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Realization of Fuzzy Logic Temperature Controller

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Abstract **- The paper proposes the realization of a Fuzzy Logic Temperature Controller. In this paper an analysis of Fuzzy Logic Controller is made and a temperature controller using MATLAB is developed. Here we used Fuzzy Logic Toolbox which is very useful software for development and testing of Fuzzy Logic system. It can be very quickly implemented and its visual impact is very encouraging. In this controller the Rule Base, membership functions and inference engine are developed either using digital systems such as memory and logic circuit or it can be developed using analog CMOS circuits. Analog Fuzzy systems are popular because of their continuous-time-processing and high frequency and low power implementation.**

Keywords **- Fuzzy Logic, Fuzzy Interface System, Temperature controller, Takagi-Sugenos type controller, Fuzzyfication, Defuzzyfication, Rule Base, Fuzzy logic toolbox.**

I. INTRODUCTION

Fuzzy logic is a mathematical system that analyzes analog input values in terms of fuzzy variables that takes continuous values between 0 and 1, in contrast to classical or digital logic, which operates on discrete values of either 0 or 1. Fuzzy logic was first proposed by Lotfi A, Zadeh of the University of California at Barkley in 1965 paper and the idea was elaborated in 1973 paper that introduced the concept of Fuzzy set. Fuzzy Logic Toolbox, also known as Graphical User Interface (GUI) tools are used to build and edit Fuzzy Interface System (FIS). The five GUI tools for building, editing and observing FIS are:

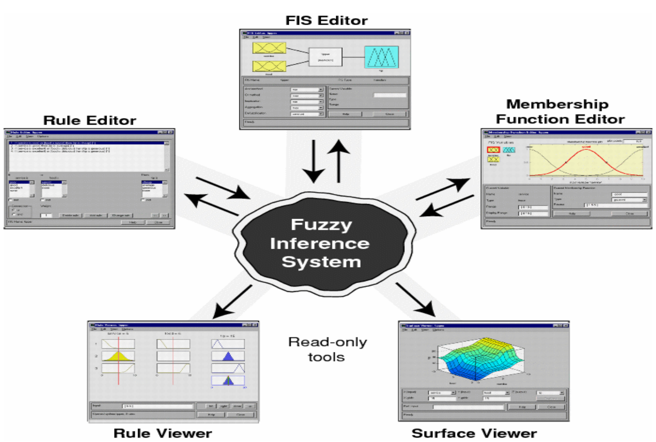

Fig-1 Fuzzy Logic Toolbox

Fuzzy Logic Controller

A control system is a device or a set of devices to manage, command, direct or regulate the behavior of other devices or systems. There are two common classes of control systems, with many variations and combinations: logic or sequential controls and feedback or linear controls. There is also fuzzy logic which attempts to combine some of the design simplicity of logic with the utility of linear control.

There are two types of Fuzzy Logic Controller-

1) *Mamdani type controller*

Mamdani introduced the fuzzification/inference/de-fuzzification scheme and used an inference strategy that is generally mentioned as max-min method. This inference type is a way of linking input linguistic variables to output ones in accordance with the generalized modus ponens, using only the MIN and MAX functions. It allows achieving approximate reasoning. One important aspect of Mamdani's method is that it is essentially heuristic and it can sometimes be very difficult to express an operators or engineering knowledge in terms of fuzzy sets and implications. More over such knowledge is often incomplete and episodic rather than systematic. There is in no specific methodology for clearly driving and analyzing a rule base of a fuzzy inference system. Here, some problems may occur when the rules have to describe a process that is too complex or to deal with a high number of variables. It can be then very difficult to define a sufficient set of coherent rules and the danger of having not enough or conflicting rules occurs. This method is currently and effectively applied to process control, robotics and other expert systems. It is especially well appropriated to execute an operators control or command action.

2) Takagi-Sugenos type controller

This type controller differs from the previous one in the nature of inference rules that only deal with linguistic variables. Takagi-Sugeno controller directly leads to real values that are not membership functions but deterministic crisp values. This method only used fuzzy sets for the input variables and there is no need of any de-fuzzification stage. Whereas the antecedents still consist in logical function of linguistic variables, the output values are resulting from standard functions of input variables. In most of the cases, only linear functions are used.

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It is not possible to derive efficient control rules by Mamdani's method when it is difficult to translate exactly a human operators or engineer's knowledge into linguistic terms. The adaptive Takagi-Sugeno's method is however efficient in such cases, provided that inference rules can be derived from the analysis of appropriate numerical data. One more advantage of this method occurs in some complicated cases where many different variables play a part in a process. When fuzzy reasoning is used to describe some processes, methods as Mamdani's one are not so powerful partly because of their nonlinearity. The use of linear relations in the consequences enables to deal with Takagi-Sugeno rules as an efficient mathematical tool for fuzzy modeling. Takagi-Sugeno's method becomes actually difficult or even impossible to apply when a control has strongly non-linear characteristic or which is moreover changing with time. The rules of Takagi-Sugeno are mainly used to realize process modeling. The method is well appropriated to the situation which is easier to observe than to express into linguistic terms.

Here, we used Takagi-Sugenos type controller.

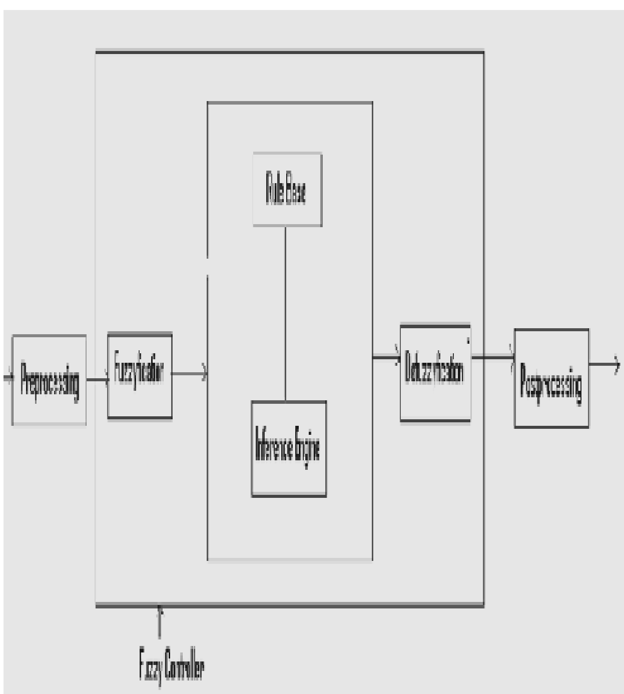

Fig-2 Block diagram of Fuzzy Controller

Blocks of Fuzzy Controller

i) Fuzzyfication

It converts each piece of input data to degrees of membership by a look up in one or several membership functions.

The fuzzyfication block thus matches the input data with the conditions of the rules to determine how well the condition of each rule matched that particular input instance. There is a degree of membership for each linguistic term that applies to that input variables.

ii) Rule Base

A set of rules specifying the combination of input membership values are stored. The controllers here for used by the inference mechanism, can therefore be applied to multi-input-multi-output problems and single- input-single-output problems.

iii) Inference Mechanism

For each rule the inference mechanism uses the membership values and according to the condition of the rule comes to a conclusion.

iv) Defuzzyfication

The resulting fuzzy set must be converted to number that can be sent to the plant as a control signal. This operation is known as defuzzyfication.

Difference between Conventional Controller and Fuzzy Controller

It is difficult to design conventional controller for the system:

1) With non-linear characteristic and decision making system.
2) With an increasing number of sensors and large quantity of information.
3) To reduce development time
4) To reduce costs associated with in corpora ting the technology into product.

But, fuzzy controller can satisfy these requirements for the following reasons:

a) Non-linear characteristics are realized in fuzzy logic by partitioning the rule space, by weighting the rules and by the non-linear membership function.
b) Rule based systems compute their output by combining results from different parts of partitions, each part being governed by separate rules.
c) In fuzzy logic reasoning, the boundaries of these parts overlapped and the local results are combined by weighting them appropriate.

Temperature Controller

The temperature controller is an instrument used to control temperature by taking an input from temperature sensor and has an output that is connected to a control element such as heater or fan.

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Fuzzy Logic Temperature Controller

The problem is to design a temperature controller which will keep the controlled temperature at a set value at 70°C within a range of 40-100°C. Temperature values are assumed to be integers. The universe of discourse that is the range of temperature is 40°C to 100°C. The temperature difference is

$$\Theta i - \Theta r = TEMP$$

Where, Θi=input temperature

Θr=relative temperature

TEMP=temperature error

As Θi varies from 40°C to 100°C TEMP varies from -30°C to +30°C. Thus, range is normalized into a derived universe of discourse (UOV) having a range within [-1, +1] and the temperature error TEMP is changed to TERR.
The UOV is divided into the following regions LN, SN, ZE, SP, and LP depending on the deviation of the set value of temperature with actual input values.

Where, LN=large negative, SN=small negative, ZE=zero, SP=small positive, LP=large positive
In addition to TERR, time derivative of temperature deviation (DELT) is used as another input to the controller having the same UOV. The output HOUT stands for controller output having same UOV which controls a blower. The membership functions are all triangular and approximately 50%overlapped between successive membership function is maintained.

Rule Table

The connectivity between the inputs is always logical AND or logical OR. Here we use only logical AND. The Rule Table for the above problem from general experience is constructed as follows. For example,
If (TERR is SN) AND (DELT is SN) then
the output of the blower i.e. HOUT should be such that the variables trying to deviate the desired output should work against. Therefore, HOUT should be LP.

This explain the following rule table :
TERR

	LN	**SN**	**ZE**	**SP**	**LP**
LN	LP	SP	LP	SP	ZE
SN	LP	LP	SP	ZE	SN
ZE	LP	SP	ZE	SN	LN
SP	SP	ZE	SN	LN	LN
LP	ZE	SN	LN	LN	LN

Implementation of Temperature Controller using Fuzzy Logic Toolbox

Membership functions and Rule bases are all entered in GUI of Fuzzy Logic Toolbox and the performance is observed using the Rule Viewer.

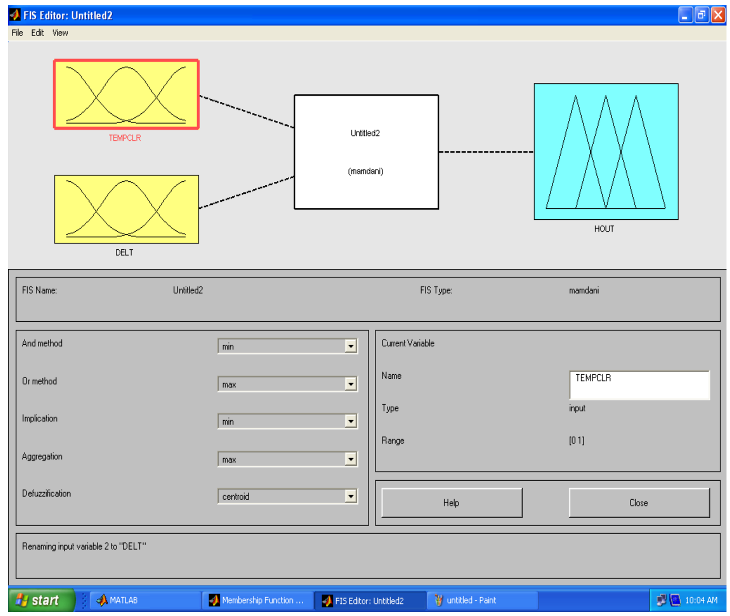

Fig-3 Inputs of Temperature Controller

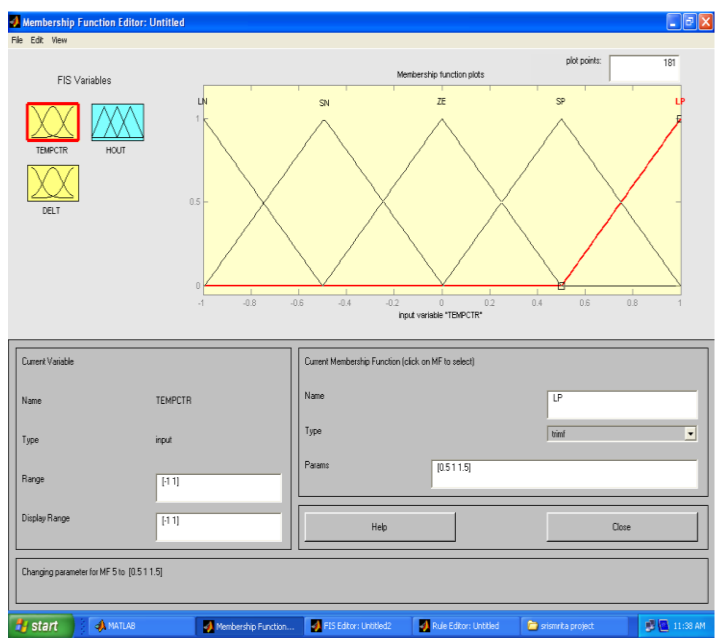

Fig-4 Membership functions of

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TERR input of temperature Controller

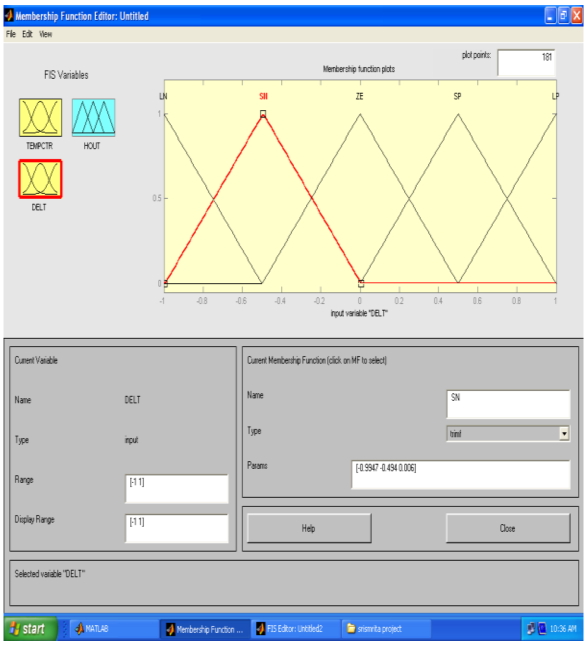

Fig-5Membership functions of DELT input of Temperature Controller

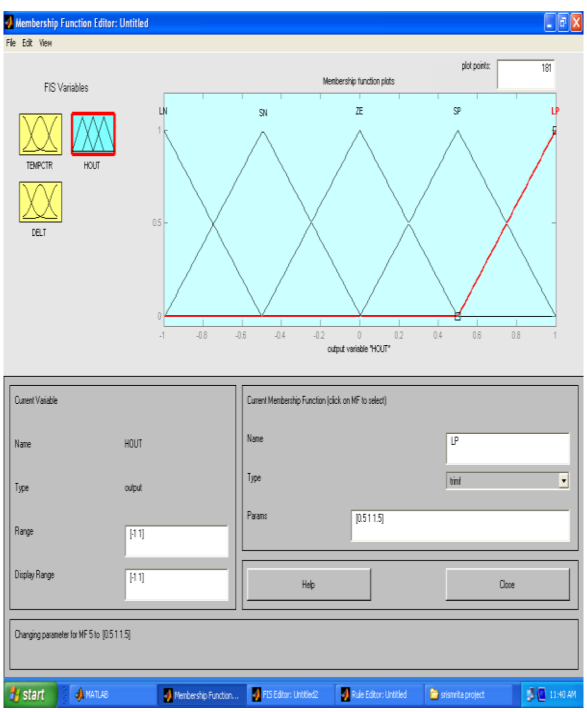

Fig-6 Membership functions of HOUT output of Temperature Controller

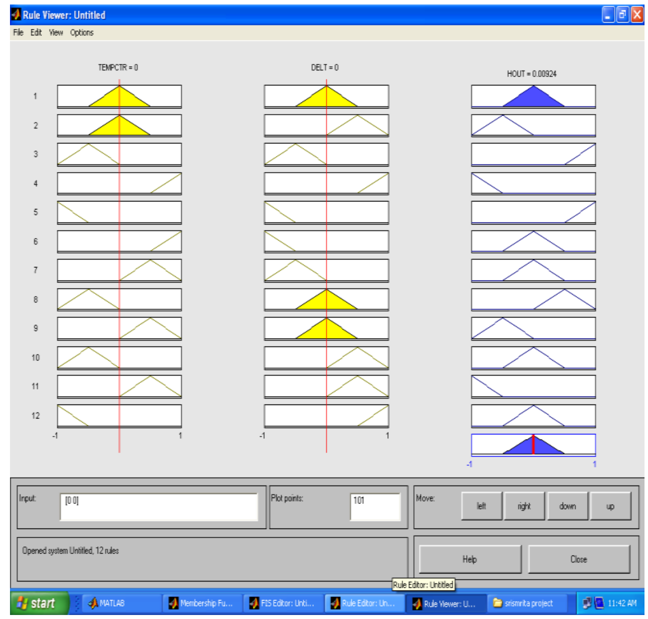

Fig-7 Rule viewer of Temperature Controller

Here, TERR=0 or DELT=0
HOUT=0.00924
(This is minimum)

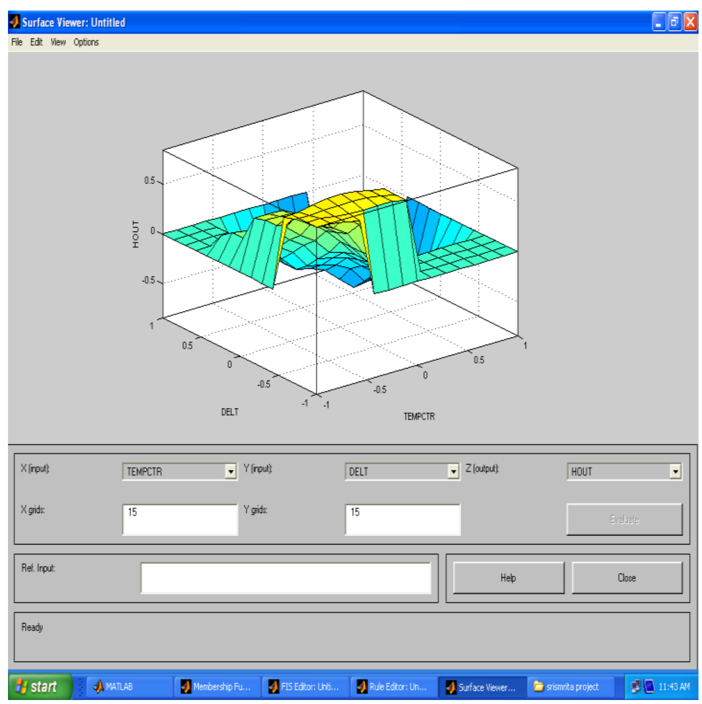

Fig-8 Surface Viewer of Temperature Controller

EXPLORING RESEARCH AND INNOVATIONS

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II. CONCLUSION

An attempt has been made here to initiate work on analog realization of fuzzy circuits, but the implementation involves a large number of MIN-MAX circuits, which is time consuming and needs elaborate simulation and testing. Research and development is also continuing on fuzzy applications in software, as opposed to firmware, design, including fuzzy expert systems and integration of fuzzy logic with neural network and so called adaptive "genetic" software systems, with the ultimate goal of building "self-learning" fuzzy control systems.

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