DEVELOPMENT OF INTERNET-BASED REMOTE LABORATORY FOR PID CONTROL EXPERIMENTS

BY

HANANI ABDUL WAHAB

INTERNATIONAL ISLAMIC UNIVERSITY MALAYSIA

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Kulliyyah of Engineering
International Islamic University Malaysia

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ABSTRACT

In control engineering education, concepts taught through lectures are often complemented by practical laboratory experimentation. However, many control-engineering classes do not include a lab component because of significant expense, space and time considerations. As a result, an interactive experiment with real world systems and equipments needs to improve the motivation of control engineering students and develop an engineering approach to solve practical problems. The Interlab project was initiated in November 2005 at International Islamic University of Malaysia. The aim of the thesis is to develop technologies that enable laboratory equipment to be controlled remotely by students through the Internet. This thesis involved design and development of lab scale missile launcher model, modeling and parameters identification of the plant, design and implementation of PID controller and development of website for remote control laboratory for control experimentation. The laboratory uses a NetMeeting; a streaming server to broadcast live video of the plant. When students do their experiment online, they would get instant feedback of their control action by observing movements of the equipment from the video. This would give students a better feel of the laboratory. Students can perform laboratory experiment on the plant using xPC Target Web Browser Interface from any computer connected to the Internet. The initial result shows that the proposed system worked as expected. The use of laboratory equipment would be optimized and students learning experience would also be enhanced.

ملخّص البحث

فى تعليم التحكم الجهازي بموجات اللاسلكية كما يفهم فى علم الهندسة فى حاجة ماسة إلى تدريب الدارسين بطريقة تطبيقية. ومع ذلك ، أن كثيرا من المحاضرات لم تتوفر فيها الأجهزة المعينة، وذلك لأنها تحتاج إلى دعم مالي صغير فى إيجادها بالإضافة إلى زمن محصور ومكان محدود. ومن هذا، فالتدريب المكثف مع تنظيم البرامج بطريقة فاعلة، وإعداد الأجهزة المتوفرة من عوامل مهمة لإيجاد رغبة الدارسين لدراستها ولحل المشكلات المتعلقة بعمل تطبيقي. وقد بدأ هذا المشروع داخل المخابر منذ شهر نوفمبر سنة 2005 فى الجامعة الإسلامية العالمية بماليزيا. وهذا يهدف لتنشئة التقنية للتحكم بجهاز من بعد الذي يمكن الدارسون أن يقوموا به بوسيلة الإنترنيت. هذا البحث يشتمل على تشكيلي، وتنشئة مطلق الأسلحة بحجم صغير ، وترقيم رياضي والتعرف على دوائر ذلك الترقيم . ويشتمل أيضا على عملية اختراع المحكم اللاسلكي (فى.أي.دي) وبناء موقع شبكة الإنترنيت داخل المخبر حتى يمكن اختبار التحكم على الجهاز من بعد. ويحتاج هذا المخبر إلى استخدام برامج حوار عبر الإنترنيت . فالدارسون عندما يقومون بهذا الاختبار ثم يستعرضونه عبر الإنترنيت حيث يحصلون منه على رد فعل عن عملية التحكم عند مراقبة تطورات الجهاز عبر الشاشة . وبهذه الطريقة تؤدي إلى انشراح صدور الدارسين الذين لهم قدرة استخدام شبكة العرض "xPC Target" من الحاسوبات المتصلة بالإنترنيت. والنتائج البديهية تدل على أن النظام المستعرض يعمل بوظيفته على ما يرام . وانطلاقا ومن هذا يستطيع تحديد استعمال المخابر إلى أقل ما يمكن، وزيادة الخبرة لدى الدارسين فى عملية التعليم والتعلم .

APPROVAL PAGE

I certify that I have supervised and read this study and that in my opinion, it conforms to acceptable standards of scholarly presentation and is fully adequate, in scope and quality, as a dissertation for the degree of Master of Science in Mechatronics Engineering.

....

Wahyudi Martono
Supervisor

....

Riza Muhida
Co-Supervisor

I certify that I have read this study and that in my opinion; it conforms to acceptable standards of scholarly presentation and is fully adequate, in scope and quality, as a dissertation for the degree of Master of Science in Mechatronics Engineering.

....

Md. Abdus Samad Kamal
Internal Examiner

....

Khisbullah Huda
External Examiner

This dissertation was submitted to the Department of Mechatronics Engineering and is accepted as a partial fulfilment of the degree of Master of Science in Mechatronics Engineering.

....

Md. Raisuddin Khan
Head, Department of
Mechatronics Engineering

This dissertation was submitted to the Kulliyyah of Engineering and is accepted as a partial fulfilment of the degree of Master of Science in Mechatronics Engineering.

....

Ahmad Faris Ismail
Dean, Kulliyyah of Engineering

DECLARATION

I hereby declare that this dissertation is the result of my own investigations, except where otherwise stated. I also declare that it has not been previously or concurrently submitted as a whole for any other degrees at IIUM or other institutions.

Hanani Abdul Wahab

Signature:........................... Date: ....

INTERNATIONAL ISLAMIC UNIVERSITY MALAYSIA

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Signature	Date

To:

My husband and my daugther

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LIST OF SYMBOLS

a_1	Denominator parameter
a_2	Denominator parameter
e_b	Back emf
g	Gravitational acceleration
i	Current
I	Current
J	Moment of inertia
K	Kinetic Energy
K	motor constant
K_e	Motor back emf constant
K_t	Motor torque constant
K_0	Numerator parameter
K_1	Artificial response constant
K_2	Artificial response constant
K_d	Derivative gain
K_i	Integral gain
K_p	Proportional gain
l	Height of the load from the surface
L	Lagrangian
L_{ind}	Inductance
m_1	Mass of the load
m_2	Mass of the shaft
P	Power motor
P	Potential Energy
R	Resistance
s	Laplace domain function
t	Time
T	Torque
u	Input voltage

V	Voltage
W	Watt
ω	Motor angular velocity
ω_1	Artificial output
ω_2	Artificial output
ω_{ss}	Steady state velocity
ω_{1ss}	Steady state artificial velocity
ω_{2ss}	Steady state artificial velocity
ω_m	Maximum speed
ω_{max}	Maximum speed
Ω	Angular velocity
α	Angular acceleration
τ_m	summation of external torques
θ	Motor rotational angle

LIST OF ABBREVIATIONS

A./D.	Analog to Digital
A.C.T.	Automatic Control Telelab
B.I.O.S.	Basic Input/Output System
U.A.R.T.	Universal Asynchronous Receiver/Transmitter
C.N.C.	Computer Numerical Control
C.P.U.	Central Processing Unit
D./A.	Digital to Analog
D.A.Q.	Data Acquisition Card
D.C.	Direct Current
D.T.E.	Data Terminal Equipment
G.U.I.	Graphical User Interface
H.T.M.L.	HyperText Markup Language
H.T.T.P.	HyperText Transfer Protocol
I./O.	Input/Output
I.B.R.L.	Internet-based Remote Laboratory
I.S.A.	Industry Standard Architecture
I.T.	Information Technology
I.T.U.	International Telecommunication Union
L.A.N.	Local Area Network
L.E.D.	Light Emitting Diode
N.I.	National Instuments
P.C.	Personal Computer
P.C.I.	Peripheral Component Interconnect
P.I.D.	Proportional Integral Derivative
R.A.M.	Random Access Memory
R.L.	Remote Lab
R.p.m.	Revolution per Minute
R.T.W.	Real Time Workshop
S.I.T.	Simulation Interface Toolbox
S.R.O.	Simulink Response Optimization
T.C.P./I.P.	Transmission Control Protocol/Internet Protocol,
V.B.	Visual Basic
V.L.	Virtual Lab
W.A.V.E.S.	Web-based AudioNideo Education System
W.W.W.	World Wide Web

CHAPTER ONE

INTRODUCTION

1.1 BACKGROUND

As the fast development in modern engineering technology, engineering education becomes an important issue in recent years. In engineering education, control engineering is one of the disciplines that focus on the mathematical modeling systems of a diverse nature, analyzing their dynamic behavior, and using control theory to create a controller that will cause the systems to behave in a desired manner.

In control engineering education, laboratory work is an important component for a holistic learning experience (Bing *et al.*, 2005). Normally, a control course requires considerable mathematical as well as engineering knowledge and is consequently regarded as a difficult course by many undergraduate students. From the academic point of view, helping the students to improve their learning on the control engineering is an important task which requires careful planning and innovative teaching methods. Traditionally, the didactic teaching approach has been used to teach the students on the concepts needed to solve control problems. This approach is commonly adopted in many mathematics intensive courses; however it generally lacks reflection from the students to improve their learning.

One significant tendency in the field of control practice is the increasing use of virtual instrumentation. In fact in major production facilities, instead of using real plant, operators are often trained in plant operation using a simulation environment of to drive virtual instruments. However, experimentation with a real plant or real object cannot be replaced by a simulation or training simulators, especially the sensations perceived by the trainee/students in the experiment. Practical education needs to be based on errors and irregularities, as occurs in mechanical, electrical or chemical systems, as opposed to the ideal icons and environments represented on a computer display.

In control engineering education, laboratory courses are an essential part of the education. Laboratory works are important for students while they are applying their control engineering theory to the experiment. This is an opportunity for the student to construct their own knowledge and put their theory and practice to get a research experience in the laboratory. However, many educational institutions do not include lab components for control engineering courses because of significant expense, space and time considerations. In addition, since the control engineering is a general subject for almost of the engineering program, the number of students who enrolled is high. As a result, engineering students have to share the equipment in the laboratory. This reduces the time students spend with the equipment and diminishes the purpose of the laboratory (Harjono, 2001) because sometimes there is not enough time for their turn in the laboratory class.

The scenario for control education is changing and new situation has to be addressed. Information technology opens a whole new world of real opportunities. Computers show a great potential to enhance student achievement. A vital aspect of control engineering education is that laboratory and practical work need to provide engineering students with a taste of real situations, measurement and instrumentation, with all their attendant problems. The new idea is allowing the students to perform real experiments, in real time, on real equipment, but over the Internet.

Fortuitously, the Internet world is truly available. The usage of Internet could not be denied. The Internet technology has significant effects on almost every single aspects of daily life and has changed the people performs their daily works. People can move faster, easier, never feel alone and the world is just on their finger tips. The World Wide Web (WWW) technologies and computer-controlled instrumentation presently allow many people to work from home instead of from office. It also has provided the facilities for people to monitor and control machinery from anywhere in the world (Davies, 2002).

Furthermore, with this power of communication, universities around the world are adapting their teaching methods to include computer and Internet technology, such as tele-teaching (Filler *et al.*, 2000). Tele-teaching is a method of teaching through the Internet either by presenting on the Internet some lecture materials, online tutorials or real-time laboratory. The real-time laboratory, which is benefit to students, as it can allow them to perform laboratory experiments on equipment from any computer, connected to the Internet (Davies, 2002). By adopting Internet-based experimentation, the above-mentioned practical experiment problems can be solved. The unique and expensive equipment can be shared between different universities. In addition, the students have the convenience for conducting experiments at their own preferable time (not only during working hours) and place since they are not required physically being at the university during working hours. Study conducted by Barker (Barker *et al.*, 1998) shows that students learn better when they have control over when and where the learning takes place. The less obvious benefit of Internet-based real-time experiments would be reduction of lecturers' and students' time and cost. This will give them to concentrate on more important task such as improving teaching and learning. For the above advantages, the development of Internet-based real-time control laboratory is naturally justified.

1.2 OBJECTIVES

The main objective of this thesis is to develop an Internet-based remote laboratory for control engineering education, which allows the students to conduct the experiments through Internet connection on their own preferable time and place. To achieve the main objective, it is necessary

a) To develop and fabricate a plant to be controlled in the control experimentation

b) To develop website and video servers for Internet access of the real time control system laboratory

c) To develop and configure software to allow PID control experiments through Internet

1.3 METHODOLGY

In order to achieve the objectives of this study, the following procedures are considered:

a) The research starts with the understanding of control system course syllabus for undergraduate engineering student

b) Selection, design and fabrication of plant to be used as case study in control laboratory experimentation.

c) Development of real-time control software.

d) Development of website and video server for Internet access of the control systems experimentation.

e) Hardware and software integration.

f) Implementation and evaluation of Internet-based remote control laboratory experimentation.

1.4 THESIS OUTLINE

The thesis outline is as follows:

i. Chapter 2: This chapter discusses literature review of technical papers and scientific papers on control system engineering laboratory.

ii. Chapter 3: Development of the hardware and software of the system is described in this chapter. Software development and architecture of the system is described by introducing the software that is used. The development of real-time control system is also to be explained in this chapter. The mathematical modeling, which consists of the model derivation and parameters identification, is explained. A series of experiments is carried out to identify the unknown parameters of the lab scale missile launcher system. Then, the design of PID controller is also discussed in this chapter.

iii. Chapter 4: The implementation of Internet-based Remote Laboratory for real-time control system is described in this chapter. The parameters identification and PID controller implementation results is also discussed in this chapter.

iv. Chapter 5: This chapter summarizes all the results obtained in the previous chapters. New development and improvement are suggested for the further study.

CHAPTER TWO

LITERATURE REVIEW

2.1 INTRODUCTION

Control engineering education combines both theory and practical experiments. Students thereby achieve knowledge and skills of control system design in order to develop controllers for achieving given performance requirements. Students are confronted with dynamic phenomena that are often difficult to explain in words or in textbooks. In addition, control engineering education faces severe problems because the ideas and phenomena involved in such areas are complex and hard to demonstrate on neither the conventional chalkboard nor the electronic virtual blackboard. Therefore the importance of laboratory experiments in control engineering education could never be overemphasized.

There is no doubt that lab-based courses play an important role in control engineering education. According to Nersessian (1991), Clough (2002) and Magin *et al.* (1986), hands-on experience is at the heart of science learning and laboratory experiences make science come alive. In addition, lab courses have a strong impact on students' learning outcomes. From the laboratory, students can apply their engineering knowledge learnt from the lectures to real engineering situations. The uses of laboratory experiments are a critical important aspect of engineering education. Experience in teaching has shown that a complementary approach in combining theoretical and practical exercise is vital for effective learning.

However, laboratory equipment is usually expensive. As a result, engineering students have to share the equipment in the laboratory. This reduces the time students