Review of Linear and Non-linear Liquid Level Control System

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Abstract
In the recent years, the industrial application of advanced control techniques for the process industries has become more demanding, mainly due to the increasing complexity of the processes themselves as well as to enhanced requirements in terms of product quality and environmental factors. Therefore, the process industries require more reliable, accurate, robust, efficient and flexible control systems for the operation of process plant. In order to fulfil the above requirements, there is a continuing need for research on improved forms of control. Advanced technology has had a significant impact on industrial control engineering. The new trend in terms of advanced control technology is increasingly towards the use of a control approach known as a Fuzzy Logic. Fuzzy control can be described as a control approach or solution that tries to imitate important characteristics of the human way of thinking, especially in terms of decision making processes and uncertainty. This review focuses on the existing control strategies for maintaining the liquid level in three major linear as well as non-linear systems such as cylindrical, conical and spherical which are widely used in process industry. From this survey, it is clear that the necessity of fuzzy logic controllers for this kind of process applications and provides the background information relating to the problems of level control in the above mentioned systems. Also it is to establish the appropriate boundaries for the research being undertaken in this area.

Keywords
Advanced Control Techniques, Process Industries, Fuzzy Logic, Linear and Non-linear Systems

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1. Introduction

Fuzzy Logic Control (FLC) has gained wide recognition as an effective control technology that has drastically reduced the development time and deployment cost for the synthesis of nonlinear controllers. Linear controllers are relatively easy to develop; on the other hand, nonlinear controllers represent a much harder synthesis problem. The intrinsic difficulty of this task has encouraged the development of alternative control synthesis techniques, such as FLC. The main characteristic of FLC is its capability to express knowledge in a linguistic way, allowing a system to be described by simple IF-THEN rules. The natural applications of FLC to control systems are found in those systems whose mathematical model is unknown, complex or where human experience can play an important role [1-2]. A relatively basic knowledge in the form of rules is all that is needed to get satisfactory control. On the other hand, predictable systems with well defined models would be better candidates for conventional control methods. Fuzzy system controllers are thus applicable where system models are unavailable or where the assumptions of a conventional control scheme break down – for example, when the systems are highly non linear. While other intelligent control schemes require offline training (for example, neural network controllers), fuzzy controllers have a relatively small computation cost. They are also very simple to implement in that the user can easily observe and check each step in the workings of the software implementation. This paper discusses about the various tank system used for liquid level with help of various control system but especially fuzzy logic control system. This would provide the better understanding why fuzzy logic control is used for interacting spherical two tank system is chosen.

2. Adaptive and Optimal Control of a Non-Linear Process Using Intelligent Controllers

This paper describes about time-optimal control for set point changes and an adaptive control for process parameter variation using neural network for a non-linear conical tank level process. Time-optimal level control was formulated us-
ing dynamic programming algorithm and basic properties of the solutions were analysed. It was found that the control is of bang–bang type and there is only one switching. In this method, a mathematical step-by-step procedure is used to obtain the optimal valve position path with one switching and is trained by neural network, based on the back-propagation algorithm. The dynamic programming procedure allows the set point to be reached as fast as possible without overshoot. An adaptive system is also designed and proved to be useful in adjusting the trained parameter of the dynamic programming based neural network for the process parameter variations.[3-5]. A prototype of conical tank level system has been built and implementation of dynamic programming based neural network control algorithm for set point changes and implementation of adaptive control for process parameter variations are performed. Finally, the performance is compared with conventional control. The results prove the effectiveness of the proposed optimal and adaptive control schemes. Comparing the servo response of control schemes obtained through real time, the neural network based DP method out performs all. For a 25% increase and 50% increase in the set change a tiny operating point, the proposed DP method gives minimum ISE and ITAE than all other control schemes. Comparing the performance of responses for process parameter variations, the adaptive control using NN performs very well as it eliminates the steady-state error. The performance indices ISE and ITAE are also minimum in this case. The following are the conclusion for selecting the appropriate controller. For servo operation, neuro based DP method can be employed. For regulatory operations and process parameter variations operations, the adaptive method using neural network can be employed.

3. An Approach to Design Fuzzy PI Supervisor for a Nonlinear System

This paper presents an approach to design fuzzy supervisor for PID controllers used for control of non-linear systems. In this approach, the design is based on an output performance criterion, namely a response with minimum settling time and without overshoot, whatever the operation conditions may be. The application used for a demonstration is a three-tank system where the connection between the tanks and the leakage in each tank are simultaneously taken into account (MIMO system). According to the proposed approach, two fuzzy PI supervisors are designed in order to modify on-line the parameters of two PI controllers. The implementation of this type of control in the simulator of the three-tank system model confirms, through the simulation results, that the output performances are reached whatever the set points, the configuration and the initial water levels in the three tanks may be[6]. By the comparison of the both types of control, it can be concluded that: - In regulation, the classical control is good and has soft solicitation of the actuator, when a disturbance is present, but it is not optimal for the complete range of operation of a non-linear system. The sliding mode control is optimal in settling time, but the actuator is highly solicited. The fuzzy control conceived is optimal, for any set point, in settling time for high values of the error (transient time). It is also optimal in regulation when the system is very close to the steady state. This type of control has been retained for the implementation on the laboratory installation using Dspace card 1102.

4. Analysis and Electronic Implementation of a Fuzzy System for the Control of a Liquid Tank

This paper presents a comparative study between a fuzzy system and a PI conventional controller for the real control of a liquid tank. The final fuzzy system is electronically implemented in a low-cost multifunction microcontroller, the PIC16C71. For non linear problems, fuzzy systems are useful tools: as shown in this paper, the performance of the fuzzy controller is superior to that of conventional methods[7-9]. The more accurate and stable regulation provided by the fuzzy controller is due, to a large degree, to the correction of the deficiencies of the PI. Fuzzy forms enable these corrections to be implemented, directly introducing knowledge of the functioning and the characteristics of the system to be controlled into the design process.

5. Development and Tuning of Fuzzy Controller for a Conical Level System

Mamdani fuzzy reasoning is designed for the non-linear, liquid level control of a conical level system. The system parameters are identified and constrained genetic algorithms are used to tune the membership functions of the fuzzy sets of the input variables. The performance of the tuned controller is compared to a PI controller on application of a sequence of set point changes. The influences of load changes on fuzzy system are compared to that of a PI controller. The fuzzy system is able to compensate for the effects of positive and negative load changes. The Mamdani type fuzzy controller with genetic algorithm tuned variables performs significantly better than the PI controller in both cases of set point changes and load changes[10-13].

6. Intelligent Controller Implementation in Real Time for a Non-linear Process

The FLC is applied to a real time control of a spherical tank system using ADAM’s module. The performance of the fuzzy controller is compared to Skogestad based PI controller tuning settings. The FLC is implemented for a sequence of set points 07cm, 10cm, 15cm, 20cm, 25 cm, 38 cm and is compared to the PI controller. The variations of level with time for the sequence of set changes for both the controllers, which shows FLC tracks the set point changes in a faster time than the conventional controller. The response to track the given
set point in a FLC is immediate, when compared to the PI controller with lesser rise time. The settling time of the FLC for a set point change is better than PI. From the Fig 4 and Fig 5 it is proved that FLC is having lesser peak time, provides no oscillatory behavior and exhibits no overshoot compared to that of counterpart controller. A change is suddenly applied and simultaneously set point changes are given to the system. The two controllers are allowed to run under these conditions and variations of level with time are recorded. It is found that the response of FLC based 2510 controller is faster for the given set point when it is given a sudden regulatory change. Also, it leads to lesser oscillation and no overshoot. The comparison based on ISE and IAE are tabulated for servo and regulatory changes. From these values, it can be seen that the FLC performs significantly better than the PI controller. It is found that for the load change both ISE and IAE values for the FLC are considerably lower than the conventional PI controller[13-14].

7. Controllers Implementation based on Soft computing for Non-Linear Process

The work described in this paper aims at exploring the use of Soft Computing techniques for designing a controller to perform control of level in a spherical tank. First, system identification of this non-linear process is done using black box model, which is identified to be non linear and approximated to be a First Order Plus Dead Time (FOPDT) model. Then the controller tuning strategy has been applied using Skogestad’s PI tuning technique. This technique has been compared with the soft computing techniques such as Genetic Algorithm (GA) for this non-linear process using cost effective data acquisition ADAM’s module in real time[15]. It is observed from the results that for both set point tracking and for regulatory change, controller based on soft computing techniques shows substantial improvement over the PI controller based on performance indices like Integral Squared Error (ISE) and Integral Absolute Error (IAE).

It is found for a level control in spherical tank process for all set point and load changes, the performance of the soft computing based controller was much superior to the conventional control. The response of fuzzy logic controller and GA based tuned controller was proved satisfactory when compared with conventional PI controller. Soft computing techniques based controllers were able to keep the process parameters in the optimum range whenever the set point and load disturbance occurred. FLC and GA tuned controller is more robust, user friendly and easier to construct than PI controller in real time.

8. Fuzzy Logic Control of Coupled Liquid Tank System

This paper presents a fuzzy control of coupled liquid tank system. The Coupled Liquid Tank system is developed at PIEAS. It has three liquid tanks coupled together. The liquid level in tank 2 is maintained using fuzzy logic. The results are compared with the PID control, mostly used in industries. The FLC developed here is a two input single output controller. The two inputs are the deviation from reference level Tank 2 error \( e(k) \), and error rate \( Ae(k) \). The two inputs error and change in error are generated by preprocessing unit. The post-T processing unit generates the control input from FLC output which is change in control input. The conventional controller is replaced by the FLC. The results are compared with that of PID control. It is obvious that FLC is a good alternate to PID[16].

9. Fuzzy Model-Based Predictive Control Applied to Multivariable Level Control of Multi Tank System

In this paper, the model predictive control scheme was employed to reduce structural response of the laboratory system - multi tank system. Model predictive control was successfully applied to the studied multi tank system. The inherent instability of the system makes it difficult for modeling and control. Adaptation of the linear internal model is the most common way of dealing with plant non-linearities in practice. The results show that the controlled levels have a good performance. The next efforts will be dedicated to the real time implementation of the proposed model predictive control strategy for level control of the multi tank system. The idea of using fuzzy neural models for non-linear system identification is not new one, although more applications are necessary to show its capabilities in non-linear identification and prediction. By implementing this idea to state-space representation of control systems, it is possible to achieve a powerful non-linear model of plants or processes. Such models can be embedded into a model predictive control scheme. State-space model of the plant allows treating of the optimization problem, as a quadratic programming problem, which is an important part of MPC. It is important to note that the model predictive control approach has one major advantage that enables to include constraints of the system variables to the control algorithm. The case study is implemented in MATLAB & Simulink environment[17].

10. Fuzzy PID Control of Non-linear Plants

This paper demonstrates the implementation and design of a fuzzy PID controller for level control of a non-linear plant. The main goal is to describe the similarity between fuzzy and conventional PID controllers. The fuzzy PID controllers are very useful when the controlled plant has non-linearities or time varying parameters. The structure of a fuzzy - neural PID controller was introduced in this work. The Sugeno fuzzy technique is used to obtain the fuzzy controller. The fuzzy PID controller is developed as a three-term fuzzy controller using the system error; the first and the second derivatives of the error or the sum of the errors. The antecedent part of the applied
Sugeno’s fuzzy rules contains a linear function, similar to the discrete equation of the digital PID controller. The simplified learning algorithm of the fuzzy – neural implemented PID controller contains two learning steps and works with simplified recurrent equations to calculate the adjustable controller parameters. The computer simulations carried out with two cascaded tanks with variable parameters satisfactorily verified the validity and robust performance of the proposed structure of the fuzzy controller. This is evident from the obtained results, where the transient responses of the system output have shown an improvement after several learning epochs with the implemented fuzzy-neural network[13,15].

11. Fuzzy PI Supervision for a Non-linear System: Design and Implementation

This paper presents an approach to design fuzzy supervisor for PID controllers used in the control of non linear system. In the proposed approach, the design is based on output performance criterion namely a response with minimum settling time, without overshoot whatever conditions may be. The application used here is three tank system where the connection between the tanks and leakage in each tank are simultaneously taken into account. According to this approach two fuzzy PI supervisors are designed in order to modify on-line the parameters of two PI controllers. The implementation of this type of control in the simulator of the three tank system model and in the laboratory installation using Rapid Prototyping, confirms through the results, that the output performances are reached whatever set points, the configuration and initial water levels in the three tanks[3,4].

12. Improved Design of FLC for a First Order Non-linear Processes with Dead Time

The Fuzzy PI controller proposed by Zhao et al. is suitable for servo responses on transfer function models and it does not work for load changes. It also does not give stable servo as well as regulatory responses for conical tank level process with dead time. In this paper, a fuzzy PI controller is proposed for servo and regulatory responses for the proposed process. It is a modified form of a Fuzzy PI controller proposed by Zhao et al. The proposed controller is tested by simulation on the chosen non-linear process and better controller performance can be envisaged in the proposed method than that of the ZN-PI controller with fixed parameters. The analysis of various simulation results based on ISE and IAE indicate that the fuzzy based scheme is able to provide a considerably better performance and robustness than a conventional PI and ZF-PI controllers in certain operating conditions[7,9].

13. Conclusion

The control of liquid level in various tanks (cylindrical, conical and spherical) by Fuzzy controllers have been more robust, user friendly and easier to construct than conventional controllers. It has been studied that the control of liquid level in tanks and the flow between tanks is a basic problem in process industries. The process industries require the liquids to be pumped and stored in tanks, thereafter pumped to another tank. Many times the liquid will be processed by chemical or mixing treatment in the tanks, but always the level of fluid in the tanks must be controlled. A common control problem in process industries is the control of fluid levels in storage tanks, chemical blending and reaction vessels. The rate of change of flow from one vessel to another as well as the level of fluid are two important operational factors. Vital industries where liquid level and flow control are essential include petrochemical industries, paper making industries, water treatment industries, etc.

Serious difficulties arise in a system when the liquid level in a chosen process varies. In many processes such as distillation columns, evaporators, re-boilers and mixing tanks, the particular level of liquid in the vessel can be of great importance in process operation. In process industries like hydro metallurgical industries, food process industries and waste water treatment industries, spherical tanks are widely used. Their shape contributes to better disposal of solids while mixing provides complete drainage, especially for viscous liquids. A level that is too high may upset reaction equilibria, cause damage to equipment, or result in spillage of valuable or hazardous material. If the level is too low, may have bad consequences for the sequential operations. The level control of liquid in a spherical tank presents a challenging problem due to its constantly changing cross section and non-linearity of the tank. Hence, control of liquid level is an important and common task in process industries. From the cases studied it can be concluded that FLC will be best suited for control of liquid level.

References


