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ORIGINAL ARTICLE

Artificial Intelligence Based Multi-modal Sensing for Flash Flood Investigation

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ABSTRACT

Flash floods are very abrupt and sudden and can devastate large areas within a fraction of seconds. Tsunami is also a grass root cause of infrastructure loss and casualties. Tsunami is caused by the release of energy inside the ocean. It has been observed that Tornados and Tsunami frequently occurred that caused more than 120000 casualties between 1992 to 2005. Several approaches and cases have been studied and applied to overcome this topmost issue. Strong and reliable flood risk management system must have the capabilities to forecast and estimate the change in the process: the hydro atmospheric and climatic development that causes flood waves and land and metropolitan exposure that leads to casualties. Techniques utilized for the early investigation of flash floods may be classified into the following categories a. Sensors and instrumentation-based b. Radar based c. Satellite images based. In this paper, researchers presented a reliable and vigor cost-effective solution for the prediction of flash floods accurately and precisely by using direct measurements with the combination of scaled conjugate gradient back propagation. Researchers have adopted direct measurement method by utilizing a couple of sensors named as PIR, ultrasonic sensor, water or humidity sensor, temperature and pressure sensors. Gas sensor has also been used to detect the increased carbon dioxide levels in the environment as the soil is saturated more and the probability of flash flood occurrence becomes sure in this situation. An appropriate mixture of estimation sensors can extensively boost the benefit of information in contrast with that from a single sensor. 48 hours of data have been recorded and processed for the false alarm identification by using Scaled conjugate gradient back propagation. Results proved that our proposed system worked better or equivalent to the other available techniques with minimized error rate. Results showed that it performed better than the existing approaches. Multi-layer perceptron (MLP) was applied to the same data set for the error and false alarm classification. Results were compared with the multi-layer perceptron and it can be easily observed that they are close enough, therefore, scaled conjugate gradient back propagation performed very well.

Keywords: Flash floods; Disaster management; Multi-modal Sensing, Sensors and Instrumentation

Author`s Contribution	Address of Correspondence	Article info.
1,2 Manuscript writing, Data analysis, interpretation and Active participation in data collection, 3,4,5 Conception, synthesis, planning of research, Interpretation, and discussion	*Tulha Khan Email: talha.khan@s.unikl.edu.my*	*Received: July 2017 Accepted: March 25, 2018 Published: June 30, 2018*

Cite this article: *Khan T, Alam M, Shahid Z, Mazliham ms, Khan S. Artificial Intelligence Based Multi-modal Sensing for Flash Flood Investigation. J. Inf. commun. technol. robot. appl.2018; 9(1):40-47.*

Funding Source: *Nil*
Conflict of Interest: *Nil*

INTRODUCTION

Flash floods are one of the topmost natural disasters. Intense and dangerous violent windstorm, tornadoes and thunderstorm are likely to end lives within a fraction of seconds. Artificial intelligence methods (AIMS) have been given a lot of significance for the hydrological and meteorological prediction as they are capable of optimization of linear and non-linear data as well. Enough number of articles have been studied and analyzed for the robust investigation of the floods. Forecasting techniques may be categorized into two categories a) Engineering and b) non-Engineering. Engineering category is about the construction of the dams and reservoirs for the safety and precautions while non-engineering techniques are based on the prediction and forecasting [1]. Usually, in short, terms monitoring the magnitude and peak of the water level have been observed [2]. Since ANN has the capability to resolve the convoluted nonlinear system, therefore, it can be acknowledged as a black box solution [3]. NNARX (Nonlinear Autoregressive with Exogenous Input) which is an extension work of ARX model has also been applied [3]. Extensive literature review for the prediction of the flash floods elaborated that a lot of methods and procedures have been applied which can be further divided into following categories a) direct measurement by the sensors and gauges b) Radar based measurements c) X- band satellite images [4].

Table 1: Comparative analysis of sensors, radar and satellite-based measurements [4].

Evaluation Parameters	SENSORS	RADAR	SATELLITE
Cost Effectiveness	High	Medium	Low
Installation Complexity	High	Medium	High
Calibration Complexity	Low	Medium	Medium
Data Assimilation	Low	Medium	High
Dimensional Resolution	Low	Medium	Medium
Short Range Monitoring	Low	Medium	Medium
Long Range Monitoring	High	Medium	High

It has been proved that real-time direct measurement from the sensors have higher accuracy and precision compared to the other procedures but still may contain some missed information and random data. Almost all of the parameters that can be considered important for the early identification of flash floods have been used to detect the flash floods like water level sensor; Rainfall drops module, ultrasonic sensors, PIR (Passive infrared) sensors, pressure sensors, and temperature sensors [4]. In PACT HAM. NODE researchers used an acoustic link for the transmission of oceanic bottom pressure to the surface unit which can easily predict the change of the oceanic bottom pressure [5]. It has been observed also from the Tesla meter measurements that at the time of the flash flood event magnetic field lines crossing through the earth surface diminished rapidly leads to negligible magnetic flux at the surface of the earth during the flood [6]. A unique solution like measurement and analysis of environmental carbon dioxide flux levels and soil humidity level have been examined with the classification process of Multilayer perceptron (MLP) for the less false alarm rate [7]. In this paper, researchers have proposed a direct measurement method from the sensors with less false alarm rate. In past several parameters like precipitation velocity, rainfall intensity, wind speed, temperature, pressure, the direction of the flow, the color of the water, soil moisture, increased carbon dioxide levels, and geomagnetic field have been recorded and documented for further processing with the AI based algorithms. In proposed research a black box data collection module has been fabricated comprising of the following sensors a) pressure b) temperature c) water level d) gas sensor for detecting CO2 and e) ultrasonic sensor. These sensors are integrated on a single module so that the fusion may be applied. A huge amount of data has been saved and can also be monitored on a real-time basis. Sensors generate false alarms when giving the output. Multi-layer perceptron MLP was also applied to reduce the false alarm rate. The paper has been divided into further subsections. In Section II some past and on-going successfully techniques have been discussed. Materials and methods have been discussed in section III. Section IV represents the results. Section V is for discussion and research has been concluded in section VI.

RECENT FLASH FLOODS FORECASTING TECHNIQUES

Several approaches have been adopted like an instrument known as (NISTARA) consisted of various sensors (fire, temperature, pressure, and rainfall) was assembled to predict the flash floods. Generally, smoke sensors have a high false alarm rate in contrast with the temperature sensors, therefore, a combo of these two sensors can be used. Evacuation route was announced on the basis of fuzzy logic depending on the many fire situations [8]. 3 Hour prediction was performed for the flood water level by using neural network NNARX structure and successfully tested in Pahang river basin [3]. Radar images cannot be considered trustworthy while rain gauges need maintenance on regular basis. Basically, X band images are obtained from ground radars after every five minutes having an angular resolution of one degree and radial resolution of 150 meters. The reflected observations are remodeled into moisture rates by using Z-R formula from Marshal Palmer and second transformed from polar grid to the Cartesian one [9]. GPS and metrological data were processed to determine PWV (Precipitable water vapors) by using Troway 2.0 developed in MATLAB. The original weighted mean temperature was employed to accurately convert zenith wet delay (ZWI) [10]. Pulse compression and all latest waveform technologies (a signal processing technique commonly used by radar, sonar and echography to improve the range resolution as well as the signal to noise ratio by superimposing of a low-level signal to a higher-level signal) are being used in armed forces but barely utilized for the detection of weather because of the scattered behavior of the water precipitation and vapor (Explained by IEEE 686-2008, Standard Radar Definitions) [11-12]. Conventional river sensors perform flash flood identification having both merit of constant and balanced observations and de-merit of deployment complexity and costing issues [13]. Geo-location data based mobile application for the flood risk management was designed [14]. To discover the tornados, WARN (Web-enabled Awareness Research Network) receives data as an input from pressure observer (lower surface ocean) and accelerometers to reveal the symptoms of tornados and tremors from the earth [15]. Watercolor can be a significant apparent parameter for the identification of flash flood as flood watercolor is in red tone and in the normal flow, it is white-blue tone [16]. A DBF (Digital Beam Forming) based radar is recognized suitable to observe the current arrangement pattern in a precise time [17]. CASA (Collaborative Adaptive Sensing of the atmosphere) in alliance with U.S National Science Foundation (NSF) were devoted together to determine the weather changes and forecasting of risky accidents by deploying tiny radars to measure the climatic and atmospheric changes [18]. Mainly Karachi flow comprises of the river system, Malir, and Lyari. Both of the rivers are used to drain out and clean out the flow of the water of heavy rainfall and thunderstorm. These riversides have been covered by the yields of the crops, illegal mound to hold water and severely stuck by the garbage and poor sewerage system. Satellite-based images were processes to obtain land use/land cover (LULC) of the Malir river watershed [19].

MATERIALS AND METHODS

In our proposed research authors have designed a multi-modal sensing device for the collection of data. This research has been branched into two phases a) collection of data b) classification of faulty data. For the data collection authors have proposed six sensors a) ultrasonic sensor for determining the distance of the water b) Gas sensor for measuring the increased level of CO2 c) Pressure sensor d) Temperature sensor e) water level sensor f) PIR sensor. An appropriate combination of transducers for the robust evaluation of floods leads towards the successful testing and validation.

A. Ultrasonic Sensor

Fig. 1 Ultrasonic ranging module

Fig. 1 represents the ultrasonic ranging module HC-SR04. It is a 4-pin sensor module. It gives off a signal of around 40000 Hz which bounces back to the module. It calculates the distance without any contact with the object. Ultrasonic sensors have been used for measuring the water distance to the coastal bed.

B. Gas Sensor

Fig. 2 MQ2 Gas sensor

The MQ2 gas sensor is used for gas leakage detection. Here it has been used to measure the increased levels of carbon dioxide. Estimation of soil containing atmospheric carbon dioxide levels as the plants receives less quantity of water from the soil due to the raised levels of carbon dioxide. Because of this novel biological phenomenon, the soil is saturated rapidly causes more floods and run-offs. Therefore, this sensor has been to calculate the amount of gas during the flash floods.

C. Water Level Module

Fig. 3 Water Level sensor

D. PIR Sensor

Fig. 4 represents the PIR (Passive infrared sensor) sensor that will sense the motion of the flash flood or the position of the flash flood in its field of view. It detects the variations in the infrared radiations. Pair of PIR sensor may also be used to identify the object motion accurately.

E. Barometric Pressure and Temperature Sensor-BMP 280

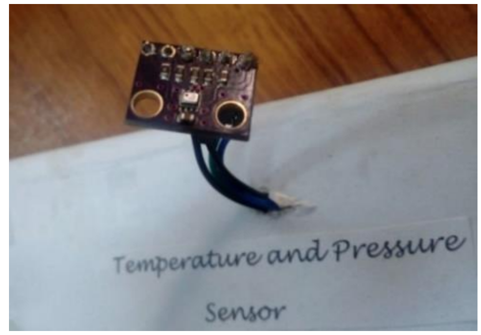

Fig. 5 shows the barometric pressure and temperature sensor (BMP-280). It has been used to measure the environmental temperature and surroundings pressure. The sensors give the precise and accurate output and can be acknowledged as a cost-effective solution. Pressure changes with respect to the altitude.

F. Arduino-Uno

Fig. 6 Arduino Uno

Arduino Uni consists of 14 digital I/O pins. Six of them can be utilized as a PWM outputs. Uno board is composed of 6 MHz quartz crystal, power jack, and a USB connection also.

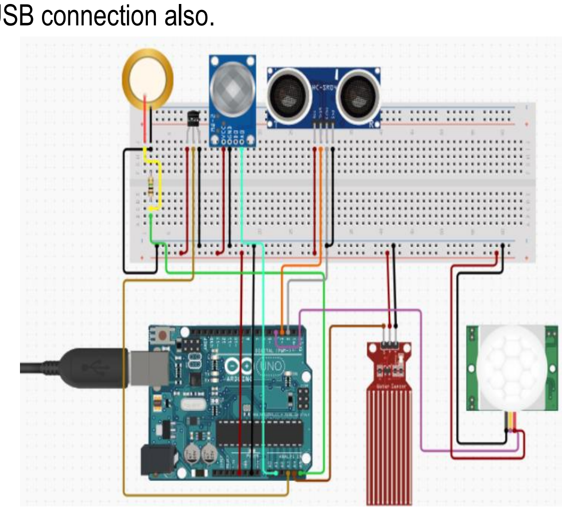

Fig. 7 Circuit Diagram

Fig. 7 represents the circuit diagram. Basically, all the sensors have been interfaced with the Arduino. Each sensor coding has been integrated on a single Arduino. Sensors like water level sensor module giving analog output. Pin configurations are as follows: A0 is connected with the Arduino analog pin 0, GND pin is connected with the Arduino ground and Vcc is connected with the Arduino Vcc. PIR sensor has been utilized to identify the movement or the motion within the vicinity of the sensor. After connecting the PIR to the +ve and -ve wire the indicating led was connected to the pin no. 7. Ultrasonic sensor, BMP 180, temperature sensor and BMP 180 have been connected with the I/O pins of Arduino. All the data of the sensors have been collected by interfacing the Arduino serially with the personal computer. Data can be transmitted wirelessly as well through the wifi module or Bluetooth module. The built-in software of Arduino was used to serially monitor the data. Log file of the data was maintained and easily data can be stored and can be used for the graphical analysis as well.

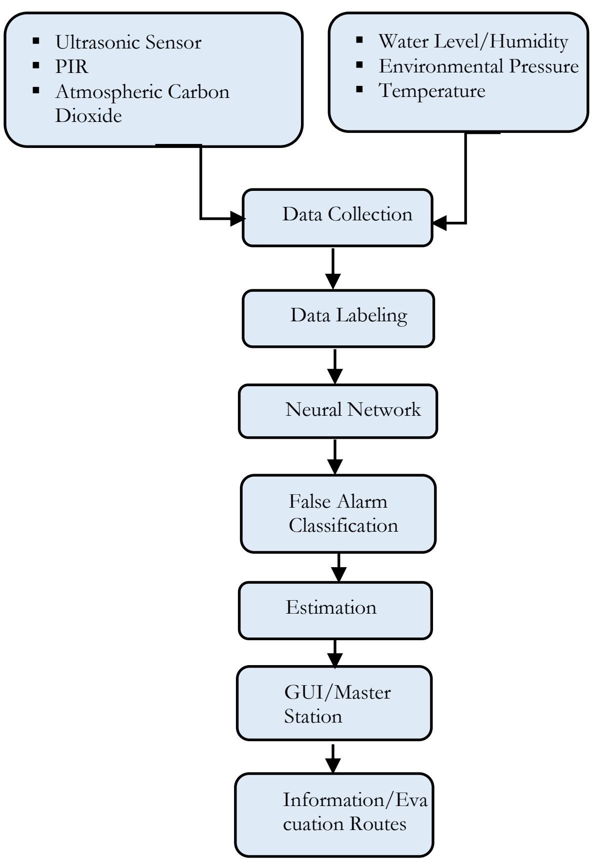

Fig. 8 Block diagram of a multi-modal sensing

Fig.8 explains the process diagram flow for the data collected from the sensors. There are six sensors which were interfaced with the Arduino Uno board. Arduino was programmed by using its software Arduino.exe. Data can be monitored and observed easily on the serial monitor by selecting an appropriate port. Data was labeled and then the neural network was applied to discriminate the false alarms. Data has been collected and gathered from the seashore of Karachi, Pakistan.

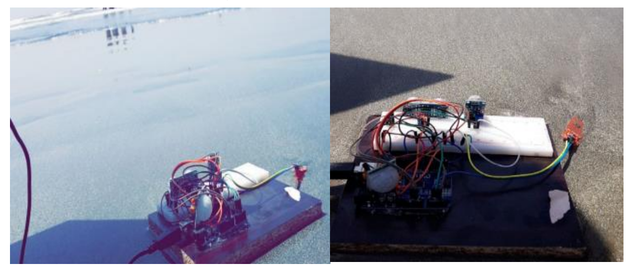

Fig. 9 Data collection from the seaside

Fig. 9 displays the data collection from the seashore at Karachi. Pakistan. Data were gathered on an hourly basis.

RESULTS

The experimental results have been obtained from the device predicting the flash floods and bad weather. Some of the data have been presented here. Actually, multiple sensors have been deployed to identify the flash flood accurately and precisely. Multiple parameters have been detected so that false alarm rate is minimized. Data can be easily collected from any location as we have collected from the seashore of Karachi, Pakistan. The observed data is given below:

A. Dataset Graphical Analysis

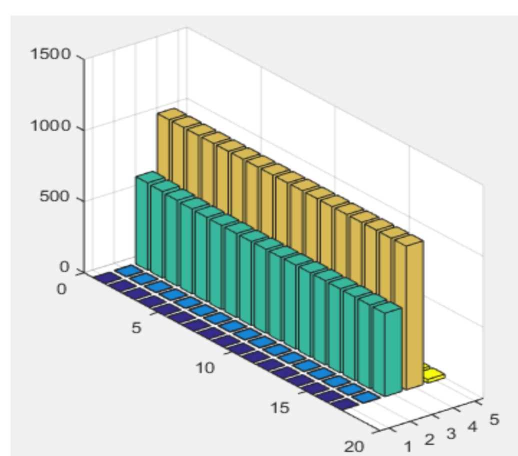

Fig. 10 Dataset graphical analysis

Dataset has been plotted using MATLAB to show the graphical analysis of data values that have crossed the threshold level of the sensitivity or activation trigger. Resolution of the sensor can also be observed.

B. Dataset Labeling and Dataset Ranges

Threshold values of the multiple sensors and ranges have been set and adjusted for the accurate and proper investigation of the flash floods. The neurons were trained through adjusting these ranges. Data labeling was performed in order to classify the data by applying Neural Networks.

PIR Sensor: Low=0, High=1

Ultrasonic Sensor:

Distance:

Less than or equal to 10.00cm, High = 1

Greater than 10.00 cm, Low =0

Water Level Sensor: Greater than or equal to 200 = High = 1

Water Sensor: Less than 200 = Low =0

Temperature sensor: Less than 30 = High = 1

Temperature sensor: Greater than or equal to 30 = Low = 0

C. Scaled Conjugate Gradient Back propagation

Initially, training of the neurons was performed and then classification by neural network was performed. For the training of the neurons scaled conjugate gradient back propagation has been applied. The main motive is to optimize the value of the weights. The 'training' function was utilized for the training purpose in the MATLAB.

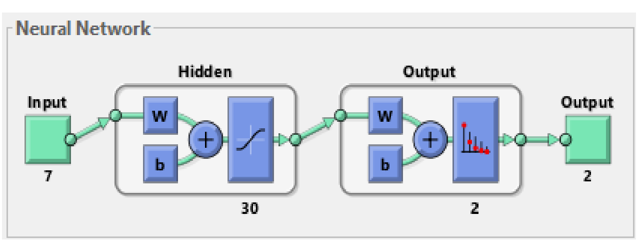

Fig. 11 Training of Neurons

Dataset has been applied data division by using 'dividerand' algorithm in the MATLAB. Scaled Conjugate Gradient was applied to train the dataset that is described as 'trainscg' for the optimization the values of the weights. The minimum excluded value (MEX) of the dataset was also estimated.

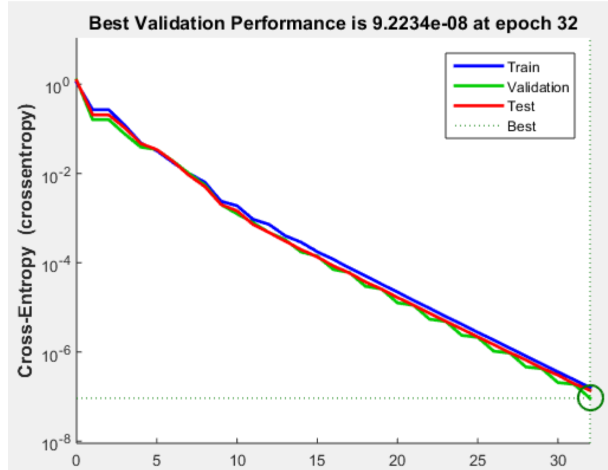

Fig. 12 Validation Performance Graphical Analysis

Fig. 11 represents the validation performance graphical analysis of the applied neural network scaled conjugate gradient back propagation. Cross-entropy can be used to determine the loss function in the optimization and machine learning algorithms.

Fig. 13 Confusion Matrix

Fig. 13 indicates the performance of the proposed classification model. Dataset was compared with the trained neurons that may be acknowledged as a supervised learning.

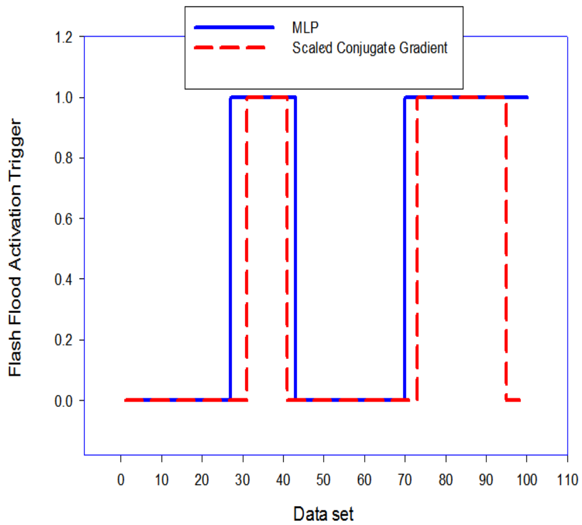

Fig. 14 Results Comparison of Scaled Conjugate Gradient (Scg) with Multi-layer Perceptron (MLP)

Fig. 14 shows the comparative analysis of scaled conjugate gradient back propagation and Multi-layer perceptron (MLP). The data set of various sensors includes PIR, temperature, pressure, altimeter, CO2 and ultrasonic sensors values. Multi-layer perceptron (MLP) was applied to the particular data set for the vigorous classification of the flash floods. The results of scaled conjugate propagation were compared with the multi-layer perceptron. Results proved that they are close enough together and scaled conjugate gradient back propagation worked better.

DISCUSSION

There are so many methodologies available applied by the authors for the robust identification and investigation of the flash floods as it can be considered one of the topmost natural disasters in the world. The proposed hardware gathered the meteorological and hydrological data accurately and precisely and performed better. The collected data was filtered out and processed to minimize the fake alerts. To execute it properly scaled conjugate gradient backpropagation was applied. The fabricated hardware comprised of various sensors achieved results correctly better than other available techniques.

CONCLUSION

Results proved that our proposed research by using scaled conjugate gradient back propagation performed better or equal to all other recent approaches. Current sensor based, radar-based and drone-based approaches cannot be considered as a cost-effective solution. False alarm rate has been minimized by using scaled conjugate gradient up to 30% and it can be further eliminated by using some other classification and optimization algorithm in future work

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