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Real-time Water Level Monitoring System in Oriental Mindoro Using Neural Networks

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Abstract: Oriental Mindoro faced an environmental problem that was caused by the massive rains from the highlands of the city. The lowlands cannot prepare for the upcoming floods with manual prediction and based on instinct. A water monitoring level was setup in three different rivers that end the streams in the city of Oriental Mindoro. This study focuses on the development of a real-time water level monitoring system to help with disaster preparedness in Oriental Mindoro. The dataset collected was from the provincial government, which shows the diversity of data that can be correlated to predict if a flash flood will occur. The dataset was tested using different algorithms such as Gradient Boosted Tree, SVM, Decision Tree, and Neural Networks. The prediction of the Neural Network model's accuracy is 98.61%, which is 0.6 percentage points higher than the Gradient Boosted Tree and more than the rest of the algorithms.

Keywords: Flood Monitoring, Neural Network, Monitoring system, Disaster Prevention, Water Level

1. Introduction

Flooding is one of the most serious issues facing the regions of Oriental Mindoro [1]. It is a periodic disaster that affects the entire province, both rural and urban, killing people and causing major damage to agricultural output, infrastructure, and local economic development [2][3]. Unpredictable heavy local rains and typhoons are also concerns. Calapan, Victoria, and Naujan are the flooding capitals of Oriental Mindoro, with an average rainfall of 306.6 mm in October and an average of 156 rainy days per year that exceed 1mm [4]. The cities are also classified as having a type III climate [5], where seasons are not very distinct, with relatively dry weather from November to April and wet weather the rest of the year [6].

Under prolonged rainfall, nearly all rivers and branches overflow into lower places, causing flooding and property damage, and large areas of land can erode at times [7]. Numerous rivers and streams cut

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through the vast plain along the lowlands for the demographic alignment of the city. A minimum of 8 to 9 tropical cycles (TC) enter the province every year, which is 45% for the Philippines and 11% globally [8]. The peak of TC forms in the months of June to November, where it is considered the wet season in the Philippines [9]. The combination of cloudiness, humidity, and rainfall are the main factors in TC, which forms in the later part of the Pacific Ocean [10]. Tropical relates to the geographical location [11] of the formation above the tropical seas, where the cyclone is the movement of the wind in neither direction, formulating an eye of the storm that may lead towards the colder temperature [12]. A rate of 7% increase in degrees Celsius due to global warming also increased 1.3% in tropical cyclone rainfall rates per year, and the total increase of 3% is projected for stronger winds from tropical storms and hurricanes [13].

Furthermore, the time difference between issuing notifications via local broadcasting and Short Messaging Service (SMS) notifications via the National Disaster Risk Reduction and Management Council (NDRRMC) had been an issue due to signal traffic [14]. The time interval of a SMS blast is 200ms, and each batch would contain 100 subscribers. This technology is used to notify customers or consumers about an emergency alert or a special notification from the sender. However, there are time ranges for sending SMS in the Philippines that are considered non-congestive. There are three best times to send SMS to people. The first is at 12:00 noon. This is considered to be one of the most popular times to send SMS, but with the use of social media messengers, the congestion at this time has been cleared. The second is 2:00 pm, when everybody is busy at work and the congestion in the network goes away. And lastly, between 6:00 pm to 8:00 pm, when everybody is concerned about going home, probably in public or private vehicles stuck in traffic jams [15].

The map (*i.e.*, Department of Science and Technology (DOST) Project NOAH) is disseminated for the public's interest in the DOST AO 003 series of 2015 on the implementation of the DOST's Data Sharing Policy [16]. It depicts locations with high flood hazards [17], which justify the risk of flooding in Oriental Mindoro municipalities and barangays. While the province suffers the aftershock of flash floods, the Provincial Disaster Risk and Reduction Management Office (PDRRMO) and the Municipal Disaster Risk and Reduction Management Office (MDRRMO) are doing rescue operations, retrieval, constituent relocation, and providing food and water supply for the victims. Hence, the Department of Agriculture (DA) provides subsidies to farmers and fishermen who have lost their products due to calamities. Furthermore, cooperatives launch calamity loans for individuals who like to avail themselves of reconstruction or reinvestment in their lands and fish pens. The agencies governing the country have different programs to help their constituents and restore the wellbeing of the nation.

However, this can be avoided by using early warning equipment such as the Marikina River Water Level Monitoring and the La Mesa Dam, which measure the level of water using ultrasonic sensors and web-based flood monitoring [18] to save lives in the city. With the current technology, the situation is capable of predicting the actual flood perspective that would reach the city. The study will focus on three rivers that cause flash floods in the lowlands of Oriental Mindoro: the Ibulo River, the Aglubang River, and the watershed Mag-asawang Tubig River. Each piece of equipment will calculate the water level and the increase in water level per minute for different critical water levels. These parameters will help determine the likelihood of flash floods in the aforementioned cities. Furthermore, this early warning system can send SMS notifications to the municipality, and the forecast is delivered through the use of a cloud-based platform that is easily accessible via the Internet with SMS Blast.

The study will benefit not only the community but also the agencies of the government that provide solutions. This would also provide information on the current situation in each particular river and the time it would take to hit the affected areas. Each minute of measurement of water height level monitoring by rPi analysis, which automatically transferred the information to the server to have preliminary data served on the server. The monitoring and estimation of flash floods will be based on different parameters. The first is the increase in water levels in the river. The second is the time interval of the increase in water. The third is the density of the water level. Fourth is the consistency of the water level to maintain the depth. And lastly, the tidal range, where the estimation of the low tide and the high tide.

2. Methodology

To produce an interactive Cloud-based system with water level detection, the researcher used a Rapid Application Development (RAD) methodology. This approach is considered to be a fast phase development of a study that consists of Requirements Planning, User Design, Construction, and Cutover.

2.1 Requirements Planning

Data for the study were gathered through interviews, research, the internet, and questionnaires. The researcher visited many municipalities, agencies, and workplaces in flood-prone areas. This proposed system was designed specifically to address several concerns, including the respondents' level of awareness of the presence of various tools to facilitate consciousness regarding the early warning system, as well as their perceived level of acceptance of the proposed website in terms of functionality, reliability, efficiency, usability, and availability. This is defined as the evaluated work plan for the concept study.

2.2 User Design

This study is divided into two parts: hardware and software. Prototyping accessories include a breadboard, an array of resistors, light emitting diodes (LEDs) for a Raspberry Pi (rPi) device, and an ultrasonic sensor.

Globe Labs API is a Globe Telecom Inc. application developed by Globe Labs. It is a developer tool that allows them to link their software applications with the Globe platform for calls, SMS, open authentication, charging, and location sensing.

Globe Labs API becomes the intermediary software program that may send and receive information by text message with the SMS API. Globe Labs are currently available for Globe and Smart sim cards.

Upon registration, the SMS subscriber receives access tokens from the Globe Labs API. This access token serves as the authentication protocol for both the Globe Labs API and the application, in this case, the BahaAlert data. Without the token, neither the BahaAlert server nor the subscribers will be able to use the Globe Labs API.

By default, the Globe Labs API runs on a Node.js server using Python scripts. Globe Labs provided the proponent with free credits (*i.e.*, a total of 1000 credits, consisting of 2000 points for outgoing SMS and 13,000 points for incoming SMS) to do API testing alongside the BahaAlert application. During the account creation process, a total of 13,000 incoming SMS messages are permitted. With the SMS blast technology, the time interval of all the registered users can be sent in 30 minutes. Thus, the notification alert can be changed to a rapid sending of information.

2.3 Construction

The dataset was cleaned using Rapidminer 9.10 software, as shown in the Figure 1.

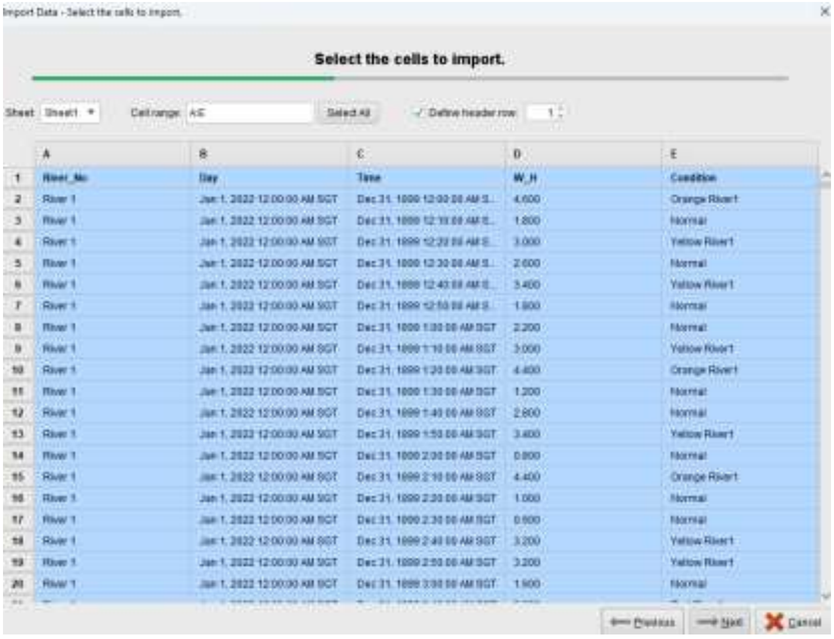

Figure 1. Data Cleaning Process

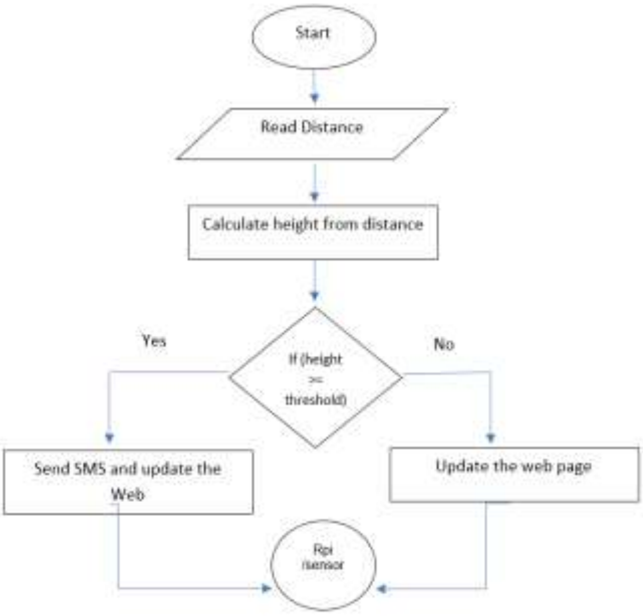

Figure 2. Procedures in the Flow of the System

The system that is embedded in the web server sends an SMS notification to the concerned stakeholders and uploads an update post to the developed web-based monitoring system. After the development of the prototype, the model underwent several tests and experiments to check the effectiveness of the system. Figure 2 shows that the ultrasonic sensor senses the water level of the flood on the river and uses the Raspberry Pi device as a means of communication protocol between the device and web server. The three rivers would merge the data, which may be suitable for predicting the flood that may occur in the lowlands of Oriental Mindoro. With the several parameters to be considered, the actual dataset that was gathered can be the basis for merging and evaluating the probability of flooding. As La Niña approaches, a more critical situation must be monitored.

The distance from the water and the ultrasonic sensor will be calculated if they reach the critical level for each river. When the level of the water reaches the threshold, it will send an SMS notification and update the server's database; hence, it will still update the database, as depicted in Figure 3.

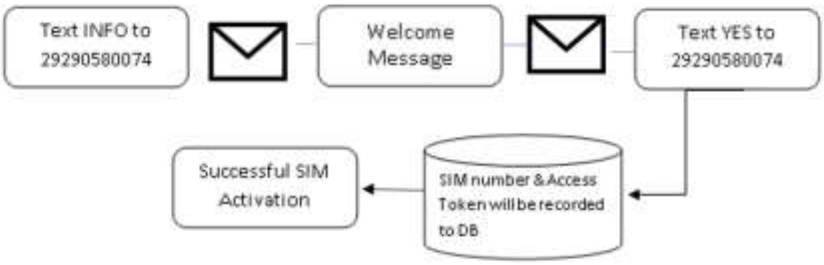

Figure 3. SMS-based Authentication and Subscription Process for Unit Subscribers Workflow

Each user in the area must register with the system to receive notification. Moreover, the MDRRMO and the PDRRMO are considering implementing the study. This will send SMS notifications to nearby communities for free.

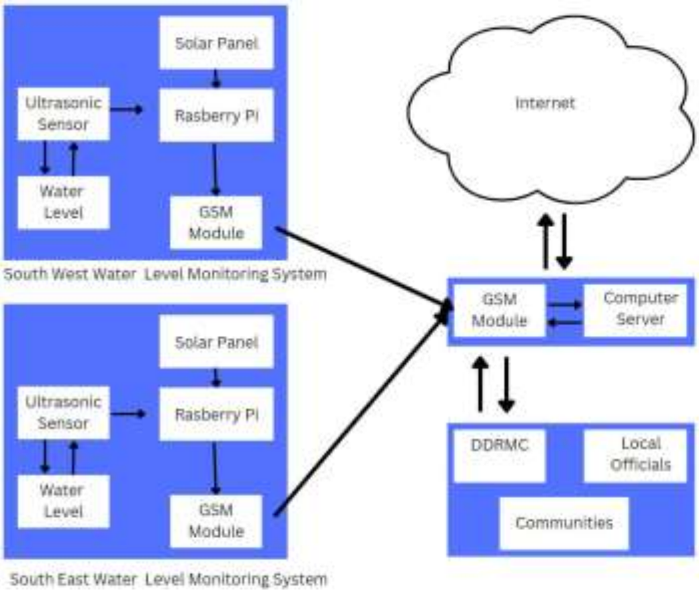

Figure 4. System Architecture

Figure 4 depicts the system architecture of the prototype. The devices from different rivers are connected to the main server as it transmits information every 5 minutes when there is consistency of data and every minute when there are irregularities so that the responses can be interactive in the web portal.

Several algorithms were tested on the dataset provided by the MDRRMO, such as SVM, decision trees, gradient booster trees, and neural network frameworks, to predict the output of the condition of the river [19]. The standard of comparison will depend on the best algorithm that fits the dataset [20]. Figure 5 depicts the process of neural network in Rapidminer software.

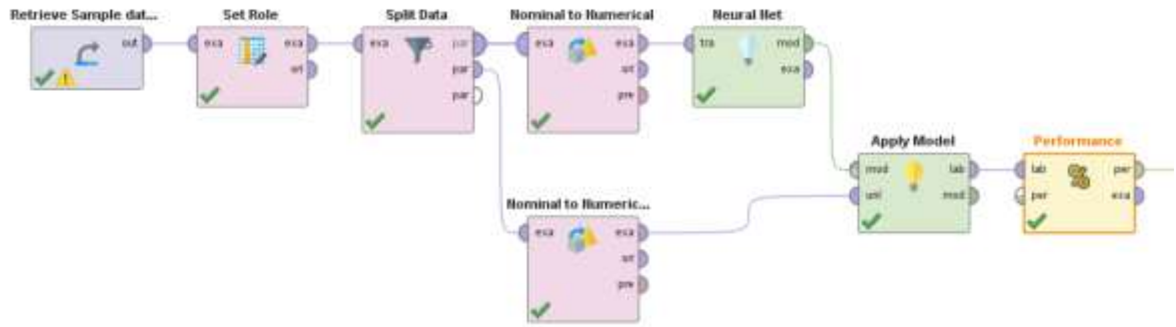

Figure 5. The Process of Neural Network in Rapidminer

2.4 Cutover

The system testing is driven by the validation, verification, and testing plan and is performed against the system, data, and technical requirements to guarantee the system is constructed to specification. System testing should also be performed in relation to the user requirements to guarantee that the system is operationally satisfactory. Prior to a larger-scale execution, the prototype or pilot concept allows for tweaks or alterations depending on user feedback. This phase's main outcome is design validation prior to full commitment.

2.5 System Evaluation

The system is evaluated using ISO 25010, where its main objective is to evaluate the system's performance using different criteria: maintainability, modularity, reusability, analyzability, modifiability, and testability.

3. Results and Discussion

After implementing the prototype in the different rivers of Oriental Mindoro, an assessment from the stakeholders – NDRRMC and the administrators – evaluated the study, which indicates the system's maintainability as scored by the fifty (50) participants in the survey. Modularity, Reusability, Analyzability, Modifiability, and Testability were rated as excellent by the vast majority of respondents. With an overall mean of 4.90, maintainability was deemed outstanding as shown in Table 1.

Table 1. Summary of Evaluation

Criteria	Rating (N = 50)					Mean
	5	4	3	2	1	
Maintainability						
Modularity	42	8	0	0	0	4.84
Reusability	42	8	0	0	0	4.84
Analyzability	44	5	1	0	0	4.90
Modifiability	43	7	0	0	0	4.90
Testability	43	7	0	0	0	4.90
Overall Mean						4.90

Table 2 shows that for the class prediction of the different predicted conditions using Neural Networks, the results on the predicted orange level on River 1, were 88.57%; the rest of the predicted condition showed a tremendous accuracy level that resulted in 98.61 percentage points.

Table 2. Result of Confusion Matrix Using Neural Network

Condition	Class Prediction
pred. Orange River1	88.57%
pred. Normal	100.00%
pred. Yellow River1	100.00%
pred. Red River1	100.00%
pred. Orange River2	100.00%
pred. Red River2	100.00%
pred. Yellow River2	100.00%
pred. Yellow River3	100.00%
pred. Orange River3	94.37%
pred. Red River3	92.31%
Accuracy	98.61%

After comparing the different algorithms found in Table 3, the neural network showed the highest accuracy for the dataset. It outperformed other algorithms by 0.6 percentage points over Gradient Boosted Tree.

Table 3. Comparison of Algorithms

Algorithms	Accuracy
SVM	95.05%
Gradient Boosted Tree	98.01%
Decision Tree	97.42%
Neural Network	98.61%

Furthermore, the study also established the importance of communication for emergency response, where the residents of the lowlands can be notified using SMS from the system.

4. Conclusion

This study implies the effectiveness and acceptance of the proposed Real-time Water Level Monitoring System for its fast and reliable results. Furthermore, using the neural network in the proposed system added strong verification through the classification of different water levels in the three major rivers in Occidental Mindoro. The study was also tested in the PDRRMO and the MDRRMO as one of the major beneficiary agencies and resulted in a 4.90 overall mean using the ISO 25010 evaluation tool.

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