DESIGN AND CONSTRUCTION OF A LABVIEW BASED TEMPERATURE CONTROLLER WITH USING FUZZY LOGIC

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ABSTRACT

In this study, the performance of fuzzy logic algorithm for a real time temperature controller system has been investigated in detail. The construction of circuit, design of the fuzzy system and experimental investigations has been reported. This system requires minimum hardware. A user friendly interface based on LabView is used for controlling fuzzy system.

I. INTRODUCTION

The idea of fuzzy logic is to model a subjective, indeterminate concept such *as temperature too high, temperature change too low***,** and so on, with intermediate values. These values are expressions of the colloquial language, what means that anybody can understand and handle it. But a computer can not deal these fuzzy arguments. It needs sharp values which define clear facts to decide upon them. Fuzzy logic extends here the classic set theory with the help of membership functions as a part of the fuzzy set theory.

The expression *temperature too high* is a different subjective statement, which can not be limited with fixed temperature points. A person would decide in regard to this expression, that the temperature belongs more or less to the variable. The degree of the membership in the fuzzy set theory is defined as a continuous function between no membership (0) and full membership (1), in comparison to the binary values (0, l) in the classic set theory [1].

Fuzzification here means to classify a value to the degree of its membership function in regard to express human like linguistic variables.

The next step in fuzzy logic is to make decisions based upon the linguistic variables (inference). They are made in IF-THEN-rules, were the IF-part describes a situation and the THEN-part contains the wished action.

The result out from all fuzzy sets of the single rules is a summary of partly contradictory and not precise statements. Methods of Defuzzification try to find a compromise from all fuzzy sets to suggest at least a precise value. This proceeding is compared with a balance of all concerned sets to a valid conclusion. Several methods of defuzzification exist to produce an exact output value. The typical value for every single result of the rules is determined in the centre of maximum method (COM). Thus the linguistic variables in the composition are not fuzzy sets but fixed values (typical values). The outputs of the single rules are added up with their weight from the aggregation. The received exact value is consequently the mean of the weighted values. Another well known method is the Center of Gravity (COG).

The numeric value of the aggregation is referred to the fuzzy set of the output fiction. The fuzzy sets are cut off at the appropriate values and the area below the cut-off point is evaluated. The resulting areas of the single fuzzy sets of each rule are superimposed on the output aggregation function. From the total area, the area center of gravity is used to determine the definite output value [2]

Temperature based equipment control is the basic requirement in domestic as well as experimental applications. Conventional temperature control methods such as PID, also called Deviation-Derivative PID, can cause a large derivative kick during some set point changes. Other problems can arise during process upsets and then how quickly a process will stabilize using this method of PID control.

The problems associated with the Deviation-Derivative PID leads to the use of the PV (Process Variable)-Derivative PID action. In the PV-Derivative PID only the P and I terms are mathematically operated after the PV/SV deviation is determined. This PID algorithm may have problems in some types of applications.

There is still yet another form of PID and that is the I-PD algorithm. In this PID action only the I term is mathematically operated on the PV/SV deviation. By using the I-PD method overshoot is minimized but the response is slower than with other types of PID control. There is one control method that uses both PV-Derivative PID and the I-PD control algorithms and it is referred to as Brilliant PID. This method will allow the setting of different types of response curves to match the process. The alternative to Brilliant PID and its response curves is Fuzzy Logic. PID provides proven control of a process that is linear and predicable. If an upset does occur that the PID was not anticipating, then the fuzzy control will be activated and the fuzzy logic will then bring the process back into a stable condition [3].

Nowadays some researches combine the fuzzy logic and PID controllers [4]. On-chip and microcontroller based fuzzy temperature controllers are generated [5].

A fuzzy logic controller gives out faster response, more reliable and recovers quickly from system upsets. It also works well to uncertainties in the process variable. Fuzzy logic controller does not require mathematical modelling and can overcome local optima to reach global optima [6].

The main motivation of this study is design and construction of a new fuzzy system controlled by computer. User interface system is generated with using LabView PID & FUZZY Toolkit 8.

This system can be applied to large systems. But this temperature controller was deliberately designed for small scale applications. Such as, biosensor applications, observations of biological reactions and kinetic studies against temperature.

In addition to these, designed fuzzy logic based system can be used in material science and physics. In these fields, small volumes of specimens are characterized against temperature. Such as, conductivity of semi conductors and polymers, light emitting and absorbing of optical materials, efficiency of fuel cells etc.

II. HARDWARE DESIGN

In this paper it was aimed that temperature based heater controller system based on fuzzy logic. The block diagram of the designed system is shown in figure 1.

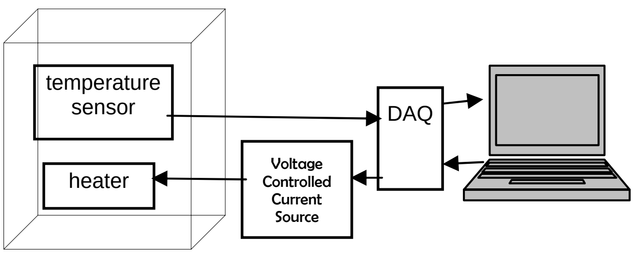

Figure 1. Block Diagram of the temperature controller system.

The temperature of the environment is obtained by LM35 temperature sensor. LM35 is a linear sensor and rated to operate over a -55^0 to $+150^0$C. Scale factor of the sensor is +10.0 mV/^{0}C [7].

Also the volume of the environment is 342,95 cm^3.

Measured temperature is digitalized and consigned to the computer with using a Data Acquisition Card (DAQ). Fuzzy logic system decides the voltage level which is sent to circuit over DAQ. According to voltage level, a voltage controlled current source circuit passes through the current across the heater. And the temperature of the environment rises to the desired level and fixed.

III. CONTROLLER DESIGN

The output from the temperature sensor is in the form of analog voltage ranges 0-0.15 V, which is digitalized by DAQ. The input variables are fuzzified and after proper defuzzification using rule base and aggregation methods, the output is evaluated which is used in control action. To achieve the accurate output from the fuzzy inference system, following steps are designed:

Step One: Define Inputs and Outputs for the Fuzzy Logic Controller
Step Two: Define frame for fuzzy variables
Step Thee: Assign membership values to fuzzy variable
Step Four: Create a rule base
Step Five: Fuzzify inputs to the fuzzy logic controller
Step Six: Determine which rule fires
Step Seven: Infer the output recommended by each rule
Step Eight: Aggregate the fuzzy outputs recommended by each Rule
Step Nine: Defuzzify the aggregated fuzzy set to form crisp output from the fuzzy logic controller.

The input variables of the fuzzy logic controller are:

Error = Set point – Measured temperature
Change in error = Current error – Previous error

First fuzzy input represents the error between measured temperature and set point. Figure 2 shows the membership function and table 1 gives the linguistic variables for error. The crisp input for second input membership function is change in error. Figure 3 shows the triangular seven-level membership function and table 2 gives the linguistic variables for change in error. Input variables are scaled to the intervals [-0.2, 1] and [-1, 0] respectively. The rule base of the fuzzy controller gives the decision that in which of the seven memberships function have to fire. Rule evaluation part has 49 fuzzy rules.

Fuzzy logic controller's output is voltage level which is applied to voltage controlled current source circuit. Figure 4 shows the membership function and table 3 gives the linguistic variables of the fuzzy output. Output variable is scaled to the interval [0, 1].

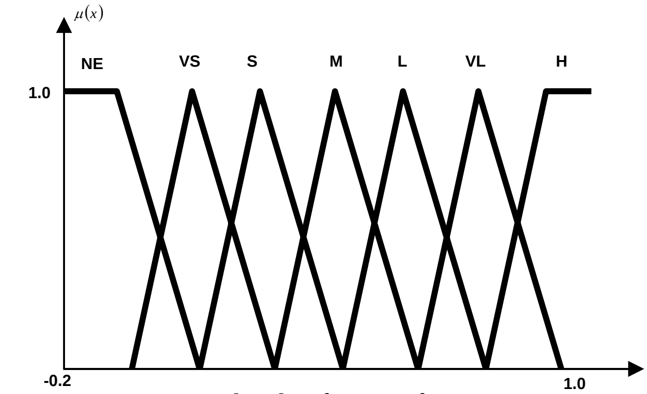

Figure 2. Input membership function for error.

FUZZY VARIABLE
NEGATIVE ERROR
VERY SMALL
SMALL
MEDIUM
LARGE
VERY LARGE
HIGH

Table 1. Error.

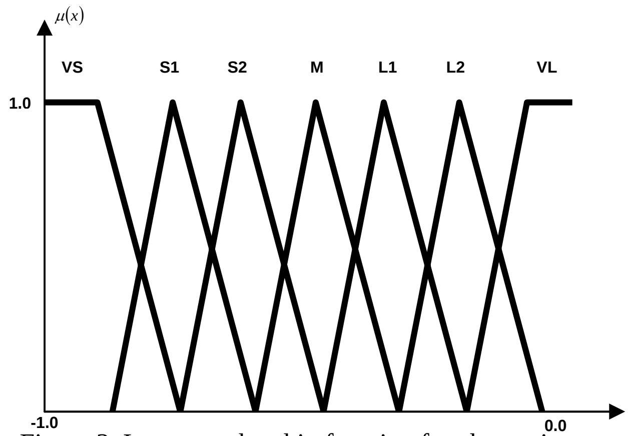

Figure 3. Input membership function for change in error.

FUZZY VARIABLE
VERY SMALL
SMALL1
SMALL2
MEDIUM
LARGE1
LARGE2
VERY LARGE

Table 1. For change in error.

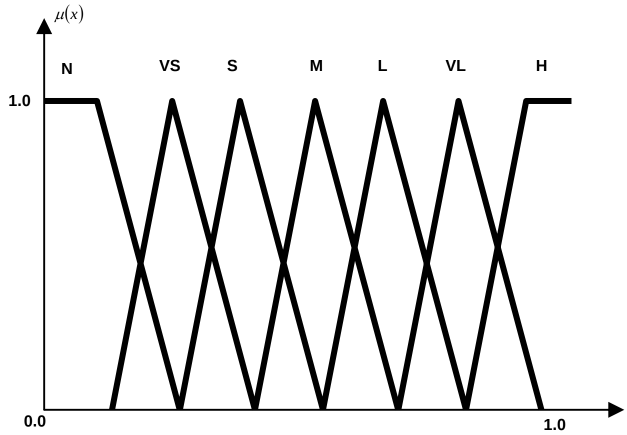

Figure 4. Output membership function for firing angle.

FUZZY VARIABLE
NO OUTPUT
VERY SMALL
SMALL
MEDIUM
LARGE
VERY LARGE
HIGH

Table 1. For output (firing angle).

IV. EXPERIMENTAL INVESTIGATIONS

In this part of the study, first open-loop heating characteristic of the controller was observed and recorded. As it can be shown in figure 5, heating characteristic is a non-linear process. For non-linear system control, fuzzy logic is a powerful and useful tool.

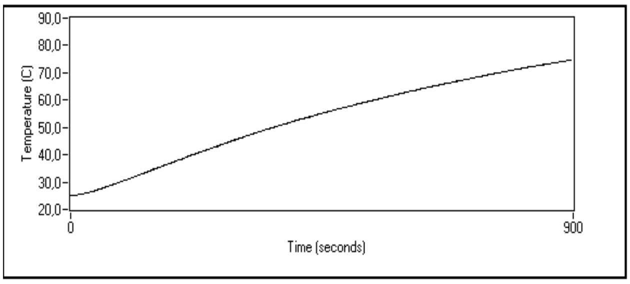

Figure 5. Heating Graph.

As presented in figure 6, the desired temperature is set to 45^0C and initial temperature is about 24^0C (room temperature). After one overshoot, the environmental temperature is arranged to desired set point by fuzzy logic.

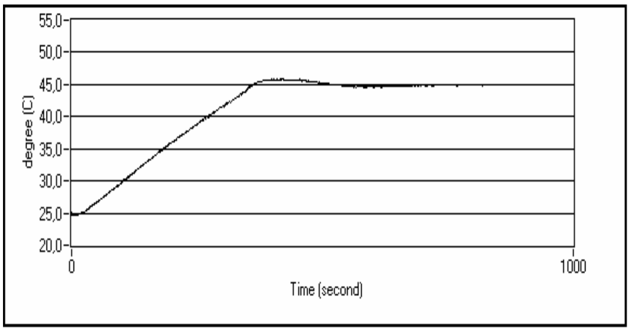

Figure 6. Measured temperature for 40^0C set point.

As shown in figure 7, the desired set point is 45^0C. The measured temperature starts from 40^0C and in a short time period it rises to the set point. Also the fluctuations about desired point could be seen.

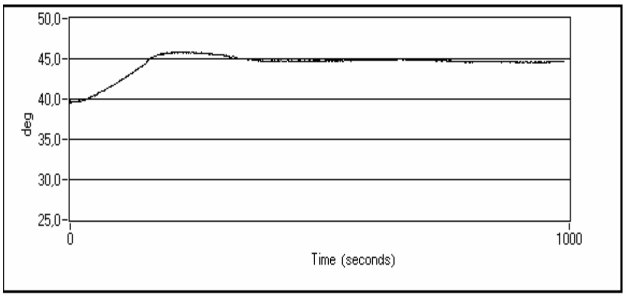

Figure 7. Measured temperature rises from 40^0C to the set point 45^0C.

V. CONCLUSION

Suggested fuzzy logic temperature controller approach is easier for implementation. Hardware part of the system consists of a temperature sensor, a voltage controlled current source and a heater which can be easily obtained from market. Software part of the system is designed by using LabView PID & FUZZY Toolkit 8. A user-friendly graphical interface allows changing parameters of the controller and set point in real time.

Fuzzy logic controller designed and implemented in this study has a range of from room temperature to 75^0C. In this range, maximum fluctuations of $\pm 0{,}3\,^0$C around the set point are observed. Figure 6 and figure 7 are selected examples of desired set points in given range.

This implemented fuzzy controller system could be used effectively in physic and chemistry research laboratories for measuring of some parameters against temperature. This fuzzy system can also be applied for industrial heating applications.
Fuzzy logic control is a case based application. The controller system suggested in this study could be modified to achieve specific goals. Such as the heating time could be shorter if membership functions rearranged or higher voltages are given by rearranging system rules.

REFERENCES

1. S. Jonda, M. Fleischer and H. Meixner, Temperature Control of Semiconductor Metal-Oxide Gas Sensors by Means of Fuzzy Logic, The 8th International Conference on Solid-State Sensors and Actuators, and Eurosensors IX. Stockholm, Sweden, June 25-29, 1995
2. V. Berg. H, Fuzzy logic: A clear choice for temperature control, I&CS, vo1.66, no.6, pp. 39-41
3. J. Wilkinson, Additional Advances in Fuzzy Logic Temperature Control, ISN: 0-7803-3008-0, 2721-2725, 1995, IEEE.
4. B. Coeyman, J. B. Bowles, Fuzzy Logic Applied to Reboiler Temperature Control, ISN: 0-7803-3643-3, 511-516, 1996, IEEE.
5. J. Knobloch, T. Presberger, Optimization of an On-Chip Fuzzy Temperature Controller, ISN: 0-7803-3225-3-6, 382-386, 1996, IEEE:
6. J. Chia-Feng, C. Jung-Shing, H. Hao-Jung, Temperature Control by Hardware Implemented Recurrent Fuzzy Controller, ISN: 0-7803-8353-2/04, 795-799, 2004, IEEE.
7. LM35 Precision Centigrade Temperature Sensors, National Semiconductors, November 2000.
8. F. Mohd-Yasin, A. Tio, M.S. Islam, M.I. Reaz, Fuzzy Logic-Based Temperature Regulator for Industrial Application: Software and Hardware Approaches, ICSE 2004, Malaysia, 517-521, 2004.
9. M. Gagandeep Kaur, A. Chauhan, P.V. Subramanyam, Fuzzy Logic Based Temperature Controller, ISN: 0-7803-9017-2/05, 492-495, 2005, IEEE.
10. L. Chin-Teng, J. Chia-Feng, L. Chung-Ping, Temperature Control with a Neural Fuzzy Inference Network, IEEE Transactions on Systems, Man, and Cybernetics-Part C: Applications and Reviews, vol. 29, No. 3, 440-451, 1999.