DESIGN OF A FUZZY BASED PID ALGORITHM FOR TEMPERATURE CONTROL OF AN INCUBATOR

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Abstract. The incubator is an apparatus that is used to regulate environmental conditions such as temperature, humidity control in an enclosure. To maintain the temperature of the incubator is difficult and challenging. This research paper proposes the design of an incubator temperature control by using fuzzy based PID. The proposed model construct of two fuzzy logic based PID controllers to control the temperature. This paper principally focuses on the designing of new fuzzy self-tuning PID algorithm. The error and changing error rate are inputs of the fuzzy based PID controller. The PID parameters are outputs of the fuzzy based PID controller. A set of fuzzy rules is used to regulate the PID parameters. The simulation result shows that the rising time, settling time & overshoot had reduced compared to PID control.

Keyword: Proportional Integral Derivative (PID), Fuzzy adaptive PID control, Membership function, Temperature control.

1. Introduction
Temperature is the major control parameter in the procedure of industrial manufacture all over the world [1]. Now a days, maintaining the temperature control is used by conventional PID controller. There have some advantages in PID control system, which has common in construction and easy to understand. It has a proper monitoring outcome for the unwavering process that can developed the exact model. As a result of the controlled of this process it has big delay. Due to the process of PID function can operate the control of temperature.

In the temperature control system, There are many kind of strategies have been applied, such as artificial intelligent fuzzy self-tuning PID, Conventional PID, Fuzzy etc [2]. The Fuzzy-adaptive PID is on the heart of whole control of the process. It can acquire the self-governing Fuzzy PID parameter control of algorithm. Fuzzy monitoring has dynamic robustness. It does not precise the accurate model of the control method, it can dependent on the learning and competence for maintaining the manipulate data of an incubator. It is suitable for control the Nonlinear Time-changing delay system. In the Self fuzzy tuning PID algorithm, which is effective and complete easily. In the temperature control system, It has been used worldwide. There have innumerable solicitation of the FLC. Various researchers had demanded the fuzzy logic is an surrounding knowledge all over different types of logic [3]. Fuzzy logic controller is the control for decision making with IF-THEN fuzzy rules. In many cases, FLC design is completed by the system error is determined by the using of computer simulations. In many different types of industry PID controller are using various application for the fuzzy controllers development around the world in past [4-7].

The Incubator is used in the hospital and laboratory for the cultivation of cell and tissue for maintaining the accurate control optimum levels for oxygen, humidity, temperature. the mammalian body of temperature is 37°C

Christina Tan, had been proposed the integrated light, humidity and temperature monitoring system for the hospital environment. The microcontroller was used in this system. An intelligent, light and the humidity control, integrated heat monitoring system had been real with the uses of illuminated general technology with the saleable process and acceptable matters which are displayed the
ecological condition dynamically. The process permits the operator concerning with the exact patient for humidity, temperature, and supply of light [8]

S.K. Mousavi, et. al. submitted an incubator with the fuzzy logic controller. In this research the authors were succeed to the three fuzzy factors such as oxygen, moisture and temperature which are the real part in the incubator. In this system they attempted to the highest ability in expressions with the born of chickens, which were born from the eggs and exact control- finally the reversion of three fuzzy multiplier. [9]

Sumardi Sadi, submitted his proposal, designed of Room Temperature Control System Prototype Industry Based on PLC. In his system, he had been showed a trial of mechanisms based on the hotness of the room. The program had encoded by the PLC. The heat room and the heat wave can be Rising and executed by LCD. In this method the temperature had used 0°C to 90° centigrade. [10]

H.Mittal and et al. had proposed The design and development of an infant incubator for controlling the different parameters. In his research, the close loop monitoring system had adjustable the moisture, light of power and hotness. LED escape the fixed volume of oxygen are easy going under a incubator for newborn baby. A PID controller had been applied for determining the process.[11]

W.Widhiada, et al, proposed on Temperature Distribution Control of Infant Incubator System based on Arduino ATmega 2560. In this research he used to the heating components as heat generation with the request of on or off control. He could proof the temperature 36°C on the comprehension 400 sec. [12] Zain-Aldeen S. A.Rahman, proposes the smart incubator based on PID controller. In his research he used ATmega1280 and Atmel AVR brain which are encoder by C program languages via the USB port. He could also DHT-11 sensor used for sense the coldness and LM35 is the sensor for the temperature sensing. In his research he showed the real measurement data including the temperature and humidity control in the incubator .[13]

T.G.T. Nindhia, et al had been proposed ‘Temperature Stability and Humidity on Infant Incubator Based on Fuzzy Logic Control’ the authors represent the LM35 Sensor, DHT22 Sensor, Arduino Uno, Arduino Mega 2560, are showed that the overshoot oscillations are high and the signal error 5% under. And represent the temperature 30.4016 centigrate increases at 0 sec and the steady temperature at 215 sec. [14]

This research paper principally focuses on the designing of new the self-fuzzy PID tuning in order to temperature monitoring on the incubator. The purpose of this system is improved and the temperature fluctuation has been decreasing. Fuzzy controlled has main branch of the temperature control. It has principally emulate the human control experience of mathematical model of the proposed system. It can control the internal temperature in the incubator. It can help to improve the various effective concept development of control system reliability on incubator. In the using of fuzzy self-tuning PID, the system has rise time, settling time, overshoot has been decreased compared to the conventional PID.

2. Theoretical Background

2.1 PID Controller

Firstly, conventional PID controller has been used to control the input voltage as well as temperature of the system. The PID works as follows:

The error signal (difference between set point and process variable) is the input of PID and the output signal is in the control signal which is equal to the summation of three parts: proportional, integral and derivative parts. Kp, Ki, & Kd are the constant of three parts respectively. The PID controller had been taken the tuning as the inputs consequently. [15]

2.2 Fuzzy-PID Design

The conventional PID cannot operate the exact value as the rise time, settling time & the overshoot are big. So PID controller parameters are tuned with fuzzy rules.
Error ‘e’ and the changing error ‘ec’ are the inputs of the fuzzy inference system. The range of the fuzzy membership function [-6 6] & output range is [0 6]. The simulation shows that rising time, settling time & overshoot had reduced compared to PID control.

### 2.3 The Control of Fuzzy principle

The Fuzzy controller is usage the rule of algorithm which are based on the fuzzy sets, which has fuzzy calculation and is achieving the nonlinear intelligent control of the system fuzzy mathematic has been used. It applies the human’s practical experience for gathering knowledge and object control. After doing the defuzzification process the value of output can be an exact good. The logical design of the control of fuzzy principle.

### 3. Methodology

This research paper principally focuses on the designing of a new self-fuzzy tuning PID algorithm for the temperature control. The purpose of the system is to improve the performance and decrease the fluctuation of temperature.

In this paper, the temperature control system uses fuzzy based PID controller. The proposed Fuzzy-PID methods are combined with the fuzzy and conventional PID. $K_p$, $K_i$, $K_d$ are the Fuzzy output controller. The system error ‘e’ and the Changing error rate ‘ec’ are the fuzzy controller input. The parameter of $K_p$, $K_i$ and $K_d$ are organized by fuzzy rules apropos the different requirement process in PID monitoring system.

PID controller can convert voltage to the temperature on the system. Here the proposed system set temperature is taken on 1 degree centigrade. Transport delay (1 second) is used in the proposed system.

![Figure 1: Simplified block diagram of the propose System](image)

![Figure 2: The schematic design of Fuzzy adaptive PID monitoring process](image)
The conventional PID controls have a discrete control law is given below

\[ u(k) = K_p e(k) + K_i \sum_{i=0}^{k} e(i) + K_d [e(k) - e(k-1)] + u(0) \] ..........................(1)

The principle of PID parameters are as follows

(1) when the error ‘e’ is large, \( K_P \) is large and \( K_D \) is small
(2) when the error ‘e’ and changing error ‘ec’ are medium the system has small Overshoot.
(3) when the error ‘e’ and changing error ‘ec’ are small, than \( K_P \), and \( K_I \) is large.
   If the changing error ‘ec’ is large than \( K_D \) is small. If ‘ec’ is small than \( K_D \) is large.
In this model, the fuzzy controller had used two inputs and the three outputs. Error ‘e’ and Changing error ‘ec’ are input of the process. And \( K_P, K_I, K_D \) are the system output.

Fuzzy -PID controller are operated with the fuzzy estimate data due to the control command table. The fuzzy estimate data are concerned with the controller of output. The model of fuzzy table are concerned with the following configuration
1. The sum of inputs and the controller of outputs are clearly.
2. The input and output of syllabic level, syllabic factors and the creation of Context expressly.
3. The region of input and variables of outputs are defined with the fuzzy subsets.
4. The control of fuzzy rules is setting on the table.
5. Acquire the control of fuzzy rules on the table.

In this method, fuzzy including PID controllers changing the different kind of parameters are calculated on the error and changing error rate as the FLC system [16].
It has three fuzzy monitoring tables, which is \( K_P, K_I, K_D \). They are acquired by calculation of the error and changing error rate.

3.1 Membership Functions

The variables of input of a fuzzy control system are mapping with sets of the membership functions, called as “fuzzy sets”. The method of connecting of a crisp value of input with fuzzy value is known as fuzzification [17]. The Fuzzy sets are defined two inputs variable: (Error ‘e’ and the changing Error ‘ec’) and the output variables are defined as a temperature of an incubator. Each of the domain input parameters are separated into seven fuzzy sets: which are (NB, NM, NS, ZO, PS, PM, PB) and seven membership functions were formed similarly. Here the Membership functions map are the input parameter into seven membership values. The membership values are actually defined on the seven subsets. The domain output are divided into seven sub-domains: (NB, NM, NS, ZO, PS, PM, PB) correspondingly. The input range of (\( K_P, K_I, K_D \)) is [-6, 6] & the output range of (\( K_P, K_I, K_D \)) is [0, 6].

The Membership function had used on the fuzzification and defuzzification process of a Fuzzy logic system. This function had used to quantify the linguistic term. For the illustration of the linguistic terms of the membership function has been plotted with temperature variation.
Figure 3: Membership function of variable (a) $K_P$, (b) $K_I$, (c) $K_D$

3.2 Fuzzy logic rules

FLC process build on the input turn, processing turn and an output turn [18]. Fuzzy logic control are produced from the error and changing error rate of the process. The Error ‘e’ and changing error rate ‘ec’, are the input of the system. In the use of fuzzy rules, we get fuzzy presumption. During the defuzzification process, we can get the three parameters values and the enhancement PID function. The parameters are being processed the sum of the variable parameters lead to the three enhancement PID function. The Fuzzy Logic rule is used to constructed the control of the output variables. The fuzzy rules are simply IF-THEN rule with the condition. Here the IF portion is called the “preceding” and the THEN portion is called the “consequential” [19]. The fuzzy logic rules are given bellow

| E   | EC  | NB  | NM  | NS  | ZO  | PS  | PM  | PB  |
|-----|-----|-----|-----|-----|-----|-----|-----|-----|
| NB  | NB  | PB  | PB  | PM  | PM  | PM  | ZO  | ZO  |
| NM  | PB  | PM  | PM  | PM  | PS  | PS  | ZO  | NM  |
| NS  | NM  | PM  | PM  | PS  | ZO  | NS  | NM  | NM  |
| ZO  | PM  | PM  | PS  | ZO  | NS  | NS  | NM  | NM  |
| PS  | PS  | PS  | ZO  | NS  | NS  | NS  | NM  | NM  |
| PM  | PS  | ZO  | NS  | PS  | PM  | NM  | PM  | NM  |
| PB  | ZO  | PS  | NM  | NM  | NM  | NB  | NB  | 

| E   | EC  | NB  | NM  | NS  | ZO  | PS  | PM  | PB  |
|-----|-----|-----|-----|-----|-----|-----|-----|-----|
| NB  | NB  | PB  | NB  | PS  | ZO  | ZO  | ZO  | ZO  |
| NM  | NB  | NM  | NS  | PS  | NS  | NS  | NS  | NS  |
| NS  | NM  | NS  | NS  | PS  | NS  | NS  | NS  | NS  |
| ZO  | NM  | NS  | NS  | ZO  | PS  | PS  | PS  | PS  |
| PS  | NS  | NS  | NS  | PS  | PM  | PM  | PM  | PM  |
| PM  | ZO  | PS  | PS  | PS  | PB  | NB  | NB  | NB  |
| PB  | ZO  | PS  | PM  | PM  | PM  | PB  | NB  | 

| E   | EC  | NB  | NM  | NS  | ZO  | PS  | PM  | PB  |
|-----|-----|-----|-----|-----|-----|-----|-----|-----|
| NB  | NB  | NB  | NS  | NM  | NM  | ZO  | ZO  | ZO  |
| NM  | NM  | NS  | NS  | MB  | MB  | NS  | NS  | NS  |
| NS  | NS  | NS  | NS  | NS  | NS  | NS  | NS  | NS  |
| ZO  | ZO  | ZO  | ZO  | PS  | PS  | PS  | PS  | PS  |
| PS  | PS  | PS  | PS  | ZO  | PS  | PS  | PS  | PS  |
| PM  | PM  | PM  | PM  | PM  | PM  | PM  | PM  | PM  |
| PB  | PB  | PB  | PB  | PB  | PB  | PB  | PB  | PB  |
Table 4: Table of membership function

| Membership function | Error ‘e’ | Changing error ‘ec’ | Output |
|---------------------|----------|---------------------|--------|
| **K_p**             | NB [-8 0 -6 -4] | [-8 -6 -4] | [-1.016 -0.0156 0.984] |
|                     | NM [-6 -4 1.5 -2] | [-6 -4 -2 -2] | [0.9998 1.999 3] |
|                     | NS [-4 -2 0] | [-4 -2 0] | [3.45 0.02] |
|                     | ZO [-1.5 0 1.5] | [-1.2 0 1.2] | [1.999 3 4] |
|                     | PS [0.25 4] | [0.15 4] | [3.45 0.02] |
|                     | PM [2.45 6] | [2.38 6] | [4.50 02 6] |
|                     | PB [4 6 8 0.04] | [4 6 8 0.04] | [5.002 6 7 002] |
| **K_t**             | NB [-8 0 -6 -4] | [-8 -6 -4] | [-1.016 -0.0156 0.984] |
|                     | NM [-6 -4 1.5 -2] | [-6 -4 -2 -2] | [0.9998 1.999 3] |
|                     | NS [-4 -2 0] | [-4 -2 0] | [3.45 0.02] |
|                     | ZO [-1.5 0 1.5] | [-1.2 0 1.2] | [1.999 3 4] |
|                     | PS [0.25 4] | [0.15 4] | [3.45 0.02] |
|                     | PM [2.45 6] | [2.38 6] | [4.50 02 6] |
|                     | PB [4 6 8 0.04] | [4 6 8 0.04] | [5.002 6 7 002] |
| **K_d**             | NB [-8 0 -6 -4] | [-8 -6 -4] | [-1.016 -0.0156 0.984] |
|                     | NM [-6 -4 1.5 -2] | [-6 -4 -2 -2] | [0.9998 1.999 3] |
|                     | NS [-4 -2 0] | [-4 -2 0] | [3.45 0.02] |
|                     | ZO [-1.5 0 1.5] | [-1.2 0 1.2] | [1.999 3 4] |
|                     | PS [0.25 4] | [0.15 4] | [3.45 0.02] |
|                     | PM [2.45 6] | [2.38 6] | [4.50 02 6] |
|                     | PB [4 6 8 0.04] | [4 6 8 0.04] | [5.002 6 7 002] |

Figure 4: Control surface of variable (a) $K_p$, (b) $K_t$, (c) $K_d$
4. Simulation results and discussion

MATLAB toolbox is used to verify the proposed fuzzy adaptive PID controller to control the temperature of the system. The simulation of MATLAB is adapting the arrangement of membership functions for fuzzy rules[20]. The proposed system can reduce overshoot and undershoot and give the good response. Figure 5 is the parallelism of fuzzy including PID control and conventional PID control. And the transfer function on the simulink model is \([1/(s^3 + 7s^2 + 15s + 9)]\) [21]. Fuzzy adaptive PID temperature control has a faster reaction, small overshoot and good stable and progressive performance compared to the conventional PID control [22].

![Simulink block diagram](image)

**Figure 5:** Simulink block diagram

In the simulation model of the system, the step-response give the primary step signal detecting the response of the dynamic system. In the performances of fuzzy logic control system is necessary to choice the appropriate error ‘e’, changing error ‘ec’. The fuzzy logic controller is used for control the temperature performance of the system.

When the system error ‘e’ is large, than the overshoot is big and the process of transition will be long. When ‘ec’ is large, than \(K_d\) is large. The system overshoot will be reduce, the speed response will slow. Here the Simulink model of temperature control system, 1 degree are the set temperature. The step time of this system is 0 and the final value is 1. The simulation time had been taken 20 sec. The parameters can be modifying in different types of system. The parameters of the conventional PID control are \(K_p=3.01, K_i=3.00, K_d=2.42\).

Figure 6 shows the response of the conventional PID and figure 7 indicates the response of the fuzzy based PID. Conventional PID and fuzzy based PID are compared in figure 7. The proposed fuzzy based PID controller provide less rise time, settling time and overshoot, shown in table 5. Therefore, the proposed fuzzy based PID provides superior performance over the conventional PID system.

|                | Rise time | Settling Time | Overshoot |
|----------------|-----------|---------------|-----------|
| Conventional PID | 4.0775    | 12.8988       | 6.4309    |
| Fuzzy PID      | 2.1599    | 4.2683        | 1.9758    |

**Table 5: Simulation of MABLAB data**
Figure 6: Response of Conventional PID output

Figure 7: Response of Fuzzy-PID output

Figure 8: Response of Conventional PID & Fuzzy-PID
5. Conclusion

A fuzzy logic control is developed to effectively control an incubator temperature. In this research paper, the process of the temperature control strategy is adopted by PID and fuzzy self-tuning PID. The temperature controller is identified based on the simulation of output curve PID and Fuzzy PID responses respectively. The proposed fuzzy based PID algorithmic of the system is efficient and absolutely under control. The analyses of fuzzy logic controllers are difficult to study and easy to solve the linguistic variables. The result shows that the proposed controller achieves an outstanding characteristics to increases the exactness of control temperature. The proposed system can be used to design the advanced temperature control system in future for several industrial applications in environmental monitoring and management of the system.

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