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An Efficient Actuator Control Mechanism using Fuzzy Logic on Embedded System

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Abstract

In this study, we proposed a fuzzy logic based control system for actuator control based on embedded systems. The proposed fuzzy logic takes input data from sensors and provides output signals to control the actuatosr. In this work, we have used a methodology of controlling to get data from temperature and humidity sensors and provide power to fan. In the proposed work five membership functions (MFs) are determined for each input/output. Here we have implemented full rules structure fuzzy logic controller and five membership functions are determined for each input/output. Hence 25 rules are specified in the rules-based of the fuzzy logic controller. The proposed method is implemented on Raspberry Pi 3. The fan actuator and temperature and humidity sensors are connected to Raspberry Pi. The fuzzy logic gets the temperature and humidity values from corresponding sensors and generates the power for fan output. The fan speed is adjusted according to the power.

Keywords: *Fuzzy logic, fuzzification, Raspberry Pi, temperature, humidity, Internet of Things (IoT)*

1. Introduction

To connect physical devices, buildings, vehicles, software, actuators, sensors which make these things to exchange information is called the internet of things (IoT) [1,2]. The Raspberry Pi is an essential platform for building the IoT projects. The Raspberry Pi is a is a mini computer having a singleton board. The development of Raspberry was carried out by Pi foundation in the United Kingdom to encourage primary knowledge about computer science in schools and colleges in emerging countries [3] Till to now several generations of Raspberry Pi have come to market. Raspberry Pi was first released in February 2004. In February 2016 the Raspberry Pi 3 B was released, and till date, it is the new mainline Raspberry Pi.

Fuzzy logic is a kind of logic where the truth values of parameters may be any real numbers having range between zero and one. The fuzzy logic is different that of Boolean logic where the values are either o or 1 exactly. Fuzzy logic is a control and flexible system methodology for solving different kinds of problems [4]. Fuzzy logic has numerous applications in several fields. For fuzzy logic controller no need of full knowledge of the model as compared to other controlling methods. The designing of fuzzy logic is very simple and robust, the fuzzy logic comprises of mainly three chunks: namely Fuzzification, Inference Engine and Defuzzification. The fuzzification components further comprises of membership functions, rules, *etc.*, [5, 6]. The procedure through which fuzzy logic map a given input to output using some formulas is called fuzzy inference. The mapping can be used for making decision. The fuzzy inference

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process includes fuzzification using membership function of crisp values, operator of fuzzy logic, and IF-THEN rules. A fuzzy logic model can be divided into four sections, namely fuzzifier, knowledge base, inference engine and defuzzifier. Mamdani fuzzy model have fuzzy rules consisted of antecedent and consequent predicts. The fuzzy logic rules are designed by an expert or team of experts depending on system need. There are many models of fuzzy logic Mamdani fuzzy logic is the most notable fuzzy logic in them usually uses for numerous application in real world.

The Raspberry Pi is a categorization of single-board computers which development was carried by Raspberry Pi foundation in the United Kingdom. The purpose of the development of Raspberry Pi is to encourage the primary computer science in schools and colleges. The first generation of Raspberry Pi that was Raspberry 1 model B was issued in 2012 February. After releasing the first model a second model was released which was an inexpensive and straightforward model called Model A. The sizes of these boards are approximately credit card. After one year two more models namely A+ and B+ were released. Another computer model has released in 2014 April for embed applications, and another raspberry model was released named Raspberry pi zero. In Raspberry Pi, the size of the raspberry was further reduced and general having the capabilities of Input/output was issued in November 2015. A new model was released in January 2017, this model name Raspberry Pi Model B which is nowadays in use and core Raspberry Pi [9, 10, 11, 12].

The objective of this work is to use efficient control the fan using fuzzy logic, we had also embed system (Raspberry Pi) and connected a fan to it. The organization of the structure of the paper is carried as: Section 2 represents the related work, Section 3 explains the proposed work and experimental work are given in Section 4, and Section 5 describes the conclusion of the proposed methodology for risk index estimation.

2. Related Work

Jasminka *et al.*, in [11] controlled fan speed by using fuzzy logic, input to the fuzzy logic is temperature and output is the required power for the fan. The fan is adjusted according to the power provided by fuzzy logic. Five MFs assigned to each input/output variable, named air temperature and output is speed rotation, and it also has five membership functions.

Zuhtuogullari *et al.*, [6] a proposed a system based on a fuzzy logic model for multicore (core2duo) microprocessors and mainboards. They developed fuzzy logic software named Fuzzy Expert System (FES) using C#.net. The purpose of this approach was to control the cooling system of the mainboard. The FES optimizes the control. The development of FES software was carried in C#.net to control the cooling methods of the microprocessor as well as mainboard cooling system. The purposed to develop FES was to control the power carried to CPU and also to central board cooling system. The FES comprises three inputs namely CPU frequency and core voltage. The FES output is best speed calculation of microprocessor fan, and then the speed values are sent to the electronic fan driver circuit via the series port. Efficient and calm cooling systems were realised using the FES.

Nandeshwar *et al.*, in [13] revised the automatic air cooler using the fuzzy logic control system is discussed. In the proposed work to fuzzy logic controllers were used for controlling temperature and humidity respectively. Inputs to this fuzzy logic are humidity, and temperature crisp input values form humidity and temperature sensors respectively. In this paper, they have used temperature and humidity values to control fan, water pump and fan two which is a room exhaust fan. For each variable, five membership functions are defined, and total 25 rules are used in this fuzzy logic.

Das *et al.*, in [14] designed a fuzzy logic for controlling temperature and humidity of a room. The proposed model has two fuzzy logic controllers to control temperature and humidity. Inputs to the first fuzzy logic are current temperature detected from the sensor, and the user set temperature. The temperature and humidity values are taken from temperature and humidity sensors. The fuzzy logic of the current temperature and user set temperature values and set the speed of fan accordingly. A threshold is also set when the temperature of the room approaches to set point. It is input for the second fuzzy logic controller to control humidity. For designing the work, they have used the Matlab-simulation. By using this method, they achieved high user comfort index.

The fuzzy logic method is a state-of-the-art technology that is used for designing solutions for a system having multi-parameter as well as for non-linear control models for defining control strategy. Fuzzy logic usually delivers the faster result as compared to conventional fuzzy logic. Isizoh *et al.*, in [15] a control system in which fuzzy logic is used for controlling temperature, which consisted of many techniques to control temperature output function.

3. Proposed Actuator Control Mechanism using Fuzzy Logic on Embedded System

The proposed model is based on fuzzy logic and Raspberry Pi. Figure 1 shows the recommended method for fan control. In the proposed system first, the temperature and humidity values are detected through temperature and humidity sensors connected to Raspberry Pi. The temperature and humidity values are then fed to the fuzzy logic module. The fuzzy logic gets the temperature and humidity as crisps values, the fuzzification converts these temperature and humidity vales to fuzzy values by using fuzzy membership functions, fuzzy rules are deployed on these fuzzy values, and the output of these rules are assigned to defuzzification and converts again to crisp output. We have designed the rules in such a way that it provides the adjusted power for the fan. In this work, we have defined for each input parameter five membership functions are determined, and five membership functions for output parameter that is required speed. Total 25 rules are defined in each fuzzy logic.

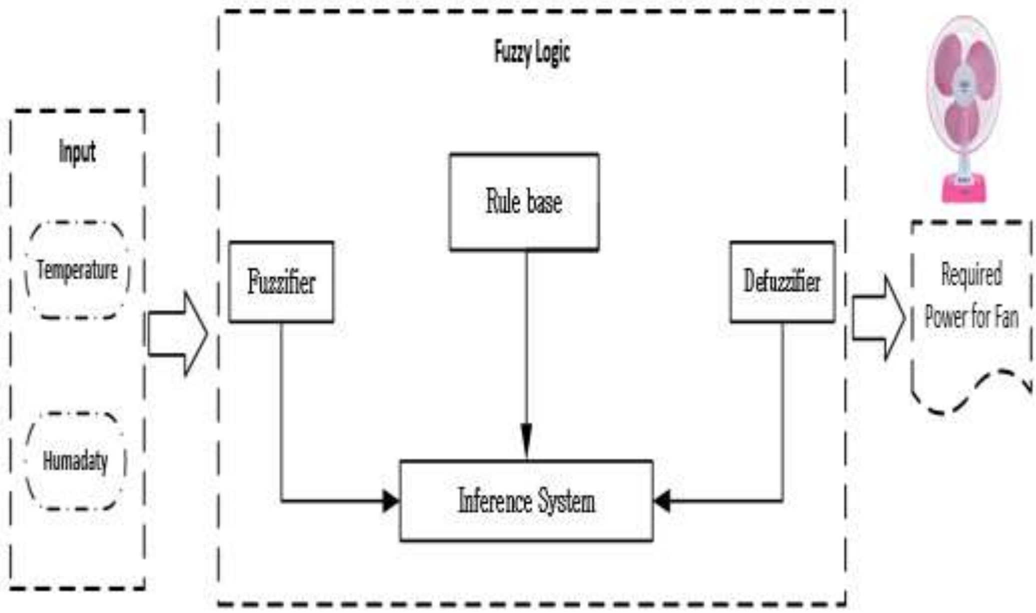


Figure 1. Block Diagram for Proposed Fan Speed Control Model using Fuzzy Logic

The sequence diagram is exposed in Figure 2; the proposed model is comprised of mainly three layers namely input layer, processing layer and an output layer. In input layer the temperature and humidity values are acquired from real temperature and humidity sensors, then the fuzzy logic gets these values and performs, fuzzification, rule inference and defuzzification operations to get adjusted power for fan speed. The fuzzy logic provides the power to adjusted power module, and the fan module gets the adjusted power, and the speed is adjusted accordingly.

The Mamdani fuzzy rules have been used in the proposed model, due to its simplicity and efficiency. The structure of the fuzzy a fuzzy rule in rules-based is shown in Equation (1) of Mamandani fuzzy logic method.

$$R^j\text{: If } x_1 \text{ is } A_1^j \text{ and } x^2 \text{ is } A_2^j \text{ and } x_3 \text{ is } A_3^j \text{ and} \ldots x_n \text{ is } A_n^j \text{ then } y \text{ is } B_j \tag{1}$$

Where Rj=jth rule and Aij (j=1,2,…….N,i=1,2,…….n), Bj = fuzzy subsets of the inputs and outputs, respectively.

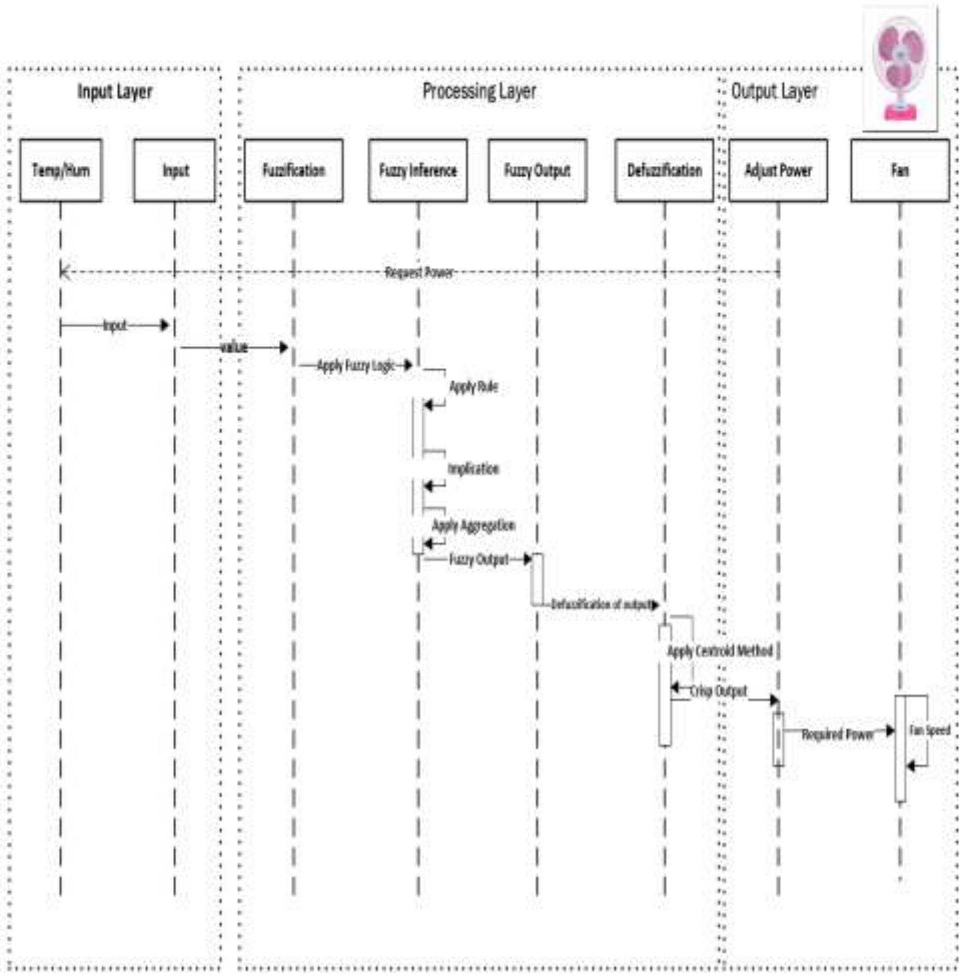


Figure 2. Sequence Diagram for Proposed Fan Speed Control Model using Fuzzy Logic for Embed System

The mathematical representation of this rule is given in as Equation (2).

$$\mu_j^R(x_1, x_2, x_3, \ldots\ldots\ldots, x_n, y) = \mu_{A_1^j} \cap \mu_{A_2^j} \cap \mu_{A_3^j} \ldots\ldots \cap \mu_{A_n^j} \cap \mu_B \tag{2}$$

Where ∩ represents the minimum operator.

The defuzzification module changes the fuzzy values into numeric values. There are many defuzzification methods, such as maximum center average (MCA), mean of maximum (MOM), smallest of maximum (SOM), center of gravity, *etc*. The LOM method is simple to implement, require less computational time and give reasonable accuracy. In the proposed work, the SOM method for defuzzification has been used; the mathematical representation of SOM is given in Equation (3).

$$\text{Crisp Output} = \frac{\sum_{\text{very low}}^{\text{very high}} \text{Truncated Area}_n \times \text{Centroid}_n}{\sum_{\text{very low}}^{\text{very high}} \text{Truncated Area}_n} \quad (3)$$

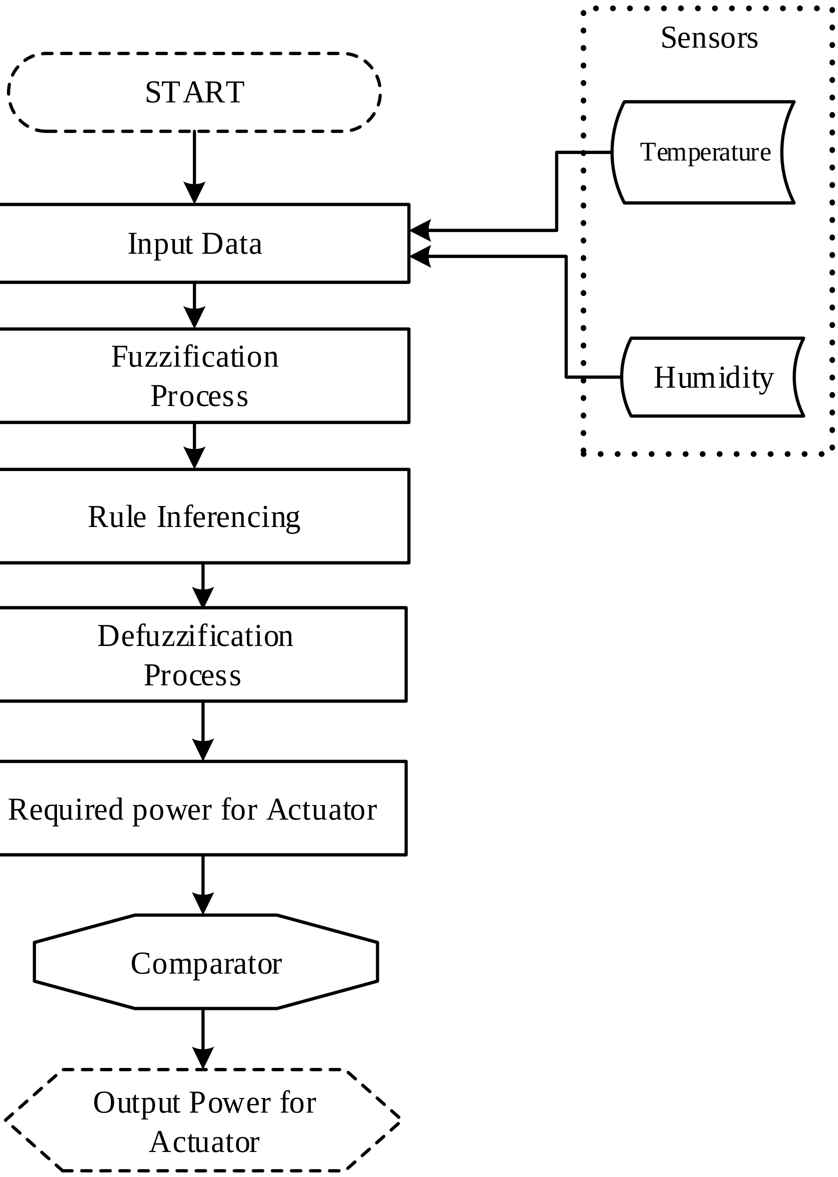
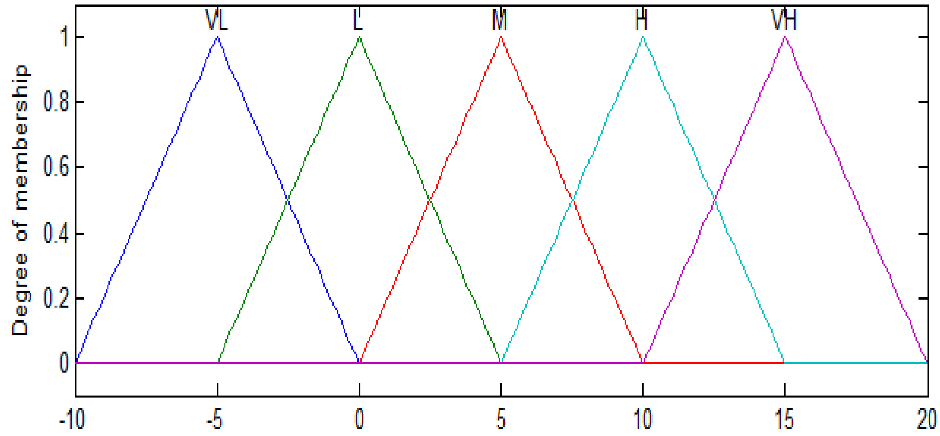
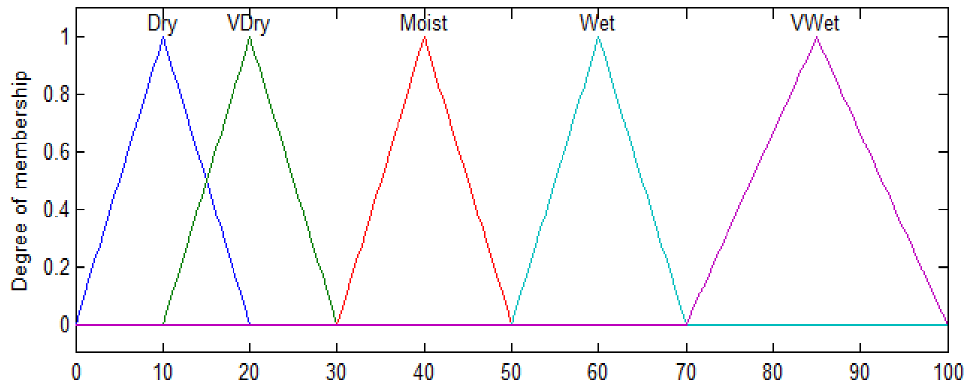


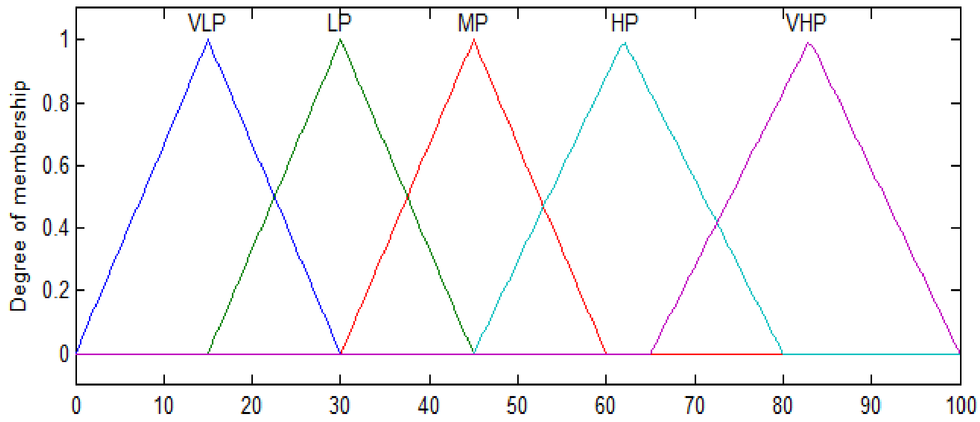
Figure 3. Flow Diagram for Fan Control Model based on Fuzzy Logic



(a) Temperature



(b) Humidity



(c) Power

Figure 4. Inpus/output Membership Functions of Fuzzy Logic in Proposed Model

The membership function for temperature and humidity is given in Figure 4, the linguistic terms VL, L, M ,H and VH for temperature are shortened for very low, low, medium, high and very high correspondingly. Similarly the linguistic terms for humidity are Dry, Vdry, Moist, wet, and VWet which are abbreviated for dry, very dry, moisture, wet and very wet. In this work we have used the Mamdani fuzzy logic with following characterization. The designed rules for fan control using Mamdani fuzzy logic have been listed in Table 1.

Table 1. Designed Rules for Fan Control using Mamdani Fuzzy Logic

Hum \ Temp	VL	L	M	H	VH
VDry	VLP	VLP	LP	MP	MP
Dry	VLP	LP	MP	MP	HP
Moist	LP	MP	MP	HP	VHP
Wet	MP	MP	HP	VHP	VHP
VWet	MP	HP	VHP	VHP	VHP

In Figure 5 we connected Raspberry Pi 3 to L9110 fan module. This is a generally found cheap module which comprises of an L9110 chip and a small motor attached. Four connections are needed between Raspberry Pi and fan actuator as shown in Figure 5.

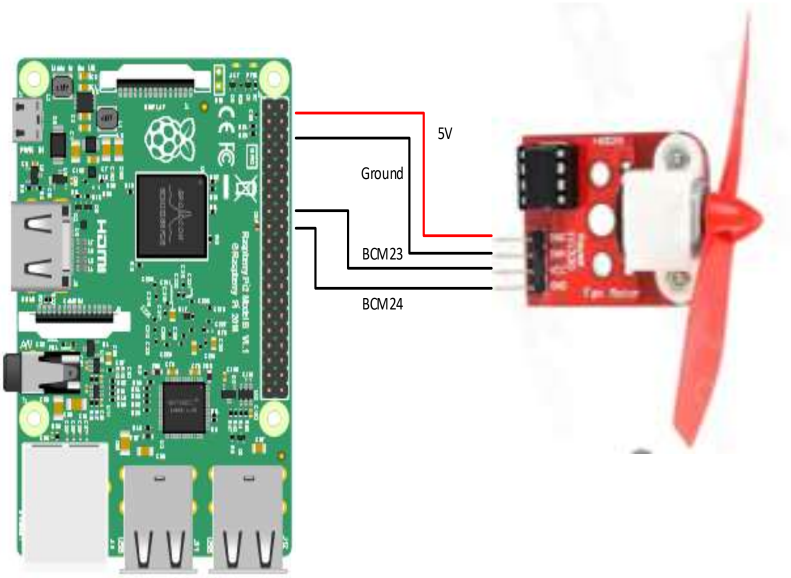


Figure 5. Connected Raspberry Pi 3 to the L9110 Fan Module

3. Experimental Results and Discussion

All the implementation of the proposed work is carried out on Raspberry Pi Pi 3. The programming language that we have used for fuzzy logic method implementation on Raspberry Pi is Python version 3.6. In the experimental section, we have applied the Mamdani fuzzy logic on temperature and humidity values to estimate required power for fan control. In the following Figures we have, we have given the one temperature, and humidity data fuzzy logic and the output is the estimated power needed for fan control for one day.

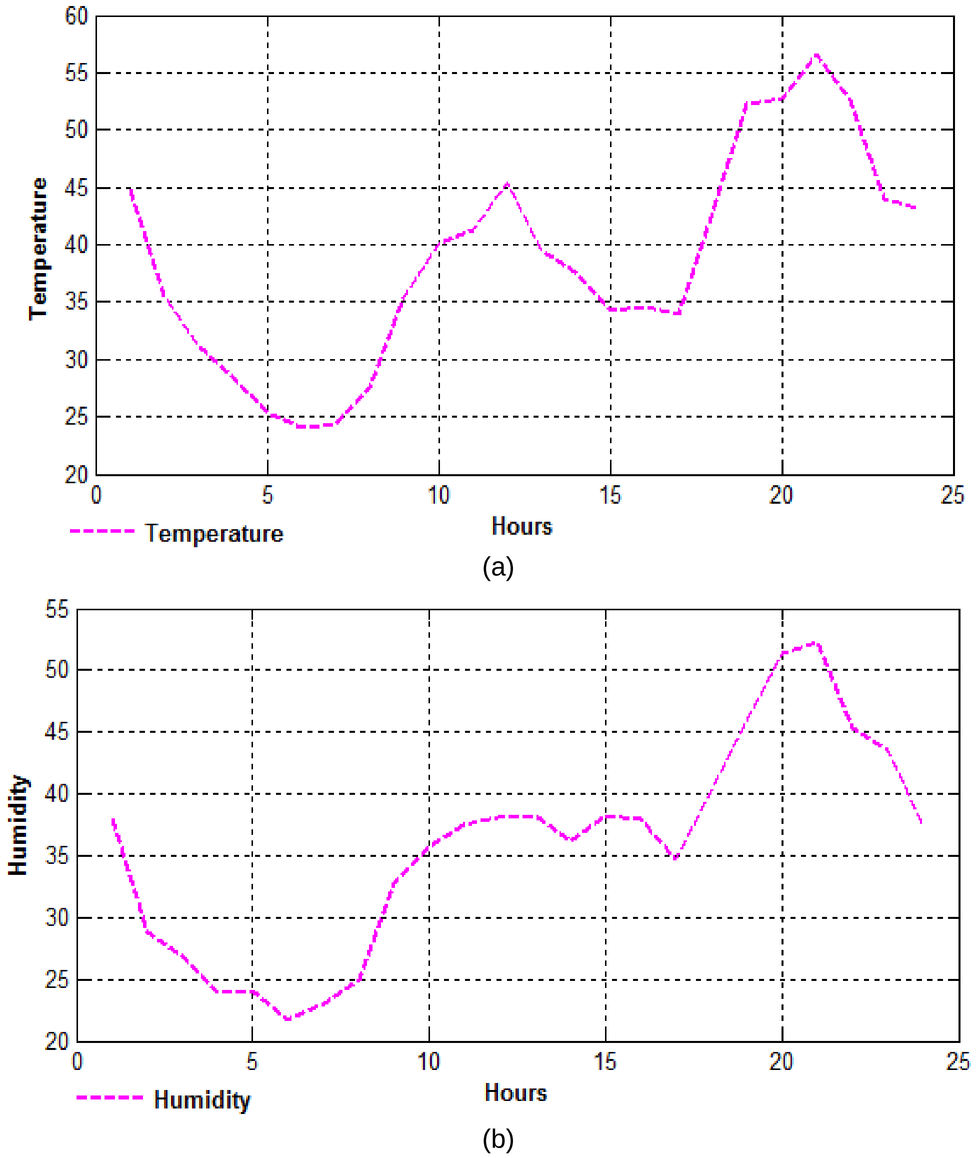


Figure 6. Fuzzy Logic Inputs a. Temperature and b. Humidity

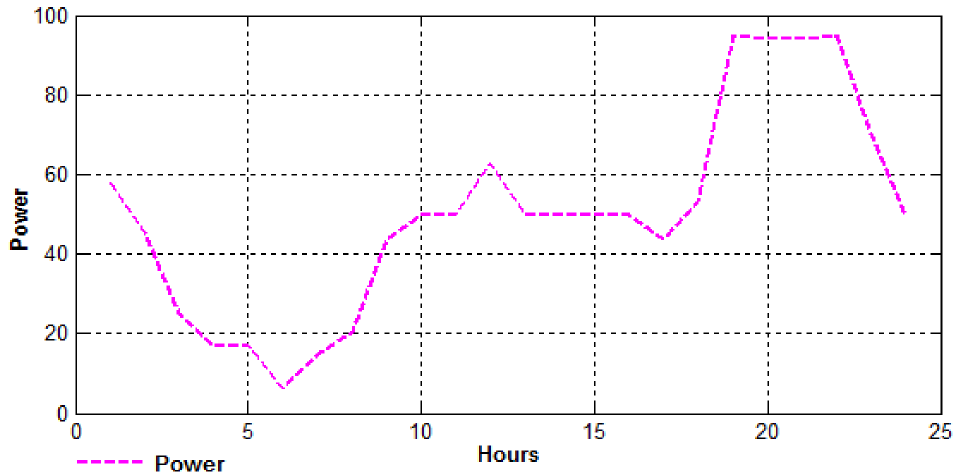


Figure 7. Required 0 power for Fan Actuator using Fuzzy Logic having Temperature and Humidity Inputs

4. Conclusion and Future Work

The purpose of this study was to use fuzzy logic to control fan for embedded systems effectively. All implementation of the proposed work has been carried out in python on Raspberry Pi. The fuzzy reasoning gets the input from sensors and applies some operations and give the required power for fan and the fan speed is adjusted according to fuzzy output power accordingly. We have specified some rules according to which the output of fuzzy logic is specified. The proposed system works effectively and can be used in many application scenarios. In the proposed work we have given one day hourly data of temperature and humidity to the fuzzy controller to get the required power for the fan. In future, we would like to consider more parameters for fan control and also would use fuzzy logic to control other actuators. In case of a high number of parameters, we would apply hierarchical fuzzy logic for dimensionality reduction because the simple fuzzy logic doesn't perform well in case of a considerable amount of input parameters. We would like to propose a method for rule designing to facilitate manager while developing rules.

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References

[1] L. Atzori, A. Iera and G. Morabito, "The internet of things: A survey", Computer Networks, vol. 54, no. 15, **(2010)**.
[2] Y.-. Chen, "Challenges and opportunities of internet of things", In Design Automation Conference (ASP-DAC), **(2012)**.
[3] V. Vujović and M. Maksimović, "Raspberry Pi as a Sensor Web node for home automation", Computers & Electrical Engineering, vol. 44, **(2015)**.
[4] G. Klir and B. Yuan, "Fuzzy sets and fuzzy logic", New Jersey: Prentice-Hall, vol. 4b, **(1995)**.
[5] J. Bonato, Z. Mark and M. Badurina, "Speed regulation in fan rotation using fuzzy inference system", Pomorstvo: Scientific Journal of Maritime Research, vol. 29, **(2015)**.
[6] K. Zuhtuogullari, I. Saritas and N. Allahverdi, "The application of the fuzzy expert cooling system for multi-core microprocessors and mainboards.", In Proceedings of the International Conference on Computer Systems and Technologies and Workshop for PhD Students in Computing, vol. 57, **(2009)**.
[7] A. S. Markowski and M. Sam Mannan, "Fuzzy logic for piping risk assessment (pfLOPA)", Journal of loss prevention in the process industries, vol. 22, no. 6, **(2009)**.
[8] C.-C. Lee, "Fuzzy logic in control systems", fuzzy logic controller, I. IEEE Transactions on systems, man, and Cybernetics, vol. 20, no. 2, **(1990)**.
[9] Pi Rasberry, "Raspberry Pi", Raspberry Pi 1, **(2013)**.
[10] Pi-Teach, Raspberry, "learn, and make with Raspberry Pi", Raspberry Pi, **(2016)**.
[11] Pi, Raspberry, "Raspberry Pi Model B.", **(2015)**.
[12] E. Upton and G. Halfacree, "Raspberry Pi user guide", John Wiley & Sons, **(2014)**.
[13] V. J. Nandeshwar, G. S. Phadke and S. Das, "Design of Room Cooler using Fuzzy Logic Control System".
[14] T. Kumar Das and Y. Das, "Design of room temperature and humidity controller using fuzzy logic", American Journal of Engineering Research (AJER), vol. 2, no. 11, **(2013)**, pp. 86-97.
[15] A. N. Isizoh, "Temperature control system using fuzzy logic technique", International Journal of Advanced Research in Artificial Intelligence, vol. 1, no. 3, **(2012)**, pp. 27-31.

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