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An Intelligent Flood Monitoring System for Bangladesh Using Wireless Sensor Network

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***Abstract*—This paper presents a neuro-fuzzy controller based flood monitoring system using wireless sensor network. The distributed sensor nodes use IEEE 802.15.4 protocol, also called low rate wireless personal area network, to collect the sensor information such as water level data from the river, rainfall, wind speed and air pressure data from a selected site. In order to validate the proposed flood monitoring system, Chadpur, a flood prone district of Bangladesh, has been considered as selected site. The sensors information are sent to the distributed alert center via Arduino microcontroller and the XBee Transceivers. At the distributed alert center, XBee Transceiver and a Raspberry Pi microcomputer are used to generate flood alert based on sensor information and two decade flood data and these data are stored in a database. Sensor information are analyzed by the intelligent neuro-fuzzy controller used in Raspberry Pi microcomputer to announce the flood alerts. The wireless sensor network is connected as mesh topology which can send signals over far distance. The performance evaluation reveals that the proposed system accurately detect flood alert compared to the existing flood alert system.**

***Index Terms*—neuro-fuzzy; flood alert system; Raspberry Pi; Arduino; wireless sensor network**

I. Introduction

Flood prediction and warning aims to reduce risk of lives and economic impact. A flood alert system supports data collection, analysis, monitor and warning. Wireless sensor nodes are used to collect site information whereas a controller is used to analyze those collected site information and thereby generates flood warning.

Nature is a blessing for the humanity. But sometimes this scenario changes as the natural calamities take place. Natural disasters have become a major concern throughout the world especially for the developing countries like Bangladesh. Every year the reiteration of these calamities is making life difficult for the rural dwellers. The progress towards a sustainable development for a better future is greatly hampered by the occurrence of many natural hazards. Because of its geographical position and meteorological peculiarity, Bangladesh is known to most of the countries due to natural hazards such as floods, droughts, earthquakes, cyclones, tidal surges, river erosion, and tornadoes.

The natural calamities caused in the rural areas are putting hindrance to the development works of Bangladesh. Every year the floods have destroyed a large part of the development activities. The plight of flood is really indefinable. Severe floods disrupted the overall living every year. It is not just the loss of the countrys infrastructure by floods causing extensive damage to the overall economy. There was average annual loss of 2,463.17 million US dollars because of flooding in the year 2014 [1]. In 2014, during the flood in the northern region of Bangladesh 149,645 people became homeless and 21 people were died [2]. During that period in the northern side of the country 8428.24 square kilometers area was affected by the flood including 673 families became poor sufferers [2]. Continuous rainfall, tidal water and the hill slope, Indias major river basin in upstream causes the flood in the north-east and north-west of the country.

Flood has become a very common phenomenon for the people of Bangladesh in the recent years. Earlier, it occurred only once in a year. But with drastic change in climate the scenario has been changed. Nowadays, the flood takes place more than once in a year and lasts longer than before. The sufferings of the affected people know no bounds. Bangladesh being one of the largest deltas in the world has a very heavy monsoon rainfall. In spite of that, it has an extensive network with almost 310 rivers.

The coastal areas of the country are inundated by tidal flood on a regular basis. The people living in those areas of Bangladesh are now well adapted to seasonal monsoon flood. This causes destructions and human agony to these floods in many regions of the country. Flood often comes with cataclysmic consequences that last longer. Sometimes this results in a great loss of property, livestock, crops and poultry. Table I shows the year wise flood affected areas in Bangladesh [3]. From the table, it can be seen that in some of the floods, the devastation knew no bounds. The loss causing by the floods are very high for a country like Bangladesh. The affected people as well as the government leave no stone unturned to fight back against the loss.

The geographical allocation of Bangladesh is very unique. Cyclones and tidal surges are very common in Bangladesh due to its location on the earth map. These disasters have an adverse effect to the 20 million people of the 15 districts and lots of offshore islands who live a very miserable life under

TABLE I
YEAR WISE FLOOD AFFECTED AREAS IN BANGLADESH [3]

Year	Flood Affected Area		Year	Flood Affected Area	
	Sq-km	%		Sq-km	%
1994	419	0.2	2004	55,000	38
1995	32,000	22	2005	17,850	12
1996	35,800	24	2006	16,175	11
1997	40,000	27	2007	62,300	42
1998	1,00,250	68	2008	33,655	23
1999	32,000	22	2009	28,593	19
2000	35,700	24	2010	26,530	18
2001	4,000	2.8	2011	29,800	20
2002	15,000	10	2012	17,700	12
2003	21,500	14	2013	15,650	10.6

TABLE II
SEVERE CYCLONES AFFECTING BANGLADESH SINCE 1960 [3]

Month	Year	Maximum Wind Speed (Km/h)	Storm Surge Height (m)	Human Deaths)
October	1960	210	4.5-6	5,149
May	1961	146	2.5-3	11,466
May	1963	203	4-5	11,520
May	1965	162	3.5	19,279
December	1965	210	4.5-6	-
October	1966	146	4.5-9	850
November	1970	223	6-9	5,00,000
May	1985	154	3.4-5	11,069
April	1991	225	6.7-5	1,38,000
May	1994	200	4.2	170
May	1997	225	2.5-4	126
November	2007	223	3-4	3,369
May	2009	92	3+	190
May	2013	88	1.5-2	17

sheer poverty. Most of these destructive calamities occur with a lot of damages either in the pre-monsoon period or post-monsoon period.

As the Bay of Bengal is considered as the breeding ground of tropical cyclones, the people in the coastal areas are always in danger fighting against the disaster. The cyclone that made coastline in Bangladesh caused in 1970 (November 12, 1970), considered as the deadliest cyclones so far. It took more than 300,000 lives along with property losses of over a billion US dollar. The devastation and the sufferings had no limit then. Another catastrophic cyclone claimed lives of about 138 thousand people on April 29, 1991. That time the cyclone with its detrimental feature raised extensive damage to property worth more than two billion US dollars. So the people living in those areas are highly vulnerable.

In the past few years, the disasters took a toll of lives and also created devastating scenes in the affected areas. The main reason behind the destruction is the lack of alarming before the events. There are some monitoring systems that are prevailing in Bangladesh. But the existing system is not at all smart enough to detect those disasters earlier than occurring. Hence is the importance of Wireless Sensor Network (WSN) systems for the detection of the natural calamities like floods and cyclones.

Wireless sensor network plays an important role in the monitoring and detection for the disasters. It gives a scope for getting the signal of any incident before causing. So if the signal of flood or cyclone can be detected early, the chance of protecting the people will be greater. In a general WSN system, there are few sensors that send signal every time to the base stations. The base station analyzes the signals and gives the decision according to its algorithm. Then the news is sent to the regions that need attention and proper steps can be taken then. Thats how WSN can be the most effective system for detecting the floods and cyclones early.

Generally, WSNs are formed by a good number of small sensing devices. In most of the practical applications, a large portion of the conceived information is accumulated at a control station. The sensor nodes actually pre-process the raw signal data that it gets. Then the gathered information are collaborated with each other on another data basis. This work is done to reduce the number of data so that the information can be transmitted to the main control station more effectively. In practice, it acts mainly as an entrance to a local area network (LAN), or to a microcontroller based system that can be based on certain algorithm.

When the data reaches the destination computer, it eventually starts analyzing the received data. This process is done according to given coding by the system provider to extract meaningful information. An action can be then suggested and carried out automatically by any microcontroller unit or by a human manually. Most of the cases the autonomous action is more preferable as it implies with precision.

Wireless Sensor Network can be very helpful for the developing countries because of their robustness, sensing accuracy, operability in the tough environments and very less human interaction [4]. Wireless sensor networks are very fast and efficient. Being wireless, the network can be expanded to a large geographical area with a good communication unit within a limited budget. A high level of fault tolerance of the sensing devices can be ensured by the redundancy of the data taken from the nodes. The connectivity of the network with the other peripherals is very simple and only relevant information can be shared between the connected networks. This provides enough scopes for the network to concentrate on a particular region and on a particular event.

In this paper, we have proposed a NFC for the detection of floods and cyclones using wireless sensor network. There are several sensors used for achieving the data from the different region. We have used microcontroller based system as well as Raspberry Pi based system. This additional feature makes the system more accurate and robust and also more effective. The proposed system is designed keeping back in our mind the situation of Bangladesh in terms of natural disasters which are very frequent.

Here, Section I introduces the scenario about various natural calamities in Bangladesh over the past few years,section II depicts the related works on the field in the recent years all over the world, section III gives the complete description about the proposed system model, section IV represents the

main algorithm that the work is done with, then the paper is concluded in the next with the references used are mentioned later.

II. Literature Review

WSN has been very popular in the recent few years in every sector. The role of WSNs is very important for the natural calamities. Lots of works throughout the world has been done on developing different models for the detection of floods and cyclones much before their occurrence. Different scientists have undertaken various projects on this topic. As the advancement of information and communication technology is on a rapid rate, researchers all around the world, are now more interested in implementing the WSN in different sectors.

A development work was done for early warning device for the increase in the flood water [5]. Three different types of alarm systems were used to provide early detection of the rise of water. To track out a super cyclone, the system design and development of a WSN along with its implementation was discussed in [6]. The necessity of the development of an Artificial Neural Network (ANN) for data collection and aggregation was also described. A research work was done to explore the flood warning systems and associated items in the context of developing countries and later proposed a system for it [7]. A design was proposed to develop a smart environment using the WSNs for developing countries like Bangladesh [8]. To predict river flood, a model based system architecture was proposed in [9]. Research work was done for WSN for environment in [10].

A sensor network using the Gumstix sensor nodes for the prediction of flood was discussed in [11]. Danish Hydraulic Institute made a MIKE 11-based flood forecasting system in Bangladesh in 1995 but could not get much interest due to its sustainability problems [12]. Deploying various types of sensors in the river bed, a new model was proposed for prediction and warning for the floods [13]. Using Geographical Information Systems with WSN, a flood prediction model was proposed in [14]. Different models for detecting the flood early had been proposed using various methods along with a wide variety of sensors [15] [16] [17] [18] [19] [20] [21]. By using Genetic fuzzy Approach, a WSN was proposed for the prediction of super cyclone in [22].

III. Proposed Model for Flood Monitoring

This paper aims to design and implement a flood alert system to predict the chances of occurrence of flood earlier as well as monitoring the flood condition in a convenient and smart way. So that the necessary steps can be taken to prevent the damages. For this project here we are using Arduino, Xbee, Raspberry Pi , GIS map and some sensors like water level measurement sensor, rainfall measurement sensor, rate of change of height of water level, wind direction measurement sensors and barometer.

Water level measurement sensor measures and indicates the water level of the river. By this analysis, it can be found out that whether the water level is below or above the safety level. Safety level differs from river to river. When the water level crosses the safety line, this sensor sends that data to the Arduino. Rainfall measurement sensors monitor the rainfall and gives the result how much it rains. From this we can be assured whether the rainfall is in safety limit or not. As our rivers get more water due to heavy rainfall, the chances of increasing the level of water is more.

By Arduino, data from this sensor is processed and the probability of occurrence of flood can be identified easily. The height of water level can be measured by level sensors and then these data are processed and compared with 20 years data stored in the database. If the rate of change of level is growing up rapidly there occurs a huge chance of flood. Wind direction measurement sensor senses the direction of wind. From the result that this sensor gives, the chances and direction of cyclone can be determined. The air pressure difference is measured by barometer.

Arduino is based on microcontroller board design. This system provides sets of digital and analog input and output pins that can be interfaced with various expansion boards and circuits. Here the sensors are interfaced with Arduino. The data from these sensors are processed with Arduino and then the output is passed to Xbee. Arduino can process the analog data. Thus convenience is there for processing the data accurately.

With the Xbee shield, an Arduino board can communicate wirelessly with other microcomputers or microcontrollers. The range of Xbee shield for the line of sight path is up to 100 to 300 feet. By putting into a command mode, the Xbee shield can be configured for a diversity of broadcast and mesh networking options. This product uses the IEEE 802.15.4 protocol for its communication. As it is compatible with Arduino, the data obtained from the nodes can be sent easily by the XBee.

At receiving part there is also Xbees which are connected with a Raspberry Pi . At receiver point Xbees receive data from sender Xbee and send them to Raspberry Pi . Raspberry Pi is a scratch card sized minicomputer. It can be plugged or connected to any display device like monitor or television. By incorporating a mouse and keyboard, the Raspberry Pi can be used as modern computer to perform any work with a very low cost and also at a higher speed. All Raspberry Pis include the same Video Core IV graphics processing unit (GPU). In case of RAM, there are various types. Different RAM size are used in Raspberry Pi , these may be 1 GB, 512 MB and 256 MB. Models are A, A+, B, B+ and Pi 2 are mostly used in working for several projects. For boot media and persistent storage the Raspberry Pi can have slots of Secure Digital High Capacity (SDHC) slot. This hardware has been going through several versions of various features. All the version have different capacity of memory and various supporting peripherals. These features have made Raspberry Pi very popular in the recent technological arena. People are more willing to work with it because of its ease of performance and user friendly operating systems and also lower cost.

Data received from Arduino is being processed by this. Here Raspberry Pi is connected with database and central

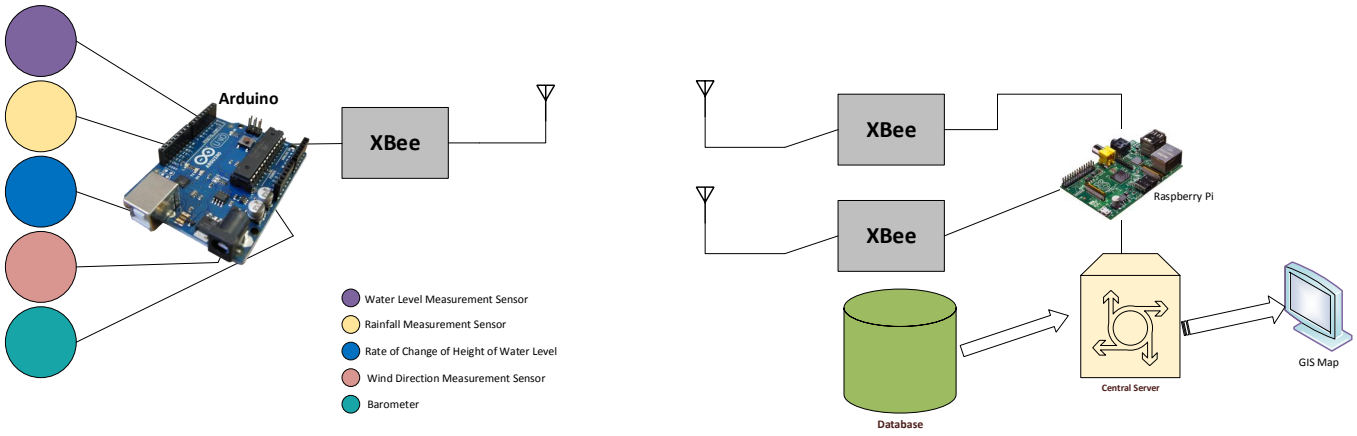

Fig. 1. Diagram of proposed model for flood monitoring system

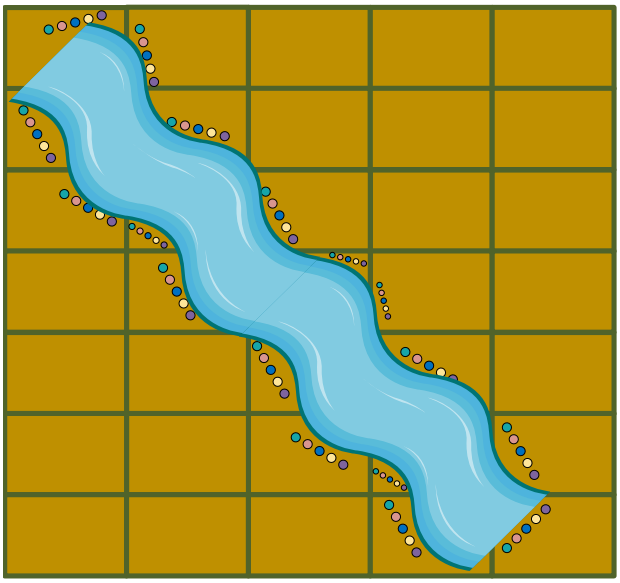

Fig. 2. Orientation of the sensor nodes in the river area

server. Rainfall, water level height, rate of change of water level height, atmospheric pressure of 20-25 years are saved in database. Central server compares this record with the output from Raspberry Pi and show the results in GIS Map. From this map the chances of flood can be predicted.

In figure. 1 The basic diagram of our proposed system is shown and in figure. 2 the orientation of the sensor nodes are shown. The output will be observed on a GIS map showing the different areas in three different colours. Red, yellow, green are three colours used for showing the chances of occurring floods in various areas.

Let us consider the river diagram from GIS MAP map. Here in raw 2, column 2 there are some sensors are placed. If the block is green the area is safe from flood. If the block becomes yellow there are chances of flood. When the colour of the block converts into red it indicates that there is a high risk of flood there.

IV. NFC for Flood Monitoring and Alert

Figure 3 shows the ANFIS model for the proposed flood alert system. The Neuro-Fuzzy Controller (NFC), i.e., ANFIS model, maps the inputs using input membership function (preceding parameters) into the output using output membership function (consequent parameters). The inputs to the NFC are as water level data from the river, rainfall, and wind speed data from the selected site. The output is the possibility of flood. Both the preceding and consequent parameters are adjusted via the learning process. The back propagation and hybrid of back propagation and least square estimation is/are used. Based on the chosen error criterion (which is the sum of squared difference between actual and desired outputs), the NFC changes the input and output membership function parameters. Fig.4 shows the steps involved for parameter adjustment of ANFIS.

The ANFIS has a five-layers. The input variable and the linguistic terms (red: low, blue: medium and gray: high) are in layers one and two respectively. The five layer shows the output linguistic variable. Neuron in the third layer are corresponds to rule based system with the possible connections.

V. Numerical Results

This section shows the numerical results of the proposed flood warning system. The simulation parameters are given in Table I. In this work Chandpur (Latitude 23.23N, Longitude 90.663E) district is considered for calculating the accuracy of the proposed model. The selected site Chandpur is situated on the bank of Meghna River. We have placed the WSN on the bank of the Meghna River. The sensor data is sent to centralized station for generating flood warning. The simulation process is done by using ANFIS. For error calculation Root mean square (RMS) method is used. Figure 4 shows

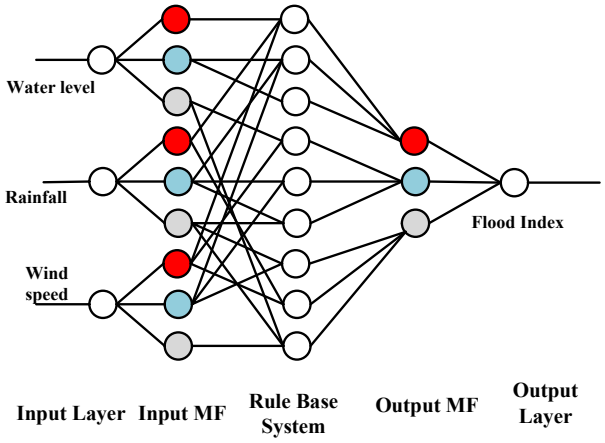

Fig. 3. NFC for Flood Alert System

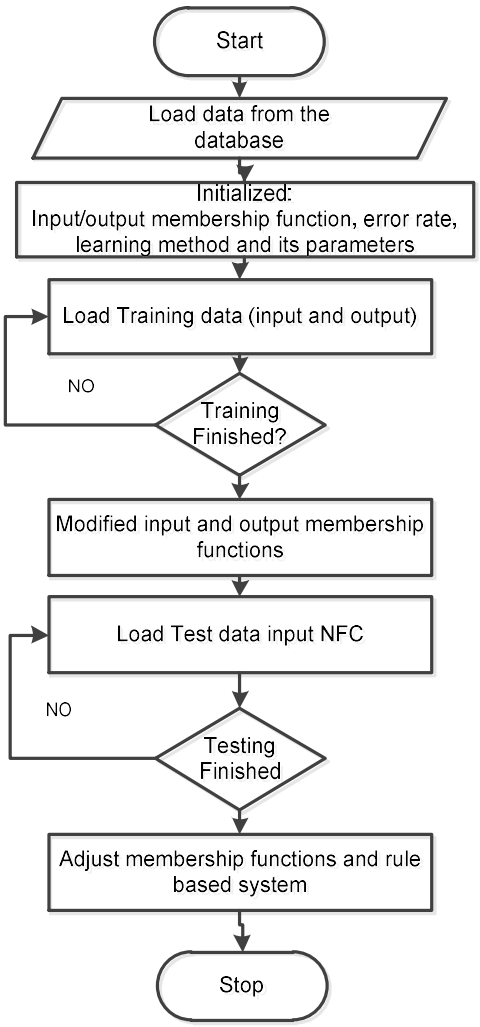

Fig. 4. Flow diagram of training and testing the ANFIS

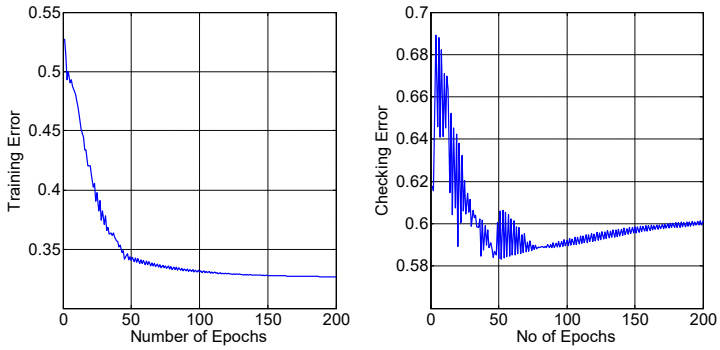

Fig. 5. Training and checking error with respect to the number of iterations (epochs).

the training and testing of ANFIS whereas Table II shows the RMSE for training and testing error.

TABLE III
SIMULATION PARAMETERS

Parameters	Value
ANFIS Type	Mamdani fuzzy
No of Rules	12 rules
Membership function	Gaussian (gaussMF)
Data Set	Bangladesh meteorological department
Training method	Back propagation
Learning rate	0.8
Maximum error	10^{-3}

Figure 5 shows the effect of number of iterations on the RMSE. It has been found that the RMSE falls with the number of iterations.

TABLE IV
SIMULATION RESULTS

Model	Output Function	RMSE	
		Training Error	Test Error
ANFIS	Constant	0.00063287	1.5905
	Linear	$9.9845*10^{-5}$	1.145

VI. CONCLUSION

A neuro-fuzzy based flood alert system using WSN has been proposed. The distributed sensor nodes use low rate wireless personal area network to collect water level data from the river, rainfall data, wind speed data and air pressure data from the selected site. The sensors information are sent to the distributed alert center via Arduino microcontroller and the XBee Transceivers. At the distributed alert center, XBee Transceiver and a Raspberry Pi microcomputer are used to generate flood alert based on sensor information. Two decades flood monitoring data have been used to estimate the duration of the flood and these data are stored in a database. An intelligent NFC is created in Raspberry Pi microcomputer which uses sensor data to announce broadcast the flood alerts.

The performance evaluation reveals that the proposed system accurately sends flood alert compared to the existing flood alert system. In future we will include more sites to validate the proposed system.

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