

Evaluation of Newly Developed Liquid Level Process with PD and PID Controller without Altering Material Characteristics

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ABSTRACT

This article explains the design of fuzzy logic controllers (FLCs) for level processes which is generally used in numerous control operations. The main purpose of the proposed design is to maintain the liquid level in the tank at the desired level. In this paper, the fuzzy logic controller is chosen as the controller for the level process because of its fault tolerance, knowledge representation, expertise, non-linearity, uncertainty, and real-time manipulation. Fuzzy logic controllers have been developed and compared in the Mamdani version. Performance on proportional derivatives (PD) and proportional-integral-derivatives (PID) controllers. Whereas traditional PD and PID controllers are simple, dependable and eliminate steady-state errors, fuzzy logic controllers are rule-based systems that are a logical model of human behavior in processes of the proposed design. The response is provided as follows: The LabVIEW software has been validated. It is used to simulate the proposed system. Comparing error indicators such as PD controller, PID controller, fuzzy logic controller integral absolute error, integral quadratic error, time and absolute error integral, time and quadratic error integral, fuzzy logic controller is observed from the simulation results. increase. It offers better performance than other controllers.

Keywords: Fuzzy Logic Controllers, Mamdani, Proportional derivative, Proportional integral derivative.

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1. INTRODUCTION

Liquid level monitoring is frequently used in many industrial processes and applications such as water purification, food and beverage processing, impure water management systems, petrochemical processes and others. Controlling these processes requires expertise and in-depth knowledge of the fundamentals and advanced techniques of process control design. Inadequate understanding of the concepts by students who are hired into executive, control engineer, process engineer and management positions in turn can lead to loss of life and property. Commercial application of Proportional Derivative (PD), proportional-integral-derivatives (PID) and Fuzzy Logic Controllers for industrial operations has been going on for several decades. To better understand this work, we give a brief description of PD, PID and FLC as follows. The PD controller is used to increase the stability of the system. The PD controller is capable of predicting future error. of the response, which improves system control. To avoid the effect of abrupt changes in the value of the error signal, the derivative is taken from the output response of the system variable instead of the error signal. Therefore, the "D" mode in the PD is designed to be proportional to the change of the output variable to prevent sudden changes from occurring in the control output due to the sudden change of the error signal. In addition, "D" directly amplifies the process noise. In PD controller there is no feedback, so PID controller is the most widely applied feedback control formula/algorithm. The PID controller has

three parameters that must be set. The proportional term (Kp), the integral term (Ti) and the differential term (Td). Figure 1 below shows the effect of the Kp and Ti changes.

In addition, many different controllers have been proposed in different fields [1], but due to the non-linearity of the system components and substitutions, these evolved feedback controllers are not can effectively control the liquid level and is quite slow on the output feedbacks. . In addition, traditional computer logic is based on two values, one (true) and zero (false), and is not suitable for human decision-making. Therefore, it is often desirable to have a system that behaves like a human. Fuzzy logic uses the entire interval from 0 to 1 and can therefore be used to closely mimic human inference. Fuzzy control is the most suitable system to obtain promising results in case of correct selection of membership and rules [2]. The process of designing a fuzzy logic system can be divided into three stages, namely, fuzzification, fuzzy inference engine and defuzzification. converting crisp value into fuzzy value is called Fuzzification process. Knowledge bases include databases and rule bases used to represent human knowledge, in the form of natural language expressions. Fuzzy inference engine is a way to map input space with output space using fuzzy logic. Defuzzification is the block that converts a fuzzy quantity into a crisp quantity.

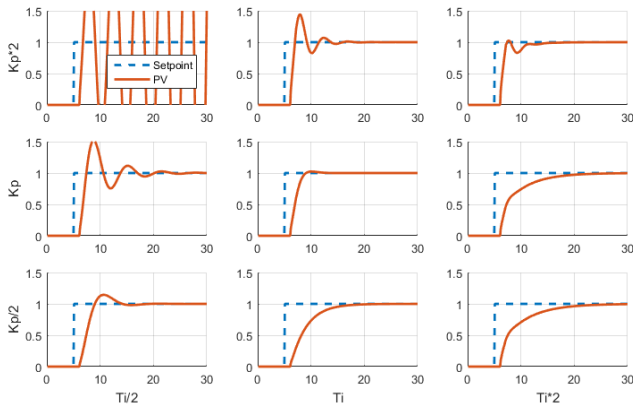


Figure 1. Effects of varying K_p and T_i

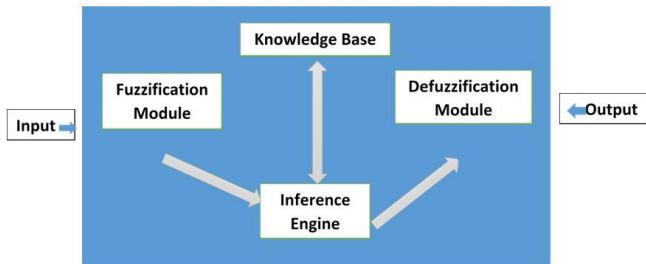


Figure 2. Representation of Fuzzy Logic Controller by block diagram

The organization of this paper are as follows: Section 2 presents the existing works in liquid level controller. Proposed process description is discussed in Section 3. Experimental results are evaluated and discussed in Section 4.

2. EXISTING WORKS

Literature survey of many studies contain process optimization and control applications have proposed for various industrial areas. Some of these studies are listed in the Table 1 as follows;

Table 1. Existing works

Authors	Proposed Work
Kwok et al., (2000)	constrained predictive control algorithm based on feedback linearization [3]
Poulsen et al., (2001)	second-order nonlinear system by variable structure controller[4]
Sbarbaro and Ortega (2007)	To control the multi-tanks systems [5]
Almutairi et al. (2007)	Diagrams of sliding mode control for the coupled tanks [6]
Lee and Shin (2009)	conventional PI (proportional-integral) controller based constrained control to liquid level system using [7]
Zhang et al. (2011)	non-linear based predictive control [8]
Noel and Pandian (2014)	nonlinear liquid level system control by artificial neural network based reinforcement learning method [9]

Sadeghi et al. (2014)	Takagi-Sugeno model for a liquid level system by parallel distributed compensation via fuzzy [10]
Singh et al. (2014)	reduced flow rate fluctuation for tank in series with PI controller [11]
Zhang et al. (2014)	liquid level in a coke fractionation tower PI controller based on predictive functional control system [8], [12]
Tao et al. (2014)	genetic algorithm for chamber pressure in coke furnace by predictive control based PID design [13]
Zhang and Yang (2014)	EGG-data-based estimation of operator functional state by incremental-PID-controlled particle swarm optimization algorithm [14]
Sahu et al. (2015)	fuzzy-PID controller for automatic generation control of multi-area power system [15]
Gizi et al. (2015)	an integrated approach programmable logic controller-fuzzy PID methodology to determine optimal PID parameter in automatic voltage regulator [16]

3. FUZZY LOGIC CONTROLLER DEVELOPMENT

To design the proposed fuzzy logic controller (FLC), the variable that can represent the dynamic performance of the controlled setting must be selected as the input of the controller. The fuzzy logic controller has two input variables, i.e. error (e) and error rate of change (de), which generates a control signal (cs)..

- Step 1: The variables of input and output are converted into Language variables.
- Step 2: variables of the Language consists of five fuzzy subsets, called as: {Big Negative (BN), Small Negative (SN), Absolute Zero (AZ), Small Positive (SP), Big Positive (BP)}
- Step 3: Every membership function has certain limits, that may be taken to the FLC

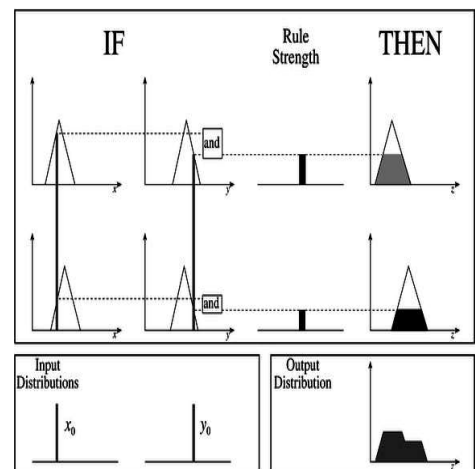


Figure 3. Mamdani fuzzy inference

- Step 4: Plotting the fuzzy logic controller rule base. The rate of change of the input error (e) and the error combination (de) that change the control signal (cs) for the fuzzy rule base is shown in the table below. 2. A table can be obtained based on 5 fuzzy language variables.

Table 2. Rule base Tabulation

	BP	SP	AZ	SN	BN
BP	BP	BP	BP	SP	AZ
SP	BP	SP	SP	AZ	SN
AZ	BP	SP	AZ	SN	BN
SN	SP	AZ	SN	SN	BN
BN	AZ	SN	BN	BN	BN

- Step 5: Block diagram of Mamdani fuzzy inference is shown below for the Selected Mamdani Fuzzy Inference System for the Fuzzy Logic Controller,
- Step 6: Error signal (ES) and differential error signal (DE) are two input variables of fuzzy controller. Errors and differential error signals are handled by a series of conditional statements such as IF the error is "HN" and change the error to "PH" THEN input to the actuator is "ZE".

4. EXPERIMENTAL SETUP

In the test setup, the process with the load variable should be a constant constant value and the setpoint value a variable with variable values. A closed loop response for a nonlinear liquid level bath is achieved, for the change of setpoint value, using the proposed Mamdani fuzzy logic controller and PD and PID controllers. To work, the Fuzzy Logic controller with a height of 20 cm from 0 to 500 s and furthermore the height is increased by 10 cm from 500 to 1000 s. To measure performance, error metrics such as integral absolute error (IAE), integral squared error (ISE), integral of time and absolute error (ITAE) and integral of time and squared error (ITSE) are taken into account for consideration..

The procedure of the experimental work can be expressed as follows:

1. 10 liters of water is used to fill the storage tank.
2. The computer based system was manipulated which is provided with all the hard-ware devices required for automatic control of ADC (Analog to Digital Converter), DAC (Digital to Analogue converter), and DLI/O (Digital Logic In / Out).
3. water level has to be set at a certain input value.
4. The steady-state values of water level is recorded by the computer based system which was set automatically.
5. A step change in the set point was carried.

6. System was manipulated to eradicate the error (ISE, ITSE, IAE, ITAE) values in water level (output variable) using Mamdani Fuzzy Logic controllers

7. The level of water versus time were recorded and plotted for the values of the errors (ISE, ITSE, IAE, ITAE).

Fuzzy Logic controller is designed to be compared with PD and PID controllers for liquid level process in Servo-Regulatory operation, Servo Operation and Regulatory Operation. The performance of the controller is evaluated by the error reduction performance index values.

Table 3 Comparison of the Performance index values of the Proposed Fuzzy Logic Controller with PD and PID in Servo Operation

Performance index values	Servo Operation		
	Fuzzy Logic Controller	PID Controller	PD Controller
ISE	1518	1585	1690
ITSE	13165	13962	14670
ITAE	4366	4572	4724
IAE	235.28	243.2	256.2

Operation of the servo for the fuzzy logic controller, PID controller and PD controller operate at a height of 50cm from 0 to 1000s and the height is increased by 50cm from 1000 to 2000s. During this servo operation, the above controller performance index values such as ISE, ITSE, IAE and ITAE are collected and tabulated in Table 3. From this table, it can be seen that the Logic controller fuzzy Product has better performance value than PID and PD Controller and the percentage of performance improvement is shown in Table 4.

Table 4. Percentage of performance improvement by FLC in Servo Operation

Performance index values	% of improvement by FLC over PID controller	% of improvement by FLC over PD controller
ISE	4.413702	11.3307
ITSE	6.053931	11.43183
ITAE	4.718278	8.199725
IAE	3.366202	8.891533

In Figure 4 it shown that it is concluded that, the Fuzzy Logic Controller can produce faster settling response and the same is given.

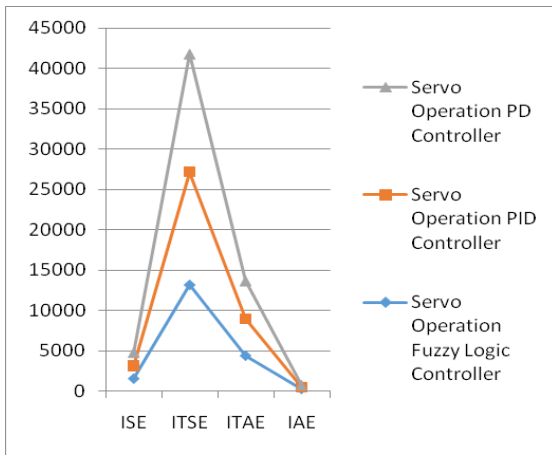


Figure 4. Graphical Representation of Servo operation Errors

Table 5. Comparison of the Performance index values of the Proposed Fuzzy Logic Controller with PD and PID in Regulatory Operation

Performance index values	Regulatory Operation		
	Fuzzy Logic Controller	PID Controller	PD Controller
ISE	1965	2062	2160
ITSE	17632	17958	18715
ITAE	5877.3	5982.5	6238.3
IAE	332.3	340.2	352.5

In the regulatory process, the Fuzzy Logic controller and the PI Neuro Tuned controller operate at a height of 60cm from 0 to 3000 s with a load change of +20% after 1000 s. During the throttling operation, the above controller performance index values such as ISE, ITSE, IAE and ITAE are collected and tabulated in Table 5. From the table, it can be seen that the Fuzzy Logic controller generates The performance values are better than that of the PID and PD controller and the performance improvement ratio is shown in Table 6.

Table 6. Percentage of performance improvement by FLC in Regulatory Operation

Performance index values	% of improvement by FLC over PID controller	% of improvement by FLC over PD controller
ISE	4.936387	9.923664
ITSE	1.848911	6.142241
ITAE	1.789938	6.142276
IAE	2.37737	6.078844

In Figure 5 it shown that it is concluded that, the Fuzzy Logic Controller can produce faster settling response and the same is given.

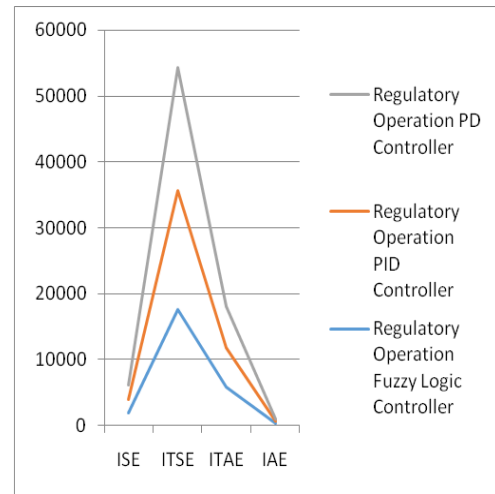


Figure 5 Graphical Representation of Regulatory operation Errors

Table 7 Comparison of the Performance index values of the Proposed Fuzzy Logic Controller with PD and PID in Servo – regulatory Operation

Performance index values	Servo - Regulatory Operation		
	Fuzzy Logic Controller	PID Controller	PD Controller
ISE	1318	1372	1418
ITSE	9165	9665	10165
ITAE	4566	4866	5366
IAE	155.28	185.42	205.28

Likewise, in servo regulator operation, the Fuzzy Logic controller and the PI Neuro Tuned controller operate at a height of 50 cm from 0 to 1000 s and a height increase of 50 cm from 1000 s to 2000 s with +20 %load changes every 1000 seconds. During servo operation, the above controller performance index values such as ISE, ITSE, IAE and ITAE are collected and tabulated in Table 7. From this table, it can be seen that Fuzzy Logic controller produces better performance values when compared for PID and PD controllers and the performance improvement ratio is shown in Table 8.

Table 8. Percentage of performance improvement by FLC in Servo Regulatory Operation

Performance index values	% of improvement by FLC over PID controller	% of improvement by FLC over PD controller
ISE	4.097117	7.587253
ITSE	5.455537	10.91107
ITAE	6.570302	17.52081
IAE	19.4101	32.1999

From this, it is concluded that the Fuzzy Logic Controller can produce faster settling response in the servo-regulatory operation and the same is given in Figure 6 .

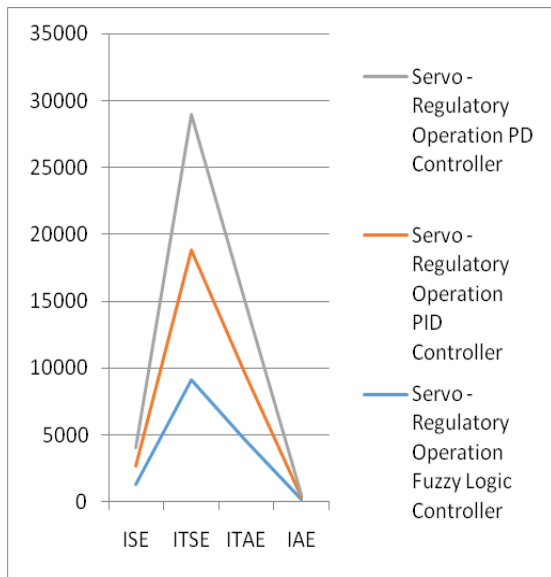


Figure 6 Graphical Representation of Servo Regulatory operation Errors

It is seen that the Fuzzy Logic Controller is capable to produce faster response with minimal error, and is also desirable for the liquid level process by the servo, regulatory and servo-regulatory process.

5. SUMMARY AND CONCLUSION

From this study based experimental process it is determined that the Mamdani Fuzzy Logic Controller for the liquid level process provide better performance between the PD and PID controller. The PID controller is better than PD. Thus, the simulation outputs are obtained for this controller by aligning the set point changes, load changes and change in set point with load changes. It clearly shows that the errors for servo, regulatory and servo-regulatory are attenuated substantially.

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