International Journal of Scientific Engineering and Research (IJSER)
www.ijser.in
ISSN (Online): 2347-3878, Impact Factor (2015): 3.791

Environmental Monitoring using Sensor Based Wireless Embedded Systems and ANN

Radhika Bajoria[1], Pavithra M.[2], Pratiksha Prabhu[3], Rajat Tiwary[4]

[1,2,3,4]B.E (Information Science and Engineering), 8th Semester,
M S Ramaiah Institute of Technology
(Autonomous Institute Affiliated to VTU) Bangalore, Karnataka, India

Abstract: ***A comfortable environment can increase the productivity in multi-folds. So it is important that the environment variables, such as temperature, humidity, light intensity and air quality (gas/smoke) are continuously monitored and adjusted to maintain a comfortable working environment with suitable threshold values on each of the variables depending on the conditions and quality of services required. Pervasive computing is one of the technological solutions that provide services in such an environment. In order to handle the challenges in monitoring, adaptability and maintenance of the ambience for a comfortable environment a sensor based wireless embedded system is designed using machine learning algorithms. In this framework the machine learning algorithms are embedded at the local level for decision making to filter the noisy and unwanted data during continuous monitoring and adaptability. The proposed model is implemented using an Intel Galileo Gen 2 board, sensors configured with the board are temperature, humidity, light, sound and gas sensors. Machine Learning algorithms are designed using Back Propagation Neural Networks which are deployed along with embedded software. Sensor data collected from the environment are used as training dataset for the Machine Learning algorithms with suitable decisive parameters. Back Propagation Neural Network is implemented to perform tasks such as predictions of the environmental parameters, expected threshold levels and averages. The main advantage of Back Propagation Neural Network is that it can fairly approximate a large class of functions. In formulating the ANN-based predictive model; three-layer network has been constructed. The Neural Network is trained and tested and the accuracy of the algorithm is determined. The neural network based prediction is integrated in real time monitoring, analysis, and control system for environmental conditions. Thus this project provides a prototype of a smart environmental monitoring system which can analyze large amount of environmental data and predict in real time to support decision-making and related tasks.***

Keywords: Pervasive computing; machine learning algorithms; Intel Galileo Gen 2 board; temperature sensor; humidity sensor; light sensor; sound sensor; gas sensor; Back Propagation Neural Network; prediction.

1. Introduction

Environmental monitoring describes the activity that needs to take place to monitor the quality of the environment. The environmental conditions play an important role in various fields such as agriculture, air and water quality monitoring, noise pollution monitoring, climate change monitoring and weather forecasting. The aim is to provide an efficient and inexpensive environmental monitoring system based on sensor networks.

The application of technology in environmental study has become an important aspect in the field of research and development. Predictions based on temperature and humidity is important to human life, industries, agriculture and various other fields. Detailed understanding of the environment can be done by using sensors and machine learning algorithms.

Environmental monitoring is a systematic approach for observing and studying the condition of the environment. It is one of the major applications of wireless sensor network. WSN consist of different sensors which are integrated and implemented to monitor different environment parameters like temperature, humidity, air quality, light intensity etc. Sensor networks are dense wireless networks of small, low-cost sensors, which collect and disseminate environmental data.

For leading healthy and pleasant life, human beings require an environment with stabilized temperature, humidity and regulated air quality, but with increase in environmental pollution due to increase in automobiles and rapid urbanization have caused an adverse effect on the environment. Therefore, environmental monitoring system is required to provide useful information about the factors deciding the environmental behavior and can help in taking appropriate measures to mitigate the negative impact whenever it is necessary.

The purpose of monitoring the environmental condition is not only to collect the data but also to perform necessary analysis in order to provide the information which is required by the scientists, planners, policy makers to make a decision on improving and managing the environment thereby resolving issues concerned with the environment.

Though there are various improvements in the instrument of environment monitoring, we are still not able to eradicate the harsh environmental effects. The main mission of environment monitoring system is to record the values of various parameters which decide the behavior of the environment and deliver these information or data to the population to warn against any danger.

Monitoring provides raw measurements of environmental parameters, which can then be analyzed and interpreted. This information can then be applied in many ways. Analysis of monitoring data allows us to assess how adverse the effects are from day to day, which areas are worse than others and whether negative impact levels are rising or falling.

Licensed Under Creative Commons Attribution CC BY

2. Related Works

Many works were done related to environmental monitoring, wireless embedded systems and Artificial Neural Networks. They are summarized below.

Kunal Dhodapkar and P. Sathya presented the construction and working of a very simple, easy to use and cost effective Environment Monitoring system which runs on battery power. It is a basic model that monitors temperature in "Celsius" and Light Intensity in "Lumens". It starts working as soon as it is switched on and continuously shows monitored data on a LCD screen and refreshes itself every five seconds. The main objective this project is to construct a simple and effective environment monitoring system for both industrial as well as day to day use for people. This is highly beneficial for low cost industrial applications, travelling situations, outdoor conditions, basic military purposes and household applications. [1]

Peter Corke, Tim Wark, Raja Jurdak, Wen Hu, Philip Valencia and Darren Moore studied the application of wireless sensor network (WSN) technology to long-duration and large-scale environmental monitoring. Real examples taken from their work in this field are used to illustrate the technological difficulties and challenges that are entailed in meeting end-user requirements for information gathering systems. Reliability and productivity are key concerns and influence the design choices for system hardware and software. Long-term challenges for WSN technology in environmental monitoring and outline our vision of the future are also discussed. [2]

Ch.Jyosthna Devi, B.Syam Prasad Reddy, K.Vagdhan Kumar, B.Musala Reddy and N.Raja Nayak presented a neural network-based algorithm for predicting the temperature. The use of neural networks us in forecasting the weather and the working of most powerful prediction algorithm called back propagation algorithm is explained. A 3-layered neural network is designed and trained with the existing dataset and obtained a relationship between the existing non-linear parameters of weather. Now the trained neural network can predict the future temperature with less error. [3]

Andrew Culclasure presented a survey of existing research on applying ANNs to weather prediction. Also, an experiment in which neural networks are used to regress and classify minimum temperature and maximum gust weather variables is presented. This experiment used a dataset containing weather variables recorded every 15 minutes over the course of a year by a personal weather collection station in Statesboro, Georgia. Data cleansing and normalization were applied to this dataset to subsequently derive three separate datasets representing 1-hour, 6-hour, and 24-hour time intervals. Three different NN structures were then applied to these datasets in order to generate minimum temperature regressions at 15-minute, 1-hour, 3-hour, 6-hour, 12-hour, and 24- hour look-ahead ranges. Maximum gust regressions were also generated for each dataset 2 at 1-hour, 3-hour, 6-hour, 12-hour, and 24-hour look-ahead ranges. Finally, neural networks were applied to these datasets to classify freezing events and gusty events at 3- hour, 6-hour, 12-hour, and 24-hour look-ahead ranges. [4]

3. Proposed Approach

The proposed model of environmental monitoring system enforces the ability to perform data acquisition on the sensor system and further perform prediction on the collected data. The sensor interface consists of temperature (grove temperature sensor), humidity (yl-69), gas (MQ-2) and light sensors (grove light sensor). Intel Galileo Gen2 board is configured and interfaced between the sensor system and the computer. Wi-Fi module, Centrino N-6235 compatible with Intel Galileo board is configured and used for wireless communications i.e., for uploading data in the web server.

The aim is to collect a data from sensors and prepare datasets consisting of environmental parameters like temperature, humidity, light, sound, air quality etc. We have performed normalization on this data to scale the dataset in the range of 0-1 using min-max normalization. This normalized data is passed to the Back Propagation Algorithm. The Neural Network is trained by updating all the weights and biases as per the errors obtained in each iteration. The proposed BPNN model is tested by using testing datasets so that it performs predictions with good accuracy and least error.

Wi-Fi connectivity is provided to the model through which sensor data is uploaded to the internet which can be accessed within the Wi-Fi range. The data is then stored in a database for further processing such as plotting a graph based on changing values.

Comparing the proposed model with the architectural model, figure 1, the physical layer comprises of the Galileo board and the sensors. The network layer comprises of the Wi-Fi module and IPv4 protocol for data communication. The Application layer comprises of the web server, database and Cloud. Horizontal interaction takes place between the individual components of each layer and in turn vertical interaction occurs between the layers through which data exchange and co-ordination happens.

Licensed Under Creative Commons Attribution CC BY

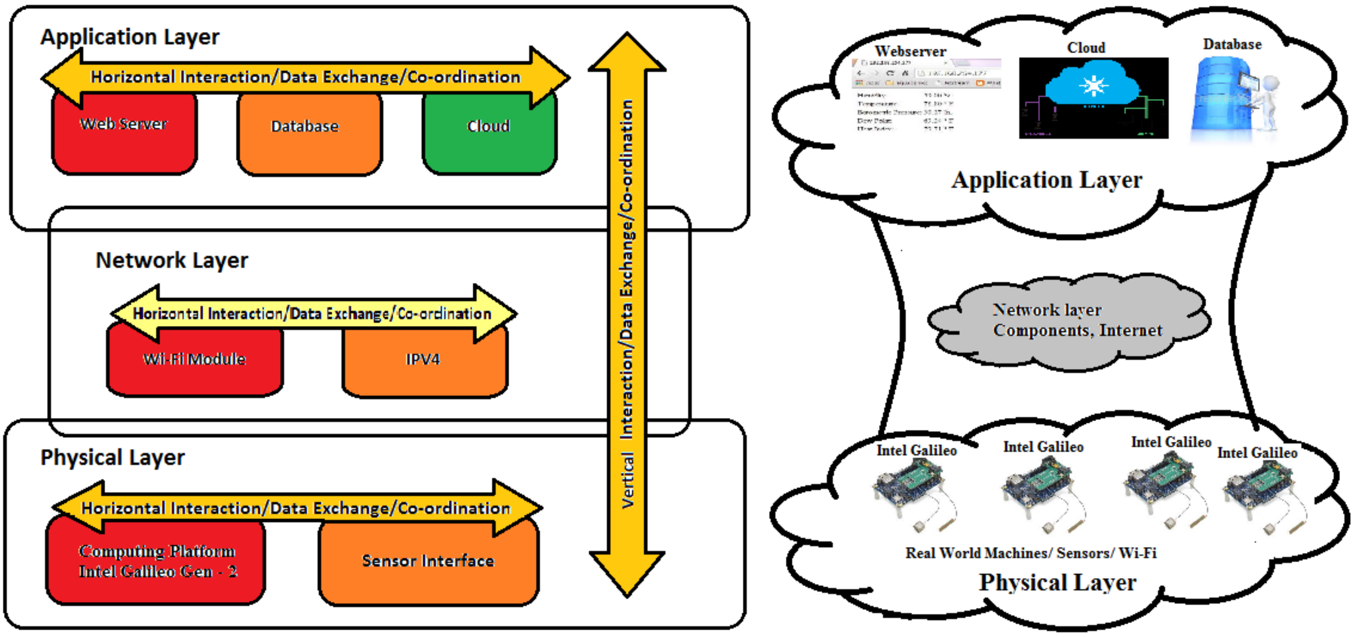


Figure 1: Architectural Model

4. Implementation

The proposed system is implemented in two phases, namely:

a) Data monitoring phase
b) Data prediction phase.

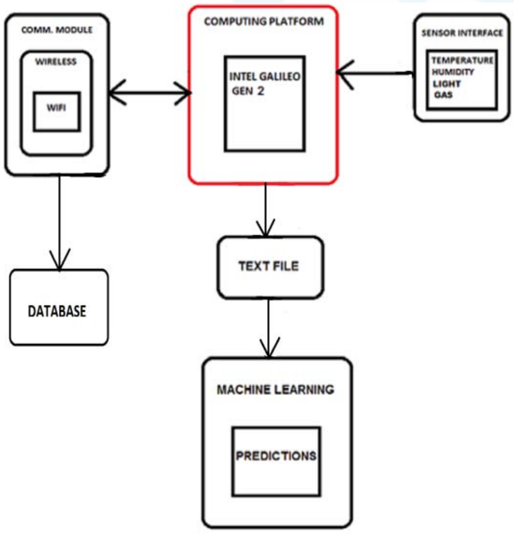


Figure 2: Generic Design of Environmental Monitoring System

In the Data monitoring phase, sensors which monitor environmental parameters such as temperature, air quality, light intensity and humidity are interfaced to the Intel Galileo board. Arduino code is run in its IDE which continuously retrieves the sensor data and displays them on its serial monitor. This data is exported into text files which are used in the data prediction phase.

In the Data prediction phase, Back Propagation Neural Network algorithm is applied to the datasets stored in text files. We have performed normalization on this data to scale the dataset in the range of 0-1 using min-max normalization.

Formula for Normalization

$$zi = \frac{xi - \min(x)}{\max(x) - \min(x)}$$

where $x=(x_1,\ldots,x_n)$ and z_i is now the i^{th} normalized data.

Formula for De-normalization

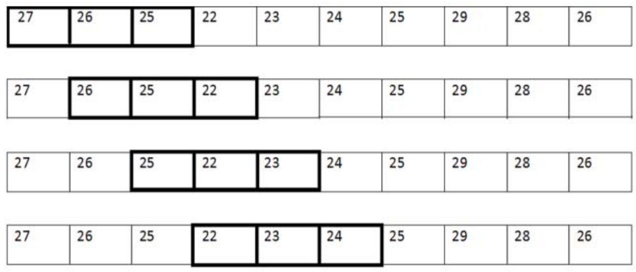
$$d = zi \times (max(z) - min(z)) + min(z)$$

where $z=(z_1,\ldots,z_n)$ and d_i is now the i^{th} de-normalized data.

This normalized data is passed to the Back Propagation Algorithm. The Datasets generated are input to the network along with weights and bias and outputs are generated accordingly. The dataset containing the temperature values is provided as input to the neural network. The number of input neurons is 3 representing the previous values from the temperature dataset. The number of hidden neurons is 3 for processing and the number of outputs is 2 representing the next two values from the dataset. For performing the time series prediction, a sliding window of size 3 is moved over the full data set to obtain the moving average. This acts as an input to the system and has been used to train the network. The cumulative errors are calculated over the inputs obtained from data. This process is repeated till the stopping condition has been reached. Similarly the other data sets are trained.

Licensed Under Creative Commons Attribution CC BY

Input window:



Output Window:

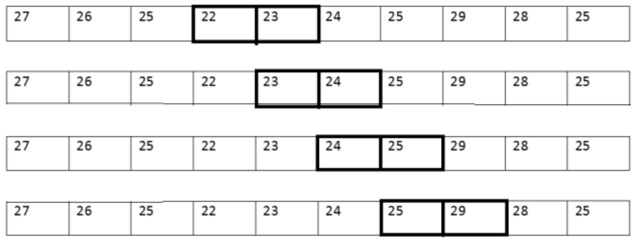


Figure 3: Input Window and Output Window

4.1 Sliding window concept used in prediction

An input pattern (of temperature values, in this case) is provided to train the Neural network. Sliding window size is set for both (input window and output window) and the window is moved accordingly. Window size depends on the number of nodes in the neural network's layer.

In the given example, a temperature dataset (27, 26, 25, 22, 23, 24, 25, 29, 28, 26) is provided. Input window size is set to 3 and the output window size is set to 2. The windows move one cell at a time.

In the first training cycle, the sliding input window contains 27, 26 and 25. The target output contains 22 and 23. The learning cycle continues predicting the temperature values until the output values match the target values. Once the output values and the target values become approximately identical and error becomes minimal, the learning cycle for the first pattern is complete and the next input pattern is provided i.e., the input window is moved over the next three values (26, 25, 22) and the output patterns slides over the next two values (23, 24) and the procedure is repeated throughout the prediction process.

The learning algorithm for the back propagation neural network is outlined below:

1. Initialize the weights with random values in the neural network.
2. Do
3. For each input pattern I in the training dataset
T = neural-net-output (network, I) ;
 forward pass P = teacher output for I
4. Calculate error (P - T) at the output units
5. Compute delta_wth for all weights from hidden layer to output layer; backward pass
6. Compute delta_wti for all weights from input layer to hidden layer; backward pass continued
7. Update the weights in the network
8. Until all input patterns classified correctly or stopping criterion satisfied
9. Return the network. [5]

To estimate the performance of the neural network, it is tested using independent data that has not been used to train the network. This gives an estimate of the generalization ability of the network; that is, its ability to classify inputs that it was not trained on.

5. Results

In the temperature prediction process, these are the values obtained from temperature sensor: 25, 24, 23, 24, 26, 28, 22 and 23.This pattern is given as the input to the neural network. The obtained results along with the errors are shown in Table 1.

Table 1: Temperature prediction dataset

Input	Expected Output	Actual Result	Error
25 24 23	24 26	23.99996 25.99992	0.00004
24 23 24	26 28	25.99899 27.99989	0.00010
23 24 26	28 22	27.98999 22.99992	0.00012

In the humidity prediction process, these are the values obtained from temperature sensor: 205, 240, 230, 247, 326, 280 and 322. This pattern is given as the input to the neural network. The obtained results along with the errors are shown in Table 2.

Input	Expected Output	Actual Result	Error
205 240 230	247 326	246.99996 325.99992	0.00004
240 230 247	326 280	325.99899 279.99989	0.00010
230 247 326	280 322	279.98999 321.99992	0.00012

The back propagation Training -Error graph explains that the error is high when the iteration is less. In the graph shown in figure, it explains that when the number of iterations is below 15000 the sum squared error is maximum (i.e. 0.40) and when the count reaches above 2000 the error value starts nearing 0.

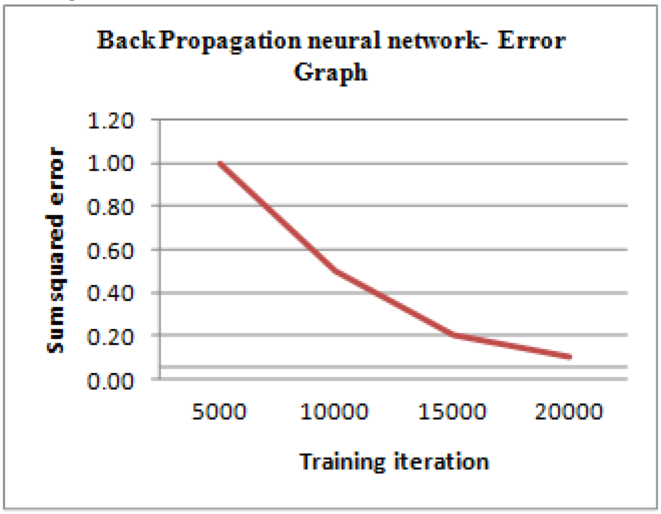


Figure 3: Back Propagation Neural Network – Error Graph

Licensed Under Creative Commons Attribution CC BY

6. Conclusion

In this paper, back propagation neural networks prediction algorithm is applied to the embedded system by providing a training dataset to the network. Through the implementation of this system, it is illustrated, how an embedded system such as Intel Galileo can be efficiently integrated with a neural network prediction model. The dataset consisting of multiple values has been trained and tested using the Neural Networks which predicts the Environmental parameters with utmost accuracy and least error. Hence a wireless system for actuation of the environmental monitoring and prediction of various conditions is provided.

In the future, environment decision making parameters can be gathered by using unsupervised learning algorithm such as Kohenen self-organizing neural network.

References

[1] Simple and Cost Effective Environment Monitoring System, International Journal of Engineering & Research Technology.
[2] Environmental Wireless Sensor Networks, Vol. 98, No. 11, November 2010 | Proceedings of the IEEE
[3] ANN approach for Weather Prediction using Back Propagation, International Journal of Engineering Trends and Technology (IJETT)
[4] Using Neural Networks to provide local weather forecasts, Electronic Theses & Dissertations, Jack N. Averitt College of Graduate Studies (COGS)
[5] An Efficient Weather Forecasting System using Artificial Neural Network, International Journal of Environmental Science and Development, Vol. 1, No. 4, October 2010
[6] A Survey on Environmental Monitoring Systems using Wireless Sensor Networks, JOURNAL OF NETWORKS, VOL. 10, NO. 11, NOVEMBER 2015
[7] A Wireless Sensor Network for Environmental Monitoring of Greenhouse Gases, ASEE 2014 Zone I Conference, April 3-5, 2014, University of Bridgeport, Bridgpeort, CT, USA.
[8] Wireless Sensor Networks for Environmental Monitoring, ijsret.
[9] Pollution Monitoring System using Wireless Sensor Network in Visakhapatnam, International Journal of Engineering Trends and Technology (IJETT) - Volume4Issue4- April 2013.
[10] A Review: QoS Architecture and Implementations in IoT Environment, Ravi C Bhaddurgatte* and Vijay Kumar B P, SMIEEE

Author Profile

Radhika Bajoria is pursuing B.E. in Information Science and Engineering, M. S. Ramaiah Institute of Technology, Bangalore.

Pavithra M is pursuing B.E. in Information Science and Engineering, M. S. Ramaiah Institute of Technology, Bangalore.

Pratiksha Prabhu is pursuing B.E. in Information Science and Engineering, M. S. Ramaiah Institute of Technology, Bangalore.

Rajat Tiwary is pursuing B.E. in Information Science and Engineering, M. S. Ramaiah Institute of Technology, Bangalore.

Licensed Under Creative Commons Attribution CC BY