IMPLEMENTATION OF MRAC, SVMPC AND PID CONTROL BASED ON DIRECT DIGITAL CONTROL APPLICATION FOR DC SERVOMOTOR

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To my husband, Zairulazha.

Thanks for your tremendous love and support.

I owe a lot to you.

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Assalamualaikum.

ABSTRACT

The project focused on speed control of DC servomotor under load variation using Direct Digital Control technique. The main objective is to design and develop GUI software for speed control experiment, where Single Variable Model Predictive Control (SVMPC), Model Reference Adaptive Control (MRAC) and PID controllers' design approaches has been applied. The main purpose of using the SVMPC is to achieve perfect control using an Internal Model Control (IMC) strategy. The desired behavior of the adaptive controller is expressed by utilizing reference model, and the algorithms have been realized using the Lyapunov method and MIT rules.

The Direct Digital Control approach is selected to replace the conventional method regarding on controlling the speed of DC motor because of its advantages in terms of cost reduction, simplicity, flexibility and give better performance than previous one. The original speed control experiment is conducted and data is recorded. Based on the information that been gathered, the controllers have been designed and the system is simulated using MATLAB to analyze their initial performance. The computer is connected to MS150 Modular Servo System via AX5412 data acquisition card and Microsoft Visual Basic 6.0 is used to conduct the experiment. Field-testing is implemented to compare the results between the original and modified system within three types of controller. Finally, the performance of the system is analyzed and validation is done in terms of time response, robustness and percentage of error.

ABSTRAK

Projek ini memfokuskan kepada sistem kawalan halaju bagi motor servo arus terus yang dikenakan pelbagai beban dengan menggunakan teknik kawalan digital secara langsung. Objektif utama projek ini adalah untuk merekabentuk dan membangunkan perisian interaktif komputer untuk ujikaji sistem kawalan halaju, di mana teknik Kawalan Model Ramalan bagi satu pembolehubah, Kawalan Adaptasi Model Rujukan dan Kawalan PID diaplikasikan bagi rekabentuk sistem kawalan untuk motor tersebut. Matlamat utama menggunakan Kawalan Model Ramalan bagi satu pembolehubah adalah untuk mendapatkan kawalan sempurna dengan menggunakan strategi Kawalan Model Dalaman (IMC). Manakala sifat kawalan yang dikehendaki diterjemahkan dalam bentuk model rujukan dengan menggunakan kaedah Lyapunov dan aturan MIT.

Teknik kawalan digital secara langsung dipilih untuk menggantikan kaedah lama dalam pengawalan halaju bagi motor arus terus kerana kelebihan-kelebihannya iaitu dari aspek pengurangan kos, fleksible, mudah dan memberikan prestasi yang lebih baik dari kaedah terdahulu. Eksperimen asal bagi kawalan halaju telah dijalankan dan data-datanya telah direkodkan. Berdasarkan daripada maklumat yang didapati, sistem kawalan telah direkabentuk dan simulasi bagi sistem dilakukan untuk menilai prestasi asal dengan menggunakan perisian MATLAB. Komputer telah disambungkan kepada sistem servo MS150 menerusi kad DAQ dan perisian Microsoft Visual Basic 6.0 telah digunakan untuk menjalankan eksperimen. Ujian terhadap sistem dijalankan untuk tujuan perbandingan di antara sistem asal dengan sistem yang telah diubahsuai. Prestasi sistem dianalisa dan pengesahan telah dibuat dari aspek tindakbalas masa, ketegapannya dan peratus sisihan dengan nilai yang dikehendaki.

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ADC	-	Analog-Digital Converter
API	-	Application Program Interface
DAC	-	Digital-Analog Converter
CD	-	Compact Disc
CN	-	Connector
CV	-	Control Variable
DAS	-	Data Acquisition System
DAQ	-	Data Acquisition
DC	-	Direct Current
DDC	-	Direct Digital Control
Err	-	Error
GPIB	-	General Purpose Interface Bus
GUI	-	Graphical User Interface
IMC	-	Internal Model Control
I/O	-	Input / Output
J	-	Loss function
LSLNR	-	Linear System Learner
MIMO	-	Multi Input Multi Output
MIT	-	Massachusetts Institute of Technology
MPC	-	Model Predictive Control
MRAC	-	Model Reference Adaptive Control
OS	-	Overshoot; operating system
PC	-	Personal Computer
PCI	-	Peripheral Component Interface
PI	-	Proportional-Integral
PID	-	Proportional-Integral-Derivative

PLC	-	Programmable Logic Control
PV	-	Process Variable
OOP	-	Object-Oriented Programming
O/P	-	Output
ISA	-	Integrated System Architecture
SP	-	Set point
SVMPC	-	Single Variable Model Predictive Control
t_p	-	Peak Time
t_s	-	Settling Time
VB	-	Visual Basic
Ve	-	Error Voltage
Vg	-	Tachometer voltage
Vin	-	Input voltage
rpm	-	rotation per minute

CHAPTER I

INTRODUCTION

1.2 Direct Digital Control Overview

The major change occurring at the present is the increasing number of user friendly software that make it possible for student to experience new and fast ways of learning. In minutes, simulation, controller and real world interfacing can be created. The software package is developed to help students to learn and explore the experiment with an interesting way. A picture worth a thousand words.

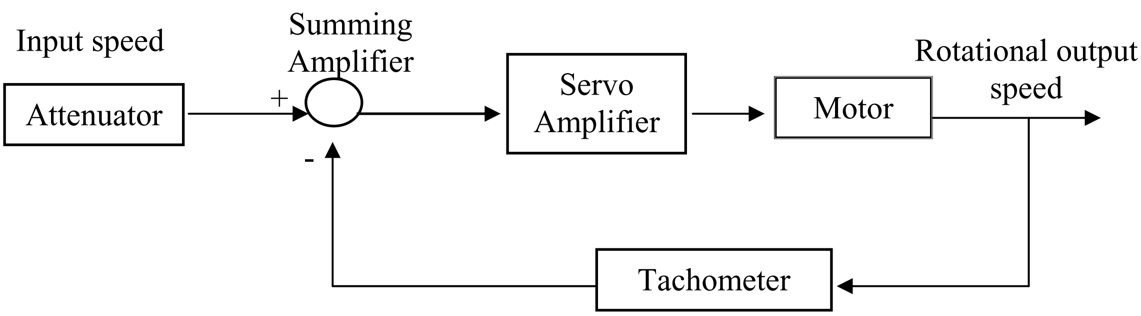
In DDC, the control laws are implemented in a digital computer as a computer programs. In realizing a real time computer controlled system in which a digital computer, specifically a microcomputer or PC is one of the major component that acts as a controller in the control loop [1]. The computer must be connected somehow to the external event and the program instructions are necessary to direct the interaction between the computer and the external activity.

There are two major parts:

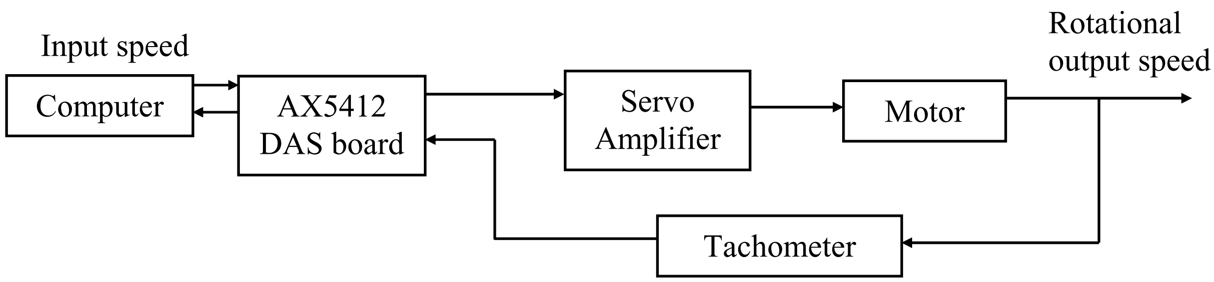
- Hardware Interfacing – connecting the computer to external equipment. Figure 1.1 shows the equipment setup for this project
- Software Design – programming the computer to carry out its control calculation (control laws) while interacting with external components. Visual Basic will be used to program the DAS board since this program is easy to learn it's code programming and user friendly

Figure 1.1: Equipment Setup

Figure 1.2 shows the comparison between the original and modified closed loop speed control system. The system (plant) under control is a continuous-time system. The 'heart' of the controller is a digital computer. The problem of realizing a digital controller is mainly one of developing a computer program.



(a)



(b)

Figure 1.2: Block Diagram Comparison (a) The Original Closed Loop Speed Control System (b) The Modified Closed Loop Speed Control System

Digital controllers present significant advantages over classical analog controllers. One of them is a greater flexibility in modifying the controller's features. For classical analog controllers, any change in the characteristics of the controller is usually laborious and expensive, since it requires changes in the structure and the elements of the controller. In digital controller, the designer has the flexibility to use the same hardware equipment to realize and test different control algorithms. This can be done because only the program that realizes the control algorithm has to be changed for every controller realization. However, the performance of the digital control is strongly dependent on many factors, among which are the sampling period, possible computational, the word length in the microprocessor and the interface devices used [2].

1.2 The benefit of Direct Digital Control

Benefit of using DDC are listed below:

i. Improve Accuracy and Performance

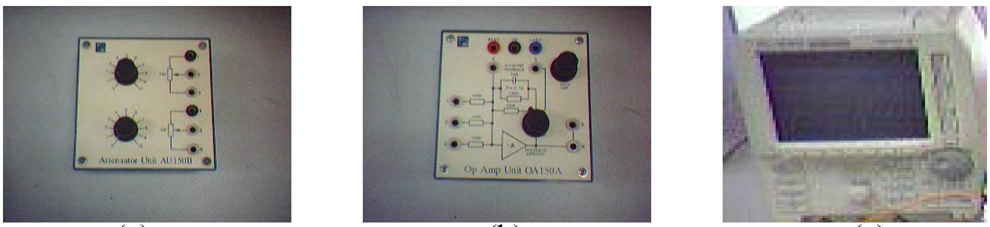
The gain provided by connecting operational amplifier and attenuator unit is different with the gain calculated because the tolerance of the gain defining resistor values, which will not be exactly the nominal values. Meanwhile, by using DDC technique the controller gain is exactly the value set by user

ii. Improve Effectiveness

By using DDC method, it is more flexible in changing set points and the overall control logic. Students are able to see system response through the virtual oscilloscope

iii. Reduce Cost

The number of hardware will be reduced since the controller function takes place in software. Figure 1.3 shows the components that will be eliminated in closed-loop speed control system and replace by software. It permits fast and low cost implementation of even more sophisticated control system since the associated control law can simply be programmed.



(a) (b) (c)

Figure 1.3: Components that been eliminated (a) attenuator (b) operational amplifier (c) oscilloscope

1.3 Objectives

The objectives of this project are as follows:

i. To apply Direct Digital Control technique on the speed control of DC motor.
ii. To improve the system performance through designing and tuning of the controllers.
iii. To design a graphical user interface (GUI) for speed control experiment and analyze the system response.

1.4 Scopes of Work

i. Applying the Direct Digital Control method towards controlling speed of DC motor.
ii. Implementing the proposed controller: MRAC, SVMPC and PID.
iii. Designing the programming structure for controller via Microsoft Visual Basic 6.0.
iv. Using AX5412 Data Acquisition Board to interface between the computer and DC Servomotor.

1.5 Research Methodology

i. Literature review to understand the concept and identify the techniques, problems and current works.
ii. Define the modeling and the method will be used for the system. Also understand the theory of conventional controllers.

iii. System identification and MATLAB simulation of the system.
iv. Conducting the procedures of the original system and get the results.
v. Learn up VB programming and the Axiom driver functions.
vi. Design and writing program to modify the system using DDC application.
vii. Interface with hardware between computer and DC servomotor through DAS card.
viii. Field-testing is conducted to compare the results between the original and modified system. Analyze the system's performance.

Design steps of work methodology can be simplified as shown in Figure 1.4.

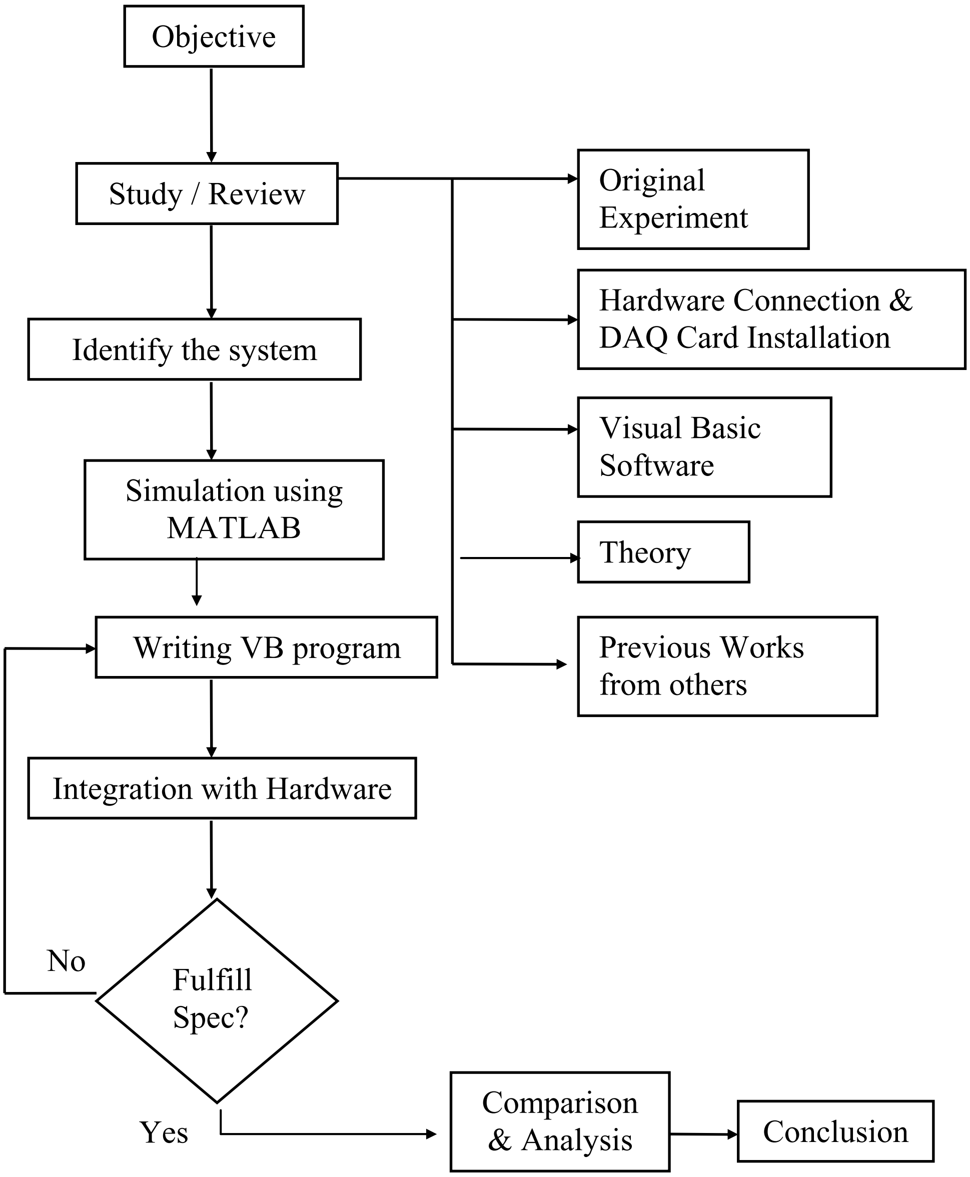


Figure 1.4: Design flow

1.6 Thesis Outline

Chapter 1: Introduction

This chapter gives the introduction to the project report, objectives, scope of works and methodology taken. It also described briefly the hardware and software used in completing this project.

Chapter 2: Literature Review

This chapter covers the literature review on the Virtual Laboratory, Enhancing Electrical Engineering Teaching Method and Design of PID controller for speed control, how it works and its components.

Chapter 3: Speed Control of DC Servomotor

DC Servomotor devices are explained through this chapter. The DC servomotor principle of operation is discussed. Device characteristics and functions are also included.

Chapter 4: Method of Analysis

There are several concepts will be introduced in this chapter. Starting with modeling of the system, discretize the analog controller and parameter tuning process of PID. MRAC and IMC controller design implementation.

Chapter 5: Direct Digital Control

This chapter will explain how the Direct Digital Control application will be implemented in this project. Including the installation and connection of the devices.

Chapter 6: Result & Analysis

The results are determined through the original experiments of the speed control, simulation and through the experiment where the used apparatus has been modified. Analysis regarding on the performance of the controller design also has been analyzed and validated.

Chapter 7: Conclusion

This last chapter presented the overall conclusion for the project. For the future work, some suggestions have been included in order to improve the work that has been conducted.

REFERENCES

[1] Benjamin C. Kuo. *Digital Control System*. Holt, Rinehart and Winston, INC, 1980

[2] P. N. Paraskevopoulos. *Digital Control Systems*. Prentice Hall, 1996

[3] Saul Goldberg, William F. Horton and Thomas Agayoff. Teaching Power Conversion in a Virtual Laboratory. *IEEE*, 2001

[4] C.C.Ko, Ben M. Chen, Jianping Chen, Yuan Zhuang and Kay Chen Tan. Development of a Web-Based Laboratory for Control Experiments on a Coupled Tank Apparatus. *IEEE Transactions on Education*, Vol 44, No.1, 2001

[5] K.K.Tan and C.Y.Soh. Instrumentation on the Internet. *Engineering Science and Educational Journal*, 2001

[6] Raymond C. Garcia and Bonnie. Enhancing Classical Control Education via Interactive GUI Design. *IEEE Control System*, 1999

[7] J. C. Basilio, S. R. Matos. Design of PI and PID Controllers with Transient Performance Specification. *IEEE Transactions on Education*, Vol 45, No.4, 2002

[8] P. E. Silveira, Souza, Biazotto. Speed Control of an Autonomous Mobile Robot – Comparison between a PID Control and a Control using Fuzzy Logic. *J. Braz. Soc. Mech. Sci*. Vol 24, No.2, 2002

[9] Feedback Instrument Ltd. *Modular Servo System MS150Mk2 DC, Synchro, & AC Basic Experiments.* Book 1

[10] M. Gopal. *Control Systems – Principle and Design*. McGraw Hill, Second Edition, 2002

[11] Norman S. Nise. *Control Systems Engineering*. John Wiley & Sons, 2000

[12] Katsuhiko Ogata. *Discrete-Time Control System*. Prentice Hall, 1995

[13] Curtis D. Johnson. *Process Control Instrumentation Technology*. Prentice Hall, 2000

[14] Karl Johan Astrom and Bjorn Wittenmark. *Adaptive Control*. Addison-Wesley Publishing Company, Inc, Second Edition, 1995

[15] E. F. Camacho and C. Bordons. *Model Predictive Control*. Springer, Second Edition, 2004

[16] Thomas E. Marlin. *Process Control – Designing Processes and Control Systems for Dynamic Performance*. Second Edition, 2000

[17] Axiom Technology Co., Ltd. *AX 5412 High Speed Data Acquisition Board User's Manual*

[18] Deitel, T. R. Nieto. *Visual Basic 6 – How to program*. Prentice Hall, 1999

[19] Richard C. Dorf and Robert H. Bishop. *Modern Control Systems*. Prentice Hall, Tenth Edition, 2005