DESIGN OF A VIRTUAL LABORATORY ENVIRONMENT FOR A WATER BATH TEMPERATURE CONTROL SYSTEM

NORHASLINDA BINTI HASIM

A project report submitted in partial fulfilment of the
requirements for the award of the degree of
Master of Engineering (Electrical - Mechatronics and Automatic Control)

Faculty of Electrical Engineering
Universiti Teknologi Malaysia

JUNE 2010

Dedicated with deepest love to:

My beloved family for their support, guidance and love.

My dearest friends for being there whenever I needed them.

ACKNOWLEDGEMENT

In the name of ALLAH, the Most Beneficent, the Most Gracious and the Most Merciful who has given me patience in completing this project.

Firstly, I would like to express my appreciation to my supervisor Prof Dr Marzuki Khalid for his contribution and encouragement upon accomplishment of this project. My gratitude also goes to Mr Zakariah Yusuf, a Master by Research student from UiTM , Mr Azizan As'arry and Mr Mohd Nasir Ayob for their willingness in sharing their knowledge that has made this work excitably fruitful.

Also not to forget my family, all my friends and for those who have helped me either directly or indirectly for their guidance and willingness in sharing knowledge towards the completion of this project. All of them had given useful ideas towards the accomplishment of this project and always spend their time especially when I face problems. I am greatly indebted for their help and willingness in reading and correcting my report.

Last but not least, I wish to express my gratitude to the mighty God for giving me good health in completing this project and throughout my studies. I am sure and believe that without the contributions from those mentioned and also without good health, it is hard and impossible for me to fulfill the objective of this project.

ABSTRACT

In technical education, laboratory components comprise as an essential part, without it engineering education remains incomplete. Experiments conducted on laboratory equipments lend a practical touch to the theoretical knowledge acquired by the students. However, setting up a specialized laboratory consisting of sophisticated and expensive equipments is an unaffordable for many universities and engineering colleges. Therefore, by developing virtual experiments, sharing of specific and expensive equipment among institution is made much easier, as it can be used from any place with secure and controlled access. In this project, the system is developed using LABVIEW 8.6. This project consists of three stages. The first stage is hardware development, which involves construction of interface circuit to allow communication between plant and computer. The second stage is to build the Fuzzy Logic Controller using LABVIEW software, where fuzzy set and rulebase are applied. The final stage is to publish the GUI module onto the web for real-time remote control.

ABSTRAK

Dalam pendidikan teknikal, komponen makmal merupakan bahagian terpenting, tanpanya pendidikan kejuruteraan menjadi tidak lengkap. Eksperimen menggunakan peralatan makmal memberikan latihan praktikal setelah pengetahuan teori yang diperolehi oleh para pelajar. Namun, menyediakan makmal khas yang terdiri daripada peralatan canggih dan mahal tidak mampu disediakan oleh banyak universiti dan kolej kejuruteraan. Oleh kerana itu, dengan mengembangkan eksperimen virtual, berkongsi peralatan khusus dan mahal antara institusi merupakan jauh lebih mudah, kerana boleh digunakan di mana saja dengan akses yang selamat dan terkawal. Dalam projek ini, sistem ini dibangunkan dengan menggunakan LABVIEW 8,6. Projek ini terbahagi kepada tiga bahagian. Bahagian pertama adalah pembangunan peranti keras, yang melibatkan pembinaan litar antaramuka untuk membolehkan komunikasi antara alat yang hendak dikawal dan komputer. Tahap kedua adalah untuk membina kawalan Fuzzy Logic menggunakan perisian LABVIEW, di mana himpunan fuzzy dan rulebase diterapkan. Tahap terakhir adalah untuk membina modul GUI ke web untuk kawalan jauh pada satu-satu masa.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF APPENDICES

CHAPTER 1

INTRODUCTION

1.1 Project Background

There have been some researches in the development of virtual laboratories; however, their implementation in e-learning is still in its early years. As such, there is a need to develop a more effective e-learning laboratory facility such that it can be more widely implemented. In this project, a water bath is used as test-beds for engaging the control experiments. An effective software package based on LABVIEW platform has been developed which consists of a Fuzzy control.

1.2 Motivation For Research

Most of the time, we gain our knowledge on certain subjects or fields through the theoretical approach. In the engineering and scientific fields, lecturers deliver their knowledge of certain subjects to the students in lectures by teaching the concepts, theories and formulas, accompanied by examples and exercises. And the students attempt to enrich their knowledge by studying books or related references from various resources.

However, all of these are merely in the sense of theory where indeed they are abstract and considerably hard to be understood thoroughly. Besides, the students seldom have the opportunity to apply the knowledge they have learnt. In view of this, hands-on experiments play a vital role in complementing the theories and concepts taught in the lectures. It is undeniable that the circulation of knowledge from lecturers to students is more effective with the aid of experiments or what we call the practical approach.

The fast growth of web technologies and the high usage of the internet have made teaching and learning via the internet to be more practical in recent years. Many universities and educational-based industries have set up portals to offer a virtual laboratory environment either as teaching aids to support conventional teaching approach or as a teaching medium for long-distance or off-campus programs.

Although e-learning to a certain extent has been quite well established, the current focus is primarily towards the development of more effective courseware and assessment tools. Another area that would need more attention is towards the development of virtual laboratories, where laboratory equipment is setup to be controlled via the internet.

The setting up of virtual laboratories fits perfectly in an e-learning environment especially for engineering and scientific programs which could provide means for students to carry out experiments via the internet. It is undeniable that learning theories or concepts through practical approach or applications is a crucial step of the learning process, especially in the scientific and engineering curriculum; however, virtual laboratories do offer many advantages.

It is often an issue to allocate the time for the students to attend the labs to carry out the experiments with guidance by the lecturers. Furthermore, the students are constrained to certain periods of time of access to the lab. This is because, in most cases, accesses to labs are only allowed during week days and working hours. This issue, however, becomes immaterial if the lab equipment is linked to the internet and the students can remotely monitor and control the equipment from somewhere else via the internet. The students can then perform the laboratory experiments at any preferred time that suits them best, even during midnight or weekends.

Inadequate resources are another issue and this is often experienced in lesser developed countries. Insufficient lab equipment or instruments in comparison to the large and increasing number of students raises another concern. Nevertheless, due to budget limitation, it might be too costly to equip and setup several sets of the experimental hardware to meet these needs. In addition, many universities nowadays offer off-campus and distance learning programs such that the lab equipment or instrument is geographically diverged from the student. The student might need to travel all the way to the lab to carry out the experiments using the instruments there. This seems rather impractical due to the cost and time consumption. Therefore, it would be more convenient to publish the lab equipment onto the web where it can be accessed worldwide, despite of geographical location.

Another major advantage in setting up virtual laboratories is that they can be used as effective teaching aids in classrooms equipped with internet facilities. A main step in the teaching approach has been partly introduced in some universities where practical examples are shown through laboratory experiments carried out by the lecturers. These practical demonstrations on the equipment have been found to be very effective for student’s understanding of the subjects. However, often engineering degree programs cater for large number of students per class and it would not be sufficient if lectures were to be held in laboratories for these hands-on demonstrations. Moreover, some of these equipments are large and bulky and they are never practical enough to be moved to the classrooms. Virtual laboratories seem to be able to offer as effective resolutions for such a teaching approach where the real physical equipments are actually being controlled and monitored.

1.3 Objectives of Project

The primary objective of this project is to setup a water bath, interfacing system and the server in the lab located in University Teknologi Malaysia, Skudai Johor. The water bath consists of the water tank itself, a temperature sensor (RTD), a heater and a stirrer. An interface system will also be mounted so that the water bath can be controlled through the server computer using the GUI module developed.

Secondly, an internet-based GUI module for virtual laboratory environment of a water bath temperature control system will be developed using LabVIEW. The GUI module will be published onto the internet so that the water bath temperature control system can be either monitored or controlled remotely.

1.4 Scopes of Project

Basically, the scopes of work for this entire project can be summarized as follows:

a) To publish the GUI module onto the web for real time remote control.
b) To create a website for the water bath temperature control system.
c) To setup the hardware together with the client-server system in the lab.
d) To publish a live experiment as a mean of teaching tool to teach and learn water bath temperature control using Fuzzy controller.
e) To build an interface module for the system to communicate with the plant.

1.5 Thesis Organization

This thesis is organized into six chapters.

Chapter 1 will present the introduction of the project, which is brief information and scope of the project is discussed. Several facts about the previous work by other researchers also have been touched.

Chapter 2 contains literature review and detail about the information and scope of the project. It is also briefed some of the LABVIEW application that involved in the virtual laboratory environment.

Chapter 3 discusses briefly on the hardware setup for the project. This chapter reveals about the water bath and the interface system that used in the project.

Chapter 4 will present the software development of the project where it can be divided into two parts which are fuzzy controller development and virtual environment development. This chapter discussed about the LABVIEW software and the block diagram used.

Chapter 5 is for results on the project and some discussions will be explained. While, for the results, all graphs, figures and comments were included.

Chapter 6 is for conclusion on the project and some review for the future recommendation works will be explained.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

Literature review is a very important part of research process. The general purpose of the literature review is to gain understanding of the current state of knowledge about the selected research topics.

This chapter also reviews related literature from the existing research on virtual laboratory environment, where the control of LABVIEW is implemented in various type of plant.

2.2 Related Works

Many researches had been conducted to find the best solution of using internet as a virtual laboratory to allow the students conduct practical laboratory exercises with real equipment without being physically present in a conventional laboratory [1]. The responses of [1] show that the students not only appreciate the flexibility of the remote access option, but also they feel that the remote option encourages them to take a deep learning approach to the material.

The implementation of [2] using TCP (Transmission Control Protocol) for communication has been developed by V. Ramakrishnan et al to serve undergraduate students in the Department of Electrical Engineering at NUS (The National University of Singapore), where the control strategies adopted include manual control, the use of a PID (Proportional Integral Differential) controller, a general state-space controller as well as a fuzzy controller. Video conferencing is implemented to offer fast and point-to-point visual feedback to the client, on the happenings in the laboratory and also allows users to control the zoom and viewing angle of the video. Based on the methodology described in [3] and [4], for the development of [2] was implemented with some new and attractive features of video conferencing for providing visual feedback to the user.

Previously, a system was developed in which the students could perform experiments by remote control via the internet. That prototype enabled students in a laboratory in Liverpool in England, to perform experiments using equipment that was in a laboratory in Wismar, Germany. Although the prototype was successful, it required the use of specialist software both in the laboratory in which the equipment was being controlled and at the client site where the students were located. Furthermore, the students could not see the actual equipment; all they could see were mimic diagrams and virtual instruments. H. Ewald and G. F. Page [5] have developed a more sophisticated arrangement which only requires specialist equipment at the site where the equipment is located. With the aid of the LABVIEW software, http-based client-server systems for the remote control of experiments were developed, built and tested, for example: a complex experiment using ultrasonic sensors. Beside the advantages of saving resources and the greater attraction of such laboratory, students can learn networking technologies more effectively and they are in a better position to assess the requirements and properties of connected automatic control systems.

The proposed method was also previously applied to control coupled water tanks by Stefanovic et al [6]. They also presented the results of researches among student populationin order to determine advantages and effects of using web laboratory in control engineering education. Therefore, by using this proposed method, sharing of specific and expensive equipment among various institutions is made much easier, as it can be used from any place with secure and controlled access

[6]. There is a little availability of real physical systems or laboratories to perform the experiments in control courses [7].

An interactive GUI environment has been developed using Microsoft Visual Basic by Sanjib et al [8]. The GUI is provided at the end user to facilitate the remote control and access of various instruments and experiment setups. The experiment has been specifically designed and optimized for a low-bandwidth remote access link.

There are various approaches found in literature that has been followed by different universities and researches for setting up remote laboratory in many application areas. The works in [2, 9] describe web-based virtual electronics laboratories, one on frequency modulation experiment and the other on coupled tank apparatus, a multi-input-multi-output (MIMO) system, developed at National University of Singapore using LABVIEW and JAVA applet programming. An online laboratory for Microelectronics test circuit utilizing JAVA applet has also been developed [10].

The work in [11] describes a web-based laboratory for remote control of an inverted pendulum using MATLAB and JAVA programming. A remote laboratory based on experiments for control engineering course has been developed at University of Texas, Arlington using Microsoft Netmeeting and MATLAB's Simulink environment [12].

Another system has been proposed [13] where it composed of an internal distributed system and an application system linked by a data acquisition (DAQ) interface card. Web-server, video server and Laboratory Virtual Instrument Engineering Workbench (LABVIEW) controller server are designed based on a client-server structure. This project involves several different programming languages, operating systems, and hardware suites, and each of them has its own advantages and disadvantages. Thus, this project focused on how to integrate varieties of computer techniques seamlessly so that a reliable system performance can be achieved.

2.3 Background of Project

Before proceeding to the next chapter, some of the theories need to be understood on how the LABVIEW part is done. In order to do the fuzzy controller, there are a lot of particular things that should be studied and only after that the virtual environment can be fully utilized.

2.3.1 Fuzzy Logic

Fuzzy logic is a method of rule-based decision making used for expert systems and process control that follows the rule-of-thumb thought process human beings use.[1] In 1960s, Lotfi Zadeh developed fuzzy set theory, the basis of fuzzy logic. Unlike traditional Boolean set theory, the fuzzy set theory allows for partial membership in a set.

Traditional Boolean set theory is two-valued in the sense that a member either belongs to a set or does not, which is represented by a one or zero, respectively. Fuzzy set theory allows for partial membership, or a degree of membership, which might be any value along the continuum of zero to one.

Membership function is a type of fuzzy set to quantitatively define a linguistic term. A membership function specifically defines degrees of membership based on a property such as temperature or pressure. With membership functions defined for controller or expert system inputs and outputs, a rule base of IF-THEN type conditional rules can be formulated. Then, with fuzzy logic inference, the rule base and corresponding membership functions are used to analyze controller inputs and determine controller outputs.

Once a fuzzy controller is defined, process control can quickly and easily be implemented. Most traditional control algorithms require a mathematical model to work on, but many physical systems are difficult or impossible to model mathematically. In addition, many processes are either nonlinear or too complex to control with traditional strategies. However, if an expert can qualitatively describe a control strategy, fuzzy logic can be used to define a controller that emulates the heuristic rule-of-thumb strategies of the expert. Therefore, fuzzy logic can be used to control a process that a human manually controls with knowledge he gains from experience. Thus it can directly translate from the linguistic control rules developed by a human expert to a rule base for a fuzzy logic controller.

Real world situations are often too uncertain or vague for you to describe them precisely. Comprehensively describing a complex situation requires more detailed data than a human being can recognize, process, and understand.

A different basic fuzzy logic concept involves rule-based decision-making processes. Human operators do not always need a detailed and precise mathematical description to optimize operation of an engineering process. In other words, they are often capable of managing complex plant situations without knowing anything about differential equations. Their engineering knowledge is perhaps available in a linguistic form such as "if the liquid temperature is correct, and the pH value is too high, adjust the water feed to a higher level."

The fuzzy inference process results in a linguistic value for the output variable. In this case, the linguistic value {0.0, 0.1, 0.8, 0.0, 0.0, 0.0,0.0} can be interpreted as *still negative small* or *just slightly negative medium*. To use this linguistic value to adjust the control, need to translate it into a real, physical value. This step is called defuzzification.

The membership functions that describe the terms of the linguistic output variable always define the relationship between the linguistic values and the corresponding real values. Refer to Figure 4.2 for more information about membership functions. In the example, you obtain a fuzzy inference result that is both fuzzy and ambiguous because you acquire the nonzero truth degree of two different actions at the same time. You must combine two conflicting actions, defined as fuzzy sets, to form a crisp real value. A solution to this problem is to find the best compromise between the two different goals. This compromise represents the best final conclusion received from the fuzzy inference process.

One of the two most common methods for calculating the best compromise is the Center-of-Area (CoA) method, also called the Center-of-Gravity (CoG) method.

2.3.2 Virtual Laboratory

Virtual laboratory allows users to access remotely to laboratory instruments or facilities through network, either Local Area Network or internet. Those physical laboratory facilities are connected to the server and made accessible to users who have accessibility to the particular network. It allows users to conduct actual experiments at anytime and from anywhere. In short, it can also be summarized as users carry out the experiment in the virtual world, which is the network system (internet or LAN) by using the actual laboratory equipment in the physical world. This is how the name “Virtual Laboratory” originates from. This technology greatly enhances the flexibility of laboratory education, and introduces students to the new paradigm of remote experimentation.

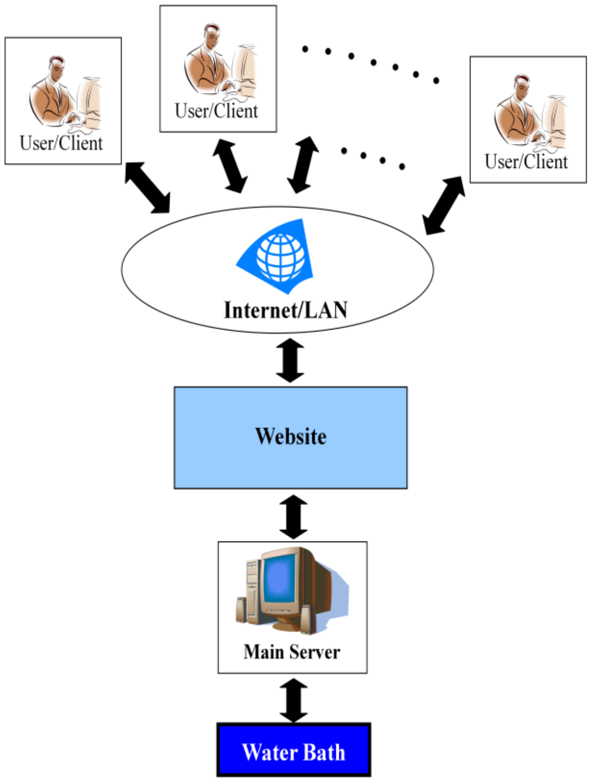

Figure 2.1: Client-Server Architecture for GUI Module

From Figure 2.1, apparently, the hardware i.e. the water bath is connected to a computer in the lab which serves as the server. It is controlled using the Graphical User Interface module running locally on a LABVIEW platform. In other words, the server computer plays the role of communicating directly with the hardware through a developed interface system. Meanwhile, the server computer is connected to the network, either to the internet or Local Area Network (LAN).

The GUI module will also be published onto the network and the module is accessible to the worldwide users. Users, or known as the clients from anywhere of the world, can remotely access and control the GUI to control the water bath, as long as they have computers with web browser and connected to the network.

Upon the connection to the server as well as the hardware, the client sees the same front panel (GUI) exactly as the local host (server), and also has the exact same functionality presented through the browser. This is a bi-directional operating system, which means, the clients or users will continuously receive real time data from the water bath plant in the lab which varies with time.

At the same time, if the clients or users manipulate the control in the GUI from their own computers (client pc), the GUI in the server computer will immediately respond to the changes made and then take action to generate any outputs necessary for experiment stimulus.

Currently, there are numerous of virtual laboratories available online in the World Wide Web. Visionlearning, supported by the National Science Foundation of the United States, is an innovative online educational resource designed for students, teachers or anyone interested in learning or teaching science. It provides a wide range of links to online experiments in its Virtual Labs and Simulations module, ranging from electrical, mechanical, thermodynamics, chemistry, optics, fluid, physics, waves and even nuclear. Especially, the experiments and demonstrations regarding to nuclear are very interesting. User is given the opportunity to control the nuclear power plant where normally we will barely have the opportunity to attend to the real nuclear plant to conduct the experiment regarding to nuclear technology. Of course, it is only demonstration and simulation. However, it is undeniable that such simulations are very crucial for the students who are learning about nuclear technology. From here, the advantages of virtual laboratory or internet-based experiments can be seen obviously.

Virtual Laboratories in Probabilities and Statistics provides online experiments regarding to probabilities and statistics in mathematics, whereby such experiments and teaching approach will aid the students in understanding those mathematical theories. Besides, Carnegie Mellon University of the United States has also developed a Virtual Lab system for chemistry experiments under the IrYdium Project funded by US National Science Foundation. The networked laboratory simulation provides an environment in which students can select from hundreds of standard chemical reagents and combine them in any way they find fit. Instructors may use this virtual laboratory in a variety of coursewares, including student homework, group projects, computer lab activities and pre-lab and post-lab exercises to support varied approaches to chemical education.

There are many more virtual labs or online experiments yet to be discovered in the World Wide Web. Nevertheless, almost all the virtual labs and online experiments in the web emphasize more on simulations and demonstrations only. There are very few websites that provide real-time online experiment. When we talk about real time, it means that the user can really access and control the lab equipment in the lab which is linked to the internet. This is "real" experiment, rather than performing merely simulation or demonstration.

Water bath is a vessel which is usually adiabatic that contains some liquidized food materials in which its objective is to control the temperature of the mixed liquid. The major components of the water bath are a water tank, a heating coil (controlled by a 2 Pole Contactor), a sensor (which is the RTD Sensor) and a stirrer. Please refer to Figure 3.2 in the next chapter, for the schematic diagram of the water bath temperature control system.

Nowadays, water bath is widely used in industries, especially food processing. It is used for producing new liquid products such as milk drinks, chocolate drinks, etc. In addition, water bath is also popular equipment in medical laboratories, where the temperature control of certain liquid is crucial.

The water bath temperature is controlled using Fuzzy Logic control. Users can control the temperature of the water bath using the controllers in the software developed using LABVIEW software An interactive Graphical User Interface is developed to facilitate the users in controlling the system. Besides, a well developed input-output device is used to interface between the server computer and the plant itself.

2.3.3 LABVIEW Software

LabVIEW is a graphical programming language that uses icons instead of lines of text to create applications. Unlike text-based programming languages, where instructions determine program execution, LabVIEW uses dataflow programming, where the flow of data determines execution [14].

By using LabVIEW, a user interface is built by using a set of tools and objects. The user interface is known as the front panel. Next, adding the code using graphical representations of functions to control the front panel objects. The block diagram contains this code. In some ways, the block diagram looks like a flowchart.

LabVIEW programs are called virtual instruments, or VIs, because their appearance and operation are just like physical instruments, such as oscilloscopes and multimeters. Every VIs uses functions that manipulate input from the user interface or other sources and display that information or move it to other files or other computers [14]. A VI contains the following three components:

a) Front panel which serves as the user interface.
b) Block diagram that contains the graphical source code that defines the functionality of the VI.
c) Icon and connector pane to identify the VI so that the VI can be used with another VI. A VI within another VI is called a subVI. A subVI corresponds to a subroutine in text-based programming languages.

The front panel is build with controls and indicators, which are the interactive input and output terminals of the VI, respectively. Controls are push buttons, knobs, and other input devices. Indicators are graphs, LEDs or other displays. Controls simulate instrument input devices and supply data to the block diagram of the VI. Indicators simulate instrument output devices and display data that the block diagram acquires or generates.

After the front panel is built, code is added using graphical representations of functions to control the front panel objects. The block diagram contains this graphical source code. Front panel objects appear as terminals on the block diagram. A terminal from a block diagram cannot be deleted since it corresponds to the object on the front panel. The front panel and block diagram constructed in this project is shown in Figure 4.8 and Figure 4.9 in Chapter 4.

CHAPTER 3

HARDWARE DEVELOPMENT

3.1 Introduction

Methodology of this project can be divided into two parts, hardware and software development. The flowchart in Figure 3.1 describes both of the hardware and software development in the project. This chapter discuss about the hardware development that used to receive signals from the plant and send it to the system. The procedures in constructing this interface circuit will be discussed in this chapter. There will be several components to make us understand better of how the interface circuit works.

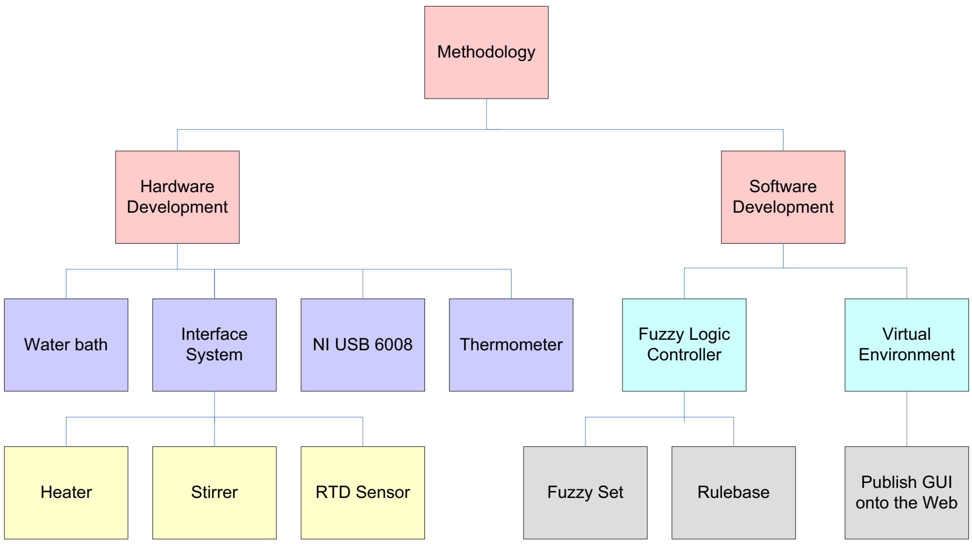

Figure 3.1: Flowchart of the Methodology.

3.2 Water Bath

Water bath is a vessel which is usually adiabatic that contains some liquidized food materials in which its objective is to control the temperature of the mixed liquid. The major components of the water bath are a water tank, a heating coil (controlled by a 2 Pole Contactor), a sensor (which is the RTD) and a stirrer. Please refer to Figure 3.2 for schematic diagram of the entire water bath temperature control system.

Nowadays, water bath is widely used in industries, especially food processing. It is used for producing new liquid products such as milk drinks, chocolate drinks, etc. In addition, water bath is also popular equipment in medical laboratories, where the temperature control of certain liquid is important.

The water bath temperature is controlled using Fuzzy Logic control. An interactive Graphical User Interface is developed to facilitate the users in controlling the system. Besides, a well developed input-output device is used to interface between the server computer and the plant itself.

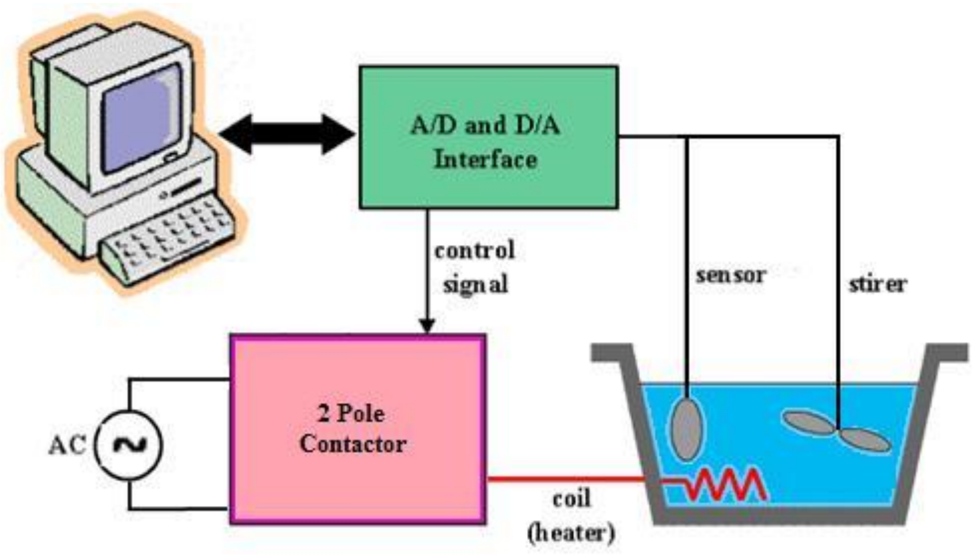

Figure 3.2: Schematic Diagram of Water Bath Temperature Control System.

Figure 3.3 shows the actual water bath that used in this project. Basically, the water bath plant itself was borrowed from Centre for Artificial Intelligence and Robotics (CAIRO) Universiti Teknologi Malaysia, Kuala Lumpur. The major part in the hardware development is actually the interface circuit between the water bath and the computer that will discussed further in the next section.

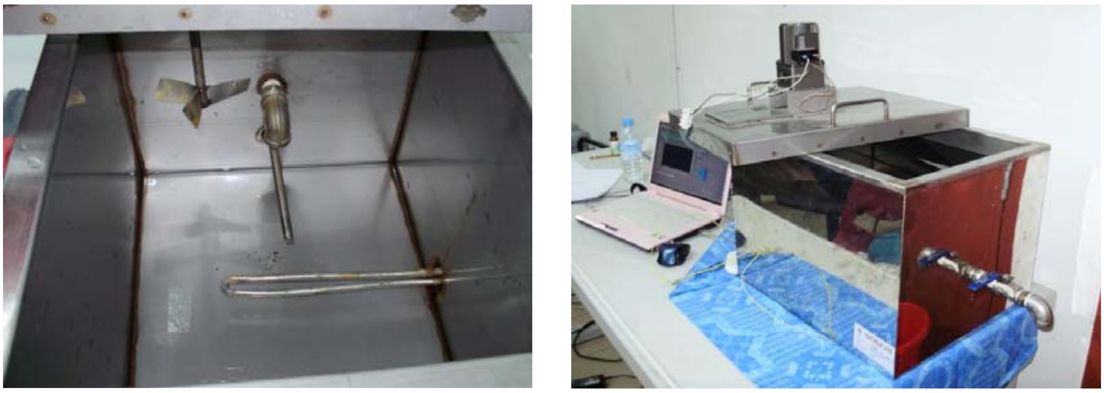

Figure 3.3: Water Bath

3.3 Interface System

The interface system plays a very important role in communicating with the physical plant, i.e. the water bath. Generally, the interface system will read the sensor level of the RTD sensor and send the reading to the water bath temperature control system in the server computer. The temperature reading will be displayed on the GUI panel and will be used for further process. When it is necessary, the server computer will send a signal to trigger the 2 Pole Contactor to switch on the heater for the purpose of heating the water in the tank until the temperature reaches desired set point. This bi-directional communication between the server computer and the plant itself is performed by the interface system. Basically, there are three major components that need to be controlled using the interface system, namely water heater, stirrer and RTD sensor.

The power supply module plays the role of supplying the entire system with required power. The input power to the system is an AC voltage 240 V, 50 Hz. This input power supply is purposely to control the heater and stirrer. The switching of the power supply is controlled by using interface device from server computer. The interface circuit is shown in Figure 3.4.

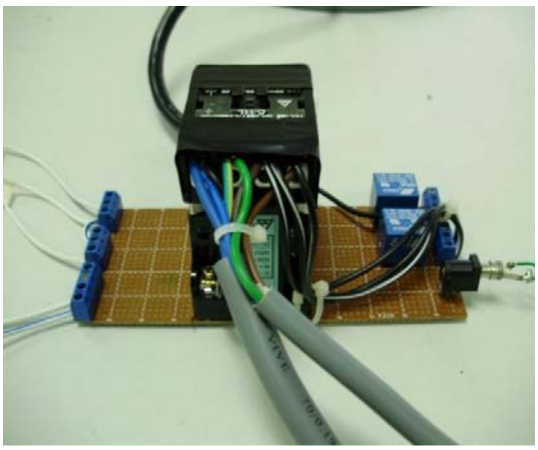

Figure 3.4: Interface Circuit

2 Pole Contactor will receive signal from the temperature control system in the server computer, where it will be triggered and switch on the heater to heat up the liquid in the tank. When there is no signal from the server computer, the output of the 2 Pole Contactor is in open circuit mode where the heater is not switched on. The 2 pole contactor will receive 5V DC input signal and 250 volt ac output. The circuit of this module is as illustrated in the figure below. The 5V relay is used to control stirrer and heater. Figure 3.5 describes the schematic diagram of the interface circuit.

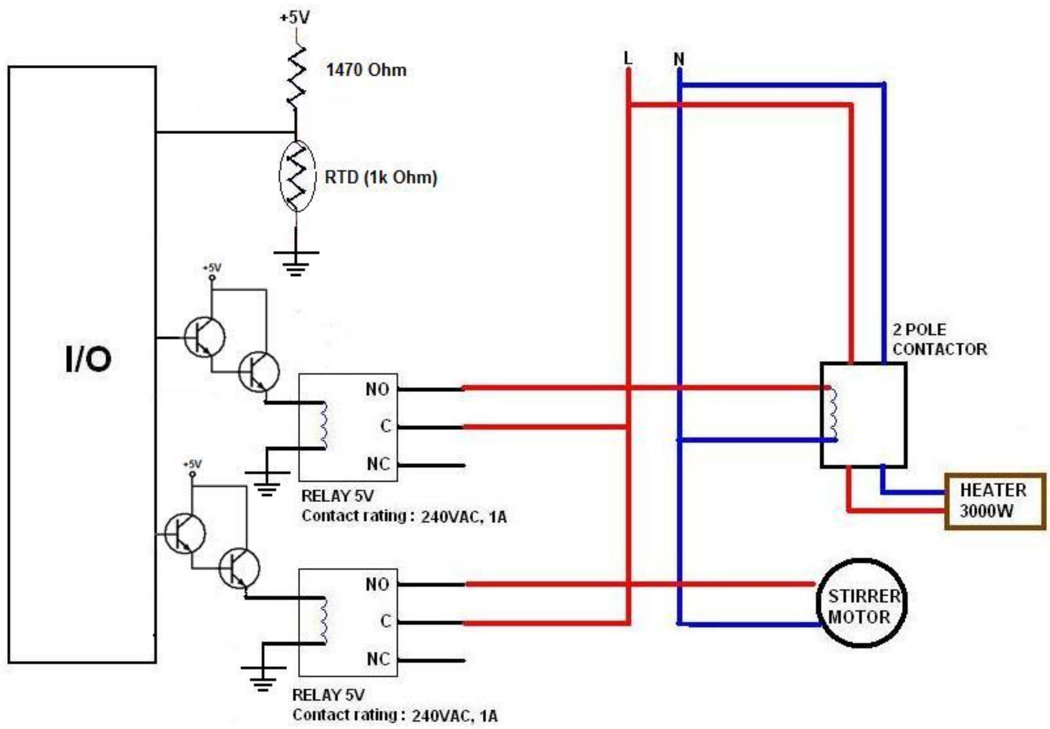

Figure 3.5: Schematic Diagram of the Interface Circuit

The temperature sensor used in this water bath system is RTD. The resistance in RTD would increase gradually as the temperature increase. The usage of this sensor is suitable as the temperature range in this water bath system is between 0 to 100 degree Celcius. Refer to Figure 3.5 the RTD is connected to a voltage divider circuit and the output is connected to analog input on NI USB 6008 device.

3.4 NI USB 6008

This module provides connection to eight analog input (AI) channels, two analog output (AO) channels, 12 digital input/output (DIO) channels, and a 32-bit counter when using a full-speed USB interface. Figure 3.6 illustrates the National Instruments Driver used in this project.

Figure 3.6: National Instruments Driver

The USB-6008 ships with one detachable screw terminal block for analog signals and one detachable screw terminal block for digital signals. These terminal blocks provide 16 connections that use 16 AWG to 28 AWG wire. Figure 3.7 shows the overall interface circuit for the system.

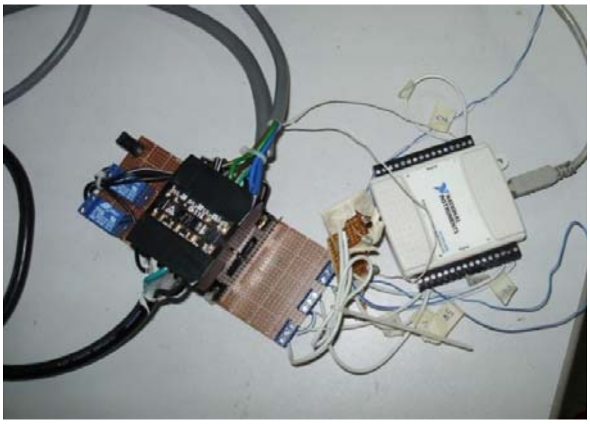

Figure 3.7: The Overall Interface Circuit including NI USB 6008.

3.5 Thermometer

Thermometer is used to read the current temperature in degree Celsius. In this project, thermometer in Figure 3.8 below is used to calibrate the temperature reading so that the exact temperature will be feed to the system.

Figure 3.8: Thermometer

CHAPTER 4

SOFTWARE DEVELOPMENT USING LABVIEW

4.1 Introduction

This chapter discussed on the software development using LABVIEW. From the flowchart in Figure 3.1 in the previous chapter, the software development can be separated into two parts, fuzzy logic controller and virtual environment. The details of each part will be explained further in section below.

4.2 Development of Fuzzy Logic

The RTD sensor, heater and stirrer in the system determine the input and output quantities of a fuzzy controller. Each quantity being measured provides information about the current process state.

Figure 4.1 shows the block diagram of the water bath temperature control system. It describes how fuzzy controller takes part in controlling the temperature.

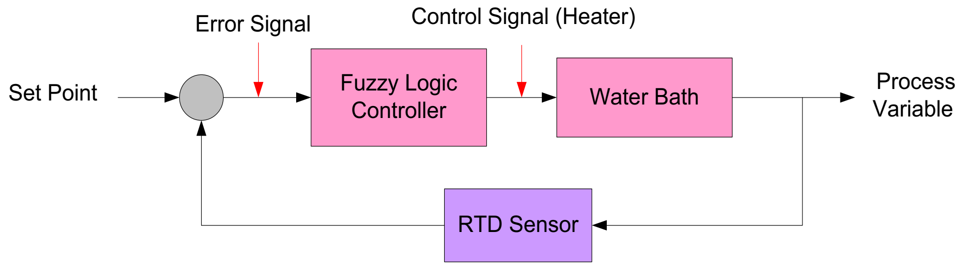

Figure 4.1: Block Diagram of the Water Bath Temperature Control System

In LABVIEW, the Project Manager front panel has a Project Description Field, indicated by the keyword description, where important project information can be entered. This description contains development ideas and other development information for the fuzzy controller.

The Fuzzy Logic Controls process the other entries, controller, date, and time. When the project is closed and saved for the first time, LABVIEW prompts to enter a project name, which then appears in the controller indication line of the Project Identification Field when open the next project. LABVIEW automatically calls the Fuzzy Set Editor when a new fuzzy logic project is created. Figure 4.2 shows the Project Manager Front Panel.

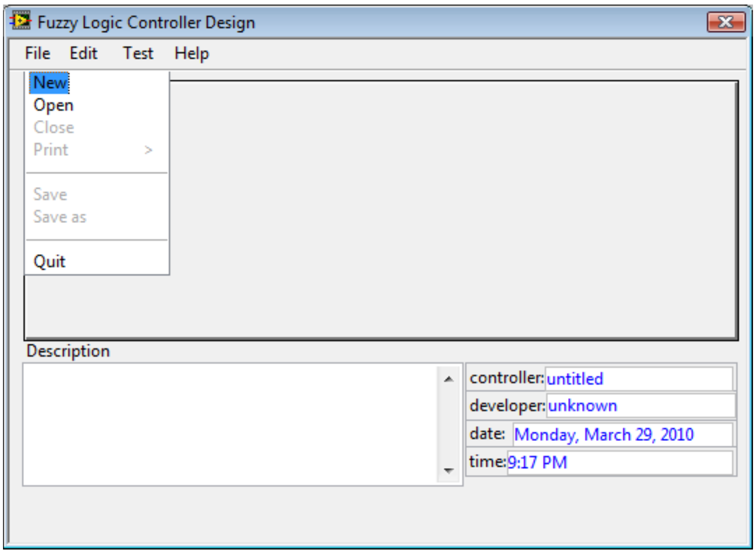

Figure 4.2: Project Manager Front Panel

4.2.1 Fuzzy Set

To design a fuzzy logic controller, the fuzzy variables need to be identified. In this case, there are one input and two outputs. Figure 4.3 below shows the configuration of the fuzzy controller.

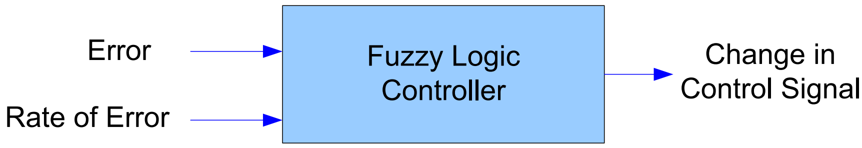

Figure 4.3: Configuration of the Fuzzy Controller

The input variables are the error in temperature of the liquid, $e(k) = r(k) - y(k)$, and the rate of change of error, $\Delta e(k) = e(k) - e(k-1)$., while the output variable is the change in the control signal, $\Delta u(k)$. Table 4.1 describes the linguistic term and label.

Table 4.1: Linguistic Term and Label

$\boldsymbol{e, \Delta e, and\ \Delta u}$	
Linguistic Term	**Label**
Negative	N
Zero	Z
Positive	P

The possible values of a linguistic variable are the linguistic terms which are linguistic interpretations of technical quantities. The temperature is measured in degree Celsius, have the linguistic interpretations *negative*, *zero*, and *positive*.

There are two input variables with the description Temperature Error setting as shown in Figure 4.4 and Rate of Error that illustrates in Figure 4.5. The input variable for Error ranges from -80.0 to 80.0. Each linguistic input variable is composed of three entirely overlapping linguistic terms. For Error, the linguistic terms NE1, ZE1, and PO1 are defined.

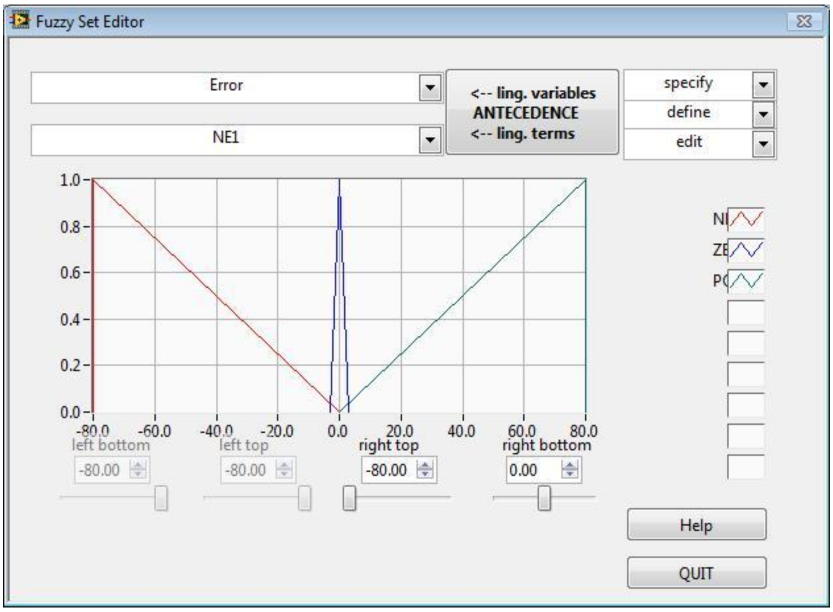

Figure 4.4: Error Setting

For Rate of Error, the linguistic terms NE2, ZE2, and PO2 are defined. The variables for Rate of Error setting range from -20.0 to 20.0. The three linguistic terms are overlapped wider than Error setting as depicted in Figure 4.5.

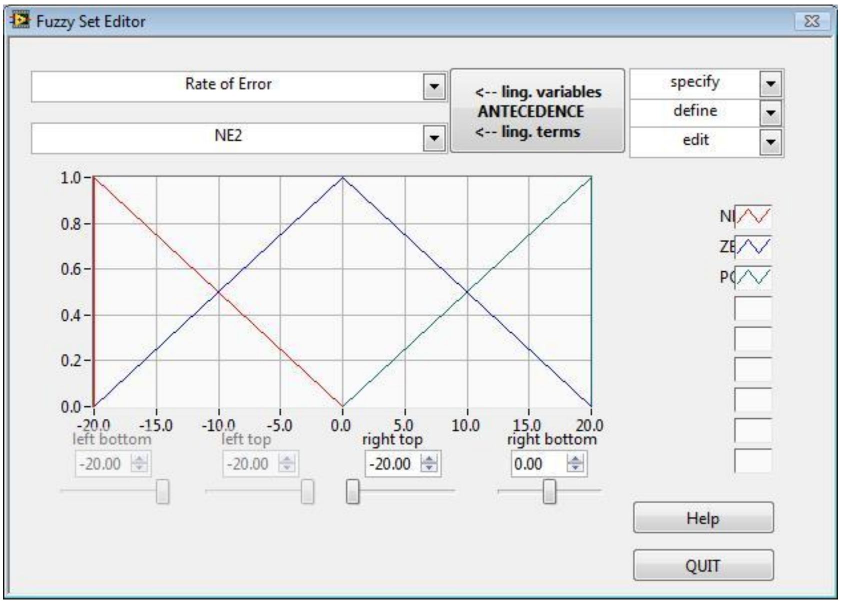

Figure 4.5: Rate of Error Setting

For the Consequence setting, the linguistic terms are assigned with Off, ZEo, and On. Each possible combination of linguistic terms for each of the input variables are assigned to a single rule with its consequence respectively as depicted in Figure 4.6. The membership function has been designed in such a way because the output of the fuzzy controller that needs to be controlled is stirrer and heater which give digital signal. So, there is no overlapping between the linguistic terms.

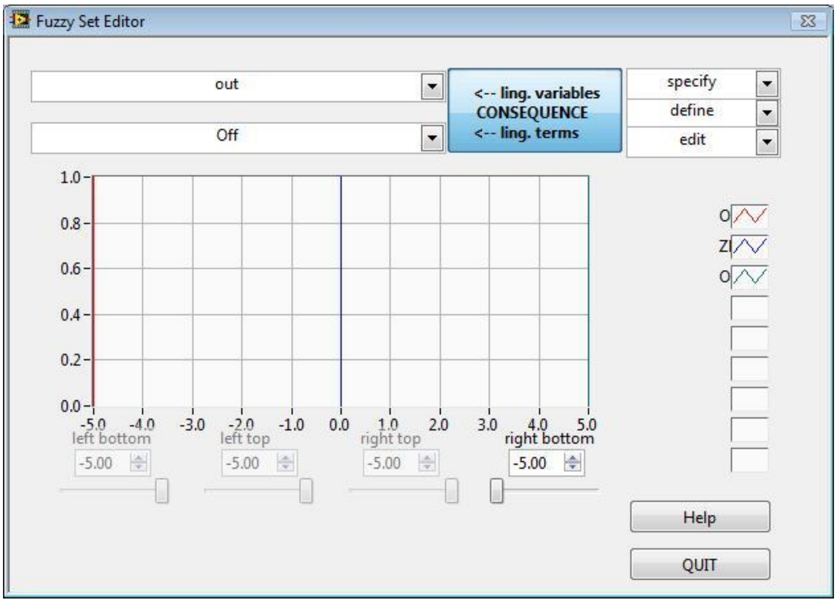

Figure 4.6: Consequence Setting

The universes of discourse need to be scaled correctly within the range of the respective variables. In this case, the scaling factor is 10000. They will act like gain control.

4.2.2 Rulebase

Every fuzzy logic system must have a rule base. The rule base is used to infer the actions that need to be taken based on the current conditions. Figure 4.7 shows the rule base for the control system.

From the Rulebase Editor front panel, the defuzzification method and inference method can be selected. In this case, Center of Gravity defuzzification and Max-min inference method are chosen.

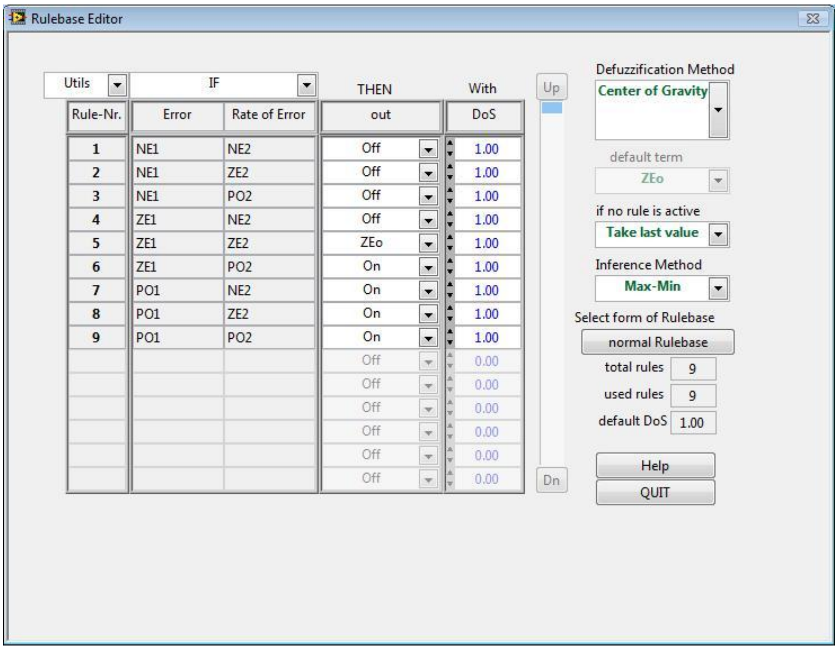

Figure 4.7: Water-Bath Complete Rule Based

The centre rule which is the steady-state rule can be written as follows:

IF Error in Temperature is about ZE1

AND the Derivative of Error is about ZE2

THEN the Change in Control Input is about ZEo

$$(IF\ e = ZE1\ AND\ \Delta e = ZE2\ THEN\ \Delta u = ZEo)$$

A rule can be written in triple form such as:

$$(ZE1, ZE2; ZEo)$$

A matrix of the rule base can be set up as shown in Figure 4.7. The second and the third column are the antecedents and the forth column in the matrix are the consequents. In many control application the Mamdani's max-min composition technique is largely used. An error reading that is observed will fire the appropriate rule or rules in the rule base. Max composition is used to determine if more than one of the same consequent resulted. This occurs when several rules are fired.

A defuzzification technique used to give a crisp output value. It is required to produce the actual signal that the plant can use. Thus, the fuzzy output value needs to be defuzzified. The output of the fuzzy controller is usually the change in the control signal. The actual control signal to the plant is thus:

$$u(k+1) = u(k) + \Delta u(k)$$

For centroid defuzzification, the value is given as follows:

$$z^* = \frac{\sum \mu_c\ z\ .z}{\sum \mu_c\ z}$$

The front panel of the water-bath control system for this project is shown in Figure 4.8. The desired temperature can be selected by key in the desired values. In addition, the current temperature can be monitored through the indicator shown. The response between the set point and process variable can be monitored in the waveform graph. While the block diagram of the overall process is depicted in Figure 4.9.

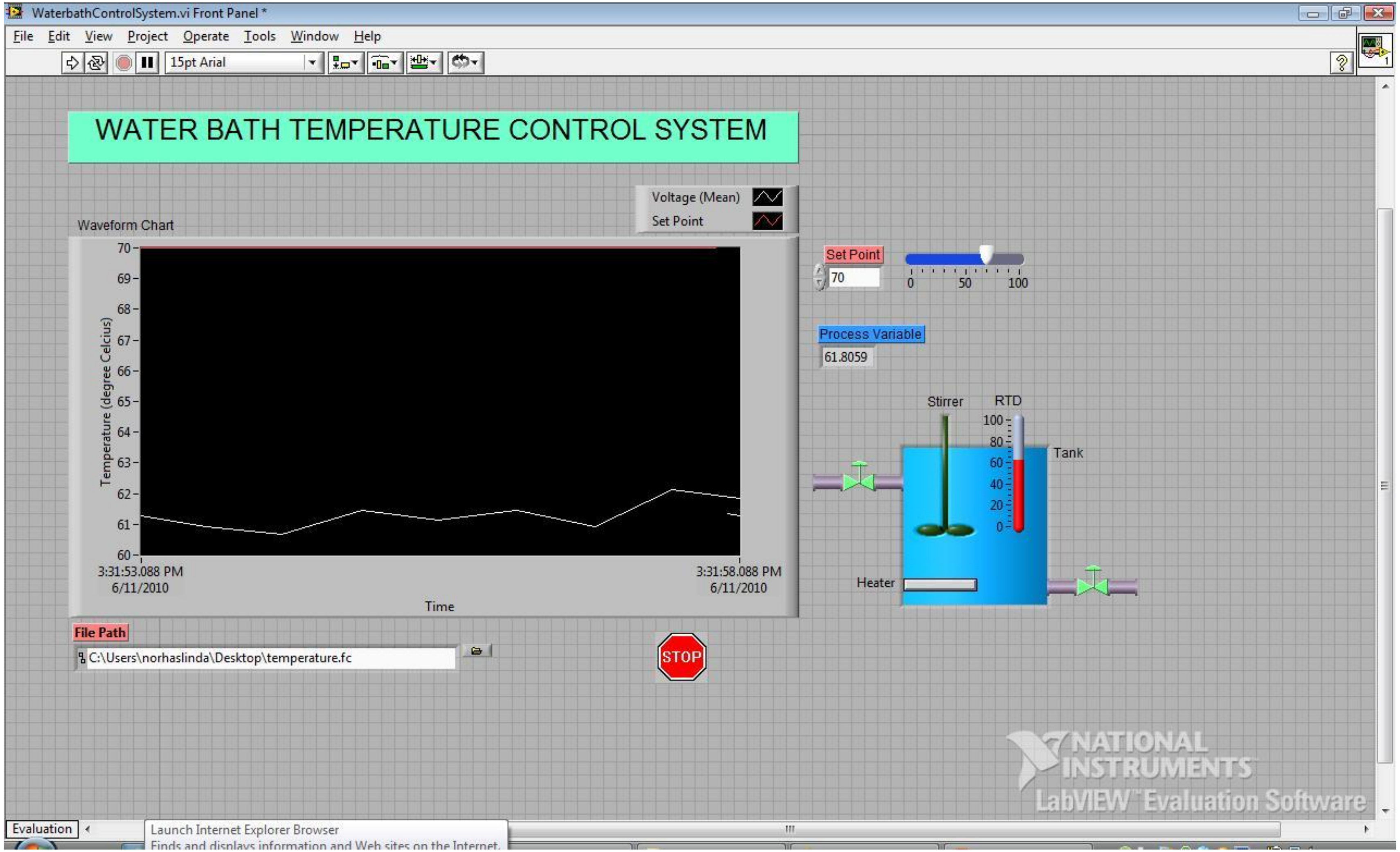

Figure 4.8: Front Panel of the Water Bath Temperature Control System

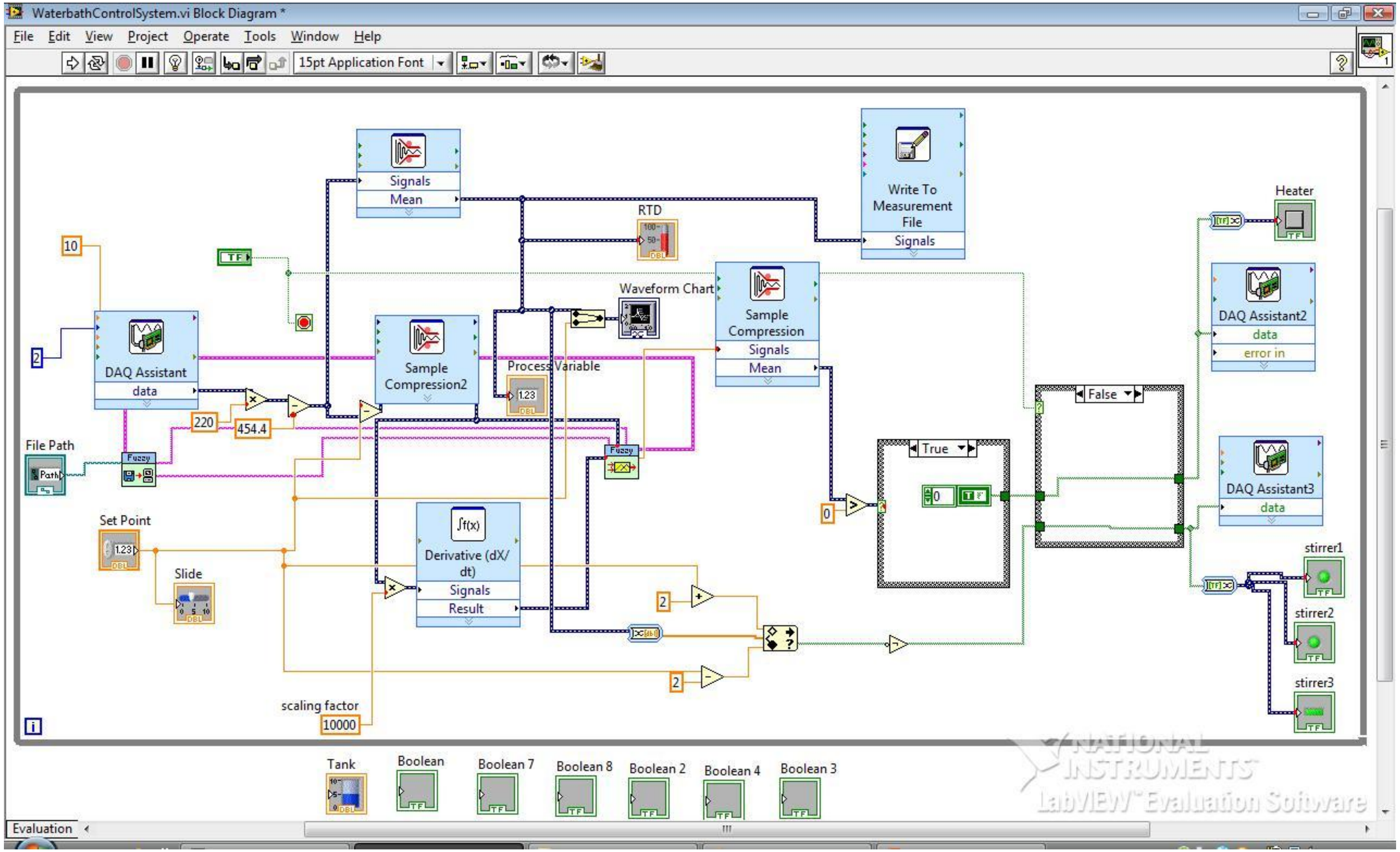

Figure 4.9: Block Diagram of the Water Bath Temperature Control System

4.3 Development of Virtual Environment

Before the GUI is published on the web, there are a few steps that need to be taken. The labVIEW Web Server need to be used to create HTML documents, publish front panel images on the Web, and embed VIs in a Web page. First Web Server must be enabled with the Web Publishing Tool as shown in Figure 4.10. Furthermore, the VIs must be in memory before being published.

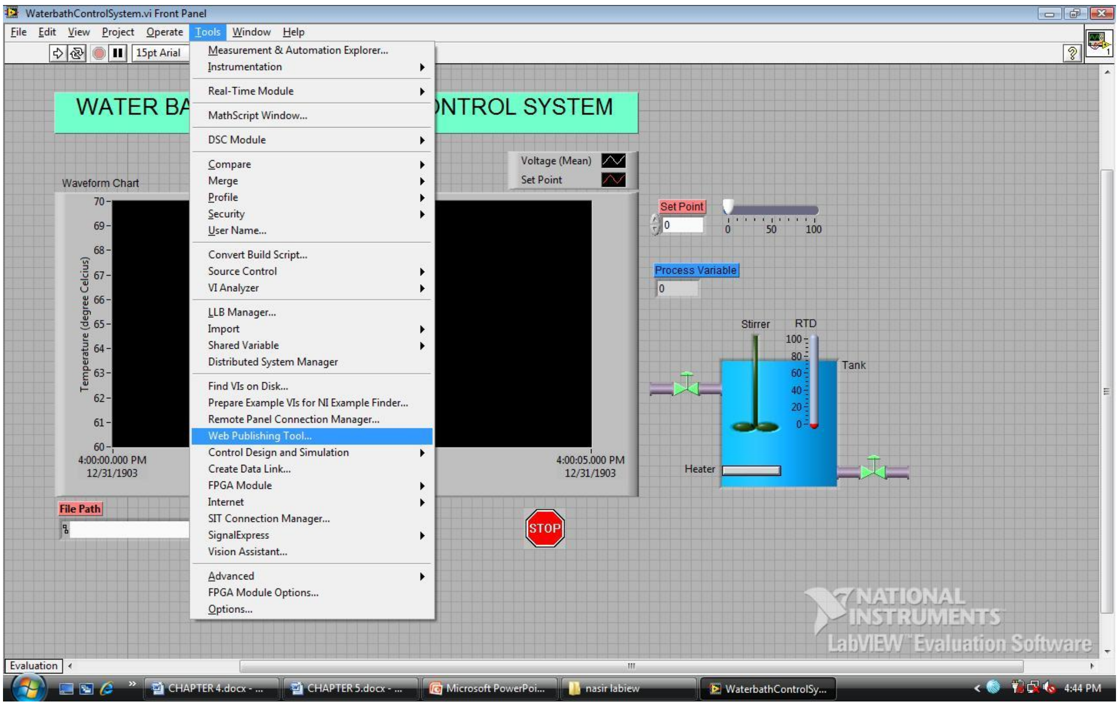

Figure 4.10: Web Publishing Tool Setting

In Web Publishing Tool, it will accomplish some tasks which are creating an HTML document and embed images of the front panel in an HTML document (but currently only Netscape browsers support animated images).

4.3.1 Publish GUI onto the Web

From Figure 4.11, Web Publishing Tool can also embed a VI that clients can view and control remotely, adding text above and below the embedded VI front panel image, place a border around an image or embedded VI, and preview the document.

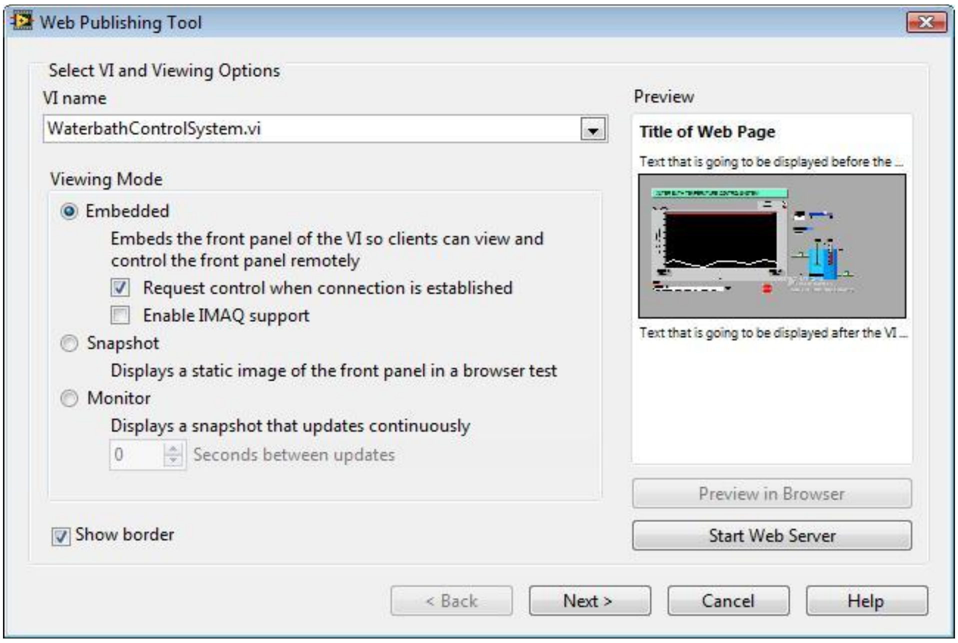

Figure 4.11: VI and Viewing Selection

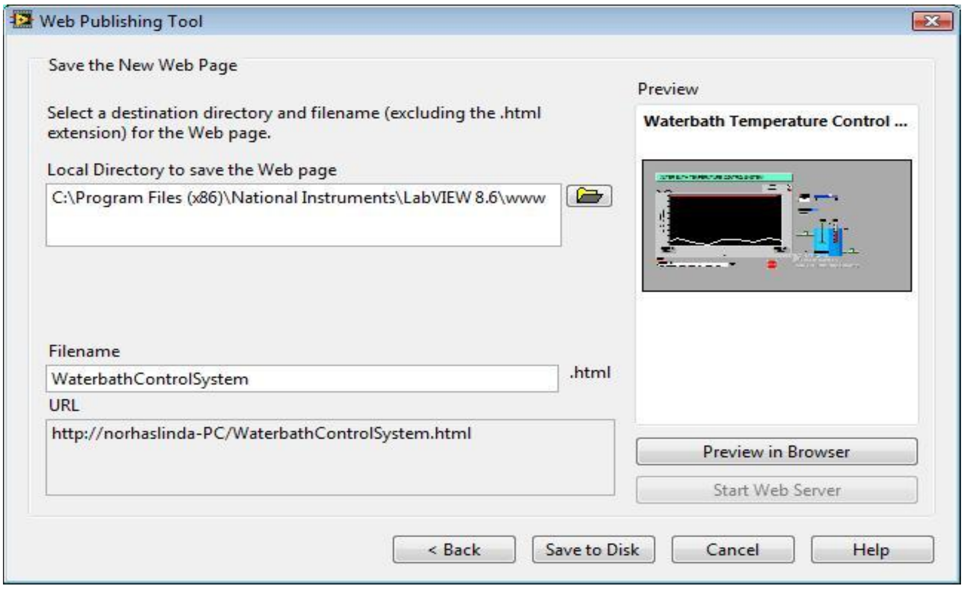

Figure 4.12: Web Page Destination Directory

Last but not least, it can save the document to disk and finally enable the Web Server for publishing HTML documents and front panel images on the Web. This can be seen in Figure 4.12. Figure 4.13 shows the URL address that will be needed to access the page from a browser.

Figure 4.13: URL Address for Water Bath System

A VI front panel can be viewed and controlled remotely, either from within LabVIEW or from within a Web browser, by connecting to the LabVIEW built-in Web Server. When the front panel is opened remotely from a client, the Web Server sends the front panel to the client, but the block diagram and all the subVIs remain on the server computer. The front panel can be interacted in the same way as if the VI were running on the client, except the block diagram executes on the server.

The server computer must first be configured before a client can view and control a front panel remotely using LabVIEW or a Web browser. By configuring the Web server, browser access to the server can be controlled and which front panels are visible remotely can be specified. In addition, it also can set a time limit on how long a remote client can control a VI when multiple clients are waiting to control the VI.

Multiple clients are allowed to connect simultaneously to the same front panel, but only one client can control the front panel at a time. The user at the server computer can regain control of any VI at any time. When the controller changes a value on the front panel, all client front panels reflect that change. However, client front panels do not reflect all changes. In general, client front panels do not reflect changes made to the display on front panel objects, but rather to the actual values in the front panel objects.

CHAPTER 5

RESULTS AND DISCUSSIONS

5.1 Fuzzy Logic Controller

The water bath temperature control system can be monitored and controlled remotely via internet. Any user can access to the server computer and the water bath temperature control system which are already setup in the lab, regardless of their geographical location, as long as they have computers, web browsers and internet connections. In addition, live experiment on the water bath temperature control system using Fuzzy controller is published in the website.

Based on the result that was obtained from the develop fuzzy logic controller using LABVIEW software, we can see that the fuzzy controller was able to identify the current temperature and try to achieve the desired set point that set by user.

All the data were collected and save automatically in Notepad. Then, the data were transferred in MATLAB software. By using the MATLAB software, all the useful data from Notepad were plot so that the waveform signal can be easily analyzed. The waveform signal when the set point was 50ºC is depicted in Figure 5.1.

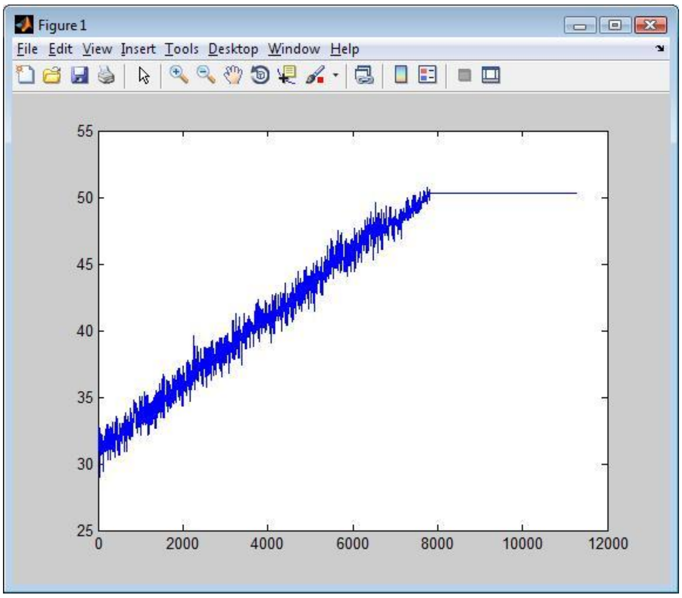

Figure 5.1: Set Point is 50ºC

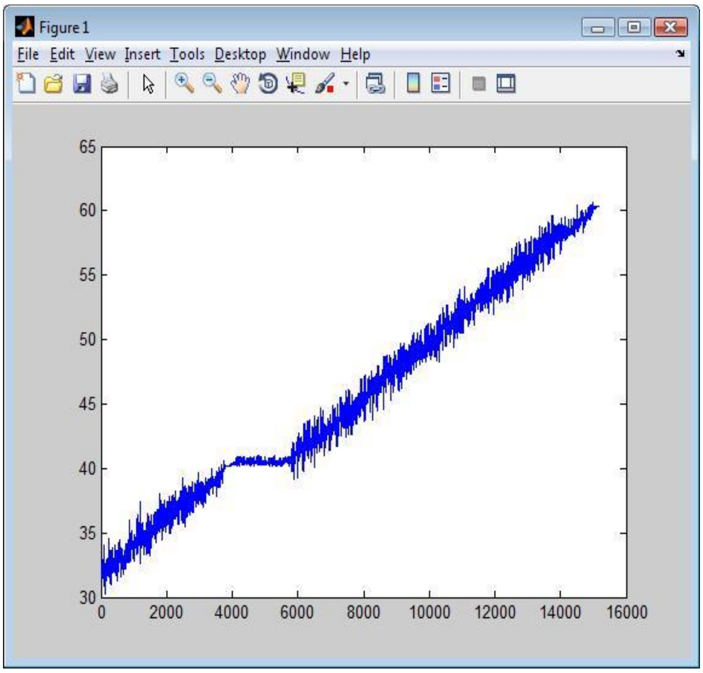

Figure 5.2: Set Point are 40ºC and 60 ºC

Figure 5.2 shows the signal waveform when the process set point was 40ºC. After five minutes the system reaches its set point, then the user change the set point to 60ºC. From 40ºC to 60ºC, generally, it takes about 10 to 15 minutes to the system to achieve its new set point. Set point 70ºC and 80ºC were set, and the waveform is as depicted in Figure 5.3.

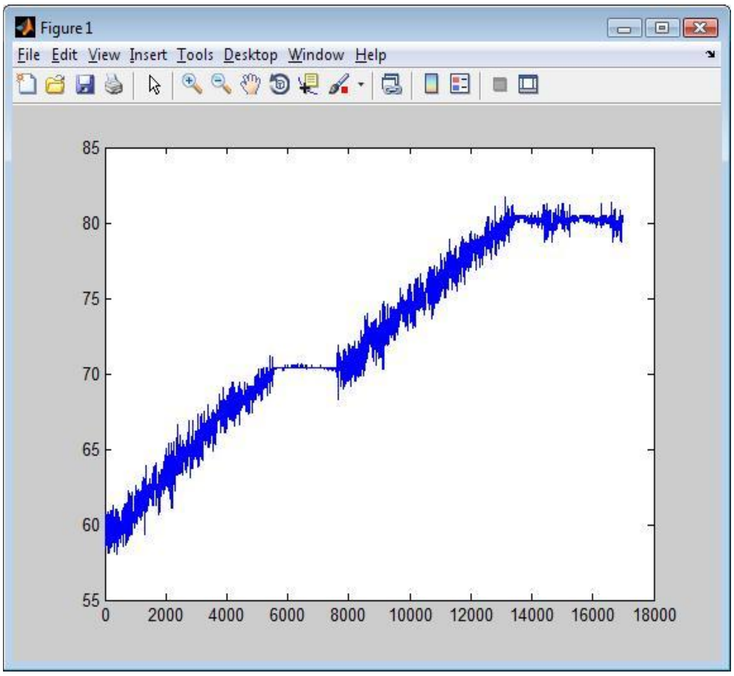

Figure 5.3: Set Point are 70ºC and 80 ºC

5.2 Virtual Laboratory Environment

This project has successfully developed the GUI for user interface. There are several parts on this project which are intentionally design to make user understand the functionality of this virtual laboratory and fuzzy logic application. Figure below shows the front panel of LABVIEW control system and the internet interfacing if the user uses the system remotely using internet.

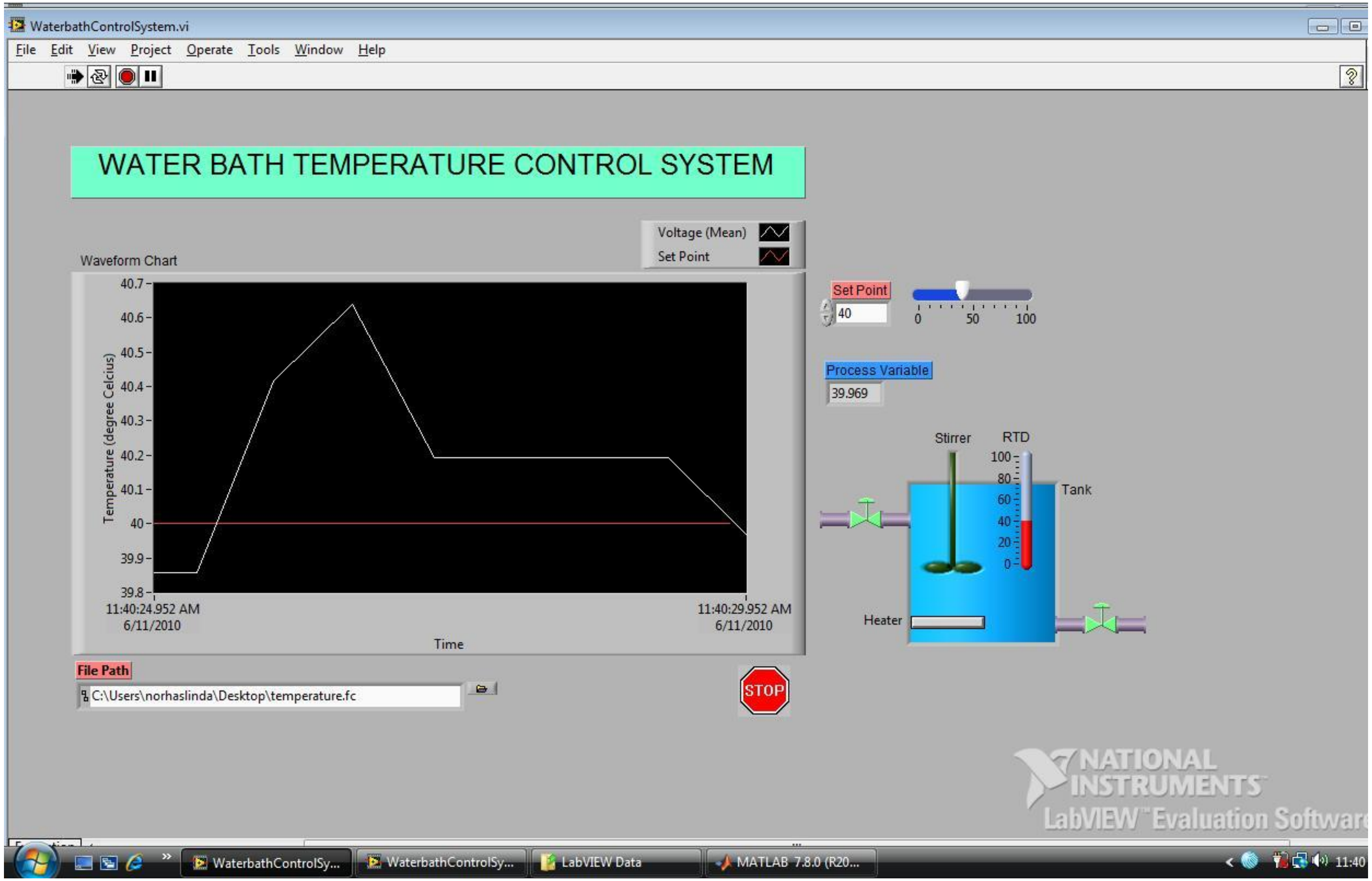

Figure 5.4: Front panel of the Water Bath Control System

CHAPTER 6

CONCLUSIONS AND FUTURE WORK

6.1 CONCLUSIONS

In conclusion, water bath, interfacing system and the server has been set up in the lab, where the water bath consists of the water tank itself, a temperature sensor (RTD), a heater and a stirrer. An interface system has also been mounted so that the water bath can be controlled through the server computer using the GUI module developed.

An internet based GUI module environment of a water bath temperature control system has successfully been developed using LABVIEW software and published onto the web where it can be fully controlled using Fuzzy Logic Controller developed, and monitored by any user despite of their geographical locations, as long as they have computers with web browsers and internet connection.

6.2 FUTURE WORK

This project can be further developed for better improvement. First, in order to minimize the chattering, the voltage divider circuit can be upgraded by adding a capacitor or an inductor. This can improve the signal waveform to be less noise.

Next, we can develop and publish more experiments regarding diverse controllers, namely PID control, Neuro-fuzzy controller and Neural-Network controller. Currently, we have Fuzzy Logic control experiments in the website. Hence, more experiments on other controllers should be developed and the present experiments in the e-learning website can also be further improved.

Last of all, more virtual laboratories for other control systems should be developed and added into the e-learning virtual laboratory website. For instance, a.c. motor speed control system and couple tank liquid level control system. A more complete and various virtual laboratories will promise a better virtual laboratory facility for teaching control system.

REFERENCES

1. Euan Lindsay, Dikai Liu, Steve Murray and David Lowe, "Remote Laboratories in Engineering Education: Trends in Students' Perceptions", Proceedings of the 2007 AaeE Conference, Melbourne.

2. V. Ramakrishnan, Y. Zhuang, S.Y. Hu, J.P. Chen, C.C. Ko, B.M. Chen and K.C. Tan, "Development of a Web-Based Laboratory for Control Experiments on a Coupled Tank Apparatus", *Proceedings of the 2000 American Control Conference, Vol. 6 pp. 4409 - 4413.*

3. C.C. Ko, B.M. Chen, S.H. Chen, V. Ramakrishnan, R. Chen, S.Y. Hu, Y. Zhuang, "A Large Scale Web-Based Virtual Oscilloscope Laboratory Experiment", *Enginering Science & Education Journal*, in press.

4. S.H. Chen, R. Chen, V. Ramakrishnan, S.Y. Hu, Y. Zhuang, C.C. Ko, B.M. Chen, "Development of Remote Laboratory Experimentation through Internet", Proceedings of the 1999 IEEE Hong Kong Symposium on Robotics and Control, Hong Kong, Volume II, pp.756 - 760, July 1999.

5. Hartmut Ewald and George F. Page, "Performing Experiments by Remote Control Using the Internet", Global J. of Engineering Education, Vol. 4, No.3, Australia.

6. Miladin Stefanovic, Vladimir Cvijetkovic, Milan Matijevic and Visnja Simic' "A LabVIEW-Based Remote Laboratory Experiments for Control Engineering Education", 2009 Wiley Periodicals, Inc.

7. L. M. Jimenez, R. Puerto, O. Reinoso, R. P. Neco, and C. Fernandez, "Remote Control Laboratory using Matlab and Simulink", IEEE International Symposium on Industrial Electronics, 2007, ISIE2007, June 4 - 7, 2007, pp 2963 - 2966.

8. Sanjib Das, L. N. Sharma and A. K. Gogoi, "Remote Communication Engineering through Internet", International Journal on Online Engineering, 2006.

9. Chi Chung Ko et. al., "A Web-Based Virtual Laboratory on a Frequency Modulation Experiment," IEEE Transactions on Systems, Man, and Cybernatics - Part C: Applications and Reviews, vol.31, No.3, pp.295-303, August 2001.

10. Ralph M. Ford, Jonathan Bondzie, and Paul Kitcho, "Java Applets for Microelectronics Education," IEEE Trans. on Education, vol. 44, No. 2, May 2001.

11. J. Sanchez, S. Dormido, R. Pastor, F. Morilla, "A Java/Matlab-Based Environment for Remote Controlled System Laboratories: Illustrated with an Inverted Pendulum," IEEE Trans. on Education, vol.47, No.3, pp.321-329, August 2004.

12. Nitin Swamy, Ognjen Kuljaca, and Frank L. Lewis, "Internet-Based Educational Control Systems Lab Using NetMeeting," IEEE Trans. on Education, vol. 45, No. 2, pp. 145-151, May 2002.

13. Kin Yeung and Jie Huang, "Development of a remote-Access Laboratory: A DC Motor Control Experiment," 2003

14. *LabVIEW 7 Express User Manual*, National Instruments, 2003.

15. *User Guide USB-6008/6009*, National Instruments, 2004.

16. LabVIEW PID Control Toolset User Manual, National Instruments, 2001.