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University, Community College and Industry Partnership: Revamping Robotics Education to Meet 21st Century Workforce Needs – Year 2 Progress

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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. 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, National Science Foundation (NSF) sponsored, project introduces a new approach for Industrial Robotics in electrical engineering technology (EET) programs at Michigan Tech and Bay de Noc Community College. The curriculum and software developed by this collaboration of two- and four-year institutions matches industry needs and provide a replicable model for programs around the US. The project also addresses the need for certified robotic training centers (CRTCs) and provides curriculum and training opportunities for students from other institutions, industry representatives, and displaced workers. Resources developed via this project are disseminated through a variety of means, including workshops, conferences, and publications. In this article, authors report on the project Year 2 progress, including the advancements in the "RobotRun" robotic simulation software development and implementation, professional development opportunities for the faculty members from the other institutions, training workshops for K-12 teachers, and robotic one-day camps for high school students.

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]. The IFR projects that 1.9 to 3.5 million jobs related to robotics will be created in the next eight years[2]. The rapid growth of robotics and automation, especially during the last few years, its current positive impact and future projections for impact on the United States economy are very promising. Even by conservative estimates[1], the number of robots used in industry in the United States has almost doubled in recent years. From 2014 to 2016, robot installations are estimated to increase about 6% a year, resulting in an overall 3-year increase[1] of 18%. Likewise, industrial robot manufacturers are reporting 18-25% growth in orders and revenue year on year. While some jobs will be displaced due to the increased rollout of robots in the manufacturing sector, many will also be created as robot manufactures recruit to meet growing demand. 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 project aims 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 between two-year and four-year institutions will match current industry needs and will provide a replicable model for the EET programs across the country. The project also addresses the need for CRTCs and provides curriculum and training opportunities for students from other institutions, industry representatives, and displaced workers.

The overall goal of the project 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.

Project Rationale and Need

*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.

On the one hand, the pipeline for an educated future workforce is already in place. According to data from the Current Population Survey[7], the share of the population aged 16 and over who have college degrees roughly doubled over the past three decades, as did the share of those with some college education. However, there is concern that the US is still not preparing a sufficient number of students, teachers, and professionals in STEM areas[10-13]. In a recent international assessment of 15-year-old students, the US ranked 28th in math literacy and 24th in science literacy. Moreover, the US ranks 20th among all nations in the proportion of 24-year-olds who earn degrees in natural science or engineering[10]. In the National Academy of Sciences (NAS) report "Rising above the Gathering Storm: Energizing and Employing America for a Brighter Economic Future," as well as in the Administration's American Competitiveness Initiative[14], five recommendations were made targeted at improving STEM education. These five recommendations seek to 1) *increase the supply of new STEM teachers, 2) improve the skills of current STEM teachers, 3) enlarge the pre-collegiate pipeline, 4) increase postsecondary degree attainment, and 5) enhance support for graduate and early-career research* [10]. Our approach aims to address, through short and long term goals, each of these recommendations.

Educational Need: Robotics is a great tool to promote STEM fields and educators have been making measurable progress toward improving STEM education from primary to tertiary levels of education, but challenges remain. Given the current shortage of student interest in STEM education, increased attention has been given to the appeal and attraction of Robotics. In the classroom, robotics can easily be used to introduce a variety of mandatory skills needed to pursue a variety of STEM career paths [14-17, 22, 24]. More specifically, a robotics platform advances students' understanding of both scientific and mathematical principles[17, 18], develops and enhances problem-solving techniques[17, 18, 20-23], and promotes cooperative learning[17-19].

While robotics can be used as an interdisciplinary STEM learning tool, there is also a strong need for industrial certification programs in robotics automation. Millions of domestic/personal robots are already on the market worldwide, from lawn mowers to entertainment robots[25]. As a result, popular interest in robots has increased significantly[16-28]. Global competition, productivity demands, advances in technology, and affordability will force companies to increase the use of robots in the foreseeable future[39-41]. While the automotive industry was the first to use robotics, aerospace, machining, and medical industries now also rely on robotic automation[42, 43]. More than ever, trained and certified specialists are needed to maintain and monitor existing robots and to develop more advanced robotic technologies[39, 44-46].

As mentioned, robotics can be used as an interdisciplinary, project-based learning vehicle to teach STEM fundamentals[29-31]. 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[35]. It is widely recognized that robotics is a valuable learning tool that can enhance overall STEM comprehension and critical thinking[29, 36-38]. The objectives behind robotic programs are clear: 1) in the short term, robotics education fosters problem solving skills, communication skills, teamwork skills, independence, imagination, and creativity[32-34]; and 2) in the long term, robotics education plays a key role in preparing a workforce to implement 21st century technologies. Currently, few universities offer specific robotics degrees. For instance, Worcester Polytechnic Institute (WPI) has offered a Bachelor of Science in Robotics Engineering[50] 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[47]. With few focused industrial robotics programs, undergraduate industrial robotics training often occurs in electrical engineering technology programs, the focus of the proposed program. Training in robotics automation is especially important to Michigan's economy. A major decline in automotive manufacturing jobs has left many areas in Michigan with high rates of unemployment. Baraga County, located 15 miles south of Michigan Tech, has one of the nation's highest rates of unemployment. Yet, Michigan has an unmet need for workers in robotics jobs[26, 48]. Filling these jobs, however, requires workers trained and certified in the following skill sets: designing, testing, maintaining, and inspecting robotic components; troubleshooting robot malfunctions; using microcomputers, oscilloscopes, hydraulic test equipment, microprocessors, electronics, and mechanics; and reading blueprints, electrical wiring diagrams, and pneumatic/hydraulic diagrams. Driven by industry needs, the new curriculum designed in this project will be adapted for both two- and four-year programs. The project 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.

Task 1: Robotics Curriculum at Michigan Tech and Bay de Noc Community College.

The paper describes the project undertaken by Michigan Tech and Bay College to update their current curriculum. The collaboration aims to develop extensive education materials that would be available between institutions for adaptation. In previous publications [4, 5], authors have described Figure 1 as follows: "It 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." There are several courses in robotics automation for two- and four-year degree institutions, as well as industry representatives that have already been developed via this partnership. These courses are: Real-Time Robotics Systems, Handling Tool Operation and Programming, and Robot Operations. Authors have already reported on these developments [51-55] and therefore the detailed description of these courses is omitted here.

Task 2: Curriculum for Students from any Institution, 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. Robotic automation has been embraced as a way to stay globally competitive, and to reduce the reliance on manual labor to perform redundant tasks. If the US doesn't want to outsource, we need to automate. 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. Certified curriculum development for all three categories is addressed in this project by developing and offering stand-alone certification programs to industry representatives, students from the other institutions and displaced workers. The list of certification programs already in place and currently developing as part of this project are listed below. The authors have provided a detailed description of each certification option in the previous publications [51-55] and therefore are omitted here.

Certification 1: Handling Toll Operation and Programming (32-hour course)—In place at Michigan Tech; to be adapted for Bay College in this project.

Certification 2: Roboguide – Robotic Workcell Assembly (8-hour course)—In place at Michigan Tech*; to be adapted for Bay College.*

Certification 3: Robot Operations (16 hours)—New, to be developed for Michigan Tech and Bay College.

Certification 4: iR-Vision 2D (32-hour course)—New, to be developed for Michigan Tech and Bay College.

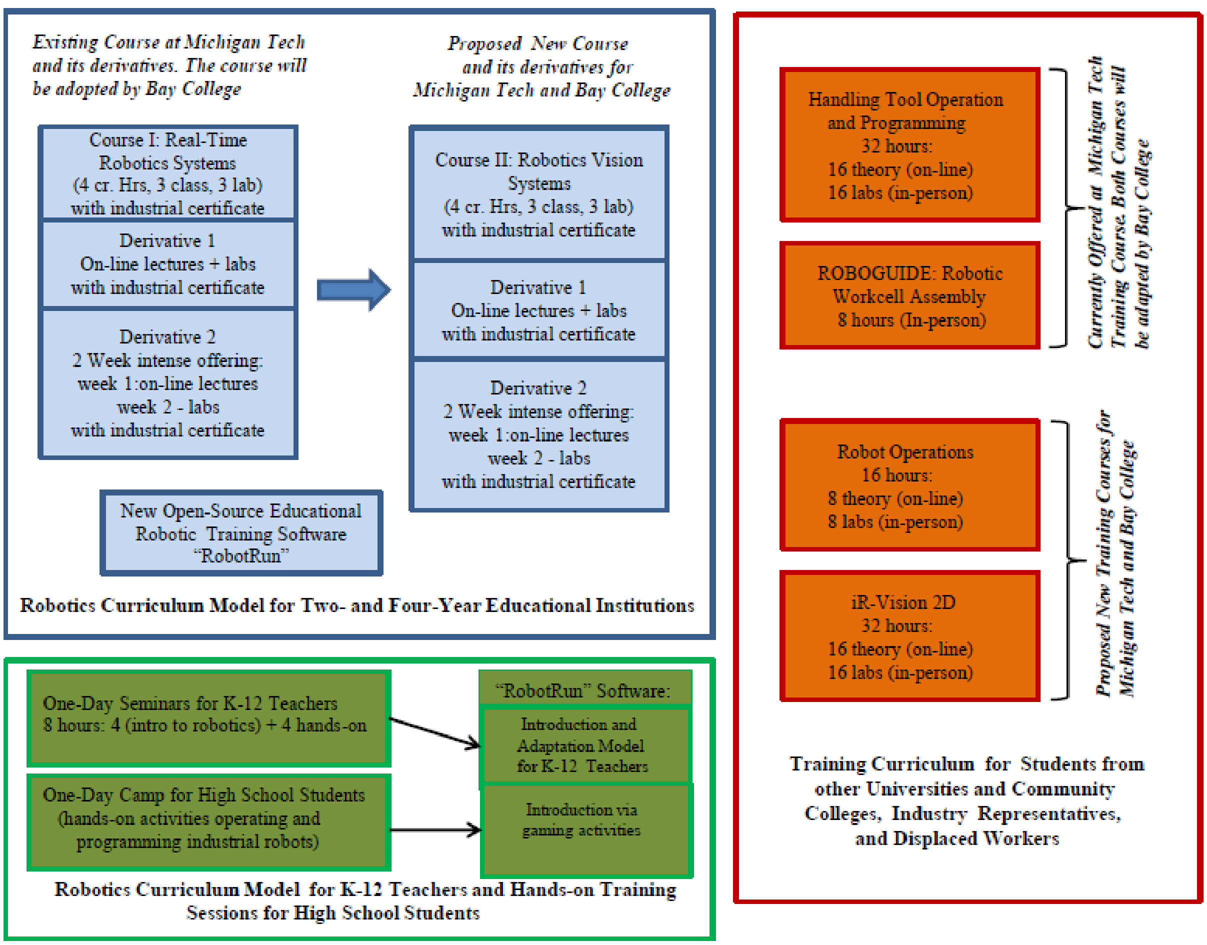

Figure 1: Proposed Robotics Automation Curriculum Development

Task 3: 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 in Year 2 and 3 of the project. 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 (in Year 2 and 3). 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.

Task 4: Professional Development Opportunities for Faculty Members from the Other Institutions

An integral part of this project’s dissemination effort are 2-day workshops for up to 12 faculty participants. The project PI has developed and will lead the workshops over the course of three years in collaboration with faculty from Bay College. The workshops are being offered for faculty members from Michigan Tech’s partner community colleges (Macomb Community College, College of Lake County, and Northcentral Technical College) that have already established articulation agreements with the EET program as well as interested EET faculty from other colleges and universities. The faculty workshops are scheduled to be conducted for three consecutive years at Michigan Tech and in Year 2 and 3 at Bay College. These workshops are offered to faculty members of two- and four year institutions and are designed to increase practical experience in Industrial Robotics as well as renew the interest and empower those seeking to revamp existing courses or develop new courses in Industrial Robotics.
These 2-day, 16 contact hour workshops are designed to be an intense, immersive experience that provide a broad spectrum of activities to participants. The workshop starts by conducting a survey and pre-test. The survey, an anonymous questionnaire, is designed to collect the participant’s feedback regarding attitudes towards different modes (in-person, online, or blended) of knowledge delivery. The purpose then of the pre-test is to assess participant’s knowledge on the specific topics introduced during the workshop. During day one of the workshop, participants will be first familiarized with the structure of the curriculum developed at Michigan Tech and Bay de Noc. The theoretical topics covered during day one include: Concepts of robotic safety in an industrial environment, overview of the FANUC robots utilized in the development of the curriculum, robotic frames and how they impact a robot’s motion, various robotic end-effectors commonly used in industry and effective programming of tool and user frames. In order to reinforce subject matter understanding, each theoretical topic covered during

the workshop is followed by a hands-on activity. A total of three laboratory exercises are offered during the first day of the workshop.
Day 2 of the workshop starts by introducing the RobotRun educational robotic simulation software. A faculty member will demonstrate its' functionality, followed by participants being tasked to create several simulation projects. Theoretical topics covered during the second day of the workshop include: Concept or robot programming, data and position register instructions and how to use conditional and unconditional instructions to improve programming efficiency. Topics mentioned above are reinforced by three lab exercises. Day 2 of the workshop culminates with a survey, post-test and closing discussions during which time faculty members leading the workshop will provide recommendations on the possible implementation of this newly-developed robotics curriculum at other institutions.
A detailed agenda of the first faculty workshop conducted at Michigan Tech in Year 1 of the project is summarized below:

Day 1:
- Topic 1: Industrial Environment Safety (30 min.)
- Topic 2: Overview of LR Mate Fanuc Robot (30 min.)
- Topic 3: Robotic Frames (1 hr.)
- Participants tour Robotic Automation Lab and learn more about both hardware and software necessary to establish a robotic automation lab at their respective institutions (1hr.).
- Lab 1: Jogging in World and Joint Modes (1 hr.)
- Topic 4: End-of-Arm Tooling (1 hr.)
- Lab 2: Teaching Tool Frame (1 hr.)
- Lab 3: Teaching User Frame (1 hr.)

Day 2:
- Faculty participants familiarized with RobotRun educational training software. The faculty member leading the session will first demonstrate the functionality of the software, after which participants will be tasked to create several simulation projects (2 hrs.).
- Topic 5: Robot Programming (1 hr.)
- Lab 4: Basic Programming (1 hr.)
- Lunch Break 12-1
- Topic 6: Data and Position Register Instructions (1 hr.)
- Lab 5: Registers and Position Register Instructions (1 hr.)
- Topic 7: Conditional and Unconditional Branching Instructions (1 hr.)
- Lab 6: Conditional and Unconditional Instructions (1 hr.)
- Survey/Post-Test
- Discussions and Adjourn

The first workshop was advertised using engineering technology listserves and was filled within just fifteen minutes after posting the advertisement! An additional 45 faculties from institutions all over the United States are on a waiting list. This unquestionably indicates a high demand for robotic training, resulting from rapidly developing industrial automation (with robotics being in the top tier) across the entire industrial spectrum. It is the authors' goal to further increase awareness of robotic training available at Michigan Tech and Bay de Noc Community College via engineering technology listservs, conference proceedings and journal publications. This project's developed resources for faculty workshops and industry robotic training can be accessed here [56, 57].

Task 5: "RobotRun" Robotic Simulation Software Development

The RobotRun software is an industrial robotics simulator which simulates the core aspects of using a real robot. The software is free and open source and is aimed at individuals and students who are interested in learning about robotics, but lack access to an expensive industrial robot or access to costly commercial robot simulator packages. The software was developed for usage by the high school, community college, and university classrooms to introduce students to robotics in an accessible way. The software includes a realistic teach-pendant that controls the robot in a way that is similar to how real robots are operated. Current beta version of the software is available online at
http://www.cs.mtu.edu/~kuhl/robotics/. The key features currently implemented in the beta version of the software are discussed next.

End Effectors:
The robot has a set of attachments, which can be fastened onto the robot's faceplate: the suction, claw gripper, pointer, glue gun, and welder end effectors. Only two of the end effectors actually have a function (explain in the robot-part interaction section), while the rest are purely aesthetic.

Frames:
The industrial robots operate in different coordinate systems - frames such as world, user, tool, and jog. Frames are used to configure special types of motion commonly used in industrial settings. Some of the frames are predefined and some can be user configures. User frames are comprised of an origin point and a set of three orthogonal unit vectors, which represent the X, Y, and Z axes. A tool frame consists of an offset vector, which defines the frame's tool tip position with respect to the robot's faceplate position, and the three orthogonal unit vectors that define the axes of the frame. The user can define ten user frames and ten tool frames. The tool frames axes function strictly as alternative coordinate systems, in which the robot can jog, to the world frame. Though, positions saved in a program are saved with reference to the tool tip of the active tool frame, they are never saved with reference to the active tool frame's axes. Yet, points are saved with reference to the active User frame's origin and axes, or the world frame in the case that no user frame is active.

A tool frames can be taught with the three-point, six-point, and direct entry method. A user frames can be taught with the three-point, four-point, and direct entry methods. Points are taught in the normal fashion: jog the robot to a position and save the values of the robot's position with the teach pendant. Any point taught for a frame teaching method that is actively being taught will be displayed in the world environment. The points are color-coded based on the point's relation to the teaching method. In the example above, the three tool tip points are shown as the gray points (1, 2, and 3), the orient origin point is orange (4), the x-direction point is red (5), and the y-direction point is light green (6). This example only lacks one type of teach point: the origin point, which is only taught in the user frame four-point method and appears blue in the world environment. Additionally, the user can move to a taught point using the teach pendant. Since every frame stores the last value of each teach point associated with the frame, a taught point can be referenced at any time by the user until it is overridden by another value. Alternatively, the direct entry method can explicitly specify a frame. The user can navigate between the different values of the frame entry with the arrow buttons and use the number pad on the pendant to input each value before confirming the entry. Similar to the taught points of a frame, the last direct entry specified for a frame is saved independent of the current value of the frame, and will appear, when the user returns to the direct entry method of that frame again.

A screenshot of the points associated with a tool frame for the six-point method as well as a direct entry approach are shown in Figure 2.

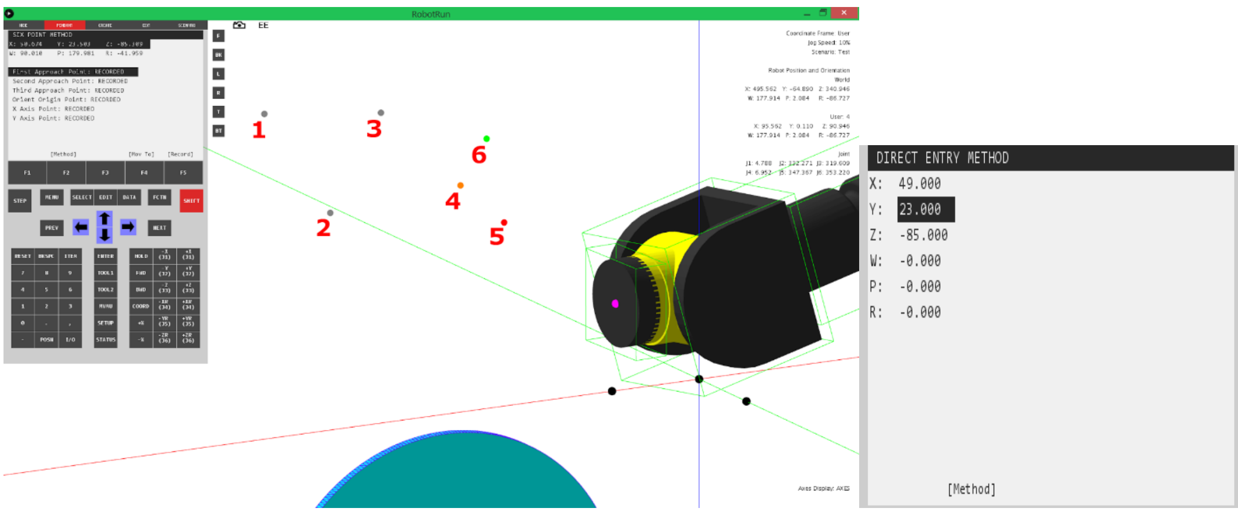

Figure 2: Screenshot of six-point and direct entry methods display

The user utilizes the teach pendant interface to create, view, edit, and delete programs to manipulate robot state information, including robot position, end effector state, internal register values, and coordinate frames. Programs are composed of a sequential list of instructions that are executed in-order, beginning either at the instruction currently selected by the user, and ending at the last instruction. The program instruction set includes a number of different instruction types, including movement instructions to modify the position and orientation of the robot end effector; register modification instructions for I/O, floating point, and position registers; and control flow instructions in the form of conditional constructs, switch statements, labels and jump label instructions, and function calls. The software features discussed above are powerful enough to simulate basic robot functioning required to create applications similar to the industry. Robots are being used drastically across the automation industry for material handling, manufacturing and assembly operations. Efforts have been made to create scenarios that replicate these operations and provide the user a strong foundation of using the different features of the software. Following are the scenarios created using the Robotrun software.

Pick and place objects from multiple stations:

The objective of this scenario is to teach the user to create a robotic workcell, as shown in Figure 3, using different fixtures and parts, learn to operate the robot to pick and place these parts on fixtures and create a simple program to record different positions to run the simulation process. Two parts are moved around three fixtures in a cyclic manner picking one part at a time using a vaccum cup selected from the set of tools. The programming involves recording pick and place positions and using I/O instruction to turn the vacuum on and off.

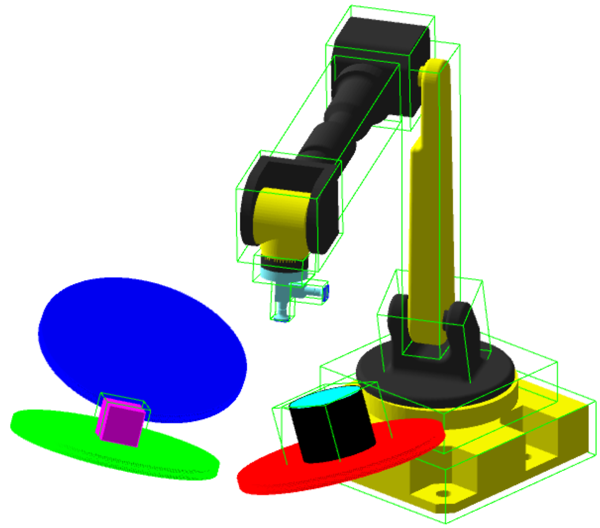

Figure 3: Workcell created to pick and place the box and cylinder on the fixtures in a cyclic manner.

Grinding a given part using tool frame and creating a user frame:

A crooked shaped part is attached to the robot face plate as shown in Figure 4 and the conical surface of this part is required to be grinded. While creating the workcell the user creates a cylindrical object representing the grinding wheel. The application demands the user to create a tool frame with the axis of rotation along the pointed tip and use the six-point method. Creating this tool frame helps the user understand the simplicity and comfort of performing this operation. The user frame creates a separate frame of reference for the robot motion. The user inserts a rectangular surface in the robot's environment and provides it a random orientation. The task is to create a frame of reference using the edges of this surface. When the user has successfully created the user frame the user can jog the robot along the edges of the rectangular surface.

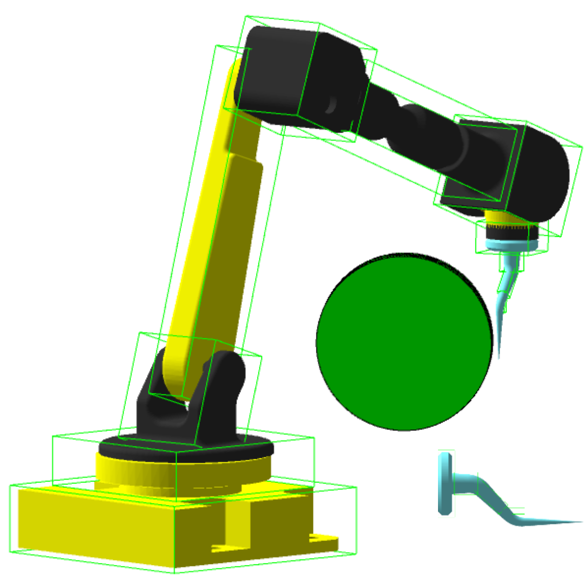

Figure 4: The robot is shown with the part that is grinded on the grinding wheel by rotating using tool frame created.

Welding application for sheet metal using circular instruction:

There is a sheet metal part available in the software library that is imported twice in the workcell and oriented as shown in Figure 5. The tool used for this operation is a welding tool and user programs the robot to move along the line joining the parts. To accomplish this task, the user first creates the tool frame using three-point method and then uses the circular instruction to program the robot to move in the circular paths. The scenario provides the user another important application of tool frame while performing this task because without it there are high chances of collision of the robot with the parts.

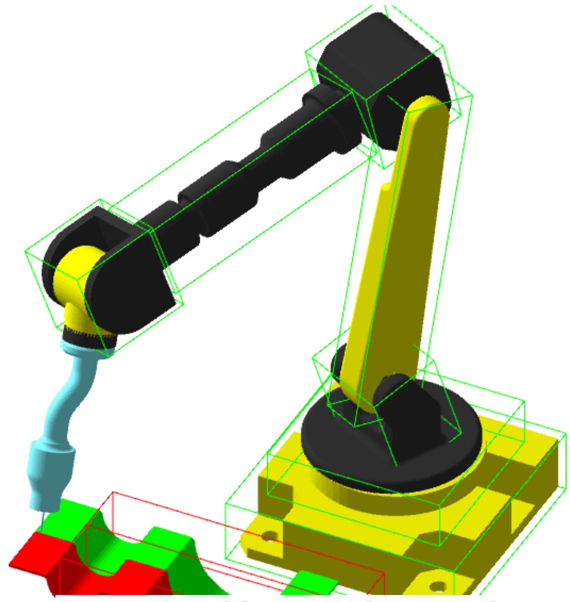

Figure 5: Welding two sheet metal parts along the path requiring linear and circular motion.

Gluing application using position registers and Offset instruction:

Gluing is generally performed by the robot by moving in a zigzag motion along the length of a part. The user inserts a rectangular sheet in the workcell as shown in Figure 6 and uses the glue tool to perform this task. The robot has to perform this motion along the length of the sheet, offset by a certain value along the breadth and repeat the zigzag motion along the length. Firstly, as the robot moves along the rectangular sheet, the user creates a user frame using four-point method. To smartly program this motion the user implements position registers and records the start position in the program. The values of this position register are used to create equations and move the robot to new positions. The offset instruction offsets the value of the position by a certain value and highly simplifies the efforts of programming. There are few other interesting scenarios that include the usage of copying and pasting feature, macro and register equations. All scenarios have been developed with the purpose of highlighting the features by relating them to real time applications. After the completion of these scenarios, the user would have excelled in implementing basic programming of robots with good understanding of using different features for different applications.

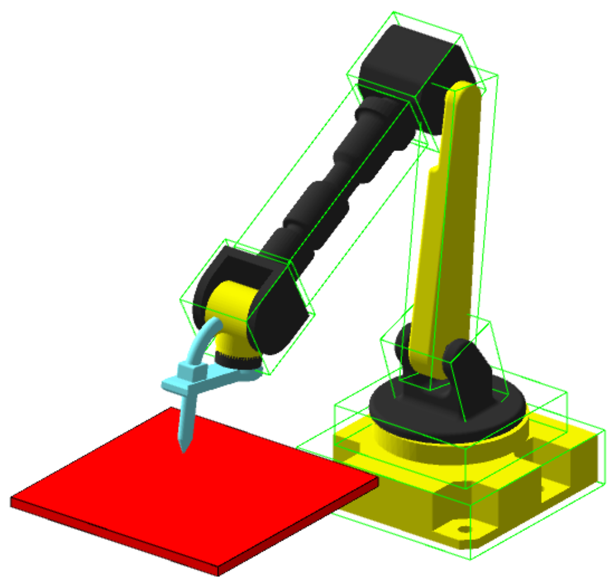

Figure 6. Applying glue on the rectangular sheet in a zigzag manner over the complete area using register and offset instructions.

Modes of Curriculum Adaptation

The four certification programs in Industrial Automation: Handling Tool Operation and Programming, Roboguide, Robot Operations, and iRVision 2D, implemented at Michigan Tech and Bay College through this project, will attract prospective students, industry representatives and unemployed workers who want to re-tool their skills, and students from other universities and colleges without a certification program. The revenue received from these certification programs will serve as a main source of funds to sustain the project and to continually enhance and update the robotics automation programs at the partnering institutions. Due to the rapidly evolving technological world, robotics automation is currently developing at a fast pace. This pace will only increase in the near future. As a result, the demand for technologists in the field of robotics is also increasing. This growing demand for highly knowledgeable technologists from the industrial sector must be supported by educational units and, in particular, by technology programs which place an emphasis on hands-on training. To build highly effective and self-sustaining programs with broad impacts in robotics automation is not a simple task. Bay College and Michigan Tech have joined efforts to build this program and to make it highly adaptable by various institutions and with different budgets. The curriculum developed in this project and open-source training software "RobotRun" will enable three modes of adaptation, which are shown in Table 1. All three modes will allow any institution to teach robotics skills; modes one and two will also allow for industrial training and certification, which will enable the other new programs to grow and expand.

Modes	Institution Budget	Adapted Project Materials, Hardware, and Software	Benefits
Mode 1	*High*	*1. All Course Materials* *2. 3-4 Fanuc Industrial Robots* *3. FANUC Roboguide Software* *4. Project developed RobotRun Software*	*1. Teach Robotics courses and certify students* *2. Provide hands-on training using industrial robots* *3. Train students on industrial and educational software packages* *4. Train and certify significant number of students from other institutions, industry representatives and displaced workers. High profit and possibility for fast expansion* *5. K-12 outreach activities*
Mode 2	*Medium*	*1. All Course Materials* *2. 1-2 Fanuc Industrial Robots* *3. FANUC Roboguide Software* *4. Project developed RobotRun Software*	*1. Teach Robotics courses and certify students* *2. Provide hands-on training using industrial robots* *3. Train students on industrial and educational software packages* *4. Train and certify average number students from other institutions, industry representatives and displaced workers. Medium profit and possibility for slow expansion* *5. K-12 outreach activities*
Mode 3	*Low*	*1. All Course Materials* *2. Project developed RobotRun Software*	*1. Teach Robotics courses* *2. Train students on educational software package* *3. K-12 outreach activities*

Table 1: Modes of adaptation by other institutions

Year 1 and 2 Project Progress

Michigan Tech and Bay College have actively collaborated during Year 1 and 2 of this project and achieved significant advancements in the proposed activities. Tables 2 and 3 provide details on which activities have already been accomplished or planned to be completed by the end of the fiscal year at the Michigan Tech and partner Bay Community College.

Activity	Status/Due Year 1	Status/Due Year 2
Get FANUC educational kits and install them on the robots	X	N/A
Meeting with partner institution Fall 2015 and 2016	X	X
Participate in ATE PI Conference	X	X
Meeting with Bay College Spring 2016 and 2017	X	May 15
Present at ASEE 2016 and 2017 annual conferences	X	June 25
Develop an Articulation Agreement between Michigan Tech and Bay College	In Progress	X
Publish journal articles	2	2 (accepted)
Develop materials for 2-day faculty workshop	X	X
Offer Faculty Workshop at Michigan Tech	X	April 15-16
Develop evaluation materials for pre- and post-tests for Industrial Robotics EET4144 Course; pre- and post- tests for faculty workshops and high school students participating in one day "Camp"	X	X
Develop Vision 2D course for traditional offering	In Progress	X
Develop Vision 2D course for accelerated offering	N/A	In Progress
Develop Materials for one day "Camp" for high school students	X	X
Develop and distribute flyers to the local high school students regarding one day robotic "Camps"	X	March 10
Conduct one day "Camp" for high school students (tentatively April)	X	April 1
Develop materials for K-12 teachers workshop	In Progress	X
Conduct K-12 teachers workshop	N/A	April 22 (tentatively)
Develop and populate the project website	X	X
"RobotRun" simulation software development	Stage I (X)	Stage II (in progress)
Annual Reporting to the NSF	Approved	NSF Deadline

Table 2 Year 1 Project Activities at Michigan Tech

Activity	Status/Due Year 1	Status/Due Year 2
Purchase and install Fanuc robots and educational kits	X	N/A
Meeting with Michigan Tech Fall 2015 and 2016	X	X
Participate in ATE PI Conference	X	X
Faculty Training at FANUC	X	N/A
Meeting with Michigan Tech Spring 2016 and 2017	X	May 15
Adapt & Modify already developed Real Time Robotics course	In Progress	X
Conduct 2-day faculty workshop	N/A	December 10-11

Offer 1-day camp for high school students	N/A	March 18 (tentatively)
Create 3 new labs for Real Time Robotics Course and share them with Michigan Tech	In Progress	X
Offer EET4144 course	N/A	X
Adapt the currently developed materials at Michigan Tech and develop additional 4 lectures and 3 labs for Robotics Vision Course	In Progress	X
Develop Articulation Agreement between Michigan Tech (EET program) and Bay College	In Progress	X
Present at ASEE 2016 and 2017 ASEE conferences	X	June 25
Participate in 2 day faculty training workshop conducted at Michigan Tech in Spring 2016 and 2017	X	April 15-16
Annual Reporting to the NSF	Approved	NSF Deadline

Table 3 Year 1 Project Activities at Bay College

Conclusion

The primary merit described in this paper NSF sponsored initiative between Michigan Tech and Bay Community College is in how it reaches EET (two- and four-year) students with current concepts and hands-on practices in Industrial Robotics that meet current industry needs. There is significant demand from industry for well-prepared specialists capable of programming, maintaining, and troubleshooting modern robots. As a result, the goal is to develop a model curriculum and associated tools that can address current and future industry expectations. In addition to enhancing STEM education at the college level, this collaborative project will provide a template for how other institutions can bridge the gap between academia and industry, and academia and K-12. These bridges are critical for providing new resources to recruit and prepare a sustainable pipeline of graduates in robotics automation. Short-term outcomes include: models for outreach that encourage early STEM interest, two certificates endorsed by industry, and faculty development workshops to reach other universities and colleges.

Development of an advanced, industry-driven, hands-on educational curriculum in robotic automation will improve the quality of STEM education for EET students at two- and four-year institutions. Once completely developed "RobotRun" robotic simulation software will be freely available for adaptation by the other institutions and high school. This will allow robotics to be taught even when the purchase of industrial robots is not feasible. Faculty development conducted at Bay and Michigan Tech includes extensive training in robotics and automation. Partnership with FANUC creates an important ongoing link between academia and industry to ensure the curriculum is regularly updated to meet emerging needs. K-12 teacher seminars will introduce advances in technology to those who play a pivotal role in inspiring future generations of engineering technologists. The new robotics courses and equipment obtained via this collaboration will attract interest of K-12 teachers and students, while simultaneously advancing undergraduate learning. Collaboration and dissemination will align Michigan Tech robotic automation education with industry needs. As a result of the project, engineering technologists will enter the workforce prepared to adapt to the complex and changing demands of tomorrow's high-tech workplace.

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