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Flash Flood Sense Module Implementation Using ANN Algorithm

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Abstract— A flood is an overflow of water that submerges land which is usually dry. Floods are one of the most commonly occurring natural disasters, accounting for more than half of natural disasters worldwide. Among floods, flash floods are short fuse weather events, that last less than six hours. A flash flood is a rapid flooding of geomorphic low-lying areas. Flash floods can occur under several types of conditions. Flash flooding occurs when it rains rapidly on saturated soil or dry soil that has poor absorption ability. Flash flood propagation monitoring system in urban areas is becoming important. In this paper the design of flash flood sensing module has been presented. The proposed system of the sense module can be implemented using ultrasonic sensor, temperature sensor. The measurement data processing can be done using ANN algorithm and L1 regularized reconstruction and the modifications that can be included are to use a Wi-Fi module which provides the data base for flash flood sensing to the internet, to use display and alert buzzer indicating exceeded water level, to add more sensors such as CO sensor, CO2 sensor so that this sense module can be used for air pollution detection, traffic congestion ,weather forecasting etc to a certain extent when flash flood is absent.

Index Terms—Flash Flood detection, Exponential Median filter, L1 regularized learning, ANN algorithm.

I. INTRODUCTION

Heavy convective rainfall often results in flooding in urban regions. The rainfall runoff process, however, is highly complex, nonlinear, and temporally and spatially varying because of the variability of the terrain and climate attributes. An intelligent traffic system covering the emergency response capacity in response to flooding impacts in low-lying area of urban region is highly desirable to drivers and passengers nowadays. A flash-flood is a sudden discharge of large amounts of water. Usually, heavy rainfall increases the level of rivers; at the same time, a dam-forming effect occurs, triggered by other phenomena like ice jams or landslides. Wireless sensor networks (WSNs) are widely used for monitoring and control applications such as environmental surveillance or industrial sensing [3], or in the present case, flash flood detection.

In this article, a new type of flash flood sensor combining ultrasonic rangefinders with temperature sensors is proposed. This sensor can be used as a backbone for an urban flash flood wireless sensor network architecture, since it can monitor pluviometry, water presence and water level with relatively high accuracy. While the measurement of distances using a calibrated ultrasonic sensor is easy, involves the estimation of a distance from time-of- flight measurements.

The emphasis of the present work is on water level detection, though this sensor can also be simultaneously used for traffic flow monitoring (by monitoring the temperature and distance of disturbances created by vehicles passing by the sensor), or rain rate detection, making it a cost-effective solution. Since simple temperature correction methods fail to provide a sufficiently accurate measurement, and that machine learning or nonlinear dynamical model-based regression methods can provide a solution to the sensing problem.

In particular, Artificial Neural Networks (ANN) have an excellent accuracy, and have a low computational complexity (for the chosen number of neurons and layers) which makes it suitable to low-power embedded platforms. The following summarizes the contribution of present article over existing work. Novel, dual use (traffic and flash flood) sensor system that addresses a key economic requirement in flash flood sensor networks (since flash floods happen very infrequently). New preprocessing scheme based on L1 regularization for real-time sensor fault detection and corresponding missing data inference. Use of multiple machine learning techniques, ranging from artificial neural networks and fuzzy logic to nonlinear regression on preprocessed sensor measurement data to estimate water levels and learn the proper compensation to apply over all environmental conditions. Implementation of the corresponding algorithms can be done on a low-power experimental hardware platform

II. LITERATURE SURVEY

In 2016, Christian Cloudel et.al. [1] proposed a new type of flash flood sensor combining ultrasonic rangefinders with passive infrared temperature sensors. This sensor can be used as a backbone for an urban flash flood wireless sensor network architecture, since it can monitor, water presence and water level with relatively high accuracy. While the measurement of distances using a calibrated ultrasonic rangefinder is easy, when environmental conditions are well known, the present problem involves the estimation of a distance from time-of flight measurements and from a model of the atmospheric layer between the sensor and the ground. Since this model is encoded by a Partial Differential Equation (PDE) which has numerous uncertain parameters, a non-model based approach to compute the water levels directly, from raw temperature and distance measurements is chosen.

In 2015, Mustafa et.al. [2] says that Floods are the most common type of natural disaster, causing thousands of casualties every year. Among these events, urban flash floods are particularly deadly because of the short timescales on which they occur, and because of the high concentration of population in cities. Since most flash flood casualties are caused by a lack of information, it is critical to generate accurate and detailed warnings of flash floods. However, deploying an infrastructure that solely monitor flash floods makes little economic sense, since the average periodicity of catastrophic flash floods exceeds the lifetime of a typical sensor network. To address this issue, a new sensing device that can simultaneously monitor urban flash floods and another phenomenon of interest (traffic congestion on the present case) is proposed. This sensing device is based on the combination of an ultrasonic rangefinder with one or multiple remote temperature sensors. Field data shows that the sensor can detect vehicles with a 99% accuracy, in addition to estimating their speed and classifying them in function of their length. The same sensor can also monitor urban water levels with an accuracy of less than 2 cm. Two of the sensors have been deployed in a flood prone area, where they captured the only (minor) flash flood that occurred over the one-year test period, with no false detection, and an agreement in the estimated water level estimate (during the flash flood event) of about 2 cm.

In 2012, Jessie et.al. [3] says that Early flood alerts system is use to create a tool to measure water level, which powered by solar cell panel. The system is supported by microcontroller and GSM modem to send the measured data via SMS (Short Message Service) into two specific clients' phone numbers that have previously been inputted into the system. Besides the capability to predict the remaining time before the flood, this system can also detect three types of water level: early flood level, flood level and low tide level after the flood with a maximum water level detection of four meters. This system focused on an accurate measurement of the height of the water level and sending a warning message of the threshold height set before to the clients. For each of water level, the system will send three messages for each client number. The setting for client phone numbers and the water level can be programmed by sending the SMS that has been formatted in the system.

In 2012,Nagender Kumar .et.al. [4] reported a mechanism for estimation of elderly well-being condition based on usage of house-hold appliances connected through various sensing units. Wireless-sensor-network-based home monitoring system for elderly activity behavior involves functional assessment of daily activities. The developed system for monitoring and evaluation of essential daily activities was tested at the homes of four different elderly persons living alone and the results are encouraging in determining wellness of the elderly. The developed home monitoring system using WSN is low cost, robust, flexible and efficiently monitor and assess the elderly activities at home in real-time. Real-time activity behavior recognition of elderly and determination of wellness function of the elderly using the activity of appliances was encouraging as the system was stable in executing the tasks for few weeks.

In 2012, Neil W Bergmann et.al. [5] proposes a novel industrial wireless sensor network (IWSN) for industrial machine condition monitoring and fault diagnosis. In this paper, the induction motor is taken as an example of monitored industrial equipment due to its wide use in industrial processes. Motor stator current and vibration signals are measured for further processing and analysis.

In 2011, Manuel Roberi et.al. [6] proposes an environmental monitoring framework based on a wireless sensor network technology characterized by energy harvesting, robustness with respect to a large class of perturbations and real-time adaptation to the network topology. The fully designed and developed ad hoc system, based on clusters relying on a star topology, encompasses a sensing activity, a one-step local transmission from sensor nodes to the gateway, a remote data transmission from the gateway to the control center, data storage in a DB and real-time visualization. A WSN-based framework for marine environment monitoring had been presented. All aspects of the environmental monitoring system such as sensing activity, local transmission (from sensor nodes to gateways), remote transmission (from the gateway to the control center), data storage, and visualization, have been designed and implemented.

In 2011, Yao Chiang et.al. [7] is aimed to establish a wireless sensor network (WSN) gateway model prior to the back-end server for diverse environmental monitoring applications. The design catalogs different sensor data with transmission load balance to incorporate heterogeneity of sensor signals, stability of data transportation, and expenditure of mobile communication. As considering a variety of sensor characteristics for environmental monitoring, the proposed WSN gateway is designed with three bridged functions, including serial listener, transaction logger and Internet listener, to enable analog and digital signal conversion, physical data classification, threshold determination, database redundancy and mobile communication. The criterion-based scheme is created for remotely updating thresholds of monitored data from the back-end server to the gateway. The model is built upon the embedded computer for low power consuming to perform efficient and stable applications. The comprehensive model design can be easily utilized for general WSN surveillance with expansibility and flexibility.

In 2004, Daniel et.al. [8] presents the ongoing effort in providing the population of the Andean region of Venezuela with a flash- flood alerting system by making use of state-of-the-art wireless communications and information technologies. A key component of the project is a Wireless Sensor Network (WSN) that is used for monitoring the environment and tracking the disaster while it evolves. Currently, the project is at its conceptual inception and system-level design is being carried out. Major design constraints and solutions will be presented with an emphasis on the monitoring system based on the WSN. The proposed system architecture solves most of the difficulties encountered in the implementation of an automated flash-flood alerting system. The WSN lends itself well for this application and practical results are expected to verify the conceptual design.

PROPOSED SYSTEM DESIGN

Sensing flash floods in cities is challenging, since the sensors must have an extended lifetime, measure the water levels in all flow conditions, and be capable of self-monitoring (to make sure they are always functional).Sensors have been investigated in the past for flood monitoring applications, in particular ultrasonic water level measurements on bridges or pressure sensors for water level measurements of river sand their measurements would be affected by their orientation with respect to the water flow. They could also be affected by debris or rocks carried by flash floods, and would need to be periodically tested in water. In the present case, the constraints detailed above prevent contact sensors such as pressure transducers from being used. Indeed, these sensors would be unable to measure static and dynamic pressures independently.

Among noncontact sensing technologies, three main technologies could be thought of: ultrasonic rangefinders and Ultra Wide Band (UWB) radars and LIDARs. Ultrasonic rangefinder is much cheaper and more accurate than both UWB and currently available LIDARs, though they can be affected by environmental parameters, such as temperature or humidity.

In this article, ultrasonic rangefinders have been chosen because of their very low cost. The sensor module of this article consists of temperature sensors and ultrasonic sensor connected to a microcontroller platform developed for the flash flood detection. The system block diagram consists of the microcontroller to which the needed sensors are directly interfaced depending on the requirement. For water level detection, ultrasonic rangefinder and temperature sensors can be used. Distance is the parameter sensed by the ultrasonic sensor whereas temperature from temperature sensor. Distance and temperature serve as the input data. This input is given to the microcontroller where the water level prediction works and produces the output. The water level estimation is done using Artificial Neural Network model.This is the basic working principle behind the flash flood detection sense module. Battery supply is provided for the working of entire system. As part of hardware modifications air quality sensors other than temperature and ultrasonic rangefinders is added to the microcontroller so that this sense module can be used for air pollution detection, traffic congestion etc when flash flood is absent . Also the water level detection output is given to wi fi device so that any user can be aware of flash flood occurrence at any time and a LCD display is also provided along with this. This is done since a sense module which monitors flash flood detection alone is less economical and obviously flash flood occurs rarely. The hardware modification that can be included are to use a Wi-Fi module which provides the data base for flash flood sensing to the internet, to use a communication interface such as GSM for providing alert through SMS, to use display and alert buzzer indicating exceeded water level, to add more sensors such as CO2 sensor, humidity sensor so that this sense module can be used for air pollution detection, traffic congestion , weather forecasting etc when flash flood is absent.

The proposed system block diagram is represented in figure 1.

The components used for the implementation of flash flood detection are Arduino mega microcontroller, ultrasonic sensor HC05, temperature sensor LM35, ESP 8266 Wifi module, LCD display and air quality sensor MQ 7. The circuit diagram also includes provision for power supply circuit using 7805 voltage regulator needed for the proper working of the system. Driver circuit is also seen in the diagram used for the working of Wifi module because the wifi module works in 3.3V but the Arduino uses 5V ie, to drive the wifi module. It also contains circuit for LED blinking and provide buzzer sound whenever there is flash flood. This serves as warning.

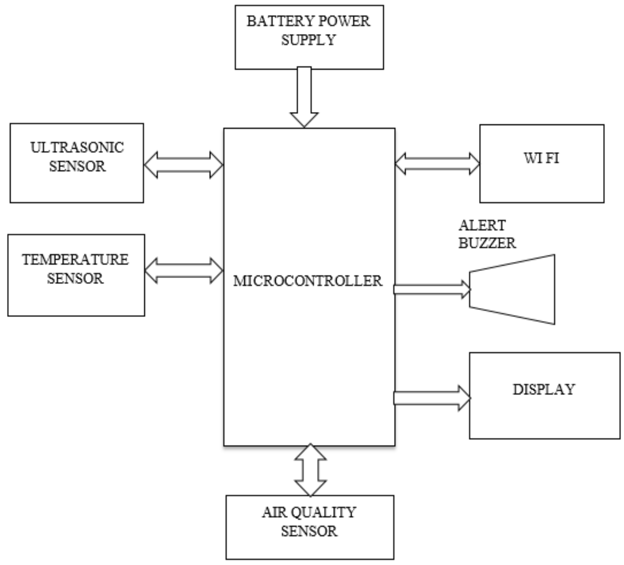

Figure 1: System Block Diagram

II. WORKING

The basic working behind the flash flood detection system is to sense the input data and provide it to the ANN algorithm to get the required output. Here the distance with respect to the ground and temperature serve as input data. Distance and temperature is measured using ultrasonic sensor HC05 and temperature sensor LM35. Then the sensed input data is given to the Artificial Neural Network.

ANNs are composed of multiple nodes, which imitate biological neurons of human brain. The neurons are connected by links and they interact with each other. The nodes can take input data and perform simple operations on the data. The result of these operations is passed to other neurons. The output at each node is called its activation or node value. Each link is associated with weight. ANNs are capable of learning, which takes place by altering weight values. Supervised learning technique is used in ANN where the input and required output is known.

The distance measured by ultrasonic sensor is strongly affected by the variation in temperature. Therefore temperature variations of the surrounding is also noted with the help of temperature sensor. The distance data measured must be constant then only the flash flood occurrence can be clearly identified. If the distance data is continuously varying with temperature the chance of flash flood occurrence cannot be identified since there is already variations in the input data. So first thing is that the distance measured due to the variation in temperature must be made on a constant level. The implementation is placed above street light in cities where the flash flood detection is relevant. So the distance set is about 5m. Whenever the water level raises above 5m flash flood is detected. For that the input distance measurement variations must be converted to a straight line at 5m. Here comes the use of ANN. The input and output is known. Input is the measured distance variations corresponding to the temperature variations and output is the straight line at 5m ie, converting the distance variations to constant level. This is the reason for choosing supervised learning technique in ANN. The hidden layer indicates the activity performed by the ANN which is actually hidden and that's why the name hidden layer. The arrows indicate the connections between the neurons through hidden layer.

First of all the initial readings of the distance and temperature are given to ANN as input and required constant level as output. With these data testing is done. By giving these input data ANN start generating equations with bias and weight values so as to provide the needed output. Testing is done until the difference between the input and output becomes less. This is known as best fit. The equation generated by the ANN at that time is used for further processing so that any variations in the distance data due to temperature is converted to constant 5m. After that threshold value is to be chosen in order to detect increase in water level. This includes the working of flash flood detection.

As part of modifications the readings obtained from ANN is given to the internet through ESP 8266 Wifi module so that any one in the worlds can access it. By adding air quality sensor to this sensor module the presence of toxic gases in the air is also detected. From the ultrasonic sensor to a certain extent traffic congestion is also identified by knowing the periodic range of distance values.

III. SIMULATION AND RESULTS

In simulation part the processing methods of temperature and distance data which serve as input is mentioned. The raw data generated by the temperature sensors and the ultrasound rangefinder have different scales,and are sometimes exhibiting inconsistencies. As the name indicates distance meaurements will be based on by reception of reflected sound wave.There will be 2 temperature data – temperature of air and ground. This is due to the variation in temperatue of ground because of tarring effect. Distance sensed through Ultrasonic rangefinder will undergo severe variations due to the temperature value diffence in air and ground. Therefore the sensor data obtained will be processed before giving it as the input to water level estimation modelled by Artificial Neural Network. It mainly involves two main processes : fault detection and missing data reconstruction. Sensor faults can be caused by multiple factors. In the present case, these faults can be mainly due to gateway failures (due to a loss of the internet connection), and brownouts of the sensor caused by faulty charging circuits in a narrow solar power input range when collecting the measurement data. First check the network faults (communication faults), which are identified by detecting time periods that have more than certain minutes without reception of data from sensors. When such faults are detected, the missing data in the blank periods are reconstructed directly by the LASSO-based formulation (least absolute shrinkage and selection operator). If no network faults further steps to remove outliers (caused by vehicles passing below the sensor), will be done. For that an exponential moving median filter can be applied to the distance data. This is shown in figure 2. After that sensor fault detection will be detected through the adaptive thresholding because of the existence of maximum and minimum limits of data sensing capability of sensors. When sensor faults are detected data with faults will be deleted and data reconstruction using Least Absolute Shrinkage and Selection Operator (LASSO) begins.All data gone through the fault detection process are stored and served to the next step, approximating the missing data to complete the measurements. L1 Regularized reconstruction method can be used. In order to reconstruct the missing data in real-time, the data generated during the previous days will be provided. This method then reconstruct data in the missing period similar to the obtained previous samples.

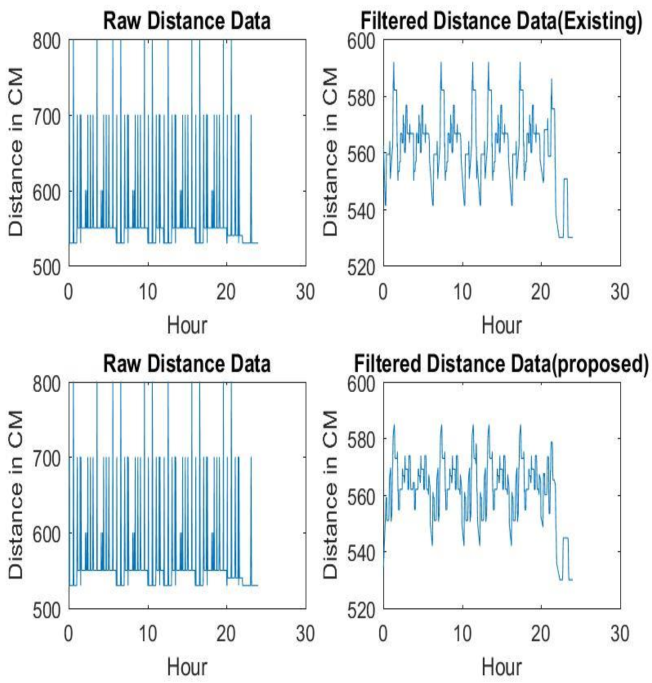

Figure 2: Filter comparison

After reconstruction normalization is done for adjusting the scale required. Since temperature variations are less temperature sensed will be same as that when it is filtered. At this stage all preprocessing steps will be over and then this distance and temperature data can be given to the Artificial Neural Network (ANN) for getting water level estimation output.

In the existing system the raw distance sensed was filtered using median filter whereas in this proposed system exponential median filter will be used since it gives better results by limiting the variation in distance to a smaller value than the other. In the figure 2, distance sensed is shown in y-axis and 24 hr is shown in x- axis. The comparison results is shown here. First row represents the results using median filter and second row represents the results using exponential median filter.

Thresholding comparison between local consensus and adaptive thresholding is done here. The thresholding comparison is shown in figure 3. The sensors will have a limit about their capability of sensing. Considering the ultrasonic rangefinder placed above a street light expected to measure a maximum height of 5m but coming to the reality the sensor will have a maximum and minimum height that can be sensed. Here in this case the limit is between 550 and 500.

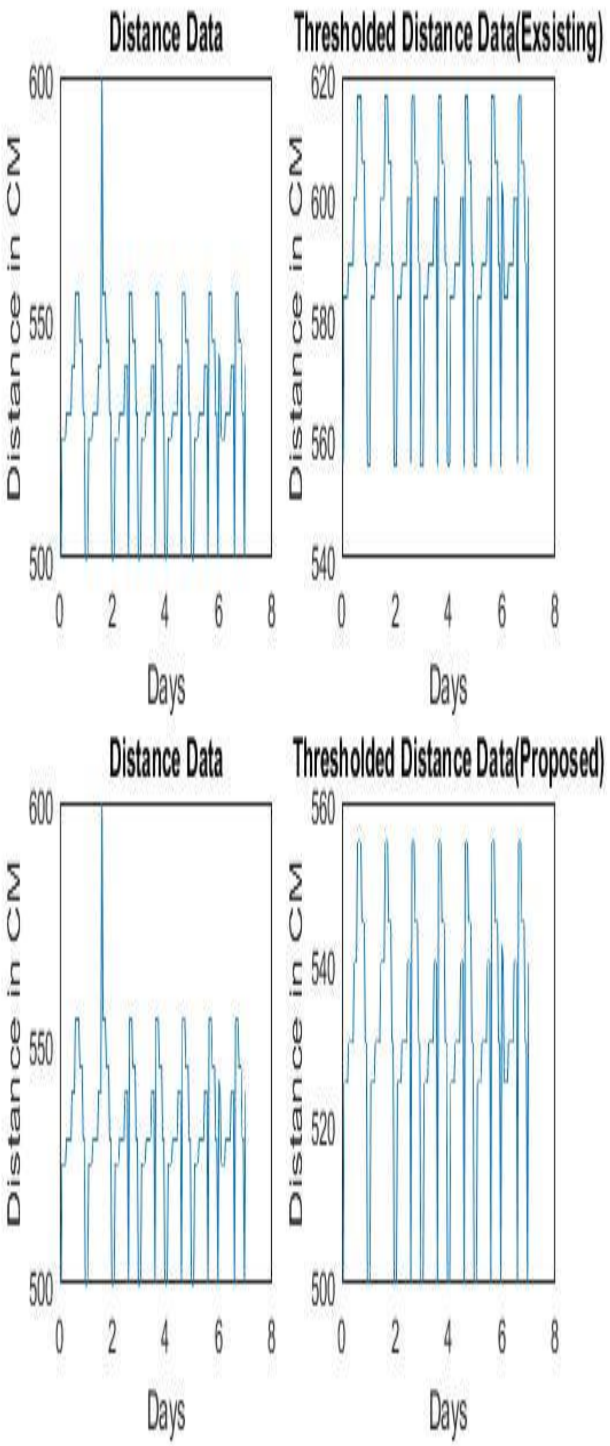

Figure 3: Threshold Comparison

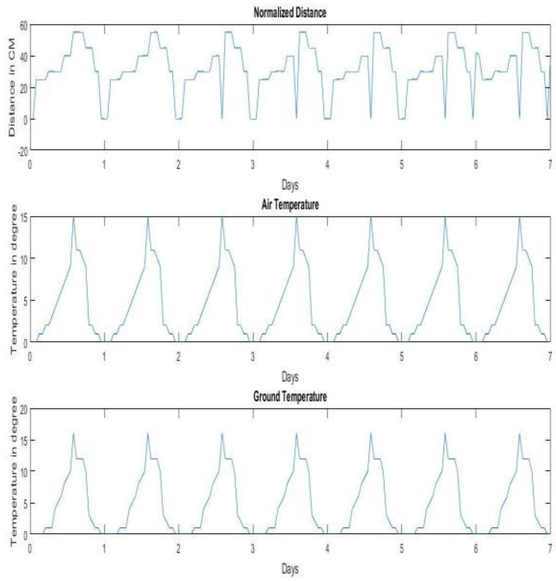

Figure 4: Normalization

In order to reconstruct the missing data in real-time, the data generated during the previous days will be used. The reconstruction not only means constructing the missing data from the past samples it also means the construction of the entire sample left by giving small part of input data. In normalization, the step done here is nothing but a conversion of the above data obtained to more suitable form for further analysis and thus obtained output is shown in figure 4. Here the water level estimation height is about 500 cm. This 500 cm is changed to 0 level or reference level so that the change in water level or distance can be easily identified from the graph. Similarly, for the temperature parameter also the change in temperature occurs to about 15°C.The input data distance and temperature are then given to the ANN tool in matlab for getting the water level estimation graph shown in figure 5.

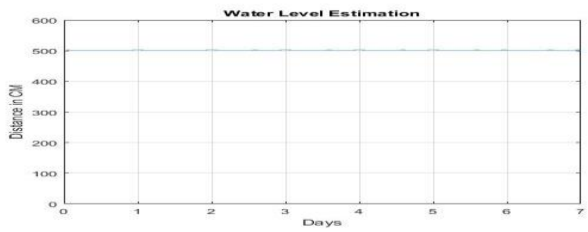

FIGURE 5: WATER LEVEL ESTIMATION

IV.CONCLUSION

In this paper the implementation details of flash flood detection using ANN is described. Nowadays the research activities going on in the field of neural network are making it as a promising factor in real world. Here the ANN's property to adjust themselves according to the given input and output is used which makes it flexible in modelling real world relationships. ANN also exhibit good convergence properties making it suitable to a low power embedded system application by choosing lower number of neurons and layers. Along with flash flood sensing the ANN algorithm is also merged using the sensors including ultrasonic and temperature sensor. This algorithm can implement on a low power microcontroller platform and can work in real time so that reducing usage of power in wireless sensor network. As a cost effective solution adding air quality sensor to this sensor module air pollution detection is also done.

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