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EFFECTS OF TIME DELAY ON DIFFERENT TYPES OF CONTROLLER FOR NETWORKED CONTROL SYSTEMS: A REVIEW

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Abstract: Networked Control Systems (NCSs) are spatially distributed systems for which the communication between sensors, Actuators and controllers is supported by a shared network. Due to the transfer data through the network between each node, NCS is running with some problems such as communication time delay and data packet loss. In this paper were view different types of controller used for compensation of time delay in NCS.

Keywords: *NCS, DC servomotor, PID controller,Fuzzy Logic, smith compensator.*

Introduction: With the development of network technology, network control system (NCS) has been an active research hot spot in recent years. Network control system (NCS) are the systems in which the communication sensors, actuators and controllers occur through a shared band –limited digital communication network [1].The control system constructed by network has many excellent character, such as high expandability ,flexible structure , low cost, reliability etc. But at the same time it has some drawbacks like time delay and packet loss which cannot be avoided [2]. Fig 1 shows the basic block diagram of network control system. This paper mainly discuss about DC servomotor (which plays the role of plant), PID controller, Fuzzy controller and smith controller (which plays the role of controller).

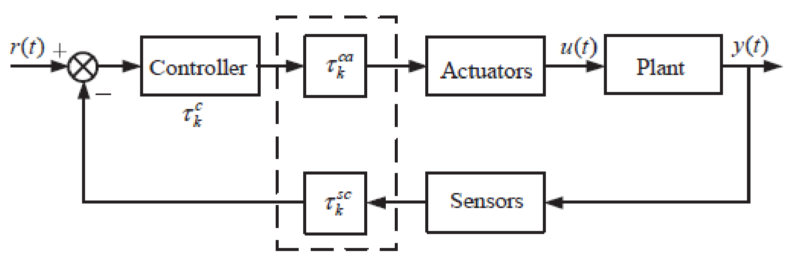

Fig.1. The system block digram of NCS

Here: r(t) is input ,y(t) is output,τ_k^{ca} is time delay from controller to actuator,$\tau_k^{sc}$is time delay from sensor to controller.

Dc servo motor:

The DC servomotor is a device which converts electric energy into mechanical energy. One of the important feature of DC servomotor is that its output shaft can be moved to specific angular position. Usually small motors which are used in laboratory is DC servomotor . It is an electromechanical device in which the electrical input determines the position of motor armature. The armature is driven by an external DC voltage that produces the motor torque and the motor speed [3]. Fig 2 shows the basic block diagram of servo system.

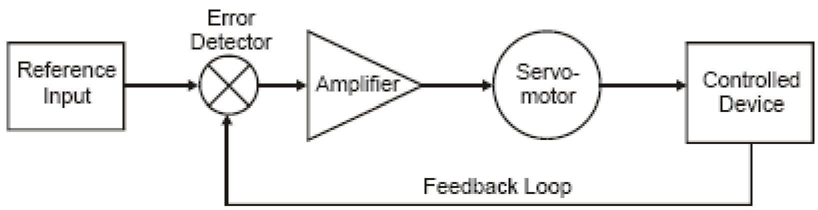

Fig.2. Basic servosystem block diagram

The servomotors used in many industries are closed-loop servo system. A reference input is sent to the error detector which compare error signal with feedback signal and generate the error signal. Error signal given to the controller to minimize the error. The speed and position of a DC servo motor can be varied by controlling the field flux, the armature resistance or the terminal voltage applied to the armature circuit. The three most common speed control methods are field resistance control, armature resistance control andarmature voltage control [4].

PID controller

Proportional integral derivative controller (PID controller) is a control loop feedback mechanism commonly used in industrial control system. The PID controller continuously calculates an error value as a difference between measured process variable and desired set points ,the controller attempts to minimize the error over time by adjustment of controlled variable, such as position of control value, a damper or the power supplied to the heating element [5],[6]. fig 3 shows the block diagram of PID controller.

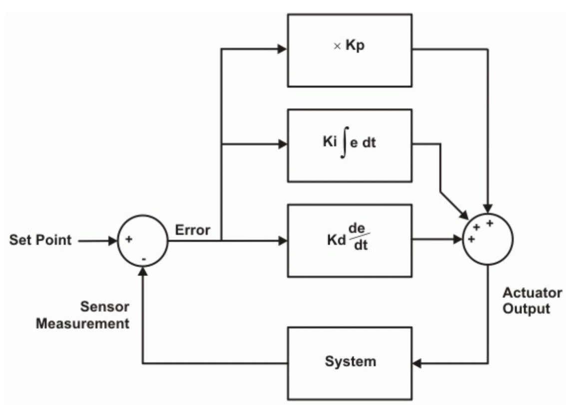

Fig.3 Block diagram of PID controller

The controller parameters are: The proportional gain *Kp*, the integral gain *Ki* , integral time constant *Ti* , the Derivativegain *Kd* and derivative time constant *Td*.

Mathematical equation of PID controller is-

Controller (t) = $k_p\theta(t) + k_i\int_0^t \theta(\tau)d\tau + k_d\frac{d}{dt}\theta(t)$

Fuzzy controller

Fuzzy logic controllers have logical resemblance to a human operator. It operates on the foundations of a knowledge base which in turn rely upon the various if then rules, similar to a human operator. Fuzzy logic controller is simpler as compared to other controller because there is no complex mathematical knowledge required. The FLC requires only aqualitative knowledge of the system thereby making the controller not only easy to use, but also easy to design [7],[9].

There are basically three essential segments in fuzzy logic controller viz.

1. Fuzzification block or fuzzifier.
2. Inference system.
3. Defuzzification block or defuzzufier.

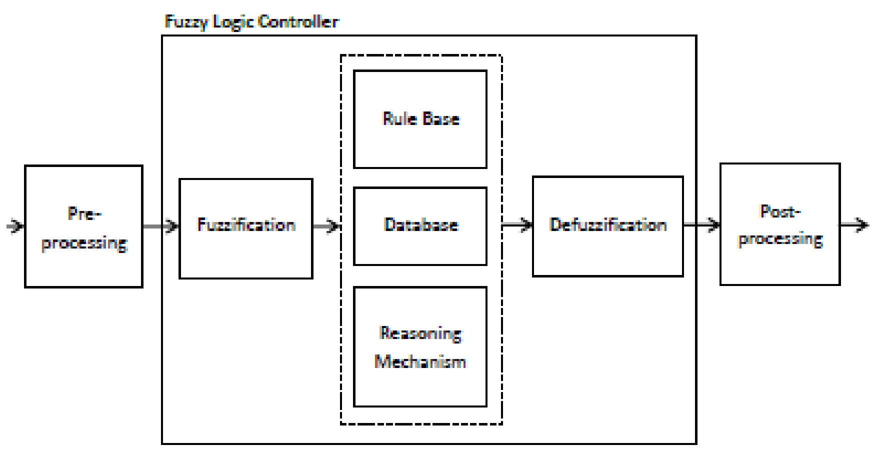

Fig.4 Fuzzy logic controller structure

Fuzzificationblock:Fuzzy logic uses linguistic variables for process information. But since the inputs to the FLC are in the form of numerical variables (crisp), they need to be converted into linguistic variables. This function of converting these crisp sets into fuzzy sets (linguistic variables) is performed by the Fuzzifier.

Inference system: It can be sub-divided into three parts i.e. Rule base, Data base, Reasoning mechanism. Rule base consists of number of if-then rules. Rule base consists of the all the defined membership functions that are to be used by the rules. Reasoning mechanism performs the inference procedure on the rules and the data given to provide a reasonable output.

Defuzzification block: Its working is just opposite to that of fuzzificationblock. It converts the fuzzy variable into crisp sets[8].

Smith predictor

The basic principle of smith predictor is that it estimates the dynamic characteristics of control process in basic disturbance, and then does the compensation. The Smith predictor is usually introduced into the network System to compensate for network delay [9] .The basic block diagram is shown in Fig.5. $D(s)$ is the transfer function ofcontroller, $Gp(s)$ is the transfer function of controlled plant and,$Gm(s)$ is the transfer function of the identification modelof controlled plant [10], [11].

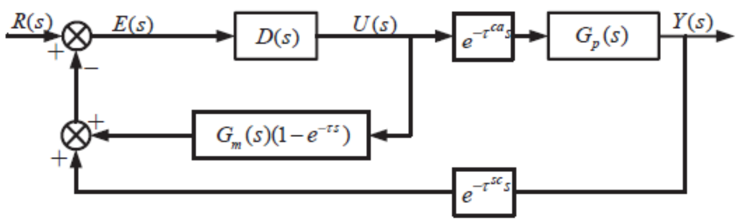

Fig.5 Block diagram of smith predictor

When $Gm(s)$=$Gp(s)$, the transfer function of the closed loop system is:

$$\frac{Y(s)}{R(S)} = \frac{D(s)G_p(s)e^{-\tau ca}}{1 + D(s)G_p(s)(1 - e^{-\tau s}) + D(s)G_p(s)e^{-(\tau ca + \tau sc)s}}$$

If the delay time τ =τ *ca*+τ *sc*, after the delay compensation, the closed loop transfer function is simplified as follows:

$$\frac{Y(s)}{R(S)} = \frac{D(s)G_p(s)}{1 + D(s)G_p(s)} e^{-\tau ca\ s}$$

Research trends in network control system for last few years

S.NO	AUTHOR	YEAR	RESEARCH WORK
1	Soucek*et al* [16]	2003	Focused on the effect of delay jitter at a fixed mean delay on the QoC. Two sources of delay jitter are identified in EIA-852-based systems: 1) network traffic induced and 2) protocol induced
2	Yue*et al*[15]	2005	Considered the problem of the design of robust memory less H∞controllers for uncertain NCSs with the effects of both the network-induced delay and data dropout.
3	Richards and Chow [21]	2005	investigated four methods—GSM, optimal stochastic, queuing, and robust control methodology—that alleviate the IP network delays to provide stable real-time control using a case study on a networked dc motor
4	Li *et al* [18]	2006	Derived linear matrix inequality (LMI)-based sufficient conditions for stability

5	Xia *et al* [19]	2006	Proposed a new control scheme consisting of a control prediction generator and a network delay compensator. However, precise delay time models are needed for implementation of the predictive methods.
6	Natori and Ohnishi [20]	2008	proposed a time delay compensation method based on the concept of network disturbance and communication disturbance observer. In this method, a delay time model is not needed. Hence, it can flexibly be applied to many kinds of time-delayed systems
7	Zhang *et al*[17]	2009	Investigated the problems of stability and stabilization of a class of multi-mode systems. Choosing the proper Lyapunov–Krasovskii functionals and using a descriptor model transformation of the system
8	Cui Hao. [14]	2010	This algorithm usesfuzzy adaptive PID control to improve the resistance ability to random disturbance and Smith predictive control to overcome the time-delay character of controlled object
9	Yu Wang , *et al* [12]	2014	To solve the problem of time delay network servo system based onSmith predictor was designed. Control strategy combines the adaptive least mean square (LMS) delay prediction algorithm and Smith compensator can compensate a certain degree of the network delay.
10	HongeRen*et al*. [13]	2015	Based on the conventional Smith predictor, an improved fuzzy adaptive PID-Smith predictor is proposed. It uses a fuzzy self-tuning PID controller as the primary controller instead of the traditional PID controller

Conclusion

After an extensive literature review, a generalized Smith predictor structure is developed. Our aim is to achieve excellent servo-motor and controller responses. From analyzing various research mentioned above it can be concluded that better servo and controller responses are achieved in the vast majority of cases when the Smith predictor is used instead of the corresponding conventional controller like PID and Fuzzy controller. Further work will concentrate on the development of an auto tuning strategy for the modified Smith predictor.

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