TEST Engineering & Management

January - February 2020
ISSN: 0193-4120 Page No. 3409 - 3415

Combined ANFIS Method and Internet of Things (IoT) to Control and Supervise The Outdoor Panels Condition

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Article Info
Volume 82
Page Number: 3409 - 3415
Publication Issue:
January-February 2020

Article History
Article Received*: 18 May 2019*
Revised*: 14 July 2019*
Accepted*: 22 December 2019*
Publication*: 20 January 2020*

Abstract:
This paper addressed the monitoring and control of a system in real time using Adaptive Neuro-Fuzzy Inference System (ANFIS) method. In real plant an outdoor panelisan important thing that must be controlled and supervised. Internet of Things (IoT) is a kind of platform to establish a network of different sensors/actuators through internet. Communication and control through secure and fast way is possible from anywhere around the world is through the use of it. It is very helpful in improving the data storage and analysis as third party interference. This paper focused on the technology improvement of the panel; IoT architecture fundamentals and advantages; application and integration of "panel" & "IoT"; and Monitoring and control condition about the panel with a single platform using mobile phone (android). The ANFIS method is used to control the fan process speed. This ANFIS model has a minimum RMSE of 0.00078182to 100 times epochs.The panel improvement is achieved using Adaptive Neuro-Fuzzy Interface System (ANFIS) and expected to make a better panel system and make it more efficient.

I. INTRODUCTION

Internet of Things (IoT) [1] is a concept which allows communicating from different devices to each other by using internet or other mediums. The main idea is connecting all devices, systems and services to share data between these elements[2]. The collected data can be used in various scenarios, for example, in automation system, automotive, computer system, microwave absorber, medical care, power engineering[3,4,5] etc. Lots of space is available on it's platform to store and analyze the data[5]. The developed software can also be usedto auto control some activities.

In this paper, the outdoor panels condition can be supervised using IoT platform[6]. The user or operator has a total access to each and every outdoor panel that exists within a region through this system. The supervision can be done smartly, quickly with high security and redundancy support system[7]. Notification system is a very important part of this architecture, it is possible to apply through android platform and it[8]. On the other hand, the efficiency of time to know the condition of the panel can be optimized in a smarter way through this system.

This paper is organized as follows: Section II describes the methodology; Section III explains the testing and data analysis and Section IV is the conclusion.

II. METHODOLOGY

It is very important to know the conditions in realtime for the outdoor panels. The real time supervised system can help the users to maintain the performance of the unit, make it workmore efficiently and minimize the disturbance. By monitoring theconditions,wecan predict the sustainability of the module. In this system, panel conditions can be monitored easily using a mobile phone, and an artificial intelligence method (ANFIS) for fan performance prediction. The steps of this research can be explained on the flowchart in figure 2.1.

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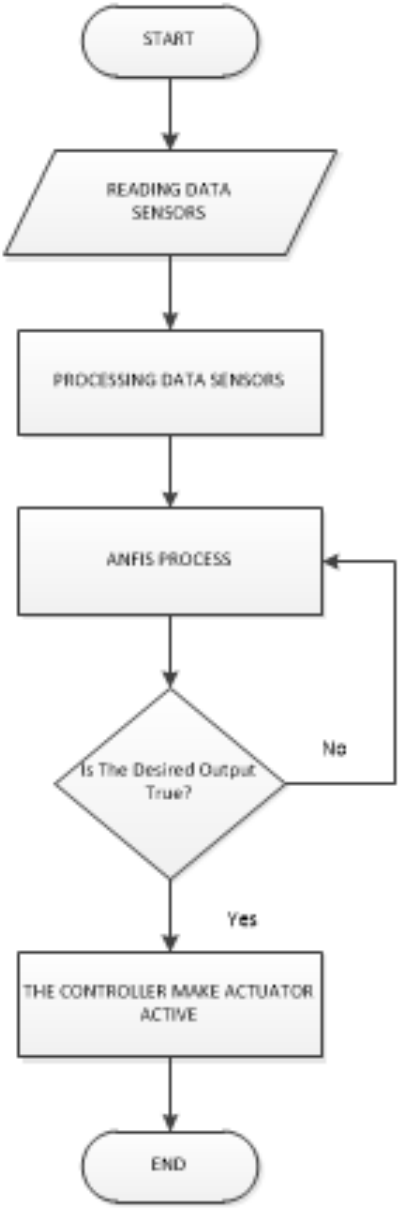

Fig 1.Flowchart System

Hardware Requirements

The hardware requirements are the necessary step to know the hardware needs by detailing the requirements to be applied to this system. In this application the hardware used is:

1. Arduino Mega Microcontroller
2. DHT11 (humidity and temperature sensor)
3. Real Time Clock DS3231 module
4. GP2Y1010AU0F Dust Sensor
5. Wemos D1 Mini
6. 12VDC Fan
7. L298N H-Bridge module
8. 12VDC Power Supply
9. Buck Converter
10. Buzzer

Fig 2.Outdoor Panel

Schematic of the Hardware Configuration System

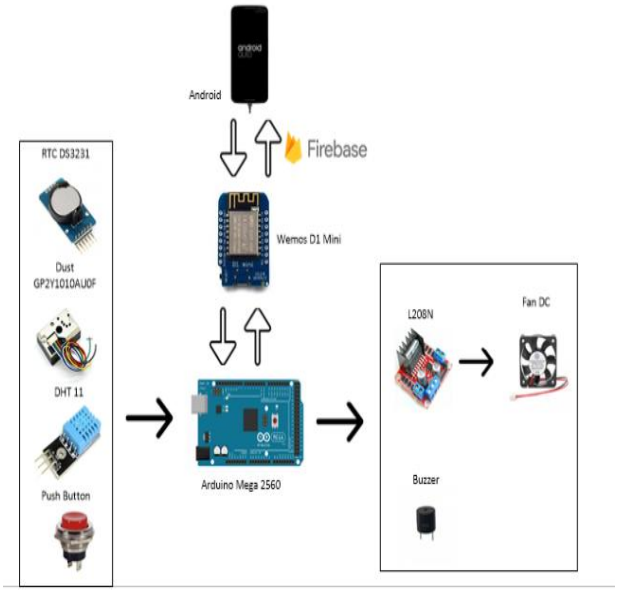

Fig 3. Hardware Configuration System

Figure 3.depicts the hardware configuration system, the detailed function of each element is listed below:

1. *The main controller is Arduino Mega.*
   The plant consists of the Arduino as the brain of all systems and governs all input / output activities of the system.
2. *2 sensors and 1 Module with specific function.*
   The used sensors are the DHT11 sensor, and GP2Y1010AU0F dust sensor controlled using areal time clock module DS3231.
   - ✓ The DHT11 is a basic, low-cost digital temperature andhumidity sensor. It uses a

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capacitive humidity sensor and athermistor to measure the surrounding air and generates an a digitalsignal output via data pin[9]. 3.

- ✓ While the GP2Y1010AU0F dust sensor serves as a detector ofdust levels in the panel.
- ✓ The RTC DS3231 module is used for timing.

3. *Arduino Data Reading.*

Sensors will send information and read by the Arduino Mega controller to perform the process of data processing execution.

4. *Activate the Actuator if the condition is not the same with the set point.*

Afterthe Arduino Mega processes the obtained data from the sensor, it will instruct the motion system on DC fan and DC motor that driven by the L298N Motor Shield Driver.A buzzer is available in case of emergency / warning alarm. The DC Fan will work if the temperature in the panel is above the set point, and the DC motor is used to clean the contained dust inside the panel.

5. *Wemos Data Sending to Firebase*

The communication system is realized using Wemos D1 Mini as a WIFI-based shield module that will send aninformationfrom the sensor to real-time Google database (firebase).

6. *Supervising Sensor Data in Real Time*

Monitoringsystemon Android smartphonecangenerate a realtime data sensor through a realtime Google databasewithemails d1 mini wifimodule, and a notificationsystem can be connected to anAndroiddevice ifthereisan emergency disturbance. This control system can be used to, run or shut down the system manually if needed. There are several methods that allow operators to access existing cabinet panels, one of them by entering username and password.

2.3. Software Requirements

Software requirements are dictated by the control system on existing hardware. The detailed software function used for this application are:

1. Arduino IDE

The open-source Arduino Software (IDE) makes it easy to write a code and upload it onto the board. It runs on Windows, Mac OS X, and Linux. The environment is written in Java and based on Processing and other open-source software. This software can be used with any Arduino board.

2. Firebase

Firebase a database thatis hosted in the cloud. Data is stored as JSON and synced in realtime to each connected client. When creating cross-platform apps with the Android SDK, iOS, and JavaScript, all clients will share an instance of realtime Database and receive updates automatically. In this system firebase is used to display the data in realtime.

Android Studio

Android Studio is an Integrated Development Environment (IDE) for Android application development, based on IntelliJ IDEA. In addition to be an IntelliJ code editor and powerful development tool, Android Studio offers more features to increase your productivity when creating Android apps.

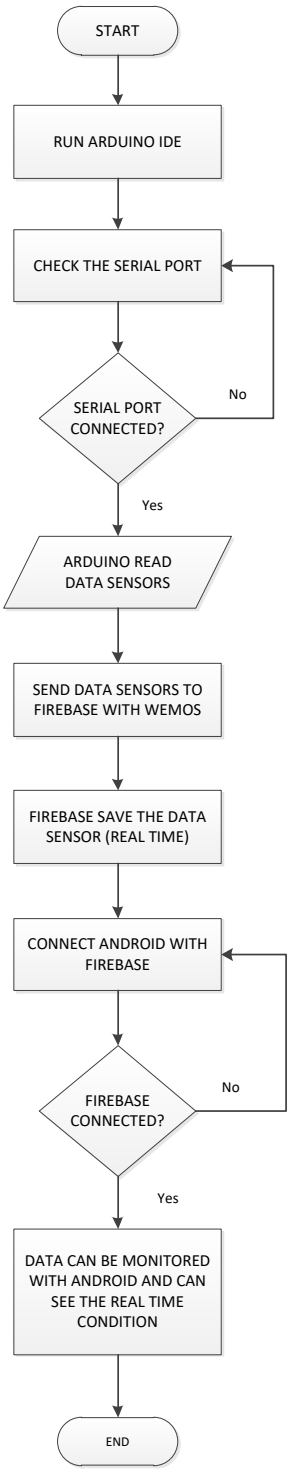

Fig 4. Flowchart of the System's Software

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Implementation:

1. First, we prepare the Arduino software to run the system.
2. Then download the main program in accordance with the system to be run.
3. Check the serial port in order to upload the program on Arduino mega hardware.
4. The Arduino will read the data from the sensor and wemos as a Wi-Fi based module will sent the information to the database.
5. Connect the android application to the real time database that has been designed.
6. If the communication is connected, then the users are able to monitor the panel conditions in real time by using android.

4.Set up and evaluation of the developed system:

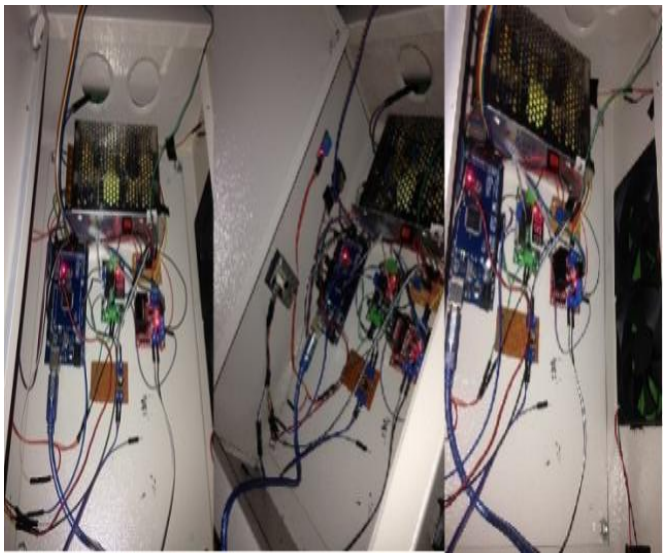

Fig 5. Inner Hardware

This is the steps of how the system being set up:

- Prepare the necessary Hardware Tools.
- Prepare and Install the necessary Software.
- Connect the12v DC fan with L298N H-Bridge.
- Connect the H-Bridge input pin to the Arduino.
- Configure theDHT11 sensor wiring on I/O interfacewith the address in the Arduino program.
- Configure theDust Sensor Wiring and matches the address in the Arduino program.
- ConfigureRTC module Wiring and matches the address in the Arduino program.
- ConfigureBuzzer Wiring and matches the address in the Arduino program.
- Interface all the sub systemsOpen the Arduino software. Declare each Arduino functions as a control variable of its own fan based on the set point of the temperature sensor. TheFan will work according to the declared command in the Arduino.
- Apply ANFIS method on Arduino. ANFIS works as a method that runs Fan based onDHT11 sensor data readings. If the temperature is overthe setpoint then the voltage on the DHT11 sensor is also increased.Then the Fan will act until the maximum speed is reached. If the temperature is under the setpoint (cold) then the voltage on the sensor is decreased.Andthe Fan will automaticallyturnoff (to minimize the power consumption).
- Programming 12VDC motor on Arduino for the ‘active’ condition and ‘inactive’ condition.
- Programming the android apps by using android studio to see the real time condition of the plant.
- Connect the android studio with real time database (firebase).
- Install and open android application. This application can serve as an interface to Monitor and control the Plant.
- Plant activity will bedisplayed on the android to know the temperature, the dust percentage, the time and the speed of the fan when the fan is active.

This stage is the stage of improvement based on the response and suggestions from lecturers and students.

5.ANFIS Training

ANFIS is an adaptive network based on fuzzy logic systems [10] and artificial neural networks [11-18]. In this research ANFIS method is used to control the speed of the fan.Retrieving the data sampling for the training ANFIS method is important. Below is a picture of the commonly used structure of the ANFIS, the fuzzy inference system is using Takagi-Sugeno-Kang fuzzy inference model[19].

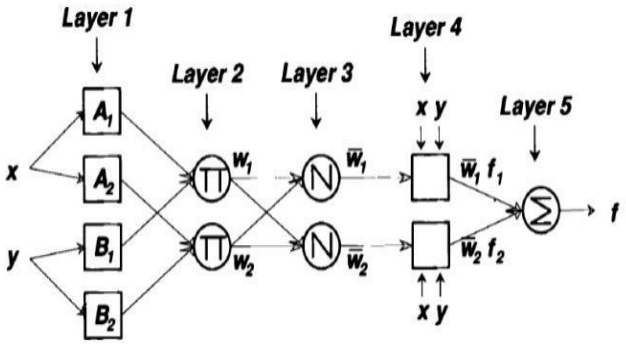

Fig 6. ANFIS Structure

Figure6.shows an exampleof ANFIS structure for two inputs *x* and *y* and one output *z*.TheANFIS method consists of 5 layers

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and each layer have some nodes.There are two kinds of nodes in ANFIS method;the adaptive node (boxed symbols) and constant node (circle symbol).The ANFIS method for each layer is described as below:

Layer 1 : Fuzzyfication

Every node (i) in this layer is an adaptive function with node function

$$O_{1,i} = \mu A_i(x), for\ i = 1,2\ or$$
$$O_{1,i} = \mu B_{i-2}(y), for\ i = 3,4 \qquad (2)$$

Where x (or y) is the input to the node(i) and A_i(or B_{i-2}) Are a linguistic label (such as "fast" and "slow").In other words,$O_{1,i}$ is the membership function of fuzzy set A (= A_1, A_2,B_1orB_2) and it specifies the degree to which the given input x(or y) satisfies the quantifier A.The membership function for A can be any appropriate parameterized membership, such as the generalized bell function:

$$\mu A_{(x)} = \frac{1}{1 + \left|\frac{x-c_i}{a_i}\right|^{2b}} \qquad (3)$$

Where (a_i,b_i, c_i) is the parameter set.

Layer 2: The Product Layer

Every node in this layer is fixed node labelled II, whose input is from layer 1:

$$O_{2,i} = \omega_i = \mu A_i(x)\mu B_i(y)\ , i = 1,2 \qquad (4)$$

Each output node represent the firing strength of fuzzy rule.Each output on this layer acts as weight function.

Layer 3: Normalization Layer

Each node in this layer is fixed node labelled N,This node calculated the ratio of weight function to the sum of all weight function.

$$O_{3,i} = \overline{\omega_i} = \frac{\omega_i}{\omega_1 + \omega_2}\ , i = 1,2 \qquad (5)$$

This layer's output is called normalized firing strength.

Layer 4: Defuzzification Layer

Each node in this layer is an adaptive node with node function

$$O_{4,i} = \overline{\omega_i} f_i = \overline{\omega_i}(p_i + q_i + r_i) \qquad (6)$$

Where $\overline{\omega_i}$ is the normalized firing strength from layer 3 and $\{p_i, q_i, r_i\}$ is the set parameter of this node.

Layer 5: Layer of Total Output

The single node of this layer is fixed node labelled $\sum$, which is calculated from all outputs from layer 4.

$$O_{5,i} = \sum \overline{\omega_i} f_i = \frac{\sum \omega_i f_i}{\sum \omega_i} \qquad (7)$$

III. Data Analysis

The testing mechanismsfor this paper are: sampling the data, train the sampling data to find the ANFIS model, filter the signal and testing model for new data.

Training Data

TABLE 1
Training Data to ANFIS Method

Test	Temperature ℃	Humidity %	"PWM" Fan	Condition
1	27.00 ℃	48.00 %	0 Rpm	
2	29.00 ℃	48.00 %	45 Rpm	
3	31.00 ℃	49.00 %	87Rpm	Cold
4	33.00 ℃	49.00 %	113 Rpm	
5	35.00 ℃	49.00 %	129 Rpm	
6	37.00 ℃	50.00 %	151 Rpm	Medium
7	39.00 ℃	50.00 %	174 Rpm	
8	41.00 ℃	50.00 %	193 Rpm	
9	43.00 ℃	50.00 %	209 Rpm	Hot
10	45.00 ℃	51.00 %	222 Rpm	
11	47.00 ℃	51.00 %	255 Rpm	

Table I shows the train data and it was processed using MATLAB to find the best ANFIS model. Fig 2.7 shows the result of ANFIS modelling.

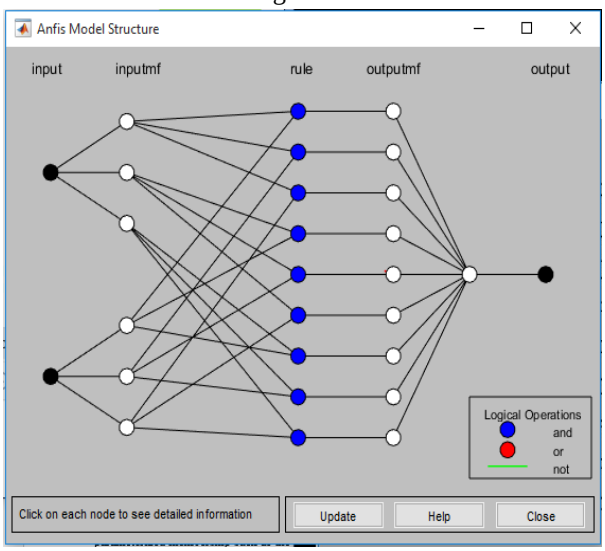

Fig 7. ANFIS Model

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Fig 8. Training Data

This ANFIS model has a Minimum RMSE of 0.00078182 with 100 times epoch. This model then used to test the data.

ANFIS Result

Testing the ANFIS model that has been generated is conducted by includingeleven data of membership function. The result is show in Table II.

TABLE 2 ANFIS Result

Membership Function	Target	Test	Error (%)
Cold	0	0.0725	0.0725
	45	44.903	0.0097
	87	87.0234	0.0234
	113	113.0616	0.0616
	129	128.9002	0.0998
Medium	151	151	0
Hot	174	174.0795	0.0795
	193	192.9197	0.0803
	209	208.9279	0.0721
	222	222.13	0.013
	255	254.9351	0.0649
Average Error			0.5768

Fig 9.Tthemembership function that used to train the data on the ANFIS method.

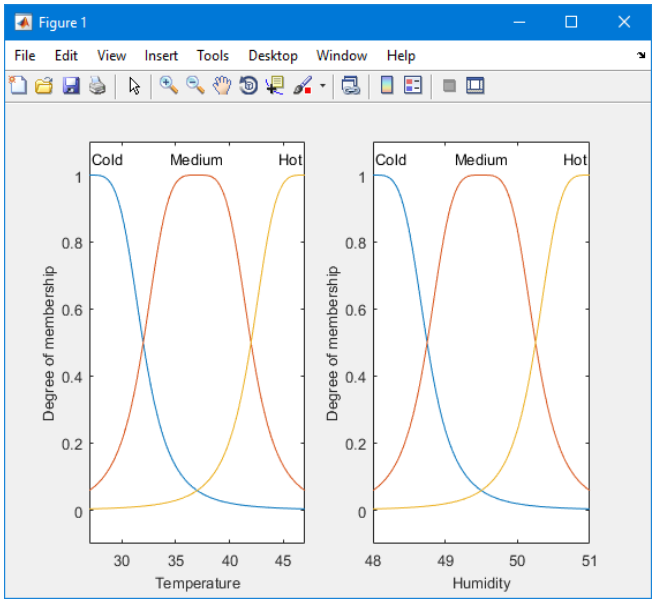

Fig 9. Membership Function. (1)Cold, (2) Medium, (3) Hot

Fig 10. shows some of therule base that are used to train the data on the ANFIS method.

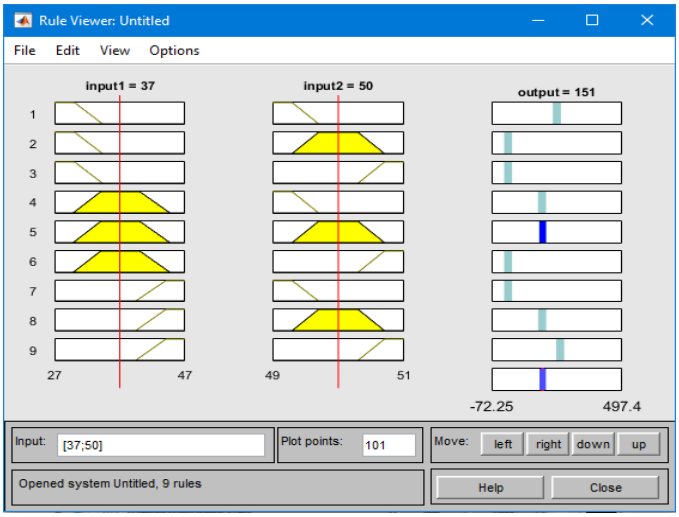

Fig 10. Rule Base

Comparison between t the table rules and the results it can be observed that they are similar. Fig 2.10 shows the data in membership function of medium with 2 inputs and 1 output, with the temperature of 37℃, humidity of 50% and the output is equal to 151 Rpm.

IV. Conclusion

The result's accuracy, using ANFIS method shows that the error value of 0.00078182 with 100 times epochs. The real time output of the dht11 sensor that is processed by ANFIS

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has a small gap from the rules that have already been made. ANFIS method can be applied to monitor and control the condition of panel effectively. This result offers an improved design of the outdoor panels that can be produced globally.

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