

IMPROVING PID CONTROLLER OF MOTOR SHAFT ANGULAR POSITION
BY USING GENETIC ALGORITHM

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For my beloved Umi, Abah, Fatma and Putra



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ABSTRACT

This study represents Genetic Algorithm optimization of PID parameters gain in model reference robust control system structure for desired position of incremental servomotor. Experiments had been took out via Lab-Volt 8063 Digital Servo system equipment at Servo Control Laboratory. The key issue for PID controllers is the accurate and efficient tuning of parameters. The plant repeatedly has a problem in achieving the desire position control and system performance have an oscillatory response and gives a slightly steady state error. This problem among other is affected by existing the nonlinearities component in the system, the system communication noise, and not optimize PID parameter. The existing PID controller tuning with the help of the offline Genetic Algorithms approach comprises of automatically obtaining the best possible outcome for the three parameters gain (K_p , K_i , K_d) for improving the steady state characteristics and performance indices. Their step responses are then compared with a tuned conventional Ziegler-Nichols based PID controller. This paper explores the well established methodologies of the literature to realize the workability and applicability of Genetic Algorithms for process control applications. At last, a comparative study done between ZN-PID experiment and GA-PID experiment shows that the GA optimal controller is highly effective and outperforms the PID controller in achieving an enhancing the output transient response with improvement percentage of rise time is 91.83%, settling time is 89.36% and maximum overshoot is 82.24%. The robust and automatic gains parameter calculator; GA based PID technique also proven to be time savers as they are much faster to be conducted than ZN method which is basically based on trial-and-error in getting the best PID values before the system can be narrowed down in getting the closest to the optimized value.

ABSTRAK

Kajian ini mengenai kaedah mengoptimumkan parameter PID dalam kawalan posisi motor servo di model rujukan untuk sistem kawalan teguh menggunakan Algoritma Genetik. Eksperimen telah dijalankan menggunakan sistem peralatan Lab-Volt 8063 Digital Servo yang terletak di Makmal Kawalan Servo. Isu permasalahan utama bagi pengawal jenis PID adalah ketepatan dan keberkesanan talaan nilai parameter gandaan. Sistem Lab-Volt itu sering bermasalah dalam kawalan untuk mencapai posisi sasaran dengan prestasi sistem mempunyai sambutan ayunan dan memberikan ralat keadaan mantap yang kecil. Masalah ini antara lain dipengaruhi oleh parameter komponen tidak selari dalam sistem, gangguan dalam sistem komunikasi, dan parameter PID yang tidak optimum. Pengawal PID yang sedia ada dibantu oleh Algoritma Genetik secara berasingan untuk mendapatkan nilai optimum bagi ketiga-tiga parameter gandaan (K_p , K_i , K_d) untuk meningkatkan kestabilan dan prestasi tindak balas. Prestasi tindak balas itu kemudian dibandingkan dengan pengawal PID berasaskan penalaan kaedah konvensional iaitu Ziegler-Nichols. Kajian ini meneroka kaedah yang telah terbukti untuk merealisasikan keupayaan Algoritma Genetik dalam aplikasi pengawalan sesebuah proses. Di akhirnya, satu kajian kes perbandingan yang dilakukan di antara keputusan eksperimen ZN-PID dan GA-PID menunjukkan bahawa pengawal optimum GA adalah sangat berkesan dan lebih berkeupayaan terhadap pengawal PID dengan meningkatkan tindak balas sambutan dengan peratus peningkatan masa menaik adalah 91.83%, masa selesai adalah 89.36% dan peratus lajukan maksimum adalah 82.24%. Bertindak sebagai kalkulator parameter gandaan yang teguh dan automatik; operasi GA-PID juga terbukti menjimatkan masa berbanding ZN-PID yang pada asasnya berdasarkan kaedah cuba-jaya untuk mendapatkan nilai PID terbaik sebelum sistem boleh ditumpukan untuk mendapatkan parameter yang paling dekat dengan nilai dioptimumkan.

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LIST OF SYMBOLS AND ABBREVIATIONS

AGA	-	adaptive genetic algorithms
DAQ	-	Data acquisition
DAS	-	Data Acquisition System
DC	-	Direct Current
DDC	-	Direct Digital Control
DSP	-	Digital Signal Processing
$F(x)$	-	fitness function
GA	-	Genetic Algorithm
GAOT	-	Genetic Algorithm Optimization Toolbox
g_{\max}	-	maximum number of generations
K_d, T_d	-	Derivative Gain
K_i, T_i	-	Integral Gain
K_p	-	Proportional Gain
K_U	-	ultimate gain
NOR	-	nonstationary optimal regulator
PC	-	Personal Computer
PID	-	Proportional integral derivative
p_c, p_m	-	probabilities
P_k	-	k-th population
P_{k+1}	-	new population
P_g	-	population
P_{g+1}	-	next population
P_0	-	first population
ZN	-	Ziegler-Nichols
μ	-	population size

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PTTA UTHM
PERPUSTAKAAN TUNKU TUN AMINAH

CHAPTER 1

INTRODUCTION

This chapter introduces the project that has been working out. The important overview of the project background and description including the problem statements, project objectives, project scopes and significant of this project have emphasized in this chapter.

1.1 DC Servomotor– An Overview

A servomechanism is an automatic device that uses error-sensing feedback to correct the error in the mechanism. A servo motor, which is a type of servomechanism, is provided with a sensor (e.g., an incremental encoder, a position potentiometer, a speed sensor) that compares the command (e.g., the applied voltage) with the actual movement (e.g., the motor position) (Ruano, 2005). Using a controller and appropriate control strategies, the error existing between the command and the actual movement can be determined, analysed, and then corrected. Servo motors are used more and more because they give much more precision and/or rapidity to the movements of a mechanical system. A robot manipulator, for example, usually contains many servo motors.

1.2 Motor Shaft Angular Position Control – An Overview

Position control system is a system that converts a position input command to a position output response besides it extensively usage in industrial application such as robotics and drive control. Modern position control systems are achieved using optical incremental encoder sensors (Ruano, 2005). This is mainly due to high

reliability (no moving parts contact each other) and low cost. It is essentially a position transducer that reports the angle of shaft displacement in discrete steps.

1.3 Proportional Integral Derivative Controller- An Overview

Proportional integral derivative (PID) control schemes are wide utilized in most of control system for a long time for it easy in structure, reliable operating and robust in performances function. One key issue for their success is that they act within the processes in restraint in a manner closely like human's natural responses to outside stimuli, that is the combined effects of naturalness (proportional action), post training (integral action) and projection into future (derivative action) (Stephen, 2011). However, it is still a awfully necessary downside a way to determine or tune the PID parameters, as a result of these parameters have an excellent influence on the stability and therefore the performance of the control system. Yet, the plants with high nonlinearity, high time-delay and high order can't be controlled effectively employing a simple PID controller.

1.4 Ziegler-Nichols Based PID Controller – An Overview

Ziegler-Nichols (ZN) is one of the most widely used method for the tuning of the PID controller gains, yet this method is limited for application till the ratio of 4:1 for the first and the second peaks in the closed loop response, thus leading towards an oscillatory response (Astrom, Hagglund, 1995). Initially, the unit step function i.e. transfer function of the plant is obtained, and by the ZN rule base, the parameters required can easily be estimated, but far from optimal.

1.5 Genetic Algorithm as Optimal Robust Controller - An Overview

Genetic Algorithm (GA) is optimization methods, which operate on a population of points, designated as individuals. Each individual of the population represents a attainable solution of the optimization problem. Individual are evaluated relying

upon their fitness. The fitness indicates how well an individual of the population solves the optimization problem. One of the popular approaches to the mathematics-based approach to optimal design of a control system has been optimal robust control, in which an objective function, often based on a norm of a functional, is optimized, whereas a controller (dynamic or static) is obtained that may tolerate variation of plant parameters and unordered dynamics (Stephen, 2011).

1.6 Project Background

Digital servomotor has been widely known to be employ in associate automation and industrial because of its excellent speed control characteristics. Servo systems contain error-driven control loops. Servo tuning is an associate integral a part of any motion system and directly impacts the accuracy and performance, which driven a properly tuned system to give higher precision and additional stability. A system is considered stable if the particular position is finite once the commanded position is finite. By mean, a system is stable if a commanded position results in the motor coming to rest at a single position. In another ways, system is considered unstable when any commanded position typically results in an exponential increase in position error. By mean a system is unstable when the attempts to achieve a position result in oscillations that never dampen. Hence, the whole system performance strongly depends on the controller efficiency and will cause the tuning process plays a key role in the system behaviour. In this work, the servo systems will be analysed, specifically the positioning control systems.

Despite a huge advances in the field of control systems engineering, the fact that the algorithm provides an adequate performance in the vast majority of applications has helped PID to be still remains the foremost common control algorithm in industrial use nowadays. PID controllers are wide used for speed and position control of servo motor. Due to some constraints in the step response of the PID tuning, a lot of strategies regarding PID controller parameter tuning have been proposed; basically on (1) Empirical methods, such as Ziegler-Nichols methods, (2) Analytical methods, for instance, the root locus based techniques, (3) Methods based on optimization, such as GA methods.

In this project, Lab-Volt 8063 Digital Servo system equipment had been used as a platform to create an optimal robust controller strategy for the linear control systems. GA during this project is used to seek out an optimal gain automatically for robust controller for linear control systems. This project had been done on this technique to examine the implication of exploitation GA in a system and to obtain best result in tuning position control of a servo motor. GA will be applied to the area of PID optimisation in an off-line tuning environment. Tuning a system off-line means that the PID parameters of the controller are updated when the system has been taken off-line. The PID values are updated using the systems input and output data after the system has been placed offline. These updated PID values are used in place of the old PID values. This process continues till the optimum PID coefficients of the system in question have been obtained.

The first important issue in designing a control system is the consideration of stability. A control system is stable if and only if all roots of the characteristic equation are placed in the left half of the s-plane. If its real parts are negative, it displays absolute stability. According to the Hurwitz test, the absolute stability of a control system can be tested by means of the coefficients of the characteristic equation, without calculation of the exact position of the roots of the characteristic equation. The goal of the control, despite disturbance $\delta(t)$ acting on the plant, is to keep the value of the controlled variable (the output variable) $y(t)$ within tolerance of the value given by the reference variable (set-point) $r(t)$ (Lab-Volt Ltd., 2010). Classical strategies for controller design use a nominal model of the plant. The robustness of the control loop is indicated by the parameters: phase margin and gain margin. The determination of appropriate controller parameters depends on the requirements of the control system. Typical requirements are: short settling time, small overshoot, good damping or small value of the squared error surface.

End of the GA optimization process, the rise and the settling times and the overshoot are compared with classically tuned system ZN method corresponding system performance. Simulation results should show the effectiveness on damping and robustness of proposed GA controller to provide the angular position control of servomotor incremental encoder Lab-Volt 8063 Digital Servo system equipment.

1.7 Problem Statements

The positioning systems are normally unstable when they are implemented in a closed loop configuration, so when the controller is introduced into the closed loop it needs to be effectively tuned. The key issue for PID controllers is the accurate and efficient tuning of parameters. Whether the user is a relative novice, or an experienced hand to handle the parameters set up is a stressful job especially for some serious uncertain systems. Typically, the adjusting of the controller parameters is carried out using trial-and-error formulas to provide a performance, which, although not deficient, is far from optimal. In this study case of motor shaft angular position control on the Lab-Volt 8063 Digital Servo plant, the servomotor controller repeatedly has a problem in achieving the desired position control and system performance have an oscillatory response, damped and gives a slightly steady state error. In this report GA are proposed as a method for PID optimisation of nonlinear systems and compared with those of traditional ZN tuning method.

1.8 Project Objectives

The main objective of this study is to run motor operation of the Lab-Volt 8063 Digital Servo plant to ideal conditions. Hence, the specific objectives of this study are:

- (i) To observe motor shaft angular position control in digital servo tuning.
- (ii) To compute the existing plant controller stability.
- (iii) To analyse the effect of the ZN tuning method and GA tuning method on the transient operation and damping on the step response of a servo positioning system used for linear position control.
- (iv) To minimize the following error of a servo system by analyse of proportional, integral and derivative tuning action on the linear position control systems.
- (v) To achieve the indicator performance specifications for optimize controller by; (i) Steady-state error $< 1\%$, (ii) Overshoots $< 1\%$, (iii) Settling-time < 2 seconds , (iv) Rise time < 2 seconds.

1.9 Project Scope

By using the Lab-Volt 8063 Digital Servo System as platform for this study, the scopes of this project are as follows:

- (i) Run test on the equipment to carry out an experiment of angular position control by using the classical ZN method tuning.
- (ii) Simulate and the plant system with PID controller using MATLAB Simulink.
- (iii) Develop GA algorithm file and simulate the plant system optimization tuning control using MATLAB Simulink.
- (iv) Analyse the effect of the ZN tuning method and GA tuning method on the transient operation, damping on the step response and following error of a servo positioning system used for linear position control.

1.10 Project Limitation

At the beginning of this project, the plan of this study was to prepare an online optimization PID controller by help of GA that will control the system plant in an independent control strategies by modifying the existence ones. Unfortunately, several problems had arise; (i) The processes done were unable to validate the interface of LabView and MATLAB Simulink, (ii) Due to inadequate expertise in understanding on how to interface personal computer (PC) with position control system through Data Acquisition System (DAS) where experimental on an actual system could not been carried out, (iii) Some of the plant technical specifications are not available for the public study, hence this create some limitation of references while investigating problems on the DAQ, (iv) Researcher in control discipline in real industry field still waiting for high computer processing capability, high Digital Signal Processing (DSP) communicator, and applications software fast computation for accurate response and quick solutions for real time optimization control system developing which is still in research and development stages.

Thus, this project is completed by resolving using offline simulation method only. The result of this study may not reflect the actual performance of the positional of DC motor system. Thus this study may not represent the robust controller and the

plant itself as it is only a simulation in MATLAB software using mathematical modelling prediction.

1.11 Significant of Study

Eventought the existing PID controller at the plant have a simple structure, it is quite challenging to find the optimized PID gains. Developing optimal control system will monitor the input and output signal of the plant and then will generate control signal so as to minimise the effect of parameter variation and at the same time to track the reference input (to avoid a following error). In other word, the optimal control system will automatically change its behaviour to accommodate the changes in the dynamics of the process and disturbances.

Since this earlier aim of this project was to embed a self-online optimal GA based PID controller into the plant are put off due to the limitations, but this project still give a important stage as part of the project development. Today industrial users are looking for a controller technology with flexibility to tailor near any system to specific needs using convenient software based control, as they call Direct Digital Control (DDC). DDC is basically a microprocessor based technology in which a controller performs closed loop functions via sophisticated algorithms and strategies. The controller function handles inputs and outputs electronically while the software provides the logic. Figure 1.1 shows the schematic of DDC.

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