq, after which it passes through the territory of Iraq to Shatt al-Arab, finally flowing in the Arabian Gulf. The course of Tigris was changed and in the present times, it meets Euphrates in the area of Karma near Basra, so the length of the river is about 1,718 kilometers. It originates from Turkey and flows into Iraqi territory which is about 1,400 kilometers. Iraq's most fertile land is located in the region between Tigris and Euphrates rivers because of the irrigation water provided by them. In addition, most of Iraq's citizens lives in that region. Baghdad, the capital of Iraq and its largest city, is divided into two parts by Tigris river (FAO 2008) as shown on the map in Figure (1) (© Bible Study 2015).

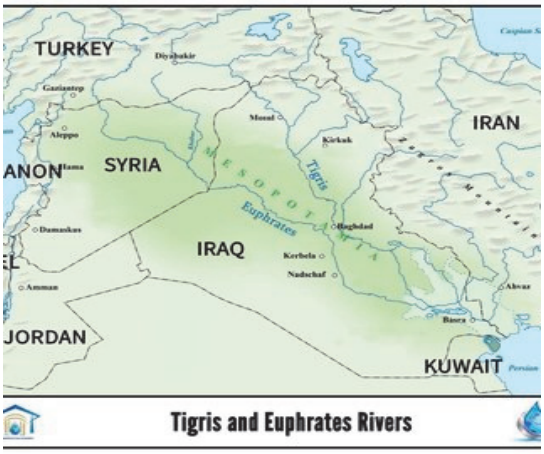

Fig. 1. The Tigris River on map

E-government refers to the use of Information and Communication Technology (ICT) in order to build an effective and efficient government to provide good services to citizens, as well as make these services available for citizens anywhere and at any time, on the other side, to make the governmental information accessible by public, finally to provide the citizens by the power to be a partner in all governmental decisions (Sarrayrih et al. 2015).

In order to make the definition of E-Government more clear, the word has been divided into two parts; the letter "E", which refers to the automation of government information and transactions, and government itself as an institution. E-government relies mainly on the services provided by ICT which has made communication between citizens and their government agents easier and faster. As a result, E-government has substantially reduced cases of bribery and administrative corruption in government institutions (Rajput et al. 2013). E-Government has four services channels which deliver the services from the government agency to the consumers. These are Government to Government (G2G), Government to Citizen (G2C), Government to Business (G2B), and Government to Employees (G2E) channels (Moon 2002).

The network of physical objects that contains of wireless sensors is called the Internet of Things (IoT), this network contains also actuators, Radio-Frequency Identification (RFID) tags, software, and connectivity to enable it to interact with people and other connected devices in achieving some common goals (Lopes et al. 2014). There is another definition for the Internet of Things (IOT), which is "IoT or smart object networking" which describes a situation whereby physical objects connected to the Internet are able to communicate with, and

identify themselves to, other devices (Thaler 2015). IoT has four types of communication models which are Device-to-Device Communications, Device-to-Cloud Communications, Device-to-Gateway, and Back-End Data-Sharing model (Internet society 2015).

Artificial Neural Network (ANN) is a network that has the ability to perform functions in a similar way to the functioning of the human brain if the problem is defined precisely. because the Artificial Neural Network (ANN) was inspired by the retinal system of the human brain. However, this system is sometimes not as accurate as in the human brain and attempts are still being made to obtain an artificial intelligence system with a similar problem solving capacity as our brains. Despite the variety of functions performed by ANNs, their structure is the same. The network consists of three layers, namely the input layer, hidden layer, and the output layer (Ostad Ali Askari et al. 2017). The type of problem determines the number of neurons in the input layer because this layer is an independent variable whose sole function is to receive the data. The hidden layer is the result of calculations performed within the network. The number of neurons constituting the output layer depends on the number of dependent variables in the network, therefore, the output layer represents the dependent variable (Keskin et al. 2015).

Water bodies, especially rivers and lakes are more susceptible to pollution than other water sources due to their direct contact with various human activities. The agricultural sector is one of the most water-consuming sectors, thus its wastewater volume is by necessity larger. Its pollutants contain not only salts dissolved in the soil, but also chemicals used in fertilizers and pesticides. Wastewater from the industrial sector also leaks into the riverbeds and because of its high toxicity, it causes serious health problems among humans. Water bodies are also affected by emissions from large plants that use fossil fuels as their source of power. These pollutants contribute indirectly to water pollution through their interaction with the rainwater, causing precipitation of acid rain that harms the physical and chemical characteristics of the water bodies, especially the lakes due to their weak water replenishment capacity, and as a result, reduced ability to self-purify (Alrobaiee 2014).

Pollution rates are calculated in the water bodies by calculating the values of the Biochemical Oxygen Demand (BOD) divided by Chemical Oxygen Demand (COD). If the values of the first are higher than those of the second, the water of the stream is polluted and unfit for human use, and often has unpleasant smell, color and taste. Water is free of pollution if the dissolved oxygen values range from 5-10 mg/l, depending on seasons of the year because of the variations in environmental temperatures (Northeast Georgia Regional Development Center 1998).

The impacts of natural disasters such as earthquakes, floods and volcanoes, and their effects such as air, water and soil pollution are considered life-threatening hazards on the Earth's surface. It is therefore essential to look for highly-sophisticated, practical and rapid methods to fill the many gaps in our lack of understanding on the changing nature of these disasters. These advanced methods can provide feasible ideal solutions for the scientific and practical analysis of the causes and transformations of these disasters before, during and after their occurrence, in order to understand their impact, dimensions and find better control and contain their effects. The best solutions for monitoring and mitigating disasters include the creation of an effective early warning system covering the geographical area of the disaster by providing the necessary information at the maximum speed, facilitating communications and movement processes, and providing accurate, real time monitoring of the changing circumstances in order to be up to date with all changes so as to contain its impact as best as possible (Saleh 2013).

2. Literature review

As we mentioned previously, the main objective of E-Government is to deliver high-quality services from the government to consumers (Nordfors et al. 2016). In the first generation of E-Government project, the consumers had to ask for the type of service they wanted and had to visit each E-Government agency website to get the service as well. Only after that, the government agency would provide them with the necessary services (Ibrahim 2014). Later, the service provision style has changed to what is called as the E-Government One-Stop-Shop, where the consumer can finish all the operations by using one government portal with a unique user name and password (Mustofa 2013). This type of service provision is called Reactive Services where the consumer has to ask for the service in order to get it. The next service provision style become known as the E-Government Zero-Stop-Shop. In this style, the government agency provides the service without any request on the consumer side by simply analyzing the consumer's profile as well as their social media information and predict the type of service needed, and then deliver the service at necessary time (Ayachi et al. 2015). One of the most important services provides by the governments to their citizens is security, whose aim is to preserve the life and property of citizens from damage whether it is due to human or the surrounding environment (Anthopoulos & Reddick 2016).

The risk of pollution is one of the most dangerous phenomena to the citizens' lives and property, therefore reason the government has to monitor this risk and try to find ways to protect its subjects by early detection and interference to control and minimize the damage caused by it (Mahmoud 2001). For effective

monitoring of aquatic environment, the remote sensing system can be used very effectively. This system is mainly composed of a Wireless Sensor Network (WSN), Cloud Computing, and Big Data in addition to many types of communication methods for data transfer (Maojing 2016). The cooperation of these technologies will produce reliable and useful data, which can helps the decision makers to take the right decision at the right time to keep citizens safe. The use of ICT in water environment monitoring has contributed significantly to reducing the risk of pollution and flooding (Wang & Tingtng 2015). In addition, it can be considered as one of the services provided by the E-Government to the citizen since government use ICT technology to provide security service to citizens. There are many types of water pollution parameters, however, those that have the most significant impact on the aquatic environment are seven (Al-Rubaiee 2014), and each one of them has its own acceptable ranges and influence in pollution.

2.1. Temperature

Air temperature, in addition to some other atmospheric elements such as sunlight, runoff speed, geographical location, the presence of groundwater, the proportion of rainfall and the proportion of the presence of aquatic plants and algae in the aquatic environment, directly effects the temperature of the aquatic environment. The ideal temperature for the aquatic environment is between 9-12°C. As the water temperature exceeds 12°C degrees drops below 9°C, the life of plants and aquatic animals gets shorter (Kale 2016).

2.2. PH

PH defined as the amount of acidity in water where some of the water molecules (H_2O) separated by the formation of positive hydrogen (H^+) and negative hydroxide (OH-) ions. Some other compounds may interact with these two ions, leading to an imbalance in the number of hydrogen and hydroxide ions in the solution. When the concentration of hydrogen ions is less, the dissolved hydroxide ions are left unpaired and then the water becomes basic. In contrast, when the concentration of hydroxide ions is less, hydrogen ions are left unpaired and the water becomes acidic. The acidity of the solution measured by counting the concentration of hydrogen ions and converting it into logarithmic scale of base 10 (Signs 2010).

2.3. Turbidity

Turbidity is the measurement of the visibility of water and it is calculated by measuring the amount of sediment and the degree of its impact on water. Rainfall leads to a significant increase in turbidity due to high amount of sediment in river water. High turbidity causes high water temperature low oxygen in addition to blocking sunlight from aquatic plants, which leads to reducing the ability of

these plants to complete photosynthesis. In addition, increasing turbidity will harm the fishes and their eggs. The minimum boundary of turbidity is between 3 NTU, and the maximum boundary is 30 NTU (Mc Caffrey 2010).

2.4. Conductivity

Conductivity is defined as the ability of water or other liquids to transmit electrical current. It is a measure of the concentration of electrolytes in water. Conductivity does not mean identifying certain types of ions in water and increased water ability to conduct electricity conductivity is an indicator of the increased amount of pollutants in water (Ramos et al. 2005).

2.5. Dissolved oxygen

Oxygen is one of the two components of water molecule, but it is also found in the dissolved form as gas (O_2). Fishes and plants living underwater require dissolved oxygen for their breathing process. There are two sources of supplying the aquatic environment with oxygen; that of the surrounding aquatic environment, and the oxygen produced by photosynthesis of aquatic plants. The higher the percentage of dissolved oxygen in water, the healthier the aquatic environment (Enderlein et al. 1990).

2.6. Total Dissolved Solids (TDS)

Solids dissolved in water are any substances other than water itself found in the aquatic environment that cannot seen by the naked eye. These include salts, minerals and water pollutants. Pure water is the water in which the concentration of solids is low. It is well-established that a small percentage of solids dissolved in water is beneficial for animals and plants living in the aquatic environment. However, the presence of large quantities of solids dissolved in water leads to damage to plants and animals living in the aquatic environment. Therefore, monitoring the proportion of solids dissolved in water on a continuous basis is very important. The maximum boundary of acceptable solid concentration is 1000 mg/l (WHO 1996).

2.7. Chlorophyll

Chlorophyll is the proportion of algae that grows in the aquatic environment. It is considered as one of the components of the fresh water system, but the presence of large amounts of algae leads to problems in the aquatic environment because they consume large amounts of dissolved oxygen in water. In addition, some types of algae produce toxic substances that affect the health of water inhabitants when they are in large quantities (Lailia et al. 2015).

3. Methodology

3.1. Data collection

In order to collect the historical data related to water pollution in Tigris river, Iraqi Environment and the Water Resources ministries were visited to conduct interviews with the employees who are experts in river water pollution and collect information related to water pollution of the river. In the Environment Ministry, there is a program called Remote Sensing Project (RSP) for detecting water pollution in Tigris River by using electronic sensors. The system consists of sensors which are installed directly on the waterway of the Tigris River and distributed on various locations along the route. These sensors can sense seven parameters to determine water quality, namely PH, Turbidity, Conductivity, Dissolved Oxygen, Total Dissolved Solids, Chlorophyll, and Water Temperature. In addition, these sensors can conduct a quality test every 15 minutes and send all the collected data to a central database using Global System for Mobile communications (GSM).

The data are then stored in a database in the form of Microsoft Excel sheets for later analysis. Unfortunately, this project was stopped after two years because of misuse. The sensors collected 85000 records for each of the seven parameters mentioned above during that period. After the remote sensing project was stopped, the Environment Ministry returned back to the traditional way of collecting samples once in 15 days. The manager of the project was contacted and the data from for the period of two years were collected, making a total number of 85000 reads for each of the seven parameters mentioned before.

3.2. Data normalization

The huge number of data points as well as the different measurement units of each one of pollution parameters makes the use of this data very difficult. Therefore, we tried to normalize the data in a different way. First of all, MS Excel was used to mark each one of parameter as Polluted or Not polluted depending on the pollution ranges for each one of parameters, as shown on the tables above. After that, a final result parameter was created and marked as "1" for polluted if there was at least one parameter outside the normal ranges, or "0" if all pollution parameters were within the accepted pollution boundaries. This classification was used to prepare the data for statistical analysis in Statistical Package for the Social Sciences (SPSS) software, version (18.0).

3.3. Pollution parameters correlation

In order to measure the effect of each of the pollution parameters on other parameter, correlation analysis between them was performed using the parametric

Pearson test on SPSS. These correlations showed the results presented on Table 2.

Table 2. The correlation between pollution parameters

1st parameter	2nd parameter	Pearson Correlation	R	R Square
CHLORO	DO	-.288	.288	0.83
CHLORO	COND	-.047	.047	.002
CHLORO	TDS	-.047	-.047	.002
COND	DO	.383	.383	.147
COND	PH	.172	.172	.030
COND	TDS	1.000	1.000	1.000
COND	TEMP	-.227	-.227	.051
COND	TUR	-.117	-.117	.014
PH	CHLORO	.059	.059	.003
PH	DO	.468	.468	.219
PH	TUR	-.166	-.166	.028
TDS	DO	.383	.383	.147
TDS	PH	.172	.172	.030
TDS	TUR	-.117	-.117	.014
TEMP	CHLORO	.290	.290	.084
TEMP	COND	-.227	-.227	.051
TEMP	DO	-.883	-.883	.780
TEMP	PH	-.255	-.255	.065
TEMP	TDS	-.227	-.227	.051
TEMP	TUR	.418	.418	.175
TUR	CHLORO	.206	.206	.043
TUR	DO	-.386	-.386	.149

- CHLORO refers to the Chlorophyll.
- COND refers to the Conductivity.
- PH refers to the amount of acidity in water.
- TDS refers to the Total Dissolved Solids.
- DO refers to the Dissolved Oxygen.
- TEMP refers to the Temperature.
- TUR refers to the Turbidity.
- R represents the Coefficient of correlation between parameters.
- R Square is used to know the Contrast Ratio of the dependent variable to predict the changes in the independent variable.
- Negative sign means an inverse relationship between parameters.

- Positive sign means a positive relationship between parameters.

It can be noted from the table that the strongest correlation is between COND (Conductivity) and TDS (Total Dissolved Solids), with very strong positive correlation values.

3.4. Water pollution prediction

The analysis was carried out in MATLAB© where an artificial neural network (ANN) was built for that purpose. In order to get the optimal type of ANN, Machine learning (ML) needs to undergo a series of trials and errors. Therefore, the network was trained for 150 times, and for each trial, one of the prediction functions, number of nodes, or number of hidden layers were changed until optimal results were obtained.

The Feed Forward Back Propagation network was used in the training. Backpropagation is an algorithm used for training and it contains of two steps; the first step is the feed forward of values to the next step, which calculates error and propagates it back to the previous layers. The training network consist of an input layer of 90 neurons, also there is one hidden layer, then the output layer. For training, 1000 epochs are used, which undergo 13 iterations. Many good results with low error rate were obtained during the network training, but the two best ones are shown on Table 3.

Table 3. Network Training Results

	Network 1	Network 2
Network Type	FEED.FW.BP	FEED.FW.BP
No. of layers	1	1
Performance function L1	MSEREG	MSEREG
No. of Neuron L1	90	90
Transfer function L1	PURLIN	PURLIN
Adoption function	GDM	GDM
Train function	LM	LM
Input Parameter	COND	TEMP
Output	POLUTED	POLUTED
Epochs	1000	1000
Iteration	13	16
Error Rate	1.58E-08	2.40E-08

4. Discussion

Water pollution is one of the human disasters. It can be caused either by nature or by human activities (Ibrahim et al. 2019). In the field of flooding and aquatic monitoring, (Shalini et al. 2016) devised a system to measure the level of water in the river. This system uses special sensors to measure water levels as the distance from the bottom of the river and send the data to the monitoring center using Wi-Fi technology, which then sends the information via smartphones using GSM technology to the decision-makers. The system provides forecasting using the Internet of Things, GSM and SMS.

In this research, after historical data obtained from a project to detect water pollution that was established on the banks of the Tigris River in the city of Baghdad in Iraq, seven types of water pollutants were identified, these parameters are (Temperature, PH, Turbidity, Conductivity, Dissolved Oxygen, Total Dissolved Solids, and Chlorophyll). Nghe et al. (2020) tried to forecast water quality by using (IoT). However, they use only four types of water pollution parameters (Salinity, PH, DO, Temperature). Ullo et al. (2020) found the relationships between elements of water pollution in order to understand the nature of the life of the aquatic environment.

The statistical analysis of the data was done using the statistical analysis program (SPSS) as shown in Table 2, the analysis results were as below:

1. Water temperature has an effect on all other pollution elements as discussed in (Boehm 2019).
2. The strongest correlation between pollution elements was (Conductivity) and (Total Dissolved Solids) by 100% correlation, which agrees with (Dennis et al. 2019).
3. The weakest correlation between pollution elements was between (Chlorophyll) and (Conductivity) and between (Chlorophyll) and (Total Dissolved Solids).

5. Conclusion

Prediction of water pollution is an important service that is provided by the government to consumers. The use of Information and Communication Technology (ICT) makes this service part of E-government services by predicting and alerting the consumers in order to reduce the damage caused by pollution or other natural disasters. Applying these services on prediction of water pollution will save a lot of time, besides budget and efforts on the side of the government in addition to people's lives and property. In this study, we tried to use Artificial Neural Networks (ANN) and Machine Learning (ML) for water pollution prediction. We used historical data from sensors installed on the Tigris River, which

generated huge amount of data as the measurements were made every 15 minutes, producing a total of 85000 measurements for each of the seven pollution parameters. The data were normalized in order to be used as input for the neural networks, which were trained to get the lowest error rate for reliable predictions.

6. Limitations and future work

Despite the amount and breadth of data that were used, there are a number of limitation of this study; the data used for analysis were somehow old because of the project of pollution sensing in Baghdad was stopped several years ago due to the misuse of devices and lack of maintenance of the system. Another important limitation is the use of old versions of the software because the new versions are under license, and therefore require investment. Future work should be focused on utilizing more recent data as well as new generation sensors to measure water pollution parameters in order to get more accurate data, and therefore better results in prediction of water pollution.

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Abstract

Water could be some-times a source of danger on people's lives and property. Although it is one of the most important elements of life on this planet. This article define the threat of water pollution in Tigris River in Iraq. by collecting a data that generated by sensors that installed in a water pollution sensing project in Baghdad city, also this article aimed to detect and analyze the behavior of water environment. It is an effort to predict the threat of pollution by using advanced scientific methods like the technology of Internet of Things (IoT) and Machine learning in order to avoid the threat and/or minimize the possible damages. This can be used as a proactive service provided by E-governments towards their own citizens.

Keywords:
Internet of Things, E-government, Water Pollution prediction, Tigris River,
Artificial Neural Network