Development of Real-Time Water Level Monitoring System for Flood Mitigation and Prediction Using Wireless Network Sensors

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Real Time Water Level Monitoring System with Wireless Network Sensors for Flood was developed to help the population on flood prone areas especially for those who live nearby by the riverbank to make early preparation before the flooding. In the system, sensors and software will be developed for measuring the fluctuation of water level. The measurement will be collected for a period to measure the water level according to nodes, and the data will be analyzed to visualizes the fluctuation according to the nodes alongside the riverbank. The system will be receiving the data from the sensors through Global System for Mobile communication (GSM). Data collected will automatically be stored into the database. The data will be used to analyze the pattern of water level fluctuation. This analysis may be helpful in prediction of future flooding.

Keywords: Flood Monitoring, Flood Prediction, Real-time Flood Sensors.

1. INTRODUCTION

Taken place nearly every year during monsoon season, flood, a regular natural disaster in Malaysia, causing devastation on life and properties [1]. Residential premises, bridges, roads, crops, automobiles and other facilities suffered through water damages. This phenomenon hence required the government to put a lot of cost and effort for reconstruction due to the devastation. Although the authorities have acted to solve this circumstances, the rate of devastation is hardly reduced due to the unpredictability of such disaster and accessibility to information that can help decision-making in counter-measuring such disaster before, during and after the disaster occurred.

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Due to lack of efficient device to notify and provide information regarding possibility of flooding, authorities such as the Department of Irrigation and Drainage (DoID) is having a hard time to predict the phenomena and the scale of its devastation. Various research has been conducted on flood mechanics and monitoring system [2-4]. However, the device that can predict the flood are yet still on papers, due to cost of implementation and reliability issues, such as accessibility to power source in remote area. For example, in developed countries, such device was already implemented as flood monitoring system, however was not applied in emerging countries such as Malaysia due to high cost. Furthermore, current flood prediction research applies various method of soft-computing method in providing prediction values according to condition of water level [7-14]. Such methods are having limitation in obtaining real-time data, hence reducing the usability of such method in real environment. Therefore, development of a more cost effective device that may comply to the requirement of real-time in soft-computing research could provide better monitoring and prediction of flooding disaster.

The objective of this project is to develop a real-time water level monitoring system for water level measurement purpose as data logger of the depth of the river in real time with real-time data processor for flood prediction. In this research, Real Time Flood Detection & Monitoring System with Wireless Network Sensors is an Infrared based system that detects the fluctuation of the water level in the river in real time while providing the rough prediction in changing of water level along the river, from upstream to downstream. The system may predict the water rising pattern based on timing scheduled [5-6].

1. SYSTEM ARCHITECTURE

Wireless Network Sensors (WMS) for the water level monitoring system is planned to be installed along Pahang River. The placing will have 200 meters gap or for every different contour. Figure 1 show the planned deployment of devices along the river. Real-Time Water Level Monitoring System for Flood Mitigation and Prediction is divided into two part: Sensors and User Interface. The sensors are used as data logging device with system interface. Within the user interface, there are two tools involve which is the data logging tools and prediction tools. The details regarding this tools is explained in the next chapter.

Fig. 1 : Simulation for nodes deployment in Kuantan City, Malaysia.

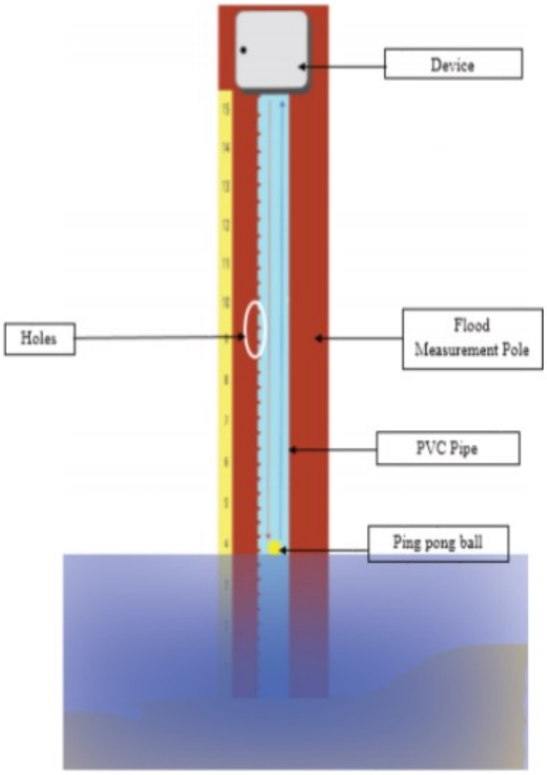

Fig. 2: Planned Design of the physical device.

The physical design of the sensors of the developed system is as shown in Figure 2. Sensors will first detect the distance between the floating ping pong ball on water surface and the device. After the data were captured, the microprocessor will send the data to central processing through GSM connection. A receiver (GSM modem) that is connected to central processing will receive the message transmitted from the microprocessor and transfer the message to database. Alarm will be activated if the water reaches danger level. Then, the data will be analysed for flood prediction. Figure 3 shows the system architecture.

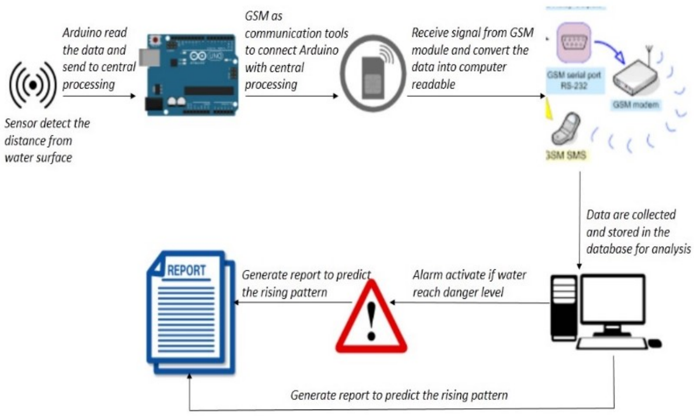

Figure 3: System Architecture.

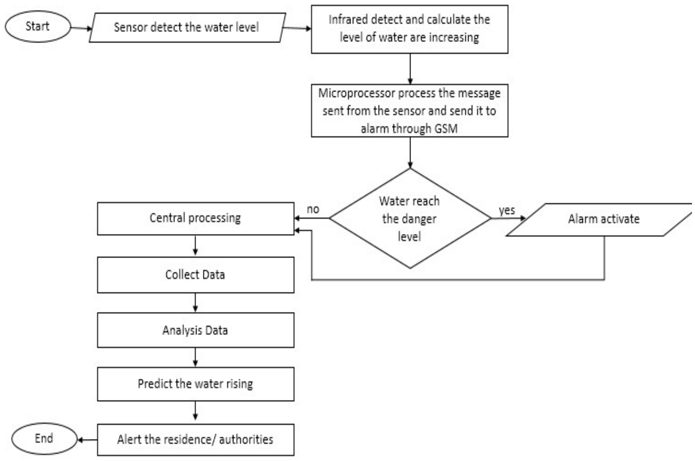

Fig. 4: System Algorithm.

Based on the system architecture shown in Figure 3, a system algorithm was designed and arranged as shown in Figure 4. To fulfill the requirement of the system algorithm, a Data-flow-diagram is constructed as in Figure 5, showing the whole flow of information inside the system. The sensor will send the water level measurement to the microprocessor as well as the authorities. Detection mechanism will send the data it received from the sensors as well as time and date of the data collected into the database. From the database, all data will be used by central processing to predict the flood and generate charts for further monitoring and flood prediction.

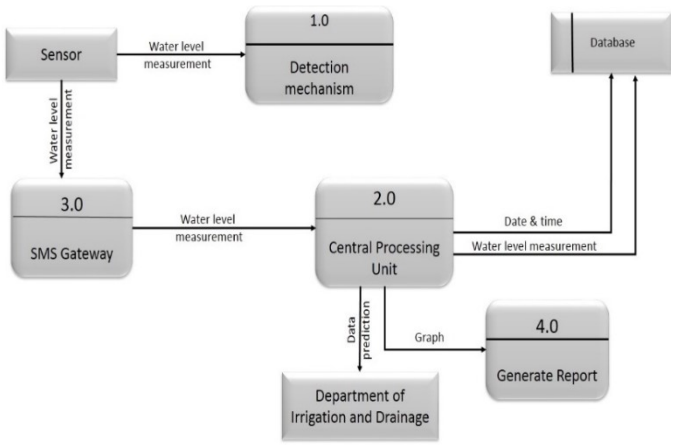

Fig. 5: Data flow diagram.

2. DESIGN & IMPLEMENTATION

In order to implement the planned design and algorithm to the system, two phase of development was conducted.

The first phase involves hardware design and implementation, where requirement of the system is analyzed and logical design was constructed.

The second phase involves software design, where the system architecture and algorithm was visualized and constructed as a software. Here, data acquisition and data keeping played major role in the performance of the system.

2.1. Hardware Design & Implementation

Here, the hardware component of the system was developed and structured to fulfill the requirement of the system. A design for the sensory device was structured before developing the software component of the system. The prototype of the device was created using a microprocessor, Infra-Red (IR) sensor and a GSM shield. Figure 6 shows the logical design of the device.

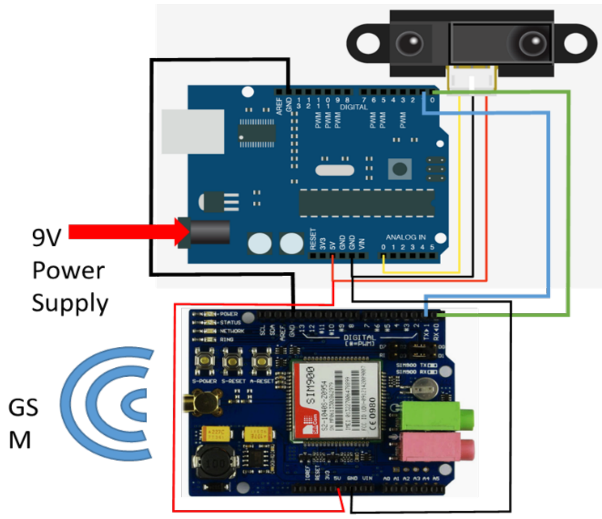

Fig. 6: Logical design.

The development process continues with the physical design. The physical design requires a complete image of final product than can give a big impact on the performance of final product. Figure 7 show the physical design for this project, where the design was based on the structure shown in Figure 2.

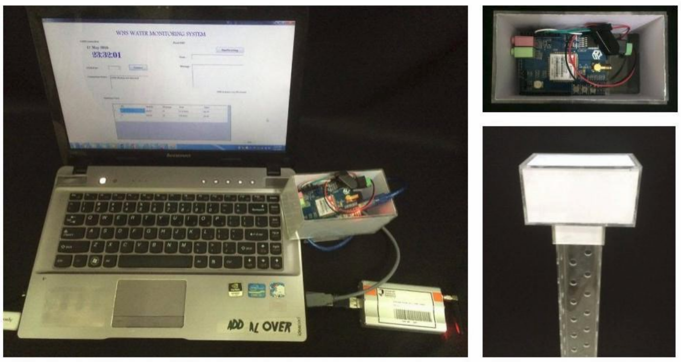

Fig. 7: Physical design.

The hardware required for this system are Arduino UNO, GSM module, GSM Modem, SHARP IR sensor, jumper wires, connectors, real time clock module, and high capacity batteries, etc. The Arduino and GSM Shield should be attached before connect the IR sensor on board. The Sharp IR sensors used are ranged between 10cm to 1m for the system prototype, however there are sensors ranging up to 5m. Due to more convenient system construction, a smaller range were used.

As in Figure 7, the sensor has 3 wires attached to it. The red wire indicates a voltage, black wire indicate ground and yellow wire is a wire for analogue to send and receive signals. These signals are read and processed by the microprocessor, and sent to the registered SIM number of the Central Processing Unit through the SIM number installed in the GSM shield attached to sensor device. GSM modem will be installed with active SIM number and connect to Central Processing Unit.

2.2. Software Design & Implementation

2.2.1 Receiving Data from Sensor Device

Central processing design & implementation requires SMS gateway interface, spreadsheet, Microsoft Access database and Visual Basic to get data from hardware devices to be processed and stored into the database. By using gateway interface, all data collected from GSM modem will be convert to spreadsheet and imported to MS Access database.

With some query, database will be added automatically whenever there is addition to new text file. The visual basic is functioned as an interface for central processing. The interface was programmed and tested using visual basic script. Figure 8 is the prototype user interface for central processing in data logging.

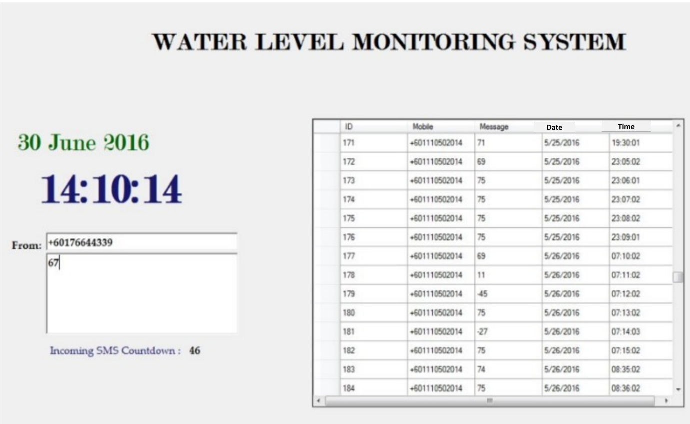

Fig. 8: Prototype of the central processing interface for data logging.

In order to determine the effectiveness of the system, the device was deployed in a controlled environment, where, three identical devices were assigned to collect the data of water level. Here the water level was manipulated to simulate the fluctuation of water level in a river. The result shows that the data collected can be saved in the database. Database table consists of message ID, mobile number (nodes identifier), water level, date and time. Message ID and mobile number is used to determine the source and the node number, while water level shows the measurement at a specific date and time. Stored data are being used to generate a graph to show the fluctuation of water level as shown in Figure 9.

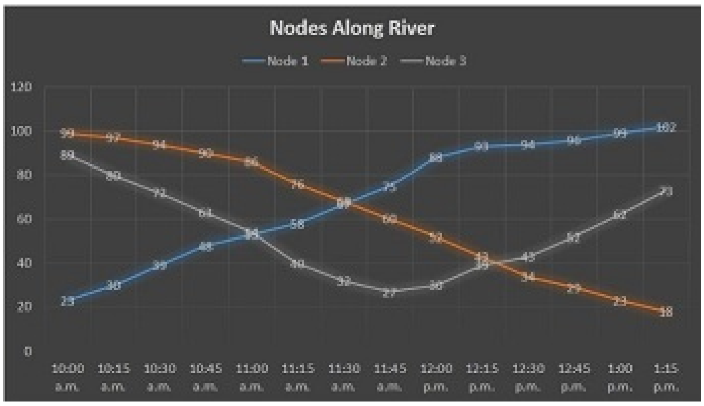

Fig. 9: Obtained Graph developed by the central processing.

From the result the developed system could generate the result effectively using the prototype sensor. Future research is to apply the system in detecting water level as well as predicting flood in a real environment, where much more constraints in the physical sensor is expected.

2.2.2 Prediction of Water Level according to Nodes

After obtaining the tools for data logging, prediction tools were developed into a form of user interface for analyzing the data obtained from the device. The prediction interface was developed separately from the data logging interface to avoid any interference between the two functions in each tool at this stage. Future research will apply both interfaces in one environment.

In order to provide an effectiveness test for the tools, a simple prediction algorithm was structured that predicts the water level of downstream nodes based on the upstream nodes.

The equation that is used to predict the water level of the downstream nodes are

$$\boldsymbol{h_n^{t+1} = \sum_{i=1}^{n-1} C_{n-1}\, h_{n-1}^{t}}$$

where,
$\boldsymbol{h_n^{t+1}}$ is the predicted water level for node ***n*** at time ***t*+1,**
$\boldsymbol{h_{n-1}^{t}}$ is the current water level for node ***n*-1** at time ***t*,**
$\boldsymbol{C_{n-1}}$ is the river coefficient at node ***n*-1** (defined as **1).**
C is defined by **1** current research due to the simulation is not considering the condition of the river, in terms of width, depth and flow speed at respective nodes. Future

research will implement these parameters under the coefficient ***C***.

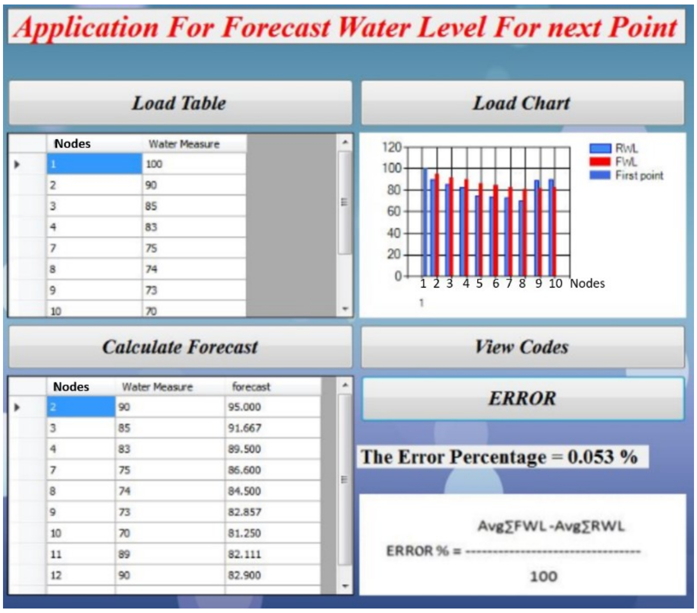

Fig. 11: Interface prototype for prediction

In Figure 11, table on the top left is referring to the water level measurement according to the nodes, where node 1 is the first node at upstream, to other nodes in downstream of a river. The water level measurement according to the table is based on a fixed data (non-real data) for testing at a fixed time **t**. The bottom left table is the water measurement at time **t+1**, with the forecast value of time **t+1** that was calculated using the above equation. The chart on top right represents the data from time **t** (RWL) with data forecasted at **t+1** (FWL). The error rate shown in the system is displayed to evaluate how far the differences between the forecasted level from the real data obtained. It is not significant in current stage of research but will be implemented for future stages where various methods and algorithms [7-16] will be implemented and compared through this system.

3. CONCLUSION

In this research, a Real-Time Water Level Monitoring System for Flood Mitigation and Prediction was developed. Prototype of hardware and software of the Real-Time Water Level Monitoring System for Flood Mitigation and Prediction has been successfully designed and developed in two tools; data logging tools and prediction tools. The device is planned to be place in selected spot along Pahang River. The central processing is planned to be installed in client's computer for time-to-time monitoring purposes. The system will send water level data obtained from notes a long the river from upstream to downstream, for a scheduled period to central processing through SMS communication. The figures in chapter 3 shows that the prototype was able to read the water level data and the system was able to retrieve the data from the device and construct a figure of the fluctuation of the water level, which could be used for analysis and mitigation of flood. Prediction tools also provide the necessary chart that can display current water level according to nodes and predicted level, for preparation of future research. Future works involve implementing the system in the real environment.

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