DEVELOPMENT OF A 3-AXIS ARTICULATED TYPE ROBOT ARM WITH A MOBILE PID CONTROLLER

This report submitted in accordance with requirement of the Universiti Teknikal Malaysia Melaka (UTeM) for the Bachelor Degree of Manufacturing Engineering (Robotic and Automation) (Hons.)

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2016

ABSTRAK

Projek ini memperkenalkan kaedah yang lebih cepat untuk membangunkan lengan robot dengan 3-paksi. Biasanya langkah dalam membangunkan lengan robot dengan 3-paksi adalah rumit dan memerlukan kemahiran professional seseornag. Dalam projek ini langkah yang mudah dan pantas diperkenalkan dengan menguna prototaip pesat dalam sistem terbenam. Laporan ini akan menerangkan kaedah-kaedah yang membina robot dalam tiga proses iaitu pembangunan perisian, pembangunan mekanikal dan pembangunan elektronik. Dalam projek ini, kawalan robot memberi tumpuan dan bukannya fungsinya. Matlab Simulink blok set akan digunakan dalam skim kawalan bersama-sama dengan Lubin Kerhuel blok set diperkenalkan oleh Mikrocip. Pada akhir projek, model fizikal lengan robot 3-paksi telah dibina dengan melibatkan teknik percetakan 3D dalam pembangunan mekanikal. Prestasi lengan robot akan diuji dan dianalisis untuk memastikan bahawa robot yang dibina boleh melakukan pelbagai gerakan dan mampu mencapai mana-mana lokasi yang diarah.

ABSTRACT

This project introduced a faster method to develop a 3-axis articulated robotic arm. As the old approach in developing an articulated robotic arm are complicated and needed professional skill, a simple and fast approach in applying the rapid prototyping in embedded system are applied. The report will explain on the method to develop the robotic arm in three main process that is the software development, mechanical development and electronic development. In this project, the control of the robot are focused instead of its application. Matlab Simulink block sets will be applied in the control scheme together with the Lubin Kerhuel block sets implemented by Microchips. At the end of the project, a physical model of 3-articulated robotic arm are fabricated. 3D printing technique are involved in the mechanical development. The performance of the robotic arm will then tested and analyzed to ensure that it can perform various standard motion and able to reach any possible pin pointed location without mistake.

DEDICATION

This report is dedicated to my beloved family, especially my mother and sister which give me spiritual support while I have hard time in completing the report and experiment. Thank you for giving me the best education you could. I hope my achievement in completing this report will complete the dream that all of those who have faith in me.

ACKNOWLEDGEMENT

This report becomes a reality with all the kind and support from different individual. There are numbers of people who I would like to extend my sincere thanks to them.

I am grateful and appreciate all the patient and afford that my supervisor Mr Shariman Bin Abdullah have given to me. With his wisdom, intelligent, knowledge and experience, he made me possible to complete this project in time. It was a pleasure working with him.

I would like to express my gratitude to all my friends, and colleagues at the University Teknikal Malaysia Melaka that provide information and did great encouragement to me in completing this project.

Foremost, I am highly indebted to my family who is always by my side when times I need them the most and give me practical and emotional support.

TABLE OF CONTENT

Abstrak i

Abstract ii

Dedication iii

Acknowledgement iv

Table of Content v

List of Table viii

List of Figures ix

CHAPTER 1: INTRODUCTION 1

1.1 Background 1

1.2 Problem Statement 2

1.3 Objective 3

1.4 Scope 3

CHAPTER 2: LITERATURE REVIEW 5

2.1 Introduction To Robot System 5

2.2 Type Of Robot 7

2.2.1 Articulated Robot 7

2.2 Application Of 3-Axis Articulated Robot 12

2.3 Power Source Selection- Electrical Versus Hydraulic 15

2.3.1 Electrical Power Source 16

2.3.2 Hydraulic Power Source 18

2.4 Implementation Of MATLAB Simulink In Robotic Field 21

2.5 Application Of PID Embedded Systems 26

2.5.1 PID Embedded Systems In Robotic Arm 27

2.5.1 PID Embedded Systems In DC Motor 28

2.5.2 PID Embedded Systems In Arduino 29

2.6 Implementation Of Rapid Prototyping 30

2.7 Summary 33

CHAPTER 3: METHODOLOGY 34

3.1 Overview 34

3.2 Project Flow Chart 34

3.2.1 Phase 1: Gather Information 38

3.2.2 Phase 2: Development Of 3-Axis Articulated Robot 38

3.2.3 Phase 3: Result And Recommendation 39

3.3 Electronic Development 40

3.3.1 Electric DC Geared Motor 43

3.3.2 Motor Driver 44

3.3.3 Digital Signal Peripheral Interface Controller (Dspic, DSC, Microcontroller) 47

3.4 Software Development 49

3.4.1 MATLAB Simulink 50

3.4.2 Lubin Kerhuel Block Set 53

3.5 Mechanical Development 56

3.5.1 Service And Maintenance Principle 56

3.5.3 Risk Analysis 56

3.5.4 Design For Manufacturability (DFM) 57

3.5.5 Material Selection 58

3.6 Expected Result 60

3.6.1 Extract And Analyzing Of Information 60

3.7 Summary 61

CHAPTER 4: RESULTS AND DISCUSSIONS 62

4.1 Hardware 62

4.1.1 Design And Fabrication 63

4.1.2 3D Printing 64

4.1.3 Test And Simulation 68

4.2 Software 73

4.2.1 Block Diagram 75

4.2.2 Performance 77

4.3 Discussion 78

4.4 Summary 78

CHAPTER 5: CONCLUSION AND SUGGESTION FOR FUTURE STUDY 79

5.1 Conclusion 79

5.2 Recommendation For Future Work 80

5.3 Sustainable Development 82

REFERENCES 83

LIST OF TABLE

Table 2.1: Summary of researches on articulated robot 9

Table 2.2 Summaries of 3-articulated robot development by different scholars 13

Table 2.3: Actuator comparison 15

Table 5.1: Density of materials 61

Table 5.2: Model information of parts 65

Table 5.3: System configuration blocks 69

Table 5.4: Operation blocks 70

LIST OF FIGURES

Figure2.1: A basic robot system 6

Figure 2.2: A 6-axis articulated robotic arm 8

Figure 2.3: 3-axis articulated robotic arm 12

Figure 2.4: An example of electrical drive system 17

Figure 2.5: Hydraulic cylinder system versus electric actuator system 19

Figure 2.6: The model of DC transit system drawn using MATLAB Simulink 21

Figure 2.7: Starting frequency of DC motor drive system simulated using MATLAB Simulink 22

Figure: 2.8: Comparison of currents between two systems simulated using MATLAB Simulink 22

Figure 2.9: The motor servo inputs and slider motion 23

Figure 2.10: Simulink model created using Simulink and QuaRC library 24

Figure 2.11: Trajectory of Qbot in Simulink simulation 25

Figure 2.12: A three-joint PUMA robot with decentralized PID controller 26

Figure 2.13: Flow chart of the PID embedded fan system 29

Figure 2.14: Result of introduction of RP in design cycle 31

Figure 3.1: Project flowchart for phase one 34

Figure 3.2: Project flowchart of phase two 35

Figure 3.3: Project flowchart of phase three 36

Figure 3.4: Schematic Diagram of the Electrical control circuit 40

Figure 3.5: A Planetary DC Geared Motor IG32E-05K 43

Figure 3.6: A 2Amp Motor Driver Shield, compatible with standard Arduino main board. 44

Figure 3.7: MD10C motor driver 45

Figure 3.8: A 40 Pins SKDS40A board 46

Figure 3.9: A dsPIC30F4011 microcontroller 47

Figure 3.10: Simulink Library Browser containing tools to operate Simulink. 50

Figure 3.11: Simulation result of a system represented in graphical method. 51

Figure 3.12: Rapid prototyping using Lubin Kerhuel blockset 53

Figure 3.13: The Design-material-process trilogy 56

Figure 3.14: Design of 3-axis articulated robotic arm 57

Figure 4.1: First motor bracket 62

Figure 4.2: Second motor bracket 63

Figure 4.3: Joint to connect motor and arm 63

Figure 4.4: Final product of the 3-axis articulated robot arm 64

Figure 4.5: Stress study for first motor bracket 66

Figure 4.6: Stress study for second motor bracket 67

Figure 4.7: Stress study for joint 68

Figure 4.8: Block diagram to control a motor 72

Figure 4.9: Settling time of the system 73

Figure 4.10: Rising time of the system 73

CHAPTER 1
INTRODUCTION

1.1 Background

The origin of the robot can be trace back to the 1500's. Leonardo da Vinci first designed a humanoid that could stand, move its arm independently, sit and several simple movements. The robot appeared as a knight in German-Italian medieval armor. However, the word robot is first used by Karel Čapek, a writer of the early 20th century in his science fiction play "Rossum's Universal Robots". The play arise the concept of robot, people start to imagine and create robot with different function. Various type of robot have been developed for example mobile robot, industrial robot, service robot, entertainment robot, medical robot, and military robot. Applications of robot are slowly occupied and involve into our daily life.

Today, the word robot stands for an intelligent programmable device operates by a computer or controller. The designs of robot are to replace human work or perform action that is impossible done by human. Therefore, repetitive and boring work, hazardous mission, long duration job and work in confined space can now be completed by using robot. Robotics refers to the technologies that involve every field that related to the design, development and control of the robot.

1.2 Problem Statement

Traditional controls of microcontroller require the user to perform a series of standard procedure. After identification of the problem, the programmer has to plan a solution to the problem using flowchart, then the steps on the flow chart are converted to a series of code. In the next step, the program is uploaded into the microcontroller. After that, translator will help in checking syntax error that may exist. Debugging will be the final process, debugging is a vital process in programming which include detecting, locating, correcting mistakes and run the program. The development process takes times and it is complicated. These development procedures require a person to understand the programming language. The programmer also has to possess characteristic like precise, carefulness, detail-oriented to avoid creating any error during the work.

Furthermore in the development of robotic arm, kinematic and dynamic analysis knowledge are required. Understanding of the drive system, robot control system, fabrication, programming and simulation knowledge are necessary. The development process involved a very large field. The development process shall be simplified to enable the rapid production of robotic arm.

Cost are another significant problem. When steps in development process are too many and field involve are too large, the cost in man power and resources are relatively higher.

1.3 Objective

An innovation of the previous prototyping method are necessary to make the process in fast pace. The method is called rapid prototyping. The objective of this research is

- To create a physical model of 3-axis articulated robotic arm.
- To analyses the data and position of each motor obtain from the experimental result in operating the 3-axis robotic arm.
- To achieve rapid prototyping in designing an embedded system by using block diagram.

1.4 Scope

In this project, the development of articulated robotic arm are limited up to 3-joint, that is three degree of freedom. Design of the robot is simple and based on the concept of conventional articulated robotic arm. The development process is primarily focusing on controlling the robot instead of its application. The steps in traditional programming of the microcontroller are being simplified. To achieve that, Lubin kerhuel blockset will be used together with MATLAB Simulink to control the robotic arm. Transformation of the block diagram into hex file will be done automatically without typing of programming code manually. The programming process will be much faster. Also, the joints of the robot will be designed to move in sequence instead of simultaneously to present the, accuracy of position the robot reach is the first thing to considered compare to advanced performance of the robot.

The robot are fabricated and meet the requirement of an articulated robotic arm. The application of the articulated robot is not limited. Hence, the robot will not be equiped with any end-effectors.

Also, the robotic arm are not necessary to be large. To allow easy operating, saving cost, at the same time permit the user to present the performance and extract the result, a robot with full arm length of one meter are enough for the job.

Futhermore, in this project the development field involving three sector of development field that is electronic development, software development and mechanical development. The field involved are too large that the simulation state will be skipped. A direct control of the robotic arm are achieved. Data that gain from actual performance from the robot are more reliable and easy to be recorded.

In a nutshell, the main purpose of this project is to accelerate the development process of articulated robotic arm which is programmable and physically functional. The robot will then be tested and analyzed at the end of the project to ensure successive and efficiency in PID control using block diagram.

CHAPTER 2
LITERATURE REVIEW

2.1 Introduction to robot system

As mentioned by Niku, Saeed (2010) in the book introduction to robotics, there are various classification and type of robotic arm such as Cartesian robot(3P), cylindrical robot (PRP), articulated robot (3R) and Spherical robot (P2R), each of them have different positioning mobility. Selective Compliance Assembly Robot Arm (SCARA) is one of the most common articulated robotic arm created under the guidance of Hiroshi Makino and it is widely used in assembly process.

With the cost of the robots are dwelling down these few year, it is very common that many manufacturing lines today are using robot to do assembly, packaging, inspection, welding and paint work.

Recent years, the robot systems replace human work by almost 50% stated in the International Journal of Innovative Research in Electrical, Electronics, Instrumentation and Control Engineering. Additional by P. Cigna et al, (1987), application of a COMAU 6-axis smart robot solved assemblies problem on motor vehicle doors, the robot can handled up to three different type of door at the same time which is cannot achieve by human. Also, loading and unloading of heavy work piece using an articulated robotic arm solve serious ergonomic problem in mechanical workshops.

As Mentioned by David Rivas et al, (2015) in the conference paper “BRACON control system for a robotic arm with 6 degrees of freedom for education systems”, a basic robot system consist of a controller computer connected with teach pendant to setup communication between human and robot, actuator to convert electrical energy to mechanical energy to perform work, mechanical arm as a manipulator driven by drivers, end of arm tooling or end effectors use to duplicate ability of human hand and sensor to extract information from the environment. Any additional device and equipment that is directly interfacing and communicate with the robot are included in the robot system.

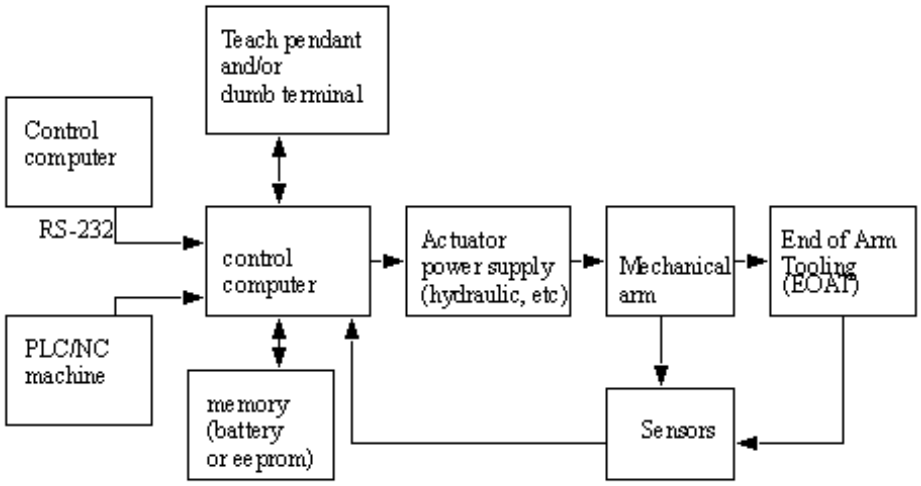


Figure 2.1: A basic robot system

(Source: <http://engineeronadisk.com/V2/book_integration/engineeronadisk-14.html>)

2.2 Type of robot

As mentioned previously, the 4 different type of robotic arm are Cartesian, cylindrical, articulated and spherical robot. However, most frequent used type of robotic arm is articulated robotic arm. Applications of robotic arm are limited due to their constraint in mobility. Further categories of robot type are stationary and mobile robot. The type of robot and their characteristic will be discussed in the following subtopic.

2.2.1 Articulated robot

Ganesan A et al, (2015) said that articulated robot also called jointed arm robot are robot with more than two rotary joints and can be up till 17 joints. The rotary joints in this type of robot allow full range of motion through multiple plans. For straight line motion along any of the three coordinate X, Y, Z axis, the robot require minimum of three joints. Due to all the joints are in rotation, the robot can perform very precise and exact movement compare to others type of robot. The robots also have two main variant, horizontal articulated robot and vertically articulated robot.

From what mention by S.Pachaiyappan et al, (2014) the main interest of articulated robot are to protect workers in confine space such as highly contaminated areas or hostile environments. As studied by Tian, Hao (2016), the advantages of robot are such as occupies minimum of floor space, achieve deep horizontal reach, high flexibility and dexterity. Extensive experiment have been carried out by using analytical method, providing an obstacle and use a machine learning method to compute an approximate model of their obstacle regions.

Articulated robotic arm imitate the ability of human arm, hence it replace most of the work done by human hand for example industrial application like inspection, assembles, pick and place application. Medical field are such as surgery and

rehabilitation purpose. Others purpose are assistance in entertainment and construction field.

An articulated robot design for inspection purpose in industrial called Articulated Inspection Arm (AIA), stated by S.Pachaiyappan et al, (2014). In the journal paper, design and development AIA with a hollow circular are done. The main function of the robot is to replace product inspection by human in extreme hazardous environment like in the nuclear power plant. Hence, the design of the robot must be able to withstand very high pressure and temperature. The research shown that circular section mechanical structure can withstand heavier load than hollow rectangular section AIA.

Another sample application of articulated robotic arm is surgical robot. Surgical robots are robot use in medical field, the robots require having very precise and safe performance. From the conference paper presented by Sung M. Seung et al, (2011) the robot contains two different end effectors. One is 5 DOF arm with gripper while another one is 4 DOF suction and injection end-effectors. These end effectors are small in size can guarantee a very safe workspace and low occurrence of error during surgery.

The evolution and improvement of articulated robot are happening every day. A table that summaries some example of next generation articulated robot is presented in next pages.

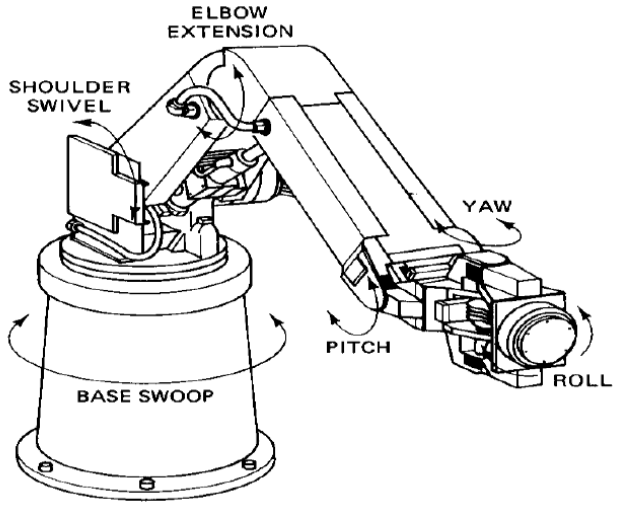


Figure 2.2: A 6-axis articulated robotic arm (S.Pachaiyappan et al, 2014)

Table 2.1: Summary of researches on articulated robot

Title	Robot type	Software used	Controller used	Applications field	Method
Design and analysis of an articulated robot arm for various industrial applications (S.Pachaiyappan et al, 2014)	Articulated Inspection Arm (AIA)	Solidworks, ANSYS	-	Industry (Inspection purpose)	Analytical calculation
Design and Control of 3-DOF Articulated Robotic Arm using LabVIEW and NI-myRIO (Ganesan A, 2015)	3-DOF Articulated Robotic Arm	LabVIEW	NI-myRIO	-	-
Microcontroller Based Robotic Arm (Mohammad Javed Ansari et al, 2014)	3-DOF and 5-DOF Articulated Robot	Proteus 8 Professional	ATmega8A	hazardous environment or accuracy task (Contain shadow mode & automatic mode)	Replica arm With potentiometer
Title	Robot type	Software used	Controller used	Applications	Method

Multi-DOF Counterbalance Mechanism for Low-Cost, Safe and Easy-Usable Robot Arm (Hwi-Su Kim et al, 2014)	3-DOF and 6-DOF Articulated Robot Arm	-	-	Serve for cost reduction, collision safety and easy teaching for the multi-DOF robot arm(Contain counterbalance mechanisms)	-
Development Of Upper Limb Rehabilitation Robot Prototype For Home Setting (Annisa J et al)	2-DOF Upper limb rehabilitation robot	AutoCAD 2007, Working Model	Funduino UNO model R3	Medical field (Stroke patients can continue the treatment safely at home)	Kinematic Analysis
Development of Manipulator including Exchange-type Multi-articulated End-effectors for Single Port Surgical Robot (Sung M. Seung et al, 2011)	4-DOF surgical robot	-	10 EA MAXON's EPOS controllers	Surgery (Generated errors during surgery could be reduced)	Kinematics and Workspace Analysis
Development of a Micro Transfer Arm for a Microfactory (Hitoshi Maekawa and Kiyoshi Komoriya, 2001)	4-DOF SCARA type micro transfer arm robot	-	-	Industry (achieving transfer and assemble tasks in the Microfactory)	Positioning Accuracy
Design, Fabrication and	2-DOF Robotic	ANSYS,	-	Entertainment or	-

Application of Arm Wrestling Robot (Zhen Gao et al, 2006)	Arm	Visual C++6.0		physical exercise	
Automatic Real-World Assembly of Machine-Designed Structures (Luzius Brodbeck and Fumiya Iida ,2014)	Articulated Robotic Arm	-	-	Various field (design and construct structures reaching outside the robot's range, improve the physical adaptability Of robotic systems.)	Fitness Function
A Study on Motion Adaptation against Robot Structure Changes (Yuki Funabora, 2009)	3,4,5-DOF Robot Arm	-	-	Various field	Estimation by Kriging

2.2 Application of 3-axis articulated robot

A 3-axis articulated robot represents an articulated robot with 3 degree of freedom (DOF). There is 3 independent ways the robot can move without violating any constraint imposed on it, stated by Ganesan A at el. (2015). by referring research paper of Mohammad Jived Ansari (2014) a 3 DOF articulated robot used 3 motor, the number of DOF is equal to the number of motor. The control of the robot achieved using microcontroller ATmega8A. The robotic arm is respond to gesture and can be programmed to move in desire path. These designs contain 2 mode that is shadow mode and automatic mode. The design help improve the function of robotic arm in various field included medicine, education, military, research and manufacturing. Another journal prepared by Gamesman A et al. (2015). Implemented LabVIEW and my-RIO to 3-axis articulated robot control. This idea opens a new variation to control an articulated robot. The processer used in the research is NI-myRIO that is capable to acquire and process real time signals, providing connection between the computer and the robotic arm.

Due to the long reach and multiple degrees of freedom, 3-axis articulated robots are used in assembling. As mentioned in journal of C. Johansson and N. Mhrtensson (1987), an example of 3-axis articulated PUMA robot is designed to have high accuracy; good acceleration and deceleration are used in assembly work.

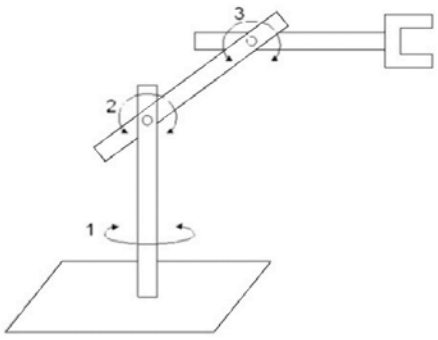
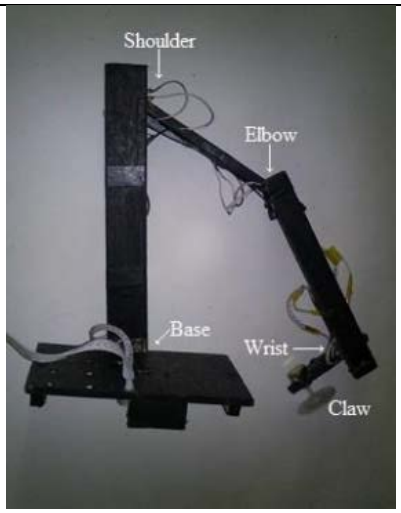
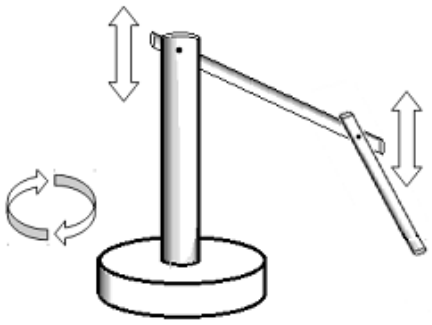


Figure 2.3: 3-axis articulated robotic arm

Table 2.2: Summaries of 3-articulated robot development by different scholars

Type of 3-DOF Robot	Processor/Controller	Characteristic	Target Application field
 Microcontroller based robotic arm (Mohammad Javed Ansari, 2014)	ATmega8A	Able to replicate the movements of the Replica Arm, providing gesture movement or in Automatic mode	Medicine, education, military, research and manufacturing
 3-DOF Articulated Robotic Arm using LabVIEW and NI-myRIO (Ganesan A, 2015)	my-RIO	Control using LabVIEW and my-RIO	Any kind of hazardous environments, mining, and many such industrial, medical Fields.