Comparative Study of a Fuzzy Logic Based Controller and a Neuro-Fuzzy logic Based Controller for Computer Fan

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Abstract
The impact of soft-computing in modern day engineering and technology cannot be overemphasized. Fuzzy logic approach as proposed by Lofti Asker Zadeh, popularized by the Japanese, has found its way into the control of many domestic and industrial appliances/machines. Unlike the popular PID controllers and the pulse width modulation based controllers, the performance of computer fan is investigated using the fuzzy logic approach with two inputs parameters, that is, the computer loads and the temperature and one output parameter which is the speed at which the computer fan operates. For the fuzzy inference system, four membership functions are selected for the inputs as well as the output. Relevant rules are set to determine the operating conditions and boundaries for the controller. In order to make the controller adaptive, neurofuzzy logic appproach is used with parameters set as the case with fuzzy logic. Training of the controller is carried out and the performance of each controller is presented in three dimensional view and two dimensional surface view with neurofuzzy based controller, in performance, having an edge over the fuzzy logic based controller.
Keywords: Anfis, Fuzzy logic, Computer fan, Controller, Performance comparison

1. Introduction

Incessant packing, malfunction, and irritating noise generated by computer due to load impact and temperature conditions has made the control of computer fan an important issue to improve and resolve [3]. Computer fan comes in various types, such as; (i) two-wire type, (ii) three-wire type, and (iii) four-wire type. The two-wire type is the oldest, giving full speed rotation once the computer system is switched on. The three-wire type is very common and has "tacho" used mainly to sense fan speed [1]. The most modern computer fan comes with four-wire with a pulse width modulation (PWM) signal in terms of revolution per minute. A four-wire computer fan, in addition to speed control, with the use of "tacho", senses the speed simultaneously making it ideal for a feedback system unlike the three-wire system. The drawback with PWM fans is that, if the duty cycle is below a threshold value, the fan either stops operation or run at a constant/stable low speed [2, 4]. Flexibility in terms of operational conditions gives room for improvement.

In order to carry out effective control of computer fan, it is important to understand the key parts involved in the overall subject, the computer fan. These are; the rotor, the stator, and the controller [8]. The rotor is the rotating part of the fan to which the compact fins are attached. The stator provides the magnetic field whose strength determines the revolution per minute of the fan. The controller on the other hand sends signals as to how the fan operates or functions. Soft-computing applications such as the use of fuzzy logic and artificial neural network as well as the combination of both are introduced to build controllers so as to improve the performance of computer fan [5, 6, 9]. Since fuzzy logic can decipher and interpret the knowledge supplied to it but cannot learn or adapt its knowledge from training example and neural network can learn from training examples but cannot explain what it has learnt, the combination of both fuzzy logic and neuro-fuzzy logic complement each other. One's weakness is other's strength and vice-versa [7]. With the use of fuzzy and neuro-fuzzy for the design of the controller on which the operations of computer fan depends, investigation into the operational flexibility is carried out with much more satisfactory results.

The rest of this paper is divided into; existing computer fan control methods, algorithm for the controller, fuzzy logic system, neuro-fuzzy logic system, results and discussion, conclusion and future research.

1.1 Existing controllers

Computer fan could be a type having no control. Once the computer system switches on, it starts and when the system goes off it stops. Some computer systems use thermostart for their operations in which an upper limit and lower limit are set for the control of the computer fan. Linear voltage regulator is another way of effecting control of computer fan. Here, variable voltage could be applied across a motor within acceptable range. Resistors have also been used in order to reduce the noise of the computer fan but it adds up to the heat of the system. Diodes and volt moddng approach where connector to ground are interghanged to to alter the voltage avilable across the fan that determine the speed of the fan. Recent method of controlling the computer fan operation has been with the use of pulse width modulation where signal in form of pulses are used to monitor

and control the speed of the computer fan. In PWM control method, control signal is directly proportional to the speed of computer fan [2].
It should be noted that the control signal being a square wave signal has a weakening effect on the performance of the fan through vibrations and noise [7].
The new trend though not fully regulated, is the use of software which can operate on linux, microsoft windows and other operating systems platforms [10, 11, 12,13].

2. Fuzzy Logic Controller

The design of the fuzzy logic controller considered in this work is shown in figure 1. The two inputs, load and operating temperature of the computer, are fed into the system. Fuzzification is carried out and made to function in line with the rule set. Inferences are drawn and defuzzificaton is carried out to obtain the required output. The result, speed is fed back for necessary comparison.

2.1 Block diagram of fuzzy logic controller

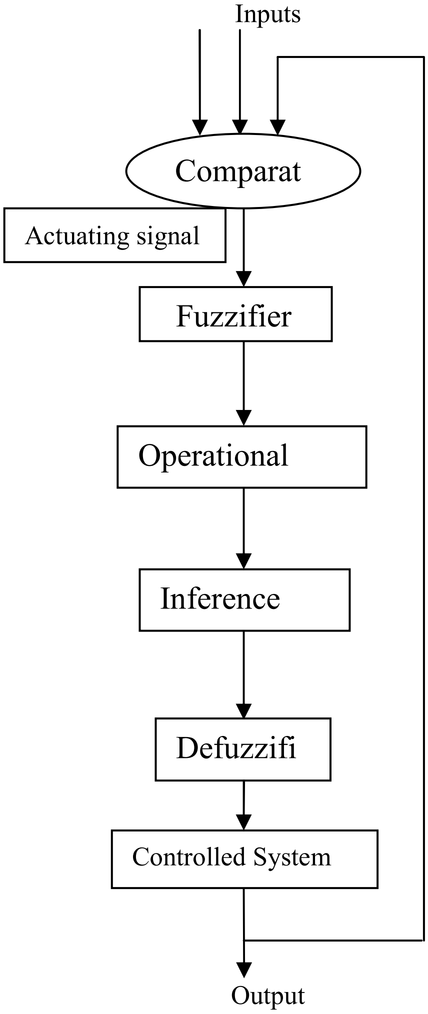


Figure 1: Fuzzy logic controller

2.2 Design Procedure

Two input variables whose values are defined represent the fuzzy sets. These variables have range definitions. The output variables is also defined by a fuzzy set. Four membership functions and truth values were defined over these ranges. The operational rules were applied to generate a result for each rule before a combined operational rules were applied which then combines the results of the rules[7,8,9]. The inputs variables were loads and temperature derivable from sensors. The output of the controller is the quantity that controls the speed of the fan. The load quantity for the computer ranges from 0% to 66.7%. The temperature quantity ranges from 39^{o}C to 56^{o}C. The output quantity which is the speed ranges from 644 revolutions per minute(r.p.m) to 745 revolutions per minute(rpm).

It should be noted that 'load' being used here refers to the 'heaviness of task' that the computer does and is rated in percentage.

With the use of fuzzy logic graphical user interface (GUI), the fuzzy inference system(FIS) for the fuzzy logic based controller is shown in figure 2 below:

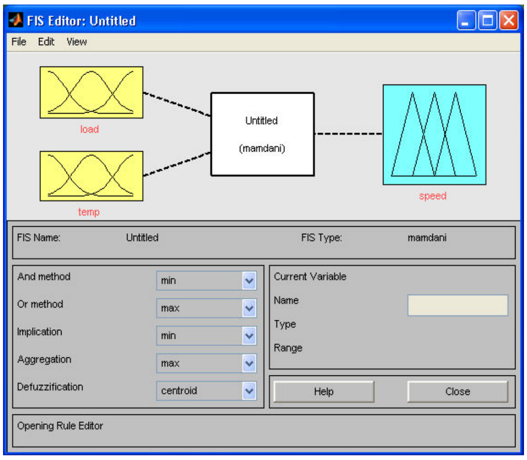


Figure 2: FIS fan controller

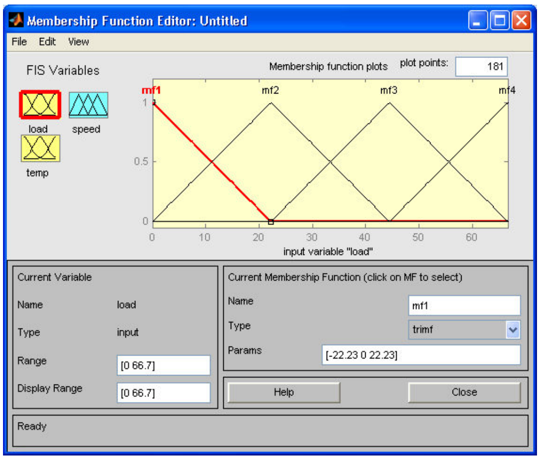


Figure 3: Membership function for load input variable

Four membership functions are drawn from each of the input parameters shown in figure 3 and figure 4 respectively.

The load membership functions are; minimum (mf1), light (mf2), moderate (mf3) and maximum (mf4) while the temperature membership functions are; very low, low, high, and very high.

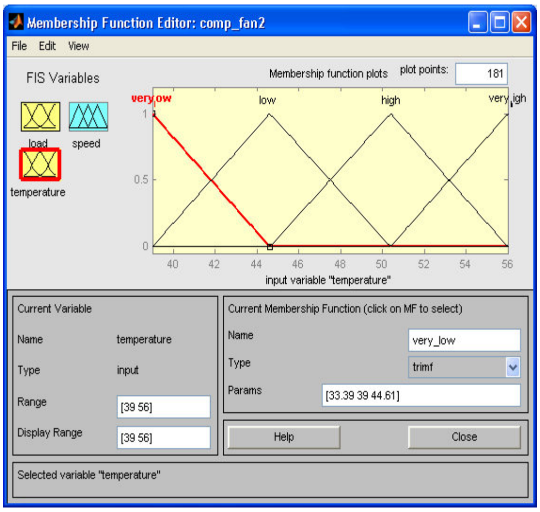


Figure 4: Membership function for temperature input

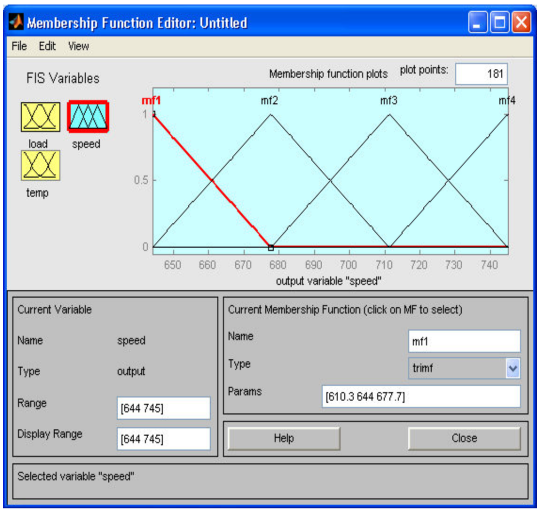


Figure 5: Membership function for the output

The output variable also has four membership functions namely; very low (mf1), low (mf2), moderate (mf3), and high (mf4) as shown in figure 5.

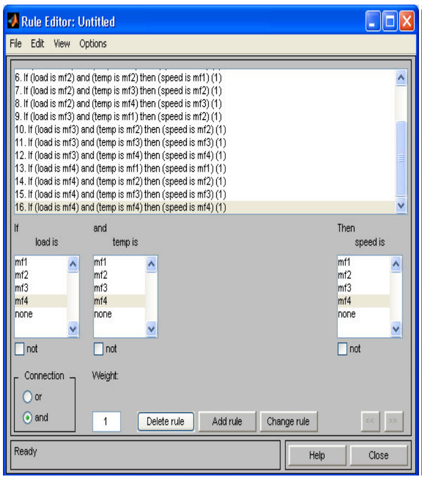
2.3 Fuzzy controller rules

The rules governing the operation of the fuzzy logic controller is given in table 1 below:

Table 1: Computer fan Fuzzy inference rules

Rules	*Load (Input 1)*	*Temperature (Input 2)*	*Fan-Speed (Output)*
1	Minimum	Very low	Very low
2	Minimum	Low	Very Low
3	Minimum	High	Low
4	Minimum	Very high	Moderate
5	Light	Very low	Very low
6	Light	Low	Very Low
7	Light	High	Low
8	Light	Very high	Moderate
9	Moderate	Very low	Low
10	Moderate	Low	Low
11	Moderate	High	Moderate
12	Moderate	Very high	High
13	Maximum	Very low	Very low
14	Maximum	Low	Low
15	Maximum	High	Moderate
16	Maximum	Very high	High

These rules in table 1 were applied to the inputs and the output of the fuzzy inference system based controller and displayed during simulation process as follows:



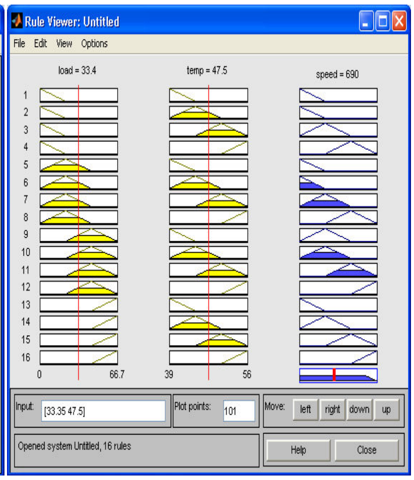


Figure 6: Fuzzy logic controller rule editor   Figure 7: Fuzzy logic based rule viewer for the controller

The interrelationship between the load, the temperature, and the speed in terms of operational control features is displayed in figure 7.

2.4 Adaptive Neurofuzzy Inference System/ Controller (Anfis)

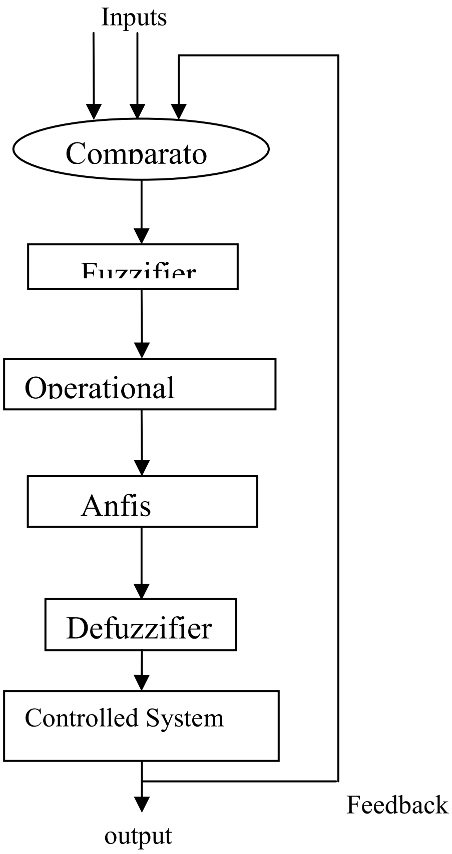


Figure 8: Block diagram of Anfis controller

For the neuro-fuzzy inference system controller, the input and output parameters has four membership functions each, same as that of fuzzy logic controller system. The output parameter, the speed, also contains four membership functions. The membership functions for the load (input1) are; in1mf1 (minimum), in1mf2 (light), in1mf3 (moderate), and in1mf4 (maximum). Figure 9 represents the membership function plot for the load.

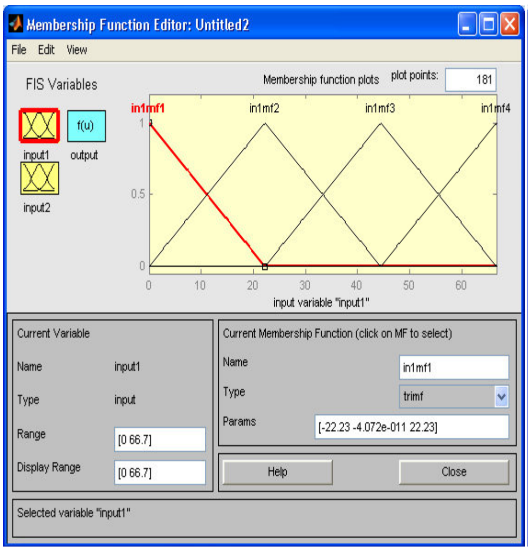


Figure 9: Load mf for the Anfis controller

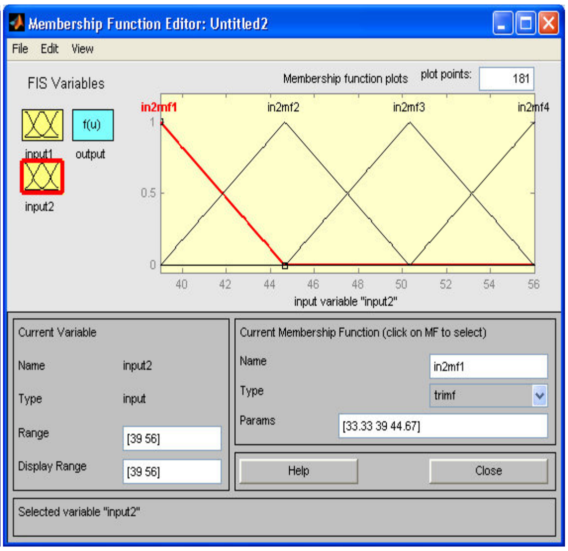


Figure 10: Temperature membership function plot

For the temperature, the membership functions are; in2mf1 (very low), in2mf2 (low), in2mf3 (high), and in2mf4 (very high). These are shown in figure 9.

The output membership function for the anfis controller is displayed below in figure 11. It has sixteen membership functions.

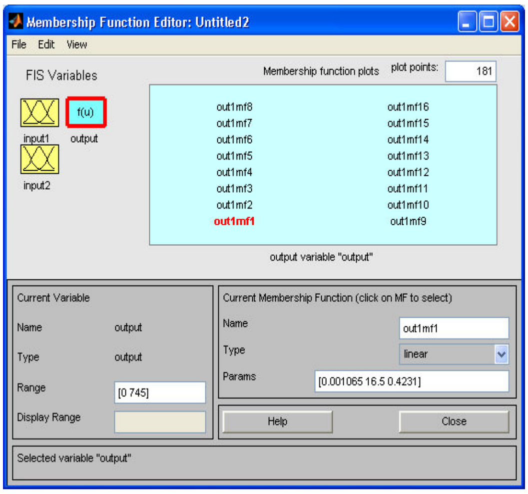


Figure 11: Anfis output membership function plot

2.4.1 Anfis Governing Rules

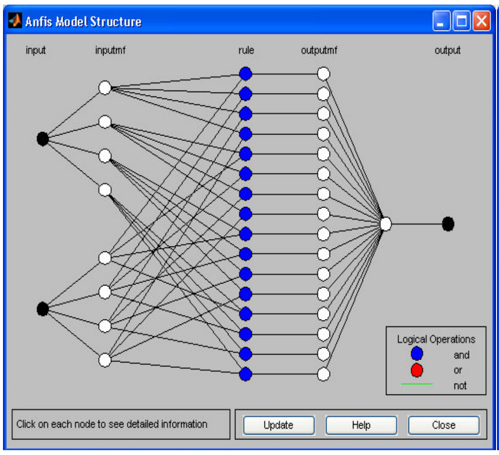
Sixteen rules are used for the design of the adaptive neuro-fuzzy logic controller. These rules are similar to that of the fuzzy logic rules earlier simulated. Table 2 gives the governing rule for the anfis controller.

Table 1: Computer fan anfis rules

Rules	*Load (Input 1)*	*Temperature (Input 2)*	*Fan-Speed (Output)*
1	Minimum/In1mf1	Very low/In2mf1	Very low/out1mf1
2	Minimum/In1mf1	Low/In2mf2	Very Low/out1mf2
3	Minimum/In1mf1	High/In2mf3	Low/out1mf3
4	Minimum/In1mf1	Very high/In2mf4	Moderate/out1mf4
5	Light/In1mf2	Very low/In2mf1	Very low/out1mf5
6	Light/In1mf2	Low/In2mf2	Very Low/out1mf6
7	Light/In1mf2	High/In2mf3	Low /out1mf7
8	Light/In1mf2	Very high/In2mf4	Moderate/out1mf8
9	Moderate/In1mf3	Very low/In2mf1	Low/out1mf9
10	Moderate/In1mf3	Low/In2mf2	Low /out1mf10
11	Moderate/In1mf3	High/In2mf3	Moderate/out1mf11
12	Moderate/In1mf3	Very high/In2mf4	High/out1mf12
13	Maximum/In1mf4	Very low/In2mf1	Very low/out1mf13
14	Maximum/In1mf4	Low/In2mf2	Low /out1mf14
15	Maximum/In1mf4	High /In2mf3	Moderate/out1mf15
16	Maximum/In1mf4	Very high/In2mf4	High/out1mf16

2.4.2 Anfis Controller Structure

The anfis computer fan controller has two input parameters, each containing four membership functions which are interconnected by a set sixteen of rules with another set of sixteen membership functions to produce a corresponding output as shown in figure 12. It should be noted that between the inputs and the output are the hidden layers.



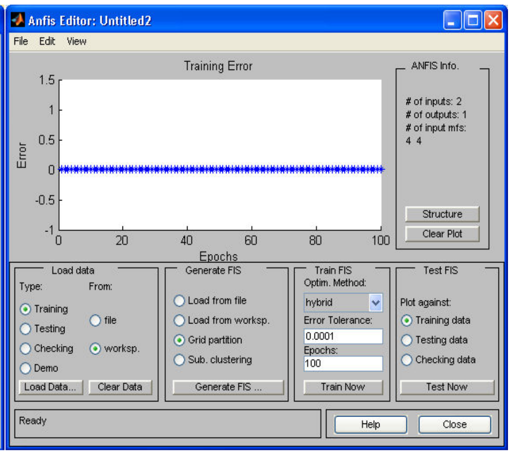


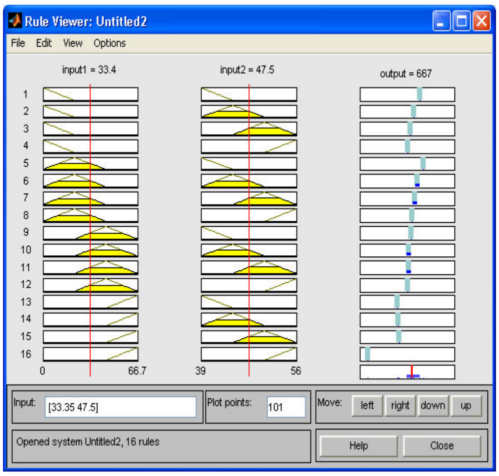
Figure 12: Anfis controller model structure

Figure 13: Anfis editor

2.4.3 Anfis Training

The training of the input data is carried out using hybrid optimization method for the train fuzzy inference system. The error tolerance for the training is 0.0001 and the number of epoch is 100 as contained in figure 13 above.

The effect of the anfis rule applied in the design of the adaptive neuro-fuzzy inference controller is shown in figure 14 below.



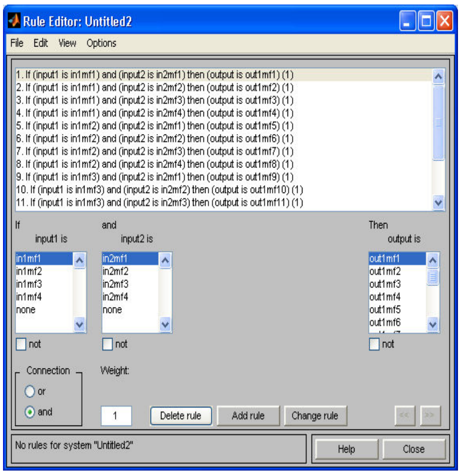


Figure 14: Anfis rule viewer

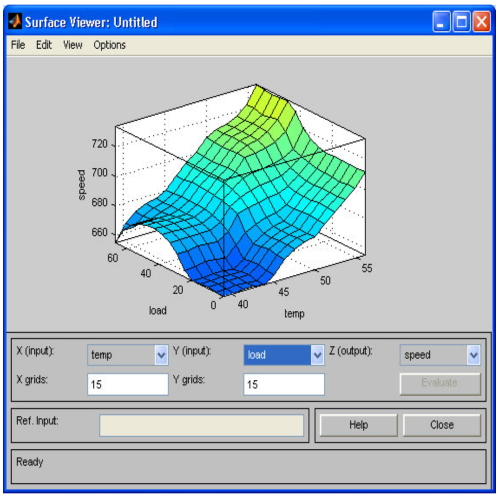
Figure 15: Anfis rule editor

Figure 15 shows the rules governing the operation of the anfis controller in the course of execution and highlighted above.

3 Results and Discussions

3.1 Fuzzy logic controller simulation results

The following results were obtained during the simulation of the fuzzy logic computer fan controller:



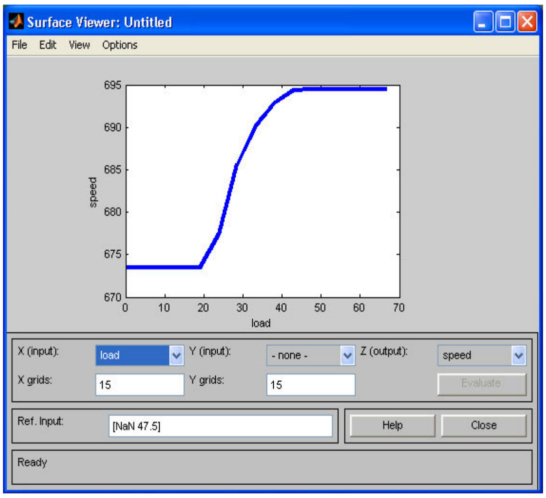


Figure 16: 3D view of the output and the inputs Figure 17: Fan speed and load

The surface view shows the three-dimensional view of the relationship between the load in percentage, the temperature in degree Celsius and the speed in revolutions per minute (rpm).
The surface view, figure 17, is the two dimensional view of the relationship between the output (speed) in revolutions per minute (rpm) and the percentage of load.
Figure 18 is the two dimensional view of the relationship between the speed (output) in revolutions per minute(rpm) and the temperature in degree Celsius(^{0}C).

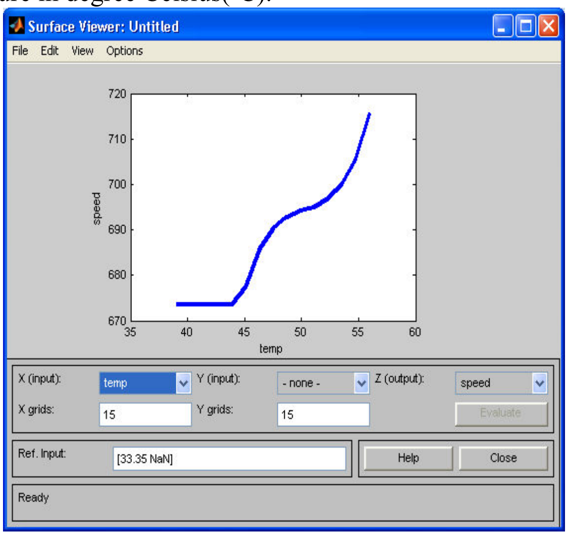


Figure 18: Fan speed versus temperature

3.2 ANFIS simulation results

The following results were obtained during the simulation of the adaptive neuro-fuzzy logic controller for the computer fan system having its output (speed) function as contained in table 2.

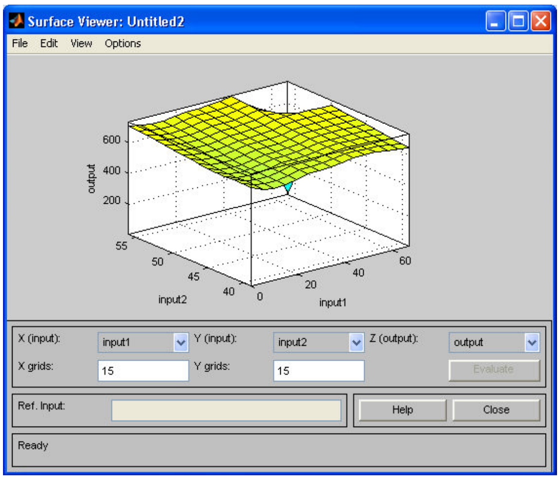


Figure 19: Relationship between the output and the inputs

Figure 19 shows the three-dimensional relationship between the speed (output) in revolutions per minute(rpm), the temperature in degree Celsius(^{0}C), and the percentage of load.

The two dimensional view of speed(output) – load(input1) relationship during simulation is shown in figure 20.

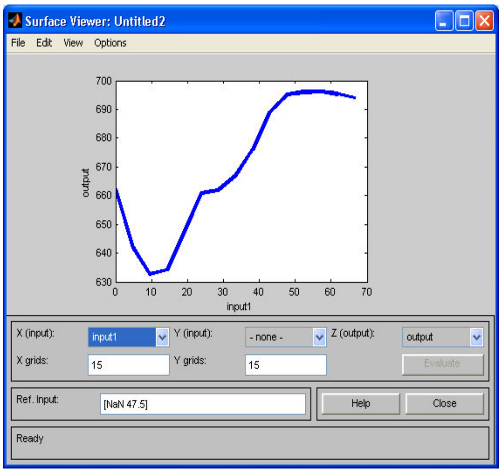


Figure 20: Anfis Speed versus load

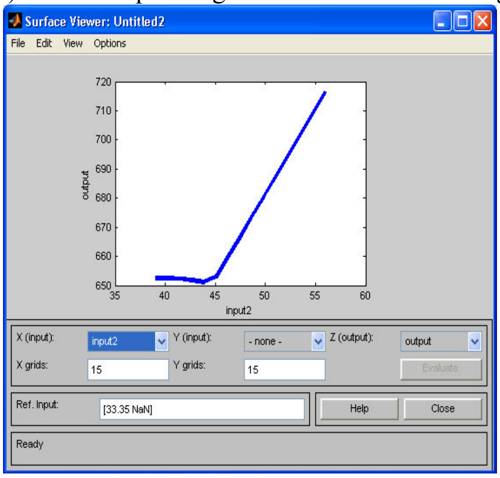


Figure 21: Anfis Speed against temperature

Figure 20 shows the two dimensional relationship between the speed (output) in revolutions per minute(rpm) and the load in percentage (%).

The simulation outcome showing the relationship between the speed and the temperature is displayed in figure 13.

4. Results Explained

The anfis controller's response to computer system functionalities is better than that of fuzzy logic controller's response. Anfis respond to the slightest parameter changes as evident in its speed versus load curve compared to fuzzy logic controller that takes time to respond to changes in parameter quantity. Also, comparison between the Anfis' speed versus temperature curve and fuzzy logic's speed versus temperature curve shows that Anfis fare better in terms performance as changes in temperature is complimented with a smooth response operation of the controller thereby saving power demand by the entire computer system, reduction of fan noise, and novel minimization of heat generated by the system. Anfis takes into considerations the initial behaviour of the computer system's fan at starting as shown in the speed versus load curve. Both fuzzy logic computer fan controller and the anfis computer fan controller show appreciable improvement to the overall control of the computer fan speed/operations.

5. Conclusion

Fuzzy logic controller and adaptive neuro-fuzzy logic controller gives new approach to controlling the operations of computer fan speed with satisfactory responses. However, neuro-fuzzy logic controller's performance is better than that of fuzzy logic controller as evident in the results obtained. In addition, training of the neuro-fuzzy controller's membership functions using neural network makes the controller suitable for use in various environment being adaptive in behavior, that is, it can reason and decide its immediate output/response based on past experiences or results.

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