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Comparison of Fuzzy Logic and Neuro Fuzzy Air Purifying System

Tamsa[1], Amrit Kaur Bhullar[2]

[1, 2]Department of Electronics & Communication Engineering Punjabi University, Patiala, India
[1]Email: tamsahans444@gmail.com
[2]Email: amritameek@gmail.com

Abstract: ***Air Quality Index (AQI) refers to the quality of air due to the presence of pollutants like Particulate Matter 2.5 (PM 2.5), PM 10 and Volatile Organic Compounds (VOCs) that make the air poisonous for us to breathe in. This study implements two different models of air purifying systems, one being Fuzzy system and second is Neuro-fuzzy system. The latter has the advantage of learning from training data set. So, air purifier system is required. This study compares the output of fuzzy and neuro-fuzzy on the basis of output relationship graphs between input and output pairs. Neuro-fuzzy air purifier system results are found to be superior in comparison to fuzzy system.***

Keywords: Air Purifier system, Fuzzy logic, Rule base, Neuro-fuzzy

1. Introduction

Some pollutants come from outdoors like VOCs (Volatile Organic Compounds) consists of benzene, and formaldehyde and black carbon emitted by vehicles and other from indoors like particles and gases. Common contaminants found indoors are Particulate Matter (PM 2.5) which are fine particles with diameter of 2.5 micrometer and PM 10 which includes mold, formaldehyde and pollen with diameter of 10 micrometer. These small particles can easily penetrate into bloodstream and cause various health issues. Quality of indoor air varies from home to home. As human health can be affected by the pollutants contained in indoor air. The most effective ways to improve indoor air are to reduce or remove the sources of pollutants through air purifiers [1]. This can be done using Fuzzy, Neuro-fuzzy. Air Quality Index (AQI) is an indicator used to describes the quality of air based on concentration of several pollutants like PM 2.5, PM 10 and VOCs in the air.

2. Literature Survey

The air purifying unit provides a comfortable environment during summers and has become an essential part of our daily lives. Research has been done in this area to include more than just one parameter and to make them robust to apply under various situations and environments [2]. The main efforts done in air purifying system are uneven conditions, extreme nonlinear factors, interaction between parameters of environment, variation in such parameters and unfeasibility to model the system accurately [3]. As human beings spend most of the time indoors so the indoor air quality of an enclosed space has an effect on the health and productivity of a person. All this has led many researchers to develop and improve the existing air purifying systems and include different parameters that can be regulated for indoor air quality. Various design techniques have been implemented for better efficiency of an air purifying system like Fuzzy, Neuro-Fuzzy. This paper consists of 7 sections. Section 1 gives introduction of the work. Literature survey of related work is described in section 2. Section 3 explains the design of air purifier system using fuzzy control algorithm and neuro-fuzzy algorithm. Comparison between results are discovered in Section 4. Section 5 concludes the paper.

3. Design of Air Purifier System

3.1 Fuzzy Control Algorithm

Fuzzy control algorithm based air purifier system works with three inputs: PM 2.5, PM 10 and VOCs and output is taken as Fan speed which is based on these inputs. As, air quality is degrading day by day and it's an urgent need to include this in every air purifying unit as these are an integral part of all houses, offices and factories. Three triangular membership functions of input as well as output have been taken as low, medium and high. The ranges are based on [1] and corresponding tabulated values are shown in Table.1. Fuzzy logic control provides a formal methodology for representing and implementing a human's experience based knowledge about how to control a system [4].

Table 1: Ranges for selecting different membership functions

PM 2.5(ppm)		
1	Low	-19.2 to 194
2	Medium	121 to 353
3	High	265.2 to 509
PM 10(ppm)		
1	Low	-14.26 to 194.5
2	Medium	102.3 to 391.8
3	High	315.3 to 541.7
VOCs(ppm)		
1	Low	-39.1 to 199.1
2	Medium	97.69 to 437.9
3	High	262.6 to 615
Fan Speed(rpm)		
1	Low	473 to 602
2	Medium	578.2 to 737
3	High	669 to 803

Based on the value ranges of Table.1. various rules generated are tabulated in Table.2.

Table 2: Fuzzy Rules

Rules	PM 2.5	PM 10	VOCs	Fan Speed
1.	low	low	low	low
2.	low	low	high	high
3.	low	low	medium	medium
4.	medium	medium	medium	medium
5.	medium	medium	high	high
6.	medium	high	medium	high
7.	medium	high	low	high
8.	high	high	high	high
9.	high	medium	medium	high
10.	high	low	low	high

3.2 Neuro-Fuzzy Algorithm

The design proposed for air purifying system using fuzzy logic then can be trained using the learning algorithms of neural networks to make it adaptive. Fuzzy logic-controlled air purifying system is trained using ANFIS Toolbox of MATLAB. After training the data 26 rules have been generated for controlling PM 2.5, PM 10 and VOCs.

The rule base for the system also changes accordingly as shown in Table.3. Where, *In1*, *In2* and *In3* represent PM 2.5, PM 10 and VOCs respectively while *mf1*, *mf2* and *mf3* represent Low, Medium and High membership functions. The Neuro-Fuzzy system structure in form of neural networks formed by ANFIS is shown in Fig.1. The effect on Fan speed by the variation in the concentration of PM 2.5, PM 10 and VOCs have been studied and shown in Fig.2. to Fig.4. by considering three cases of input and output.

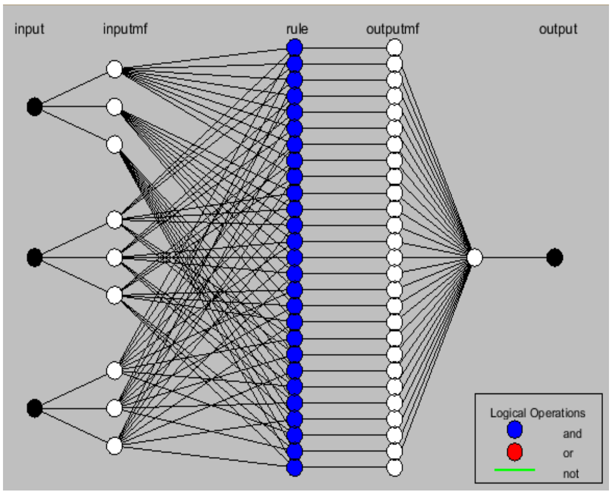

Figure 1: ANFIS structure

Table 3: ANFIS rules

Rules	PM2.5	PM10	VOCs	FAN SPEED
1.	In1mf1	In2mf1	In3mf2	Out1mf2
2.	In1mf1	In2mf1	In3mf3	Out1mf3
3.	In1mf1	In2mf2	In3mf1	Out1mf4
4.	In1mf1	In2mf2	In3mf2	Out1mf5
5.	In1mf1	In2mf2	In3mf3	Out1mf6
6.	In1mf1	In2mf3	In3mf1	Out1mf7
7.	In1mf1	In2mf3	In3mf2	Out1mf8
8.	In1mf1	In2mf3	In3mf3	Out1mf9
9.	In1mf2	In2mf1	In3mf1	Out1mf10
10.	In1mf2	In2mf1	In3mf2	Out1mf11
11.	In1mf2	In2mf1	In3mf3	Out1mf12
12.	In1mf2	In2mf2	In3mf1	Out1mf13
13.	In1mf2	In2mf2	In3mf2	Out1mf14
14.	In1mf2	In2mf2	In3mf3	Out1mf15
15.	In1mf2	In2mf3	In3mf1	Out1mf16
16.	In1mf2	In2mf3	In3mf2	Out1mf17
17.	In1mf2	In2mf3	In3mf3	Out1mf18
18.	In1mf3	In2mf1	In3mf1	Out1mf19
19.	In1mf3	In2mf1	In3mf2	Out1mf20
20.	In1mf3	In2mf1	In3mf3	Out1mf21
21.	In1mf3	In2mf2	In3mf1	Out1mf22
22.	In1mf3	In2mf2	In3mf2	Out1mf23
23.	In1mf3	In2mf2	In3mf3	Out1mf24
24.	In1mf3	In2mf3	In3mf1	Out1mf25
25.	In1mf3	In2mf3	In3mf2	Out1mf26
26.	In1mf3	In2mf3	In3mf3	Out1mf27

Case I: When PM 2.5, PM 10, VOCs are low and Fan speed is low: When all the inputs i.e. PM 2.5, PM 10 and VOCs are taken as low.

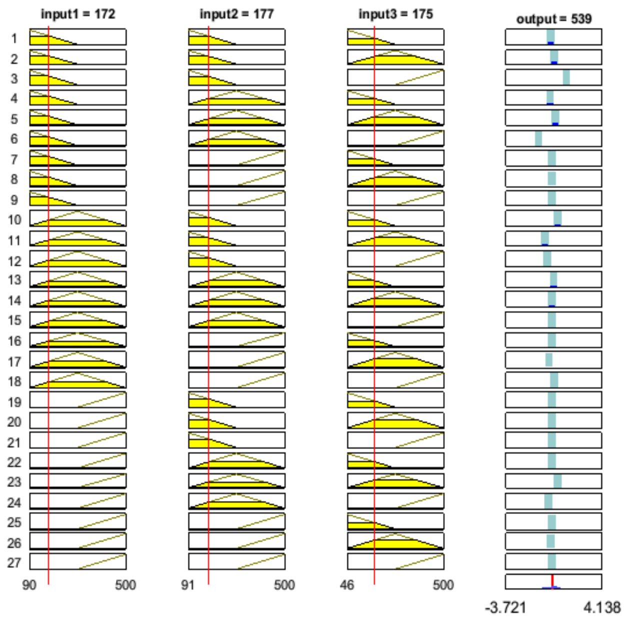

Figure 2: When PM 2.5, PM 10 and VOCs are low

As can be seen in Fig.2. when PM 2.5, PM 10 and VOCs are low. Fan speed is 539rpm that comes under low range. As the air is clean and there is no need for fan to work on high speed and thus saves energy.

Case II: When PM 2.5, PM 10 and VOCs are medium and Fan speed is medium: When all the inputs PM 2.5, PM 10 and VOCs are taken as medium.

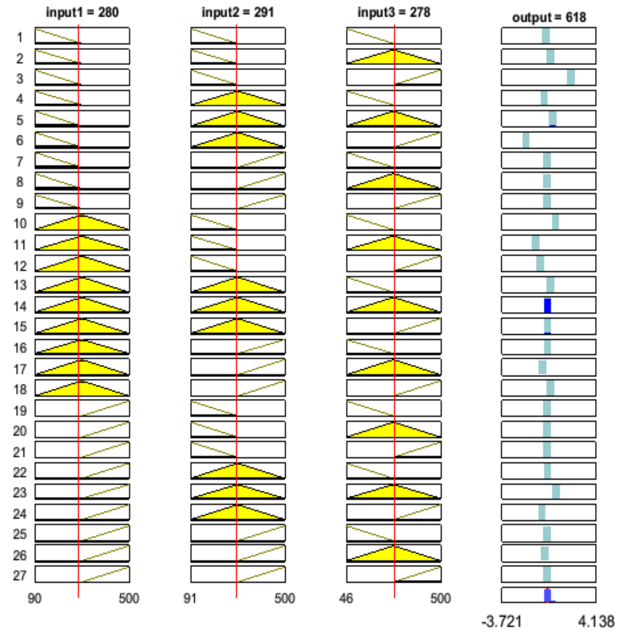

Figure 3: When PM 2.5, PM 10 and VOCs are medium

As can be seen in Fig.3. when PM 2.5, PM 10 and VOCs are medium and Fan speed is medium as 618rpm, the air is less polluted and fan works on medium.

Case III: When PM 2.5, PM 10, VOCs are high and Fan Speed is high: When all the inputs i.e. PM 2.5, PM 10 and VOCs and are taken as high.

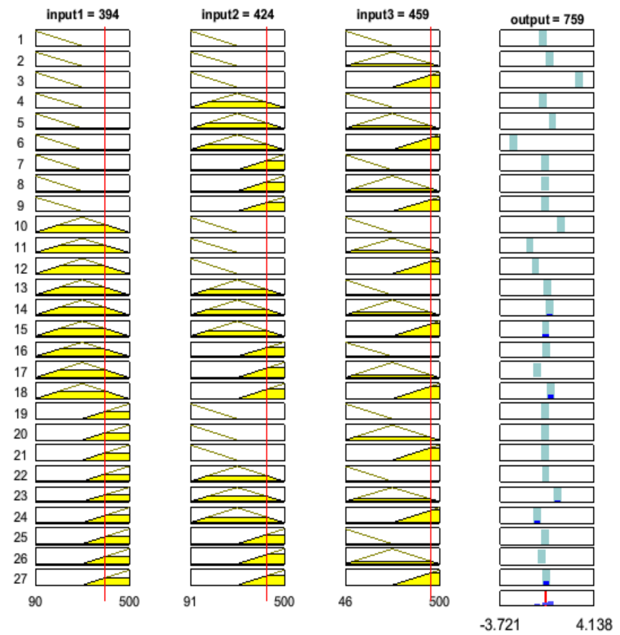

Figure 4: When PM 2.5, PM 10 and VOCs are high

As can be seen in Fig.4. when PM 2.5, PM 10 and VOCs are high the fan speed is high as 759rpm. Fan speed increases to reduce the pollutant and clean indoor air.

4. Experimental Results

For comparison of Fuzzy and Neuro-Fuzzy, outputs are taken for designed rule base. The results obtained after simulation of fuzzy logic control-based air purifying system using MATLAB are shown in Fig.5-8.

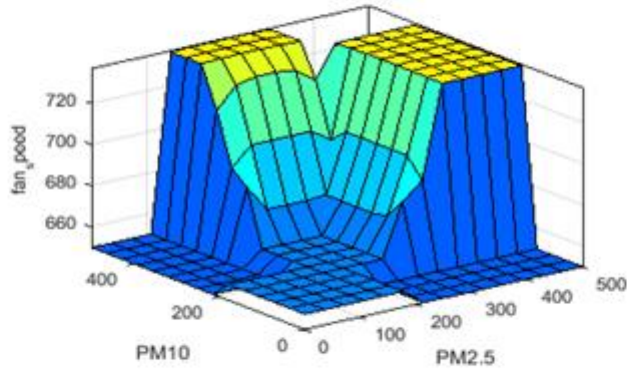

Figure 5: Surface view of fuzzy controller

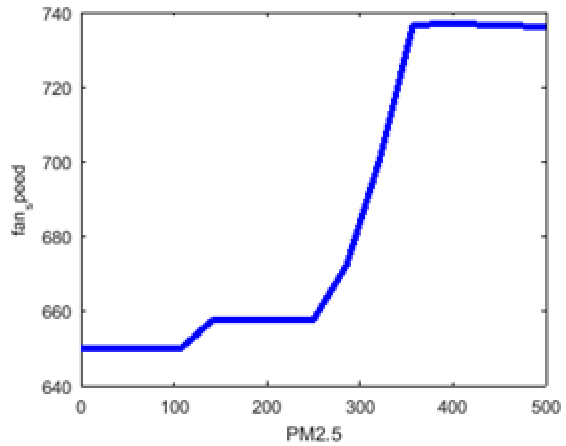

Figure 6: Fan speed v/s PM 2.5 for Fuzzy controller

The graph of Fig.6. shows the relationship between fan speed and PM 2.5 as the concentration of PM 2.5 is increasing in air the fan speed is increasing to decrease the concentration of PM 2.5 in the air.

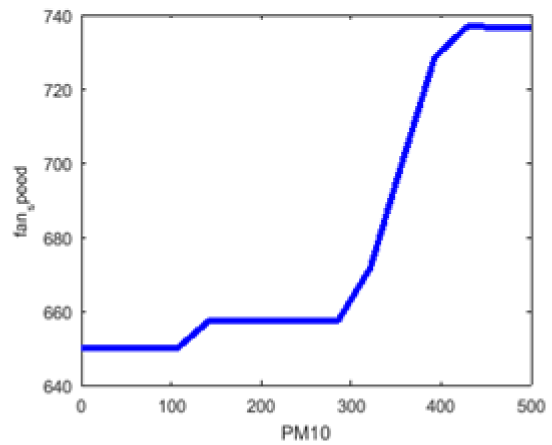

Figure 7: Fan speed v/s PM 10 for Fuzzy controller

Fig.7. This graph shows that relationship between fan speed and PM 10 as when the concentration of PM 10 increases the speed of fan increases to remove the PM 10 in the air.

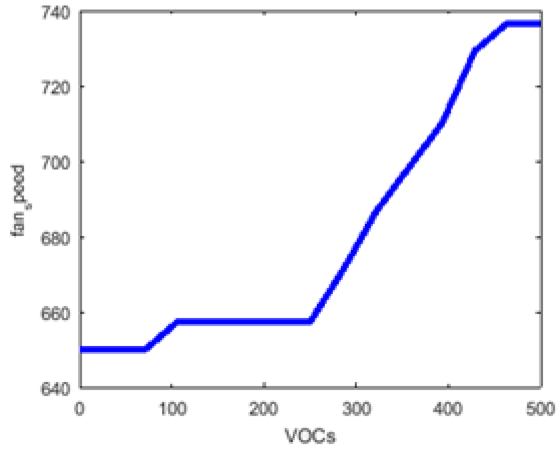

Figure 8: Fan speed v/s VOCs for Fuzzy Controller

The graph in Fig.8. shows the relationship between fan speed and VOCs as more the value of VOCs higher will be the speed of fan to remove the VOCs from the atmosphere.

The results obtained after simulation of Neuro-Fuzzy logic control-based air purifying system using MATLAB are shown in Fig.9-12.

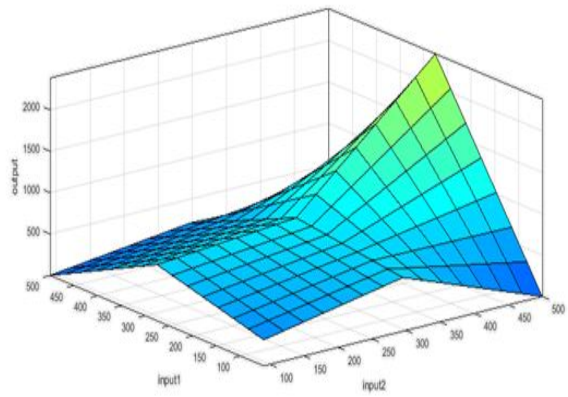

Figure 9: Surface view of ANFIS controller

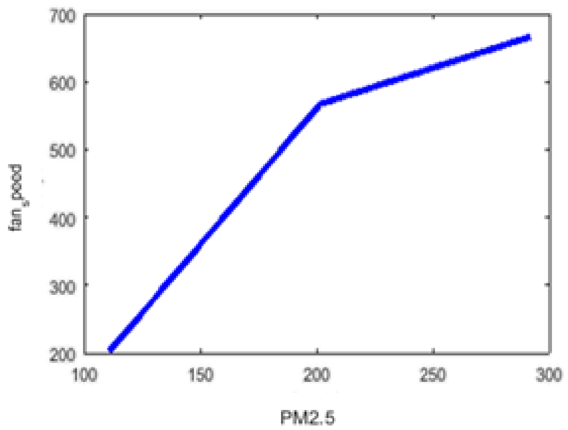

Figure 10: Fan speed v/s PM 2.5 for ANFIS

Fig.10. shows the relationship between fan speed and PM 2.5 as fan speed is sharply increases to remove the concentration of PM 2.5 in the atmosphere.

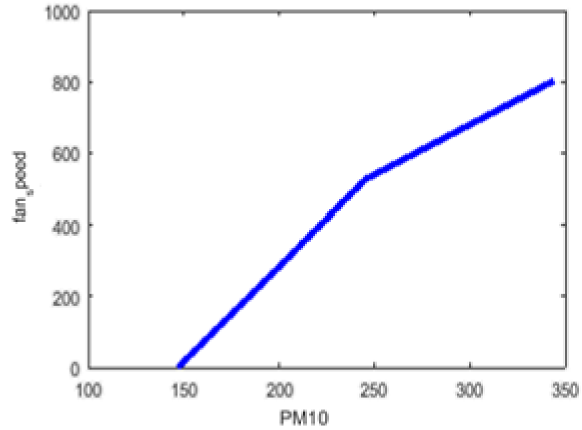

Figure 11: Fan speed v/s PM 10 for ANFIS

Fig.11. shows the relationship between fan speed and PM 10 as fan speed. When the concentration of PM 10 is within safe limits the fan is not working but as soon as it reaches hazardous value fan speed constantly increases to remove the concentration of PM 10 in the atmosphere.

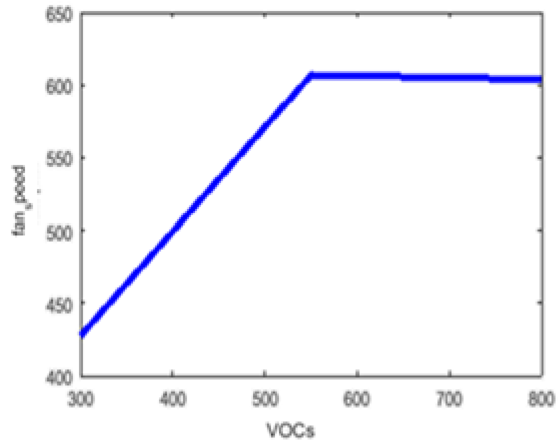

Figure 12: Fan speed v/s VOCs for ANFIS

Fig.12. shows the relationship between fan speed and VOCs. Fan speed is constantly increasing up to 600rpm and then remains constant.

From these simulation results it is evident that neuro-fuzzy algorithm gives a better control than fuzzy logic algorithm for PM 2.5 and PM 10. In neuro-fuzzy based design the relation is almost linear between PM 2.5, PM 10 and Fan speed.

5. Conclusion

Neuro-fuzzy algorithm is definitely superior to fuzzy logic algorithm as it inherits adaptability and learning. It can be concluded from the simulations that neuro-fuzzy control gives a better output for PM 2.5 and PM 10 and for VOCs it provides energy efficient approach as till the time VOCs are in safe limit the fan does not work and as soon as the VOCs come in hazardous range it starts working and makes room environment safe for inhabitants. In comparison to fuzzy algorithm, neuro-fuzzy algorithm makes the air purifying system energy efficient.

6. Future Scope

A comfortable and healthy indoor air environment is favorable to occupants. In recent years, indoor thermal comfort has been improved greatly due to the development of air purifying systems. The new-style air supply modes either possess prominent potential of energy saving or can provide a comfortable and healthy indoor air environment or both of them.

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Author Profile

Tamsa is pursuing M.TECH final year in department of Electronics and Communication Engineering at University College of Engineering, Punjabi University, Patiala. She has done her B.TECH in trade electronics and communication engineering from University College of Engineering, Punjabi University, Patiala. She has presented many papers in national and international conferences. Her topic of research is fuzzy, neural networks and machine learning.

Amrit Kaur received her B.Tech Degree in Instrumentation Engineering in 2001, M.Tech in Instrumentation Engineering from Punjab University Chandigarh in 2005 and Ph.D in 2020. She is currently an Assistant Professor at Punjabi University Patiala in Electronics and Communication. She is having more than 15 years of teaching experience. Her research interests include optimization, fuzzy, neural networks, Control systems and machine learning.