

**AC 2009-2354: A PROJECT-ORIENTED APPROACH IN TEACHING ROBOTICS
APPLICATION ENGINEERING**

Yuqiu You, Morehead State University

A Project-oriented Approach in Teaching Robotics Application Engineering

I. Introduction

Automated robotic systems are critical components in implementing flexible manufacturing systems (FMS) which is the current trend for improving productivity and flexibility. Using robots in actual manufacturing platforms is a decision to improve flexibility and to increase the agility of the manufacturing process. To prepare students in the manufacturing technology program for their future careers in modern manufacturing companies, a new curriculum in Robotics Application Engineering has been developed and applied in the semester of spring 2008. This paper describes the course and laboratory of Robotics Application Engineering for students of manufacturing technology program (ITMT) in the Department of Industrial and Engineering Technology (IET).

There are four Robotics courses offered in the IET Department spanning from 100 level to 400 level to teach concepts, operation, programming, maintenance, interfacing, and application developments of industrial robots. Robotics Application Engineering is taught as a 400 level course for senior undergraduate students in the ITMT program. This course teaches engineering design of a specific robotics problem and implementation in the laboratory. Topics include industrial engineering techniques, hardware interfacing, software interfacing, and control devices for robotics applications. An interdisciplinary approach is used. The challenge in teaching this course is the integration of knowledge and skills from mechanical engineering, electronic engineering, and computer programming for students in manufacturing technology program.

In the Robotics Interfacing Engineering class, weekly labs are set up which account for the same amount of time as the lectures. The outcome of this curriculum is to help students to explore available equipment and technologies in industrial robotic applications, understand hardware and software interfaces, and gain skills in interfacing, programming, and communication techniques required in building industrial robotic applications. In this paper, the devices and software used in developing this new curriculum and the laboratory development are demonstrated.

The number of industrial robots used in actual manufacturing platforms is increasing therefore the students who graduate from the ITMT program are required not only to understand the operation and programming processes but also to have the knowledge and skills in robotics interfacing and application development^[1]. Most students in the IET department can better understand the topics if they can see how they work. Therefore, this course has been developed by using a project-oriented approach. The lectures and lab activities are concentrated at a robotic application project in which students need to apply what they have learnt in the class.

The textbook used for this course is *Industrial Robots Programming: building applications for the factories of the future* by Norberto Pires^[2]. The lectures mainly focus on industrial robot manipulators, control systems, software interfaces, interface devices and systems, and examples of manufacturing robotic systems. Students attending both lectures and labs will obtain better understanding of control systems, interfacing, system integration, programmable logic

controllers (PLCs), and industrial communication network. Students will also gain skills in application design, hardware interfacing, PLC programming, TCP/IP communication, and Visual Basic programming. There are seven lab activities developed for this course by applying various hardware and software in building robotic applications. This paper describes the lab activities with student feedback. The main objectives of the labs include: (1) know the important aspects of designing and building robotic manufacturing cells which include the capabilities of the actual industrial equipment and the available computer and software technologies; (2) know most of the industrial robotic equipment currently available including industrial robotic manipulators, control systems, and programming environments; (3) learn software interfaces that can be used to develop distributed industrial manufacturing cells; (4) understand the mechanisms and techniques used to interface robots with computers; (5) practice software interfacing with PLC programming and VB interfacing; and (6) know several available devices and systems that can be used to program, control, and supervise industrial robotic manufacturing cells.

II. Pedagogical design

As a technology-driven course, the Robotics Application Engineering class is focused on problem solving and skill acquisition. Since students in the ITMT program have a diversity background and understanding of electronics, computer technology, and computer programming, the lectures are designed to incorporate understanding contexts, engage with other learners, and apply the reflection/action education principles. Short, interruptive lectures are mixed with demonstrations, video clips, exercises, lab activities, and whole class involvement (problem solving and troubleshooting).

The course is concentrated at activities to design and build a specific robotic application. The class is divided into two groups with seven group members in each, and each group works on one project of building a robotic application. The lectures starts with an introduction to robotic control systems exploring different control systems that have been applied in industrial robotics applications. Then Programmable Logic Controllers (PLCs), the most popular controller that used in building industrial robotics applications, and PLC programming methods are introduced and demonstrated. Students practice with PLC programming on the Allen-Bradley Logix 1000 controllers for motor control in the lab after the lecture. After that, hardware interfacing methods are introduced and discussed in lectures. Students learn RSLinx for PLC interfacing, basic Visual Basic (VB) structure and coding, and DDE method used for interfacing between RSLinx and VB interface. Students also practice with these methods and skills in their lab activities. Manufacturing networks are then taught including different types of technologies and protocols that can be applied in industrial robotics communication. Software interfacing is the next topic covered in lectures discussing establishing TCP/IP server, image server, and wireless communication between a remote computer and the robotic systems. Students gain programming and interfacing experience from the lab activities and learn trouble-shooting and testing techniques with the guidance from the instructor. After all these lab activities, a prototype of a remote controlled robotic motion system has been constructed. At last, some modern manufacturing robotics application are introduced to the class such as speech interfaced industrial robotics application with advanced speech recognition and text-to-speech technologies, CAD program interfaced application with image process technology, and remote controlled robotic system with pocket-PC (PDA) control technology.

III. The robotic project

This course is project-oriented, and the project that students work with is constructing a simple prototype of a remote controlled robotic motion system. The hardware components of the system include two DC motors with two wheels, a AB logix 1000 controller, a laptop computer, a wireless hub, an Internet camera, and a wireless card. Software applied in this system include RSLinx for the communication between PLC and the laptop, VB applications for HMI interfaces, TCP/IP server for wireless communication, and image server for the camera. The physical set up of the motion control system is shown below in Figure 1.

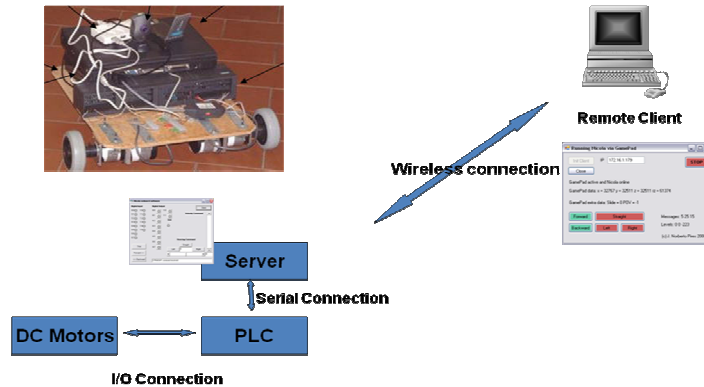


Figure 1: Physical Setup of the Robotic System

The system with wheels can then be controlled to complete movements like moving forward, moving backward, and making turns from a remote client computer with VB client application installed. And video stream from the camera can be viewed on the remote client computer through the communication between the image server and the image client.

By constructing this prototype, students explore different technologies across multiple disciplines and practice with techniques and skills that required in designing, programming, and constructing modern industrial robotics application.

IV Lab Activities

Lab 1: Design the prototype of your robotic system

The purpose of this lab is to define the major functions and features of the robotic system according to the instructor's requirements, design the prototype with available hardware and techniques and examine the available devices and technologies available for industrial robotic systems. Students create a 3D model of their robotic system in CAD and identify each hardware components in the system. As shown in Figure 2, the system include a power unit that consisting with DC motor (24V, 50W), planetary gearhead 25:1, and its control circuit, a PLC with input and output modules, a laptop computer, a wireless Ethernet card, an Internet camera, a USB hub, batteries, and two wheels.

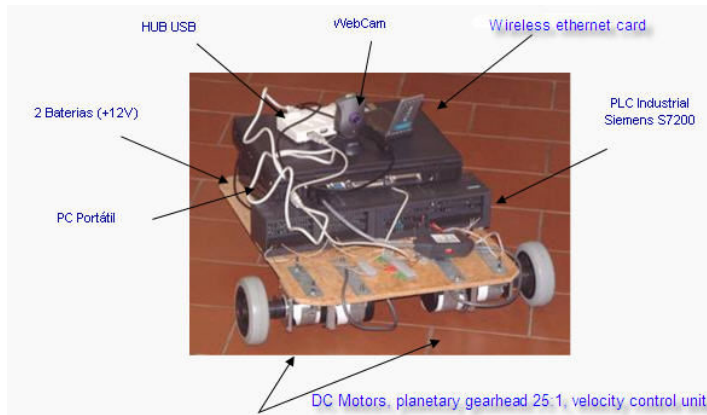


Figure 2: Robotic system prototype with components identified

Lab 2: Programming Motor Control with Micrologix 1000

The purpose of this lab is to understand the functions and I/O configuration of Micrologix 1000 controller, gain basic ladder logic programming skills, and understand logic operations in PLC programming. In this lab students first learn the skills on programming, running, and troubleshooting the controller from the hand-held programmer. Then, students wire the circuits for a simple motor control application, and run their PLC programs for this application. The equipment used in this lab include a power supply unit, DC motors, 1761-L32BWA Micrologix 1000 controller with hand-held programmer, limit switches and wiring tools. Figure 3 shows the wiring diagram for sinking input configuration on the Micrologix controller.

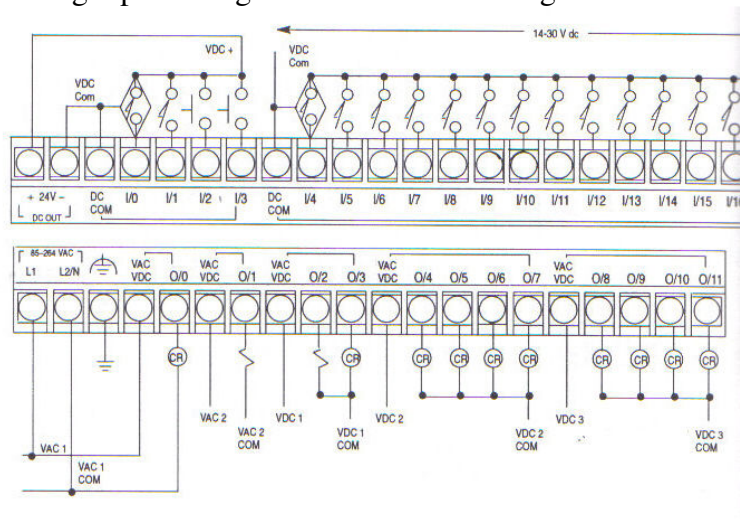


Figure 3: Wiring diagram
(courtesy of Rockwell Automation)

Lab 3: PLC programming for your robotic system (part one)

The purpose of this lab is for students to gain ladder logic programming experiences, and programming PLC for motion control with two DC motors. The functions of students' PLC program is to use limit switches to control two DC motors (two wheels of your robot) for following movements: Start / Stop; move forward and move backward. The equipment used in

this lab include a power supply unit, DC motors, 1761-L32BWA Micrologix 1000 controller with hand-held programmer, limit switches and wiring tools. Students need to design and draw the ladder logic program with input/output wiring, wire input/output devices to the controller, and enter the program into the PLC by HHP and verify the program.

Students wire two spring-return switches to the input module of the controller. Use the Power Supply A to supply a 15V VDC to each switch. The wiring diagram is as below:

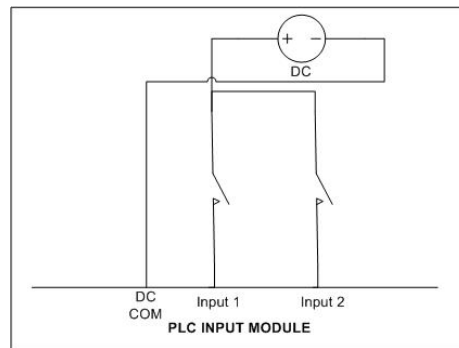


Figure 4: Input wiring diagram

Students then wire one DC motor to the output module of the controller. Use the 5V VDC power supply and the Power Supply B to supply a 5V VDC to the two circuits of motor control. The wiring diagram is as below:

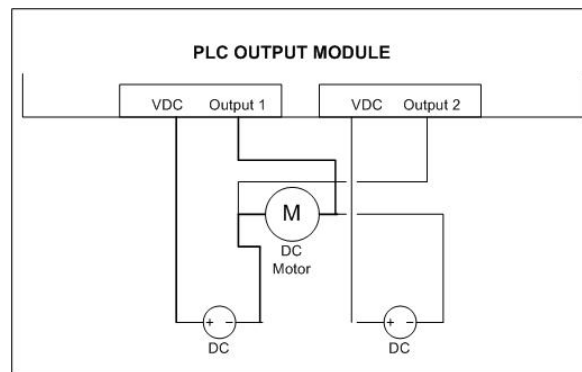


Figure 5: Output wiring diagram

Lab 4: PLC programming for your robotic system (part two)

The purpose of this lab is for students to keep programming the PLC program for their robotic system by applying timer instructions. The equipment used in this lab include a power supply unit, DC motors, 1761-L32BWA Micrologix 1000 controller with hand-held programmer, limit switches and wiring tools. The purpose of the program is to use Timer instructions in creating time delays for the motion control. Students wire one switch and one motor to the input/output module respectively, draw a ladder logic program to generate a 10s time delay before the motor starts, then enter the program into the controller.

In this lab, students have to totally understand PLC programming language and the functions of the controller used. For those students who have no experience with PLC, it takes longer for them to get the lab completed.

Lab 5: Building the physical setup of the robotic system

The purpose of this lab is for students to build the physical setup of their robotic systems including building the frame, assembling the wheels, wiring control circuits, and testing motors and their control programs. The equipment used include two HN-GH12-2412T DC motors, 1761-L32BWA Micrologix 1000 controller with hand-held programmer, spring-return switches, wiring tools and other materials for physical setup. To test the motors, students need to wire two spring-return switches to the input module of the controller, using the power supply A to supply a 15V VDC to each switch (refer to lab 4 instruction). And turn on the controller to make sure the controller get input signals from the switches after wiring. Then two motors are wired to the output module of the controller. Use power supply B to supply a 5V VDC to the two circuits of motor control. And students use the ladder logic program they created in Lab 4 to control the movement of the two DC motors.

In this lab, each group needs to submit a final CAD drawing of their system physical setup, complete the assembly of frames, wheels, hubs, and motors, a wiring diagram of their control circuits, and a diagram of their final PLC program for motion control.

Lab 6: VB programming for simple applications

Visual Basic is the most popular language used in industrial applications. The purpose of this lab is to learn the basics of Visual Basic Interface programming, understand the concepts of controls, objects, events, and event procedures, and gain experiences in GUI design and programming statements. Since most students in the ITMT program have little or none programming background, this lab is designed to help students understanding the control types, data types and logic structure of VB programming. A simple example is used in this lab to teach students how to create interfaces by VB programming. In this lab, instructions are given to students to construct a wage calculating application by VB programming. The control types that introduced to students are in the table below, and the sample codes that given to students for this lab are shown as in Figure 6.

Table 1: Control types in basic VB programming

Control Name	Control Type	Description
Label1	Label	Displays the message "Number of Hours Worked".
Label2	Label	Displays "Hourly Pay Rate"
Label3	Label	Displays "Gross Pay Earned"
txtHoursWorked	Text box	Allows the user to enter the number of hours worked.
txtPayRate	Text box	Allows the user to enter the hourly pay rate.
lblGrossPay	Label	Displays the gross pay, after the cmdCalcGrossPay button has been clicked.

cmdCalcGrossPay	Command button	When clicked, multiplies the number of hours worked by the hourly pay rate.
cmdClose	Command button	When clicked, ends the application.

```
'This procedure calculates and displays the gross pay.
Private Sub cmdCalcGrossPay_Click()
|   Dim sngPay As Single
|   'The next line calculates the gross pay.
|   sngPay = Val(txtHoursWorked.Text) * Val(txtPayRate.Text)
|   lblGrossPay.Caption = FormatCurrency(sngPay)
End Sub
```

```
'This procedure ends the application.
Private Sub cmdClose_Click()
End
End Sub
```

Figure 6: Sample codes for lab 6

It is difficult for students to totally master VB programming within 2 or 4 hours' lab sections. Some of them even still cannot understand the reason of learning programming in a manufacturing technology course. However, this lab gives students the opportunity to practice with simple interfacing between mechanical system and a PC computer, and gain experiences in hardware and software integration. Actually, most students show increasing interests in VB interfacing in and after this lab.

Lab 7: VB interfacing and RSLinx

The purpose of this lab is to learn the basics of Visual Basic Interface programming, understand the concepts of Dynamic Data Exchange (DDE) technology, know how to setup DDE link properties for VB text controls, and set up serial connection between a PC and the Micrologix controller. In this lab, RSLinx is used to support the communication between the laptop and the Micrologix controller. Students are required to setup and configure the communication between RSLinx and the Micrologix controller, create their VB interface for motor control, and test their VB program on their robotic system. Figure 7 shows a successful configuration of the RSLinx communication, and Figure 8 displays the configuration window.

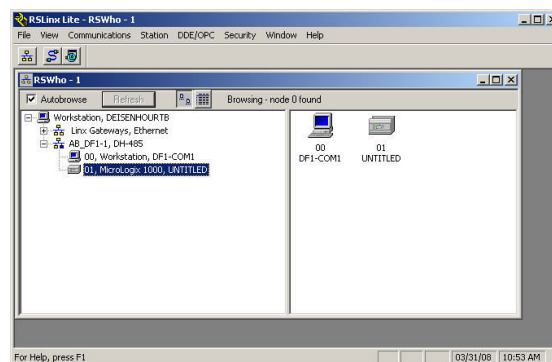


Figure 7: RSLinx interface

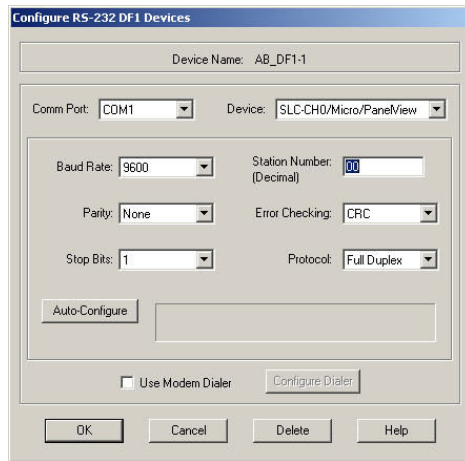


Figure 8: RSLinx configuration window

An example of students' VB interface for motor control is shown in Figure 9.

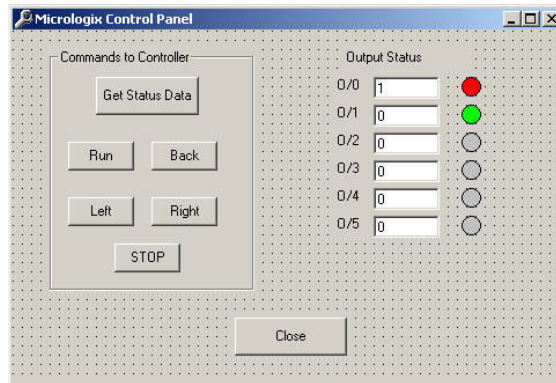


Figure 9: VB interface for motor control

In this lab, students are excited in working with programs and software applications. To improve their learning interest, the codes to implement DDE method have been given to the students. It is important for manufacturing students to understand programming method rather than make them feel frustrated in programming. The sample codes are shown below:

```

Private Sub Command1_Click()
Dim Input1 As Integer
Text1.LinkTopic = "RSLinx\My_Prog"
' Set the application name and topic name.
Text1.LinkItem = "N7:22/0"
' Set LinkItem.
Text1.LinkMode = 2
' Set LinkMode to manual.
Text1.LinkRequest
' Update text box.
Text1.Text = Input1
If Input1 = 0 Then

```

```

Shape1.FillColor = QBColor(12)
Else
Shape1.FillColor = QBColor(10)
End If
End Sub

```

Lab 8: TCP/IP server and the image server

The purpose of this lab is to establish the TCP/IP server for remote communication and the image server to get video stream from the camera. It is difficult for students in manufacturing technology program to understand and master all these contents in computer and networking technology. The lab is to provide experience for students to work with the TCP/IP server and the image server. Therefore, students have a broader view on how computer and networking technologies can be applied in industrial robotics applications, and have hands-on experience on working with the TCP/IP server and the image server. Procedures are given to each group to establish the TCP/IP server and the image server. Most students are very interested in the applications. The TCP/IP socket server interface is shown in Figure 10 below. The interfaces of the image server and client are shown in Figure 11 and Figure 12.

```

C:\G:\msdn_vision\Debug\socksrv2.exe
SOCKSRV-Vision 2.0 (C) J. Norberto Pires 2003
Listening on port 54321 with protocol TCP
Connecting to new client
Accepted connection from 127.0.0.1, port 2070
Received 26 bytes from client:
@SOURCE rita beatriz dina
Cmd = SOURCE
Par1 = rita
Par2 = beatriz
Par3 = dina
SOURCE - Command New Data
Command to VIDEO SOURCE: @SOURCE rita beatriz dina

```

Figure 10: The TCP/IP socket server interface

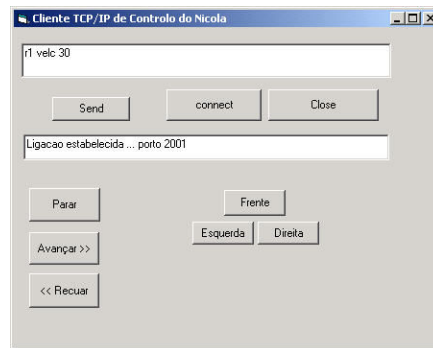


Figure 11: The image server interface

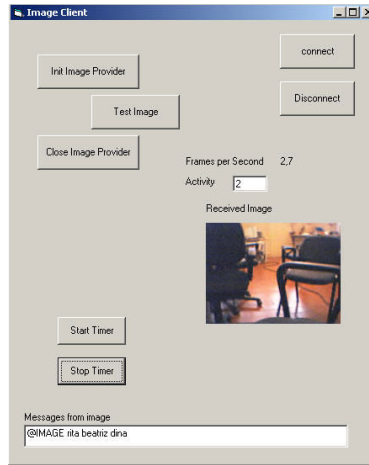


Figure 12: The image client interface

VI. Conclusions

A set of lab activities has been developed which can let students explore various technologies that have been applied in building industrial robotics applications, learn principles and theories in different technologies, practice with motion control, PLC programming, PLC interface, RSLinx configuration, and experience with computer and networking technologies like setting up the TCP/IP server and the image server. There are two groups working on two systems. One group has successfully implemented the system integration and achieved their goal, while the other group encountered some technical problems. However, feedback shows that these labs can motivate students' interest in industrial robotics, help them gain hands-on experiences in applying multiple disciplines. Here is the comment quoted from one of the students in the class:

“This class was a great hands-on learning experience. The robot project was a difficult project due to the time and the amount of different traits that must be used in completing the project. I believe I was able to learn more from this class than any of the other robotics classes.”

VII. References

- [1] Robert N. Bateson (2002), *Introduction to Control System Technology*, 7th Edition, Prentice Hall.
- [2] J. Norberto Pires (2007), *Industrial Robots Programming: Building applications for the factories of the future*, Springer Science and Business Media, LLC.