Innovative Curriculum Model Development in Robotics Education to Meet 21st Century Workforce Needs.

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Abstract

Recently, educators have worked to improve STEM education at all levels, but challenges remain. Capitalizing on the appeal of robotics is one strategy proposed to increase STEM interest. The interdisciplinary nature of robots, which involve motors, sensors, and programs, make robotics a useful STEM pedagogical tool. There is also a significant need for industrial certification programs in robotics. Robots are increasingly used across industry sectors to improve production throughputs while maintaining product quality. The benefits of robotics, however, depend on workers with up-to-date knowledge and skills to maintain and use existing robots, enhance future technologies, and educate users. It is critical that education efforts respond to the demand for robotics specialists by offering courses and professional certification in robotics and automation. This paper introduces a new approach for Industrial Robotics in electrical engineering technology (EET) programs at Michigan Tech and Bay de Noc Community College.

Keywords

Robotics; STEM; Industrial Certification; Robotic Software

Introduction

Many existing jobs will be automated in the next 20 years, and robotics will be a major driver for global job creation over the next five years. These trends are made clear in a study conducted by the market research firm, Metra Martech, "Positive Impact of Industrial Robots on Employment"[1]. Many repetitive, low-skilled jobs are already being supplanted by technology. However, a number of studies have found that in the aggregate, the robotics industry is creating more jobs than the number of jobs lost to robots. For example, the International Federation of Robotics (IFR) estimates that robotics directly created 4 to 6 million jobs through 2011 worldwide, with the total rising to eight to 10 million if indirect jobs are counted. The IFR projects that 1.9 to 3.5 million jobs related to robotics will be created in the next eight years[2]. Furthermore, jobs that were previously sent offshore are now being brought back to developed countries due to advances in robotics. For example, Apple now manufactures the Mac Pro in America and has spent approximately $10.5 billion in assembly robotics and machinery[3]. Such rapid growth of robotic automation in all sectors of industry will require an enormous number of technically sound specialists with the skills in industrial robotics and automation to maintain and monitor existing robots, enhance development of future technologies, and educate users on

implementation and applications. It is critical, therefore, that educational institutions adequately respond to this high demand for robotics specialists by developing and offering appropriate courses geared towards professional certification in robotics and automation. In addition, certified robotic training centers (CRTCs) will be in high demand by industry representatives and displaced workers who need to retool their skills. This paper introduces a new approach for Industrial Robotics in electrical engineering technology (EET) programs at Michigan Tech and Bay de Noc Community College. This initiative between Michigan Tech and Bay de Noc Community College is intended to demonstrate and test an effective approach for teaching emerging topics of Industrial Robotics in electrical engineering technology (EET) programs at both the university and community college levels. The curriculum and software developed in this initiative will match current industry needs and will provide a replicable model for the EET programs across the country.

Workforce Need

In 2014, ManpowerGroup surveyed nearly 40,000 employers across 41 countries and territories as part of its annual Talent Shortage Survey[4] and identified that employers are having the most difficulty finding the right people to fill jobs in Japan 81%, Brazil 63% and the US 40%. In fact, two occupations in the US: technicians (primarily production/operations, engineering or mathematics) and engineers top the list of 10 jobs employers have difficulty filling. In addition, the American Society for Training and Development (ASTD) reports major skill gaps in the US. The 2013 ASTD report states that US organizations spent ~$164.2 billion on employee learning[5] in 2012. The US is facing an alarmingly high replacement need for STEM professionals[6,7]. For instance, the projected replacement rate in mathematical science is 29.5%, in physics it is 28.5%, in mechanical engineering it is 26%, and in electrical engineering it is 23%. It is estimated that during this decade, employers will need to hire about 2.5 million STEM workers, drawing largely from engineering and engineering technology programs that are known for equipping graduates with the tools to enter the workforce, for the first time, prepared[8,9]. This requires an innovative curriculum that involves hands-on opportunities for practical problem solving.

Educational Need

Given the current shortage of student interest in STEM education, increased attention has been given to the appeal and attraction of Robotics. The interdisciplinary construction of robots, which involves motors, sensors, and programming, makes it a useful pedagogical tool for all STEM areas. In the classroom, robotics can easily be used to introduce a variety of mandatory skills needed to pursue a variety of STEM career paths[10-14]. More specifically, a robotics platform advances students' understanding of both scientific and mathematical principles[12,15], develops and enhances problem-solving techniques[12,15-19], and promotes cooperative learning[12,15,20]. While robotics can be used as an interdisciplinary STEM learning tool, there is also a strong need for industrial certification programs in robotics automation. As mentioned, robotics can be used as an interdisciplinary, project-based learning vehicle to teach STEM fundamentals[21-23]. Understanding the valuable role robotics education plays in helping students understand theoretical concepts through invention and creation, many universities include components of robotics research in curricular offerings[24]. It is recognized that robotics is a valuable learning tool that can enhance overall STEM comprehension and critical thinking[21,25-27]. Currently, few universities offer specific robotics degrees. For instance, Worcester Polytechnic

Institute (WPI) has offered a Bachelor of Science in Robotics Engineering[28] since 2007. Universities that have graduate degrees focused on robotics include Carnegie Mellon University, MIT, UPENN, UCLA, WPI, and the South Dakota School of Mines and Technology (SDSMT). Michigan State University has a well-established Robotics and Automation laboratory, but it is utilized for graduate robotics courses and research. Very few universities across the US offer a degree and/or certification specifically in robotics automation. In fact, Lake Superior State University (LSSU) is one of very few universities in Michigan that specializes in robotics automation; however, it does not have a program to certify industry representatives[29]. Driven by industry needs, the new curriculum designed in this project will be adapted for both two- and four-year programs. This initiative aims to address the current US workforce need for properly prepared STEM professionals, train current industry representatives and displaced workers in robotics automation, educate K-12 teachers with the current art of industrial robotics, and promote STEM fields among K-12 students.

Current Industry Partnership

Michigan Tech's EET department has an established collaborative relationship with FANUC Robotics America Inc., the leading company specializing in the development and production of innovative and intelligent robotic solutions. FANUC Robotics supports Michigan Tech's School of Technology, as well as other STEM programs by providing significant educational discounts to purchase of resources that would otherwise not be feasible. The FANUC Robotics Certified Education Robot Training (CERT) Program promotes understanding of FANUC Robotics' automation solutions through the development and implementation of integrated classroom instruction and student projects. The CERT program is a new certification available to qualified universities. The EET department at Michigan Tech is a Certified Training and Education Site for FANUC Robotics Material Handling Program Software and iR-Vision 2D and the collaboration between Michigan Tech and FANUC continues to bloom. In 2013, Michigan Tech became a FANUC Authorized Certified Training Facility. Under this agreement, Michigan Tech is a regional training center specializing in industrial automation, eligible to train and certify students from other institutions, industry representatives, and displaced workers. Michigan Tech is one of only three existing FANUC Authorized Satellite Training Programs in the United States, and the only one in the state of Michigan[30].

Current State of Robotics Automation at Michigan Tech and Bay de Noc Community College.

The cross-disciplinary robotics automation training program at Michigan Tech was successfully launched in 2009. The current success of the program, CERT experts, and industry collaborations make Michigan Tech the ideal partner for Bay College. Bay College will adapt Michigan Tech's existing curriculum in Robotics Automation, and implement and evaluate the robotics curriculum in a two-year degree program. This partnership of two- and four-year institutions will not only serve as an exemplary model of collaboration, but will also develop a full spectrum of robotics curriculum adaptable at various levels of education.

Robotics Automation Curriculum Development for EET Programs

This project will have a significant impact on the curriculum at both institutions - Bay College and Michigan Tech. During this collaborative initiative, a broad spectrum of educational material will be developed and made available between institutions for adaptation. Figure 1 depicts the proposed models in robotics curriculum development which will impact three different educational groups: 1) two- and four-year institutions; 2) students from other universities and community colleges, industry representatives, and displaced workers; and 3) K-12 teachers and high school students.

Model of Robotics Curriculum for Two- and Four-Year Educational Institutions: The robotics curriculum at Michigan Tech will be enhanced by adding a new course Robotics Vision Systems and by developing new, state-of-the-art educational robotic simulation software called RobotRun. Bay College has no robotics-related courses in its current curriculum. Through this collaboration with Michigan Tech, Bay will add two new courses and utilize the open-source robotic training software in the classroom. The robotics courses being developed as part of the partnership with Michigan Tech will fit seamlessly into this degree to provide students with an entry-level understanding of robotics and automation technology. As shown in Figure 1, the current curriculum at Michigan Tech in robotics automation includes one Real-Time Robotics Systems course (4 credit hour: 3 hours of recitation and 3 hours of weekly lab) covering all the theoretical and practical aspects of the knowledge required for technologists involved in the robotics automation industry. Essentially, this course is the building block for future coursework in the mechanics, control, and programming of robotic systems. Close collaboration with industry in the initial design of this course also helped to advance an industrial certification program that is endorsed by industry. Students who successfully complete the course get certified and are issued a FANUC industrial certificate in "Handling Tool Operation and Programming." To further promote the course development and make the course offering model more flexible, two derivatives of the course have been developed. The first, a hybrid version of the course, has been successfully implemented several times since 2012. In this version of the course, the theory, quizzes, and exams are delivered online, but students still have an opportunity for hands-on training during weekly 3-hour labs. This model allows for more flexible scheduling of the class, which in turn helps students who work while attending school. The second course derivative involves an intense two-week structure with the same amount of theory and hands-on practices in a condensed time period. The first week involves an introduction to the theoretical content, culminating in the midterm exam. In the second week, students are completely immersed in the hands-on activities of operating and programming FANUC industrial robots.

Robotic Vision Systems: Vision systems are being used increasingly with robot automation to perform common and sometimes complex industrial tasks, such as: part identification, part location, part orientation, part inspection and tracking. The Robotics Vision Systems course will be designed as a 4 credit hour course (3 hours of recitation and 3 hours of weekly lab). The course will introduce topics on: 1) safety, including laser safety; 2) basics of optics and image processing; 3) setting up lightning conditions required for the successful vision error proofing and camera calibration; 4) teaching tool, application, and calibration frames; 5) performing 2D calibration and 2D single and multiview robotic processes; 6) performing 3D calibration and 3D single view robotic vision processes. The course will include 12 laboratory exercises, totaling 36 hours, with the goal of providing students the opportunity to configure and execute real-life, industry comparable, robotic vision scenarios. In addition to the traditional offering, two

derivatives (a hybrid and 2-week intense version) of the Robotics Vision Systems will be developed and implemented at both institutions – Bay College and Michigan Tech.

Open-Source Robotic Training Software - RobotRun: During the course of this project authors will develop an engaging, free, and open-source robotic training software aimed at helping students learn the basics of programming robotic arms. The software will act as a simulator where a user can write a program and then view how that program performs when run on a virtual 3D robotic arm displayed on the screen. Although robotics play an essential role at a variety of manufacturing facilities, there is currently no accessible and free software that can give students the opportunity to learn about using the robotic hardware without purchasing expensive, complex, proprietary software packages. This software is intended to be used alongside the other training materials developed as a part of this project, but it will also be made available online for anybody to download and use. The open-source and free nature of the developed RobotRun training software will have a significant and broad impact by: 1) enabling institutions unable to obtain expensive industrial robots to adapt and teach the developed robotics courses; 2) providing K-12 teachers with the opportunity to promote STEM education to students by introducing the appealing concept of robotics via an interactive training environment, at no cost to K-12 institutions; 3) providing displaced workers wanting to improve their robotics skills with an intuitive, interactive and complete tool to succeed.

Curriculum for Students from any Institutions, Industry, and Displaced Workers

While robots play a role in all STEM fields, robots are key components of most manufacturing industries – from health to automotive sectors. To provide support for the industry, educational institutions need to: 1) develop a training curriculum with industrial certification available to students from institutions where a robotics curriculum is not available; this will make those students more valuable in the job market; 2) provide effective, certified training to industry representatives who need to retool their skills to match rapidly developing technologies, especially in the field of robotics automation; 3) provide displaced workers with the opportunity to enhance, or acquire new, skills in robotics and enter the in-demand robotics job market.

Certification 1: Handling Toll Operation and Programming (32-hour course): The course is designed to be both practical and progressive. The content offers easily applied guidance to personnel involved in manufacturing with current robotic systems on site, or who may be asked to engage in implementing robotic systems in the near future. The course includes a discussion of scholarly and practical robotic topics ranging from kinematics and programming to practical application areas and economic concerns. Topics include: the development of industrial robotics; an overview of the mechanical design, control, programming, and intelligence; organizational and economic aspects; robotics in operation and various applications. Hands-on experience is an essential part of this course and will occupy 70% of course time. The lab exercises are devoted to practical aspects of programming FANUC Robotics robots. This 32-hour course is designed to be offered partially online. The first 16 hours are devoted to theoretical content delivered online. The remaining 16 hours provide extensive hands-on experience working in the lab at Michigan Tech or at Bay College manipulating and programming FANUC industrial robots. The course culminates in a certification exam and participants successfully passing the exam will receive a certificate issued by a FANUC-certified instructor.

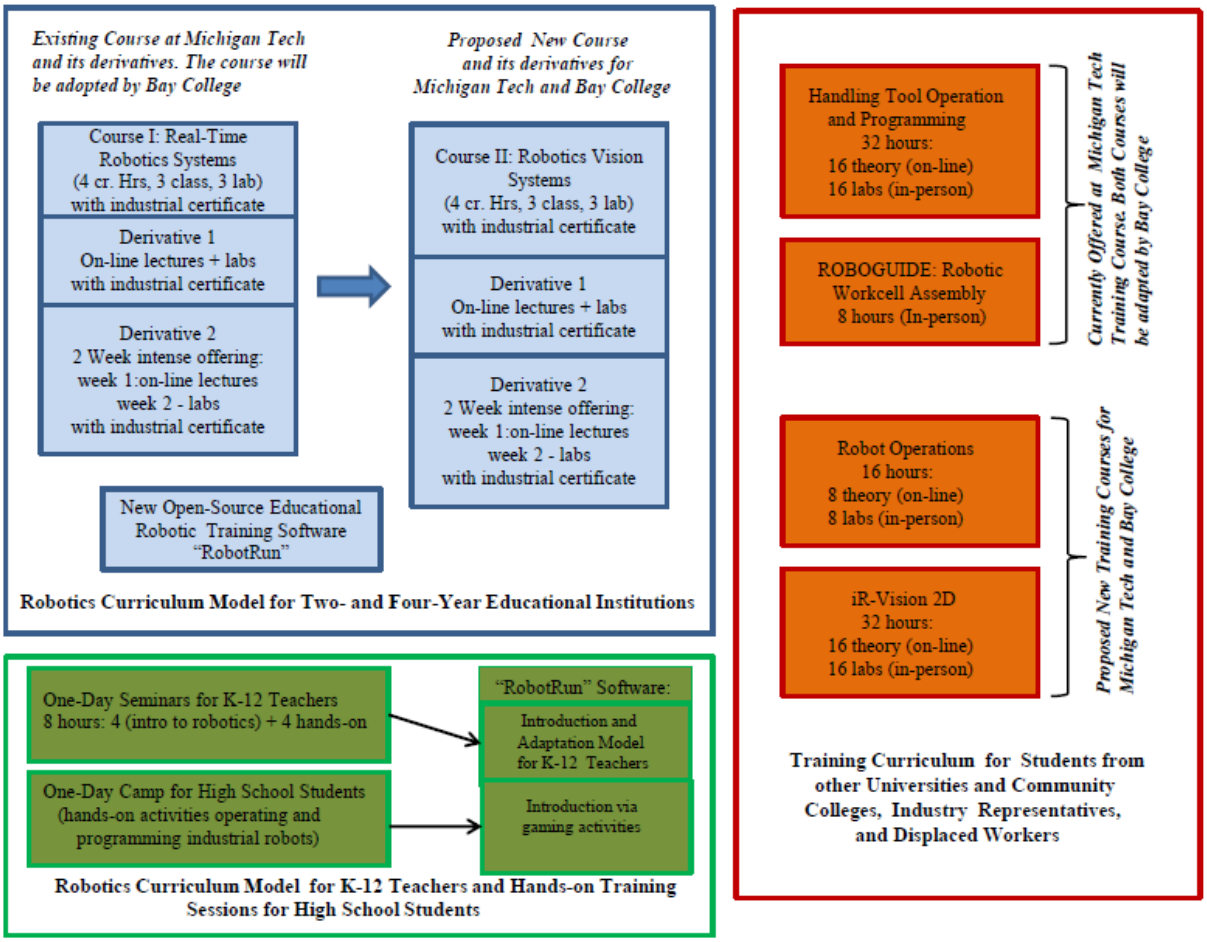

Figure 1: Proposed Robotics Automation Curriculum Development

Certification 2: Roboguide – Robotic Workcell Assembly (8-hour course): FANUC Roboguide software is widely used in industry; therefore, there is a great need to train workers in this software. As a result, an 8-hour training course that provides participants with a foundation for understanding all software features has been developed. By the end of the course, students assemble a fully functional virtual robotic workcell that includes the robot, end-effector, several fixtures and industrial parts that the robot can manipulate. Students program the robot to execute "pick and place" operation, run simulation in step-by-step and production modes, and compile a file that can be further transmitted to the physical FANUC robot for real-time production. This one-day training can be offered on demand and in conjunction with the other existing and under development certification courses.

Certification 3: Robot Operations (16 hours): There is a great demand in the industrial sector for robot operators that don't necessarily need to have very in-depth programming and theoretical skills. This course is intended for the person who operates or may be required to perform basic maintenance on FANUC robots via the standard application software package. It will teach students how to safely power up, power down, jog the robot to predefined positions, and set up different frames of operation. In addition, it will cover tasks and procedures needed to recover from common program and robot faults, and teach basic programming skills. The course will not

address the set-up and operation of specific software features and options nor will it teach in-depth programming skills. These are covered in the 32-hour Handling Toll Operation and Programming course.

Certification 4: iR-Vision 2D (32-hour course): Vision systems are being used increasingly with robot automation to perform common and sometimes complex industrial tasks, such as: part identification, part location, part orientation, part inspection and tracking. This course will teach students how to set up, calibrate, teach, test, and modify iRVision applications using FANUC robots. The course will include detailed discussion of hardware and software setup, establishing the communication link between the robot and teaching computer, teaching single- and multi-view processes, and programming. The course will culminate in a certification exam in which the participants will have to demonstrate an understanding of the theoretical background, as well as, the ability to successfully set up, calibrate, program and utilize the FANUC robot equipped vision system. Participants passing the exam will receive a certificate in iRVision 2D.

Model Robotics Curriculum for K-12 Teachers and Hands-on Training Sessions for High School Students

As a way to encourage more (and more diverse students) to consider careers in robotics, faculty members from Bay College and Michigan Tech will promote robotics automation to K-12 teachers and high school students. One-day seminars for K-12 teachers will be conducted at both Michigan Tech and Bay College. During the seminar, participants will: 1) learn concepts of industrial robotics; 2) learn the basics of programming FANUC industrial robots; 3) try the robotic software "RobotRun"; and 4) work with faculty to consider ways the software can be integrated into the K-12 curriculum. Participating teachers will be provided with 4 hours of theory and 4 hours of hands-on operating and programming with FANUC robots and the "RobotRun" simulation software. To promote the field of robotics directly among the high school students, one "day camp" will be conducted yearly, at both institutions. Students will: 1) learn basic principles of industrial robots; 2) operate and program FANUC industrial robots; 3) utilize the gaming environment of the "RobotRun" simulation software to play embedded games and conduct basic programming tasks. Due to the remote location of Upper Peninsula schools, very few programs targeting STEM fields are available. The proposed camps will provide high school students with the extraordinary opportunity to learn and get engaged in STEM-related activities using the appealing nature of robotics. This early-age engagement in STEM activities will help to create a clear path for the students to continue education through postsecondary institutions.

Conclusion

The overall goal of the described in this paper collaborative project between Michigan Tech and Bay de Noc Community College is to help meet the nation's forthcoming need for highly trained Industrial Robotics workers. Strategies include developing, testing, and disseminating an updated, model curriculum, laboratory resources, and simulation software package suitable for use in both 2- and 4-year EET programs. To complement this effort, outreach to K-12 students and teachers will work to enlarge the pipeline and diversity of students interested in careers in robotics. Programs will also be offered to students at other institutions and to workers in industry to broaden impact.

Upon successful implementation of the project described in this article, the following objectives will be achieved:

1. Provide Electrical Engineering Technology (EET) two-year and four-year students with current and relevant skills in Industrial Robotics.

2. Provide "stand-alone" programs to train and certify students from other institutions, industry representatives, and displaced workers.

3. Develop new "RobotRun" robotic simulation software and make it available at no cost for adaptation by the other institutions. This will allow current concepts related to industrial robotics to be taught even in locations without access to current robotics hardware.

4. Train faculty members at similar institutions to build expertise in Industrial Robotics using state-of-the-art FANUC Robots.

5. Develop a pipeline and encouragement for 2-year students (particularly underrepresented students, many of whom attend community colleges) to explore options in 4-year EET degree programs.

6. Conduct robotics-oriented seminars for K-12 teachers to expand their knowledge in engineering and science and increase the awareness of the role the field of robotics plays in STEM education.

7. Conduct robotic workshops for high school students to increase their interest in STEM fields, utilizing the appealing concepts of robotics and automation to attract participants.

8. Disseminate the new curriculum and software widely to significantly impact the future electrical engineering technology workforce by encouraging enhancements in other EET programs.

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