Enhancing College of Technology and Engineering Technology Programs with Industrial Robotics Concentration

Dr. Maged Mikhail, Purdue University Northwest

Dr. Maged B.Mikhail, Assistant Professor, Mechatronics Engineering Technology Ph.D., Electrical Engineering, Tennessee State University, Nashville, Tennessee, August 2013. Dissertation title: ”Development of Integrated Decision Fusion Software System For Aircraft Structural Health Monitoring” M.S., Electrical Engineering, Tennessee State University, Nashville, Tennessee, May 2009. Thesis title: ”Development of Software System for Control and Coordination of Tasks among Mobile Robot and Robotic Arm.” B.S., Electrical Engineering University of El Mina Cairo, Egypt, May 2001.

Enhancing College of Technology and Engineering Technology Programs with an Industrial Robotics Concentration

Abstract

Robotic accomplishments can enable businesses\ industries to improve performance, by reducing errors and improving quality and speed, and in some cases achieving outcomes that go beyond human capabilities. Robotics also contributes to productivity, as it has done historically [1, 2].

In today's highly automated manufacturing environment it would beneficial to have a concentration program in robotics that can be taken by Mechanical Engineering Technology, Electrical Engineering Technology or Mechatronics Engineering Technology majors.

The mission of the Robotics concentration is to conduct world-class research and teaching to train future generations of thinkers and creators.

Robotics concentration students at [University Name] will be a part of an intellectually stimulating environment where they will participate in project-based courses and are encouraged to make high-impact contributions to research.

The undergraduate Robotics concentration is designed to help students meet their professional objectives. Each course in this concentration contains a significant level of robotics and automation principles for high-demand occupational areas. Students choose to use this certificate as a career preparation tool for entry into employment.

The robotics concentration consists of a four course sequence starting from Programmable Logic Controllers (PLC) followed by Programming Industrial Robot (PIR), then Integrated Robot Systems (IRS).The fourth course comes from the students' primary area, focusing on robotics sub-system. The details of each course including hardware/software that are been used for each course will be disused in this paper.

Background

[University Name] is a regional university located in Hammond, Indiana (30 miles south of downtown Chicago). Owing to Chicagoland's rich heritage in industrial processing and manufacturing, PNW is and has been uniquely positioned to prepare its students for engineering and technology roles throughout these industries. However, the College of Technology (COT) as a part of PNW has recognized, in recent years, that experience with robotics and hands-on courses with automation are missing in the curriculum and program of study. Having robotics courses in the curriculum is very important due to the rapidly changing landscape of industrial manufacturing, automation control, and networking technologies. In consultation with some of PNW's industrial partners, PNW has identified that courses in robotics are crucial for engineering technology students and will provide them with the skills that are needed for the workforce. Through PNW's commitment to quality teaching and providing the best learning experience to the students, the robotics laboratory was created and equipped with several FANUC industrial robots. In the near future, classroom computers will have FANUC Robotics ROBOGUIDE simulation software

available for students to practice as well. The creation of the robotics concentration is the last step to maximizing the use of the robots and meeting industrial demands for the benefit of the students [3,4].

Introduction

Industrial automation involves the use of machines to perform manufacturing processes with levels of speed, precision, consistency, and stamina beyond the capacity of any human worker. The main advantages of automation consist of reduced production costs, improved quality and reliability, and decreased waste. Although the implementation of machines in the industry is nothing new, the implementation of robots into the manufacturing industry is. Not too long ago robots were seen as a just a futuristic concept, but after years of rapid technological advances, they are now useful and reliable. Today, a robot can be described as a flexible and reprogrammable machine with a multi-functional manipulator that is designed to perform a variety of operations. Robots can work in hazardous environments and perform jobs that are boring, repetitive, and difficult for humans to complete. Many new job positions are created that involve the integration, operation, design, and maintenance of robots. The use of robots in the industry has increased substantially over the past few years due to the ever-increasing applications they can be used for. The robotics industry is currently on its third generation of advancement. In this generation there is a demand for harvesting, navigation, medical, and personal robots. The demand for robots with artificial intelligence is also increasing among many others [5]. In order for Purdue University Northwest students to stay on track with industrial demands, it is crucial to offer them a robotics concentration program. Since the uses for robots are constantly expanding and evolving into virtually every field, it is beneficial for engineering technology students to be prepared for the future. Exposing students to industrial robots will help them be prepared for employment in the robotics industry and enable students to make educated decisions when dealing with robots in their careers. The industry is looking for robotics graduates with the skills for programming and integrating a robotic system. Engineering technology students study various engineering disciplines such as mechanical, electrical, and computer engineering. Robots combine several of these engineering disciplines and having a concentration about them ensures that students apply and combine concepts that were taught in other courses. Providing hands-on courses allows students to gain valuable experience. The certificates that the students will obtain through the completion of the concentration are indispensable. Students will be proud of their achievement and can use the certificates to find employment in industries that use robots. Graduates can find abundant employment opportunities in automotive and aerospace manufacturing, machine tool companies, the packaging industry, system integrators, nuclear power companies, and robotic manufacturers [6, 7].

Overview

Since 2010, the demand for industrial robots has accelerated considerably due to the ongoing trend toward automation and continued innovative technical improvements in industrial robots. According to the International Federation of Robotics (IFR) statistical department,

“Between 2011 and 2016, the average robot sales increase was at 12% per year (compound annual growth rate (CAGR)). The number of robot installations had never increased so heavily before. Between 2005 and 2008, the average annual number of robots sold was about 115, 000 units. 2009 is excluded because of the global economic and financial crisis, which caused an exceptional plunge in robot sales that year. In 2010, robot investments, which had been restrained in 2009, were the main driver of the significant increase. Between 2011 and 2016, the average annual supply rose to about 212,000 units.” This is an increase of about 84% compared to the average annual supply between 2005 and 2008 and a clear indication of the tremendous rise in demand for industrial robots worldwide as shown in Figure 1.

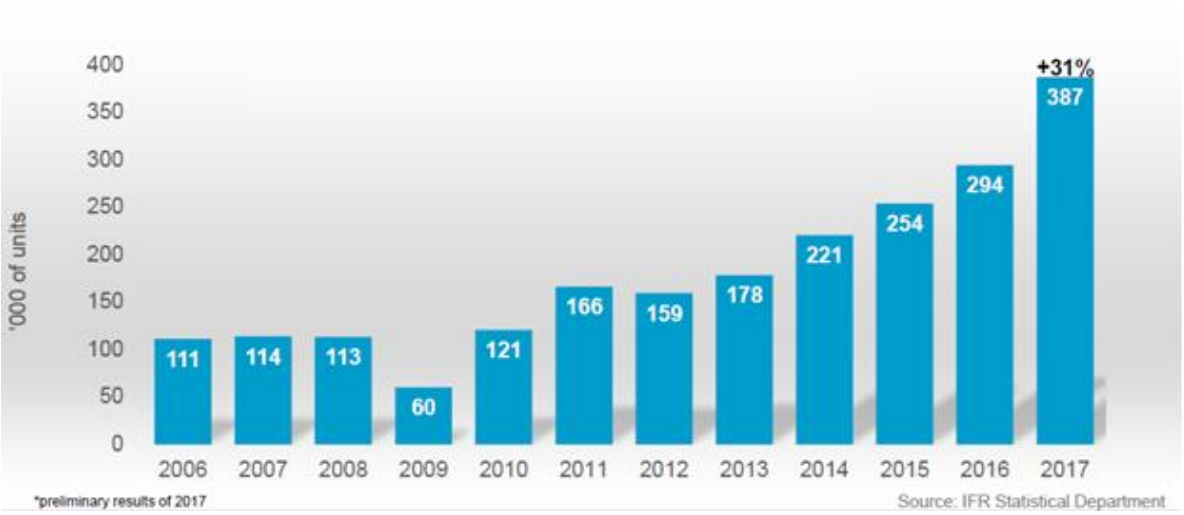

Figure 1: Estimated worldwide annual shipments of industrial robots between 2006-2017 [8].

Figure 2 shows the annual supply of industrial robots by industries between 2015 and 2017. This figure clearly shows that there was an increase in demand in all the major industries. In 2017 there was a record growth for industrial robots with the highest demanding industries being the automotive (+21%) and electrical (+27%) sectors. The metal industry saw the highest increase of 54% in 2017 from 2016. Figure 3 also shows the growth of industrial robots by region, with Asia/Australia having a significant increase in the past few years. Although the growth in the Americas has been relatively low, there is still a steady increase. This statistical data provided by the IFR Statistical department make it clear that the demand for industrial robots is increasing and is expected to continue increasing over the next few years.

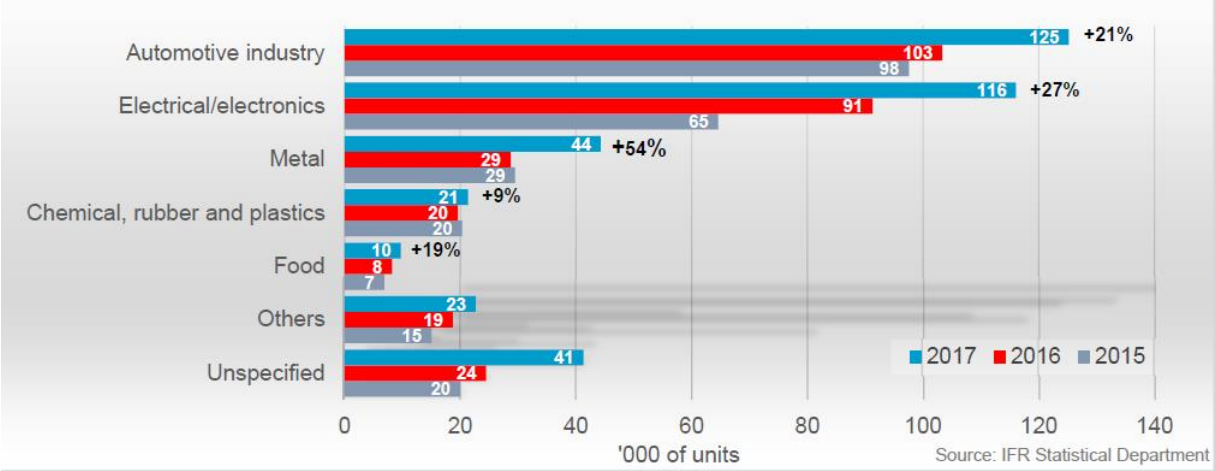

Figure 2: Estimated annual supply of industrial robots by industries worldwide 2015-2017 [9].

The statistical that was provided above stresses the need for a robotics concentration. Purdue University Northwest can provide Engineering Technology students with this concentration to meet the demand for graduates with robotic skills in industries. Based on the enrollment rates over the last three semesters that a robotics course has been offered, it is clear that there is increasing demand from students as well. The steady growth in enrollment has shown that students want to learn about robots and recognize that robots are the future. Having a robotics concentration at PNW impacts the students and the industries in the area positively. The robotics concentration is going to attract more students to the university and will further increase the enrollment of each course.

	Semester	**Students Enrolled**
1	Summer 2017	13
2	Spring 2018	15
3	Fall 2018	21

Graduates of robotics-related programs often work in the field of engineering. The U.S. Bureau of Labor Statistics (www.bls.gov) expects employment in engineering to grow at an average rate from 2016-2026, with mechanical engineering positions expected to increase by an estimated 9%, and electrical/electronics engineers by 7%. Many old manufacturing techniques will need to be replaced by new robotic methods and will require engineers with experience in robotics. Manufacturing applications of robots include arc welding, assembly, CNC Milling, CNC Motion Control, CNC Turning, complex machining, dispensing, sealing, laser cutting, machine tending, material removal, painting, palletizing, part transfer, picking & packaging, and spot welding. The use of industrial robots have now expanded beyond the manufacturing industry and are now applied in healthcare, exploration, security, entertainment, environmental construction protection, and in other fields and service applications, with an exciting and significant impact on industry

and society. Job titles might include automation technician, robotics technician, engineering technician, robotics engineer, mechanical engineer, and software engineer. The wide use of robots allows for graduates to feel confident that they can apply their education and secure a job.

Manufacturing and industrial companies are increasingly relying on engineers to develop technologies, such as robotic technologies, that will increase efficiency and reduce production costs. This reliance helps fuel the demand. According to the Bureau of Labor Statistics, as of 2017, the median annual salary for electrical and electronics engineers, for instance, was $97,970, while mechanical engineers brought in a median of $85,880. These salaries attract students to the university and they hope that they can get a top-notch education to increase their employability. The robotics concentration will help students gain valuable experience and be comfortable integrating robots into a manufacturing process.

Structure of the Concentration

The robotics concentration consists of a four-course sequence. The first course is ECET 26200: Programmable Logic Controllers that is taken by all students in the Mechanical Engineering Technology (MET), Electrical Engineering Technology (EET) or Mechatronics Engineering Technology (MCET) programs. This course is the prerequisite for the next course, Industrial Robotics Programming. Hands-on programming will be based on industry standard FANUC robots. In a third course, students will use their knowledge from two previous courses to learn Robotic System Integration. The fourth course comes from the students' primary area, focusing on robotics sub-system improvements such as motor drives for EET majors, end tool design and construction for MET majors, and process control improvements for MCET majors. Further details for each course are given below.

Course 1: Programmable Logic Controllers (PLC) (2xxx level)

This course is an introductory course that covers basic concepts about programmable logic controllers. It also focuses on performing motor control and process control related functions on external input and output devices. Topics include: sequencing, switching, timing, data manipulation, counting, actuation signal control, analog and digital inputs/outputs. This course also covers motor sizing, servomotor drives, and Human Machine Interface (HMI).

Course 2: Programming Industrial Robots (3xxx level)

This course is an introduction to industrial robotics motion control. Students will be exposed to the components, operation, programming, troubleshooting, and applications of a typical FANUC, six-axis industrial robot. Hands-on activities will include manual teach programming, testing with simulation software and programming of advance movements. Students also learn how to perform maintenance, and deal with the safety issues associated with robots.

Course 3: Applications of Industrial Robots for Advanced Manufacturing (4xxx level)

In this course students will learn how to integrate robotics into a manufacturing process. This will look to cover more advanced robot programming methods and teach student show to integrate PLCs, vision systems, conveyers, motors, radio-frequency identification (RFID) along will several other components.

Course 4: Control Drives

The final course for the robotics concentration will allow engineering technology students to specifically apply and use subsystems of a robot that directly relate to his/her major. This course will be more complex and will look to use the full capabilities of industrial robots. Students will learn how to troubleshoot problems in the robotic system and be able to streamline the use of robots in a manufacturing process.

Concentration Hardware, Software, and Space

The robots currently available to students are called the FANUC LR Mate 200*i*D/4s. There are four of these robots at the Commercialization and Manufacturing Excellence Center (CMEC). These robots are available to support the course labs that are included in the concentration. Students work in groups with these robots during the laboratory sessions. These educational robots are typical six-axis short arm industrial robots and are relatively easy to integrate and learn how to use. The robots are capable of demonstrating several industrial applications and allow for future integration of a vision system and other field input devices. This hardware is essential for this concentration because it provides hands-on equipment for the students and offers an active course approach. The programming of the robot is completed by using the teach pendant. The five major parts of a robot includes the controller, manipulator, end effector, power supply, and means for programming. Students learn about each of these five components during the laboratory sessions and look to use each robot to its maximum capabilities. Other types of hardware that is necessary for a robotics concentration includes, peripheral equipment, PLCs, conveyors, HMI, and various other inputs/outputs. There are also various intelligent features that are available for future integration such as RVision (integrated vision), force sensors, and machine loading/unloading devices. The CMEC building offers adequate space for laboratory work and the excess space allows for further integration of conveyors and robots. The pictures below show the current setup of the robots in the CMEC building.

The LR Mate 200*i*D/4s is a compact robot with the approximate size and reach of a human arm (550mm). The design of the arm minimizes interference to peripheral devices and allows operation in suitable spaces. The advantages of having this type of robot are as follows. Lightest mechanical unit in its class and enables easy system integration and installation flexibility with multiple mounting methods [4].

- The most advanced servo technology and highly rigid arm enable smooth motion without vibration in high-speed operations.
- Enhanced wrist load capacity allows for greater efficiency and the ability to handle multiple workpieces.
- The robot's controller is a standard enclosed controller that enables reliable operation under a factory environment with dust and oil mist.

One robot currently has an integrated vision system and it is shown above in the bottom right picture. Three of the robots are on temporary table setups that allow for quick transfer of the robot onto a different setup. This is good for future projects and integration of the robots with other equipment. The robot on the permanent table is shown above on the bottom left side of the pictures. This robot already has several integrated safety features and has a table that shows the work envelope of the robot.

Currently, the only robotic simulation software available to students is RobotRun. This software allows students to learn how to operate a robot without access to a real robot. This free software functions similar to other expensive robot simulation software because it provides the basics of operating a robot, setting up and using coordinate frames, programming effector paths, and allows the robot to interact with objects in the environment. The software also simulates a teach pendant which the student uses to control the robot. By using both the hardware and the software, students demonstrate their knowledge of programming a real robot and a virtual robot. Another software that will be used in the near future is called ROBOGUIDE. This simulation software is the leading offline programming product on the market for FANUC robots. This software allows users to create, program and simulate a robotic workcell in 3-D without the physical need of a robot. With virtual robots and workcell models for offline programming, ROBOGUIDE enables visualization of single and multi-robot workcell layouts before actual installation. This software can be used by students to expand their knowledge on the integration of a robot into a manufacturing process. In this concentration it is important for students to know the expenses of an actual robot, therefore it is beneficial for students to learn how to design and use a virtual robot prior to integrating an actual robot.

Certification

Robotics concentration students at PNW will be a part of an intellectually stimulating environment where they will participate in project-based courses and are encouraged to make high-impact contributions to research. All the robotic training courses offered at PNW are in compliance with courses offered at FANUC Robotics with the course content excelling FANUC's requirements. Upon fulfilling all the course requirements, students receive a FANUC certificate of course completion. This certification is from the FANUC Certified Education Training Program (CERT). It ensures that students are rewarded for the hard work that they put into these rigorous courses. Providing students with an official document for completing all the objectives that are set by

FANUC gives them something to put on their resumes and impress employers. At least two certificates can be earned through the completion of this concentration.

Feedback

It is crucial for the university to receive feedback on this new concentration. All the new courses will need to be refined and revaluated to ensure that the proper teaching methods and equipment is provided to the students in order to meet industrial demands. Feedback can be retrieved from the students after each course is offered. Several questions will be answered regarding the course content and teaching methods. Feedback from industrial partners is valuable as well in order to ensure that they are satisfied with what PNW has to offer. Advisory board meeting feedback is important as well for the development of this concentration. Some possible feedback that would consider the robotics concentration a success is as follows.

- With the advancement of robotics it is good for people to become knowledgeable and more aware of robotics and their place in society. It opens another avenue for students and workers to accept as a possible solution to a workplace problem or potential implementation.
- Students now have the opportunity to learn more about robots if they wish to pursue a career in robotics and can now potentially implement them in their work environment.
- By having industrial robotics courses at PNW, it improves the probability of having more robotics/automation jobs in the area. Companies are more likely to install robots in their facilities if they know they have technicians/engineers nearby who can program and maintain those robots. This in turn creates a workforce in the area around the school for technicians and engineers specialized in robotics.
- Having a concentration in industrial robots is a great investment for the university, the students, and the industries in the area because it gives the students a chance to learn about robots and in turn benefits the industries because robots can increase productivity and quality. It is beneficial to PNW and especially to the students who acquire hands-on knowledge on how to operate, control and maintain robots because the enrollment rate will increase when students can be guaranteed a proper education and secure a job.
- By having these courses and facilities, greater opportunities are made available for the students. They may not have known the specific details regarding robotic use in industry, but now they can now learn of and practice these new skill sets firsthand. These students can now enter the workforce with a better understanding of industrial robotics and will thus be able to more adequately fulfill their applied role from a more knowledgeable standpoint.

Conclusion

Overall, it is clear that having a robotics concentration for engineering technology students at Purdue University Northwest will benefit the students, surrounding industries, and the university as a whole. The programming industrial robots course that was offered to students during the fall 2018 semester has proven to be a huge success. The students have enjoyed the course and

appreciate the robots that were provided to them by the university. The impressive projects that were completed by students show their understanding and the test scores prove that they were able to learn a great deal about industrial robots. The goals for the initial assessment that was conducted to show that the robotics concentration is beneficial have been met. Student enrollment in the next course is relatively high and this is only expected to increase as other students hear about the success from the previous course offerings. The high ratings from the students show that there is definitely a demand for a robotics concentration and that the university should move forward with this plan. In conclusion, the demand for robots is increasing, therefore enhancing college of technology and engineering technology program with an industrial robotics concentration is indispensable.

References

1- International Federation of Robotics. (2017), *Executive Summary World Robotics 2017 Industrial Robots.* Retrieved December 9, 2018, from https://ifr.org/downloads/press/Executive_Summary_WR_2017_Industrial_Robots.pdf

2- Product Handling Concepts. *A Brief History of Automation*. (2016, September 7). Retrieved November 15, 2018, from https://www.phcfirst.com/words-in-motion/2016/9/7/a-brief-history-of-automation

3- FANUC Robotics America, Inc. 2007. *Courses*. Retrieved November 15, 2018, from https://www.fanucamerica.com/support-services/robotics-training/CourseDetails.aspx?CourseNumber=J2P0310

4- Newcomer, J. L. (2016, June), *An Industrial Robotics Course for Manufacturing Engineers* Paper presented at 2016 ASEE Annual Conference & Exposition, New Orleans, Louisiana. 10.18260/p.26208

5- Hooker, J. B., & Druschke, V., & Kuhl, S. A., & Sergeyev, A., & Parmar, S. Y., & Kinney, M. B., & Alaraje, N., & Highum, M. (2017, June), *Enhancing Industrial Robotics Education with Open-source Software* Paper presented at 2017 ASEE Annual Conference & Exposition, Columbus, Ohio. https://peer.asee.org/28275

6- Alghamdi, B., & Lee, D., & Schaeffer, P., & Stuart, J. (2017, August), *An Integrated Robotic System: 2D-Vision based Inspection Robot with Automated PLC Conveyor System* Paper presented at 4th International Conference of Control, Dynamic Systems, and Robotics (CDSR'17), Toronto, Canada. 10.11159/cdsr17.136

7- FANUC Robotics, Handling Tool Application Programming Training Manual. 2016

8- Bureau of Labor Statistics, U.S. Department of Labor, *Occupational Outlook Handbook*, Electrical and Electronics Engineers. (2018, April 13). Retrieved from https://www.bls.gov/ooh/architecture-and-engineering/electrical-and-electronics-engineers.htm

9- Bureau of Labor Statistics, U.S. Department of Labor, *Occupational Outlook Handbook*, Mechanical Engineers. (2018, April 13). Retrieved from https://www.bls.gov/ooh/architecture-and-engineering/mechanical-engineers.htm