University, Community College, and Industry Partnership: Revamping Robotics Education to Meet 21st Century Workforce Needs – NSF-sponsored Project Final Report

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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 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 match 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 were extensively disseminated through a variety of means, including workshops, conferences, and publications. In this article, authors provide final report on project outcomes, including various curriculum models and industry certification development, final stage of the "RobotRun" robotic simulation software, benefits of 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 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 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. In the manufacturing sector, the recent growth was 41% in just three years - the number of robots per 10,000 workers employed in 2008 was 96 and reached 135 in 2011. 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. 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 at Michigan Tech and Bay de Noc 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. Authors have provided significant coverage on the rationale of the workforce development and educational need in robotics education and the details of this in-depth research can be found in our previous publications [2-15, 18, 20-25]

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.

Specific project objectives include:

1. Provide Electrical Engineering Technology (EET) two-year and four-year students with current and relevant skills in Industrial Robotics by:
    a. Updating both the two-year and four-year electrical engineering technology curriculum to include skills in industrial robotics relevant to current industry needs.
    b. Enhancing the existing Industrial Robotics laboratory at Michigan Tech and establishing a similar laboratory at Bay Community College to demonstrate the value of state-of-the-art, hands-on training experiences and support the course changes.
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.

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, 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, iR-Vision 2D, and Robot Operations. Authors have already reported on these developments [2, 4, 8-10, 20] 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 [12, 17, 22, 25] 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.

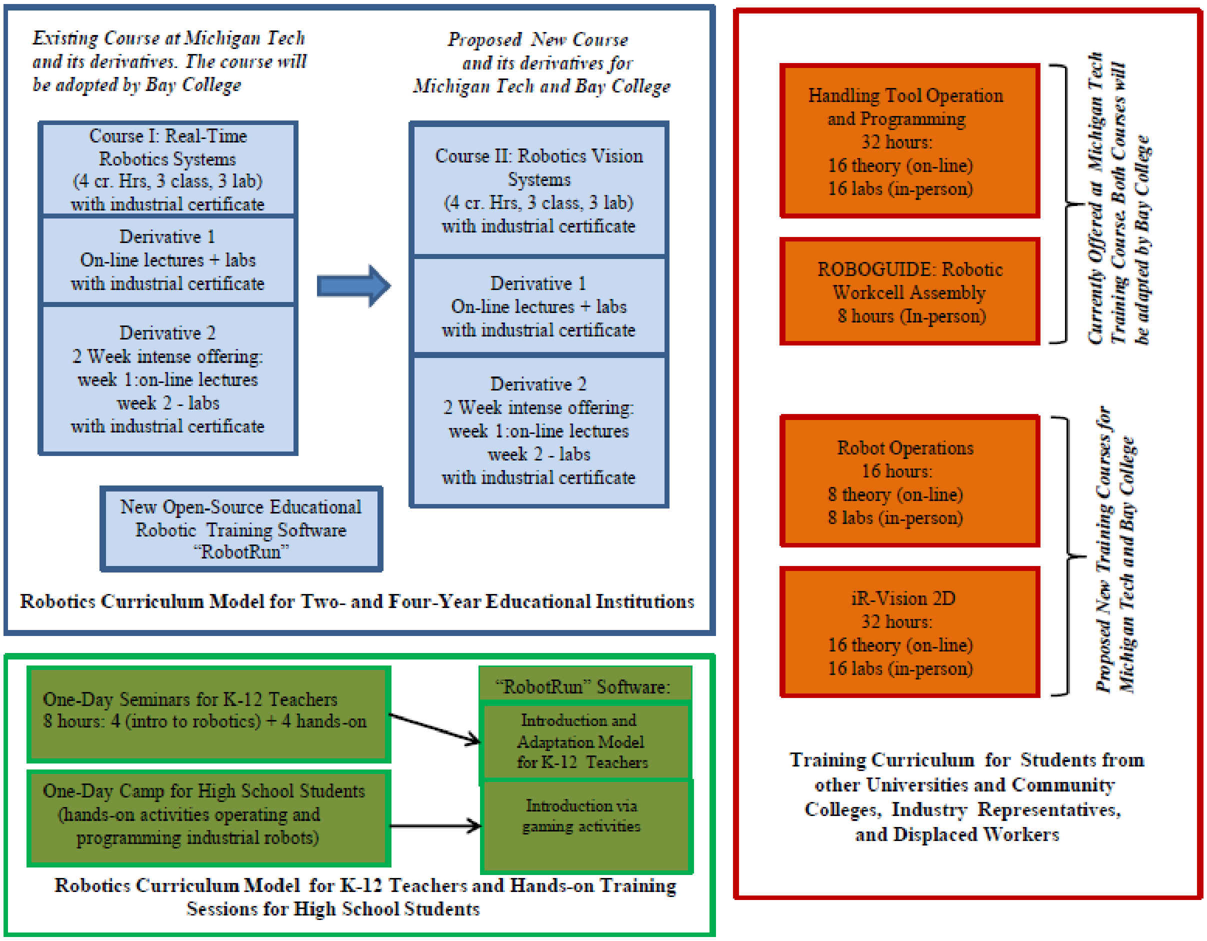

Figure 1: Proposed Robotics Automation Curriculum Development

Task 3: Robotic Automation Laboratories at Michigan Tech and Bay College:

The School of Technology at Michigan Tech offers high-quality, up-to-date academic programs aimed at meeting the immediate and future needs of industry. As a technology program, we offer significant hands-on lab experiences and applied research opportunities to undergraduates. These experiences complement the classroom experience and prepare our students for careers in a wide range of industries.

Developed Integrated Robotic Workcell at Michigan Tech

The industrial automation laboratory at Michigan Tech has four FANUC training carts, each comprising of a FANUC LR Mate 200iC robot, R-30iA Mate Controller, Sony XC-56 camera, air supply and a computer. These robots have an option for interchangeable end-effectors such as suction cups and 2-finger parallel grippers, which provides flexibility in developing a variety of application scenarios for the laboratory exercises. Approach of integrating three FANUC robots with a conveyor, programmable logic controller (PLC), safety guards, through beam sensors and vision systems in a single integrated robotic workcell are described in our previous publication [13, 15, 18] and therefore omitted here. Instead, authors describe possible application scenarios enabled by the developed robotic platform. Figure 2 depicts the overall layout of the integrated robotic workcell.

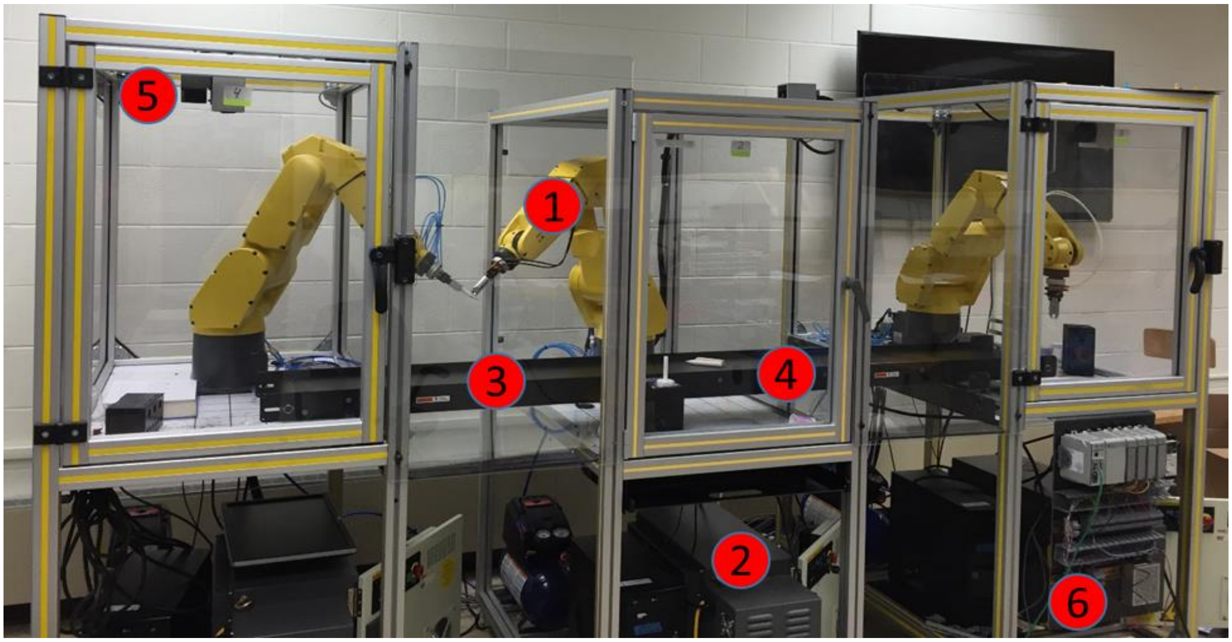

Figure 2. The work cell consisting of 1) Robot 2) Robot Controller 3) Conveyor 4) Sensors 5) Vision system 6) Control Panel

Application Scenarios of Lab Exercises.

Using the above setup to run the robots using PLC, a number of applications can be developed to perform tasks such as packaging, manufacturing and assembly of parts. Using the above system, students can create their own and innovative projects for the Robotics Vision course. To provide hands on experience to the students and explain the working of the integrated system, different lab exercises have been implemented as a part of the course and are discussed next.

Jenga Blocks Production and Palletizing

This exercise lets students relate to the various palletizing applications that are used throughout the industry. There are a few wooden blocks placed on the conveyor in a random orientation as shown in Figure 3.

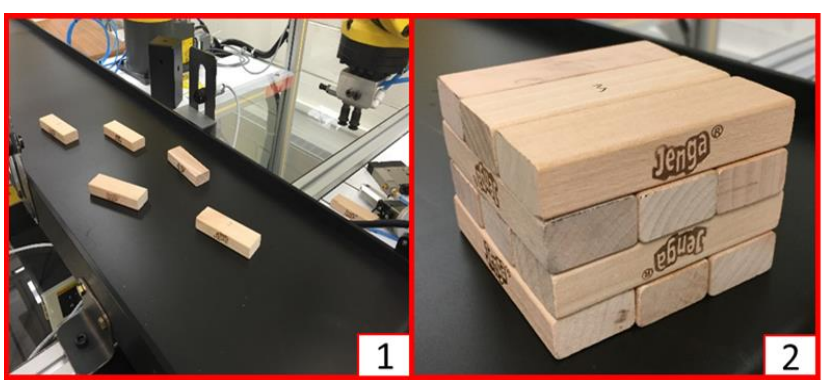

Figure3. 1) Randomly placed Jenga blocks travelling on conveyor 2) Final Pallet formed by the robot

The robot's vision system has to detect the blocks moving on the conveyor, stop the conveyor and, using the vacuum cup end-of-arm-tooling, pick up the blocks and form the final pallet. This is done using the palletizing option provided on the FANUC controller where number of rows, columns and layers of the pallet are defined along with the robot's approach and retreat points from the pallet. The second task is to teach the image of the block to the iR-Vision system's camera which is mounted exactly above the conveyor. The camera's search window is defined on the conveyor closer to the robot for easy approach. After the vision process is defined by the students, a program is written to integrate the vision with the palletizing program.

Having completed this exercise, students learn to create shorter programs on the teach pendant for palletizing applications. They also learn the procedure of the iR-Vision system that involves camera calibration, teaching geometric pattern to the camera and programming the vision instructions.

Marker pen color sorting and assembly

The main objective of this exercise, demonstrated in Figure 4, is to train the students the ability of the robotic vision system to differentiate between color and understand the importance of lighting conditions for the vision system. It also gives an insight to the students about the

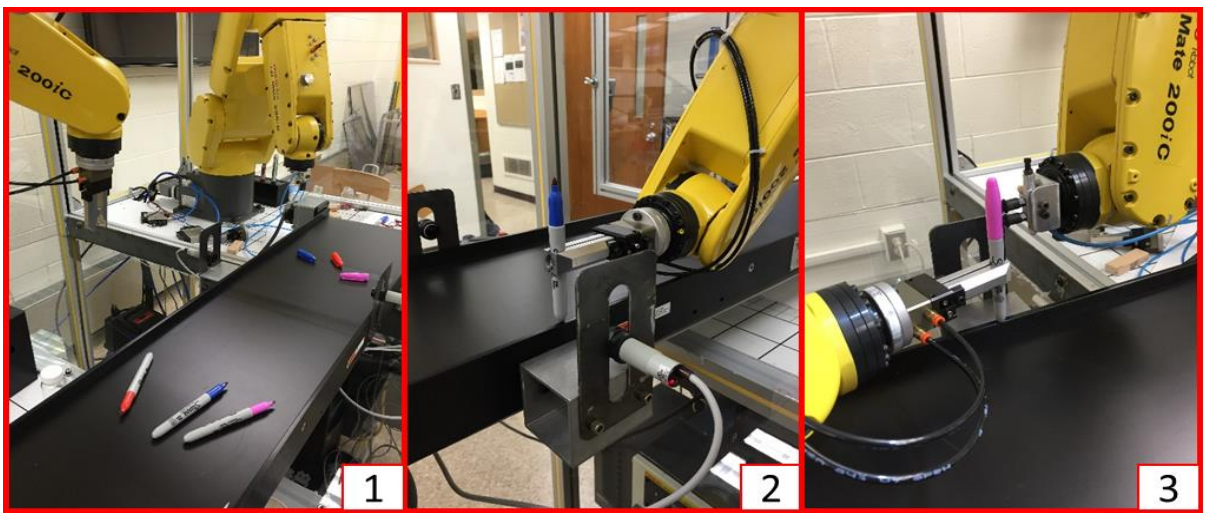

Figure4. 1) Inital setup with open markers and caps 2) Robot 2 picks the open marker and places it for assembly 3) Robot 3 assembles the cap on the marker

working of multiple robots controlled safely with the PLC. Three teams work on three different robots to program individual tasks.

The color of the markers, blue, red and pink are chosen in the increasing order of contrast. The belt being black in color makes it difficult for the robot to detect the dark colors such as blue. The students have to adjust the environment lighting and create enough brightness for the camera to detect the blue contrast. The caps are placed in the search region of robot 3 and the open

markers are placed in the region of robot 2. The robot 2's vision system detects the markers position and orientation in ascending order of contrast (blue, red and pink).

The robot 2 picks up the marker and places it on the flat surface for assembly. The through beam sensor confirms the presence of the marker and the robot 3's vision system finds the blue cap. The robot 3 picks up the cap from the conveyor and places it on the marker. The robot 3 tightens the cap, as shown in Figure 5, and sends signal to the PLC that it has completed its task. Now, the robot 2 places the blue marker on the conveyor. After the above process is completed for all the three markers, the conveyors start to move and brings the markers in the search region of robot 1. The robot 1 detects the markers and places them on the tray.

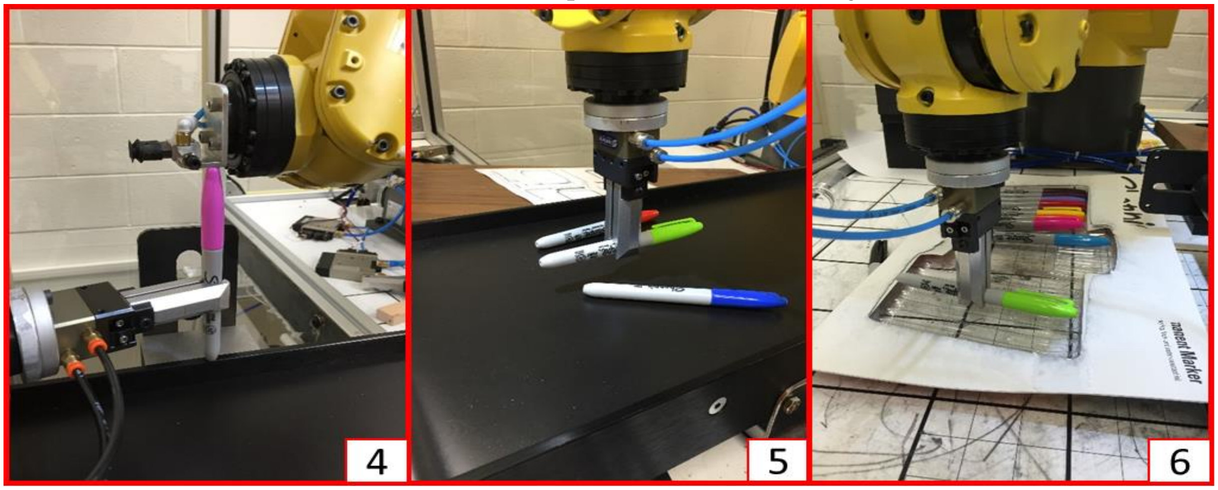

Figure 5. 4) Robot 3 tightens the cap by pressing it on the marker 5) Robot 1 picks the assembled marker 6) Robot 1 places the assembled marker on the tray

Combining three of these robotic carts into a single robotic work cell was developed with an aim to enhance the laboratory usage of these robots along with providing hands-on experience to students. The course will aim to have many such lab exercises in future.

Task 4: Develop new "RobotRun" robotic simulation software and make it available at no cost for adaptation by the other institutions.

To provide an effective robotic training to the university and community college students, industry representatives and displaced workers laboratory exercises must be integrated into the classroom environment. However, industrial robots are expensive and not every institution can afford to obtain them. Even though the hands-on training conducted on industrial equipment is preferred, the computer robotic simulation software can be a valuable substitute. Existing industrial robot training software is often too expensive and in many cases excessively cumbersome for schools to provide for students or for students to acquire on their own. For example, high schools and community colleges may want to provide students with a basic level of experience with programming industrial robots. If the software is accessible and free, such training software could provide a platform for anyone to learn more about industrial robotics. In this paper, we describe the development of "RobotRun", a software package that simulates an industrial robot and teach pendant controller. The software allows students to practice basic programming tasks, which control the movement and function of the robot. This software is suitable for use in high-school outreach activities and in any degree program, which focuses on industrial robotics such as two- or four-year Electrical Engineering Technology programs. "RobotRun" is written in the Java and provides a 3D view of a robotic arm, allows the use of different end-effectors, and allows simulating different factory environments and processes. In addition, the system allows students to learn about controlling the end-effector in different coordinate frames and programming paths that the robotic arm should follow. The teach pendant controller resembles real teach pendants and therefore provides students with a learning experience that can be transferred to real-world industrial robotics applications.

The RobotRun software[11, 13] is an industrial robotics simulator that simulates the core aspects of using a real robot. The software was developed[14, 16, 23] for usage by the high school, community college, and university classrooms to introduce students to robotics in an accessible way. Current beta version of the software is available online at http://www.cs.mtu.edu/~kuhl/robotics/.

Implementation Detail: Inverse Kinematics

One of the most important and complex aspects of the "RobotRun" software is the inverse kinematics system. This system calculates how to orient each segment of the arm when given a user-specified position and orientation for the end effector in the world frame. When the end effector is moving along a path, the inverse kinematics problem must be solved for each frame and the user expects the movement to be smooth and natural looking. The problem is made more complex by the fact that there are some end effector positions that are invalid because they are outside of the robot's range or would cause the robot to self-collide. Our solution, which resulted from making multiple attempts at solving the problem, relies on a well-known approach called the Jacobian Pseodoinverse. The general strategy is to calculate a matrix, which represents how small changes to each joint influences the end effector position and orientation, called a Jacobian matrix. Given this matrix and a target point for the end effector, we can calculate how each of the joints need to be changed to get the end effector to its intended position by inverting the Jacobian and multiplying this matrix by the vector pointing from the robot's current point to its target point. While this calculation should, in theory, result in the exact joint angles needed to move the end effector to the target position, it is not always feasible to obtain the inverse of the Jacobian, either due to time constraints or because the matrix is simply not invertible. To avoid these problems, we instead calculate the pseudoinverse of the Jacobian using a function provided by the Apache Commons Math Library to obtain a reasonable approximation of the matrix inverse. If the joint angles that result from this operation are within a certain margin of error from the target point, the inverse kinematics calculation is considered successful and no further operations need be done. If, however, the resulting position or orientation of the robot is too distant from the target, we begin the inverse kinematics calculation again using the result obtained from the previous calculation as the robot's new starting position, and continue in this fashion until either a tolerable result is obtained or the calculation limit is reached. By repeatedly performing this series of calculations, the algorithm should converge on a solution that is within our levels of tolerance. Note that, for the purposes of the software, a position consists of 12 floating point values which describe both the Cartesian position and orientation of the robot in space, and the joint rotational values that the robot has when occupying that position in that orientation. With extensive testing and troubleshooting, we have arrived at a solution with runs quickly on commodity hardware and provides a sufficiently accurate solution.

Application Scenarios

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 6, 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 vacuum 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.

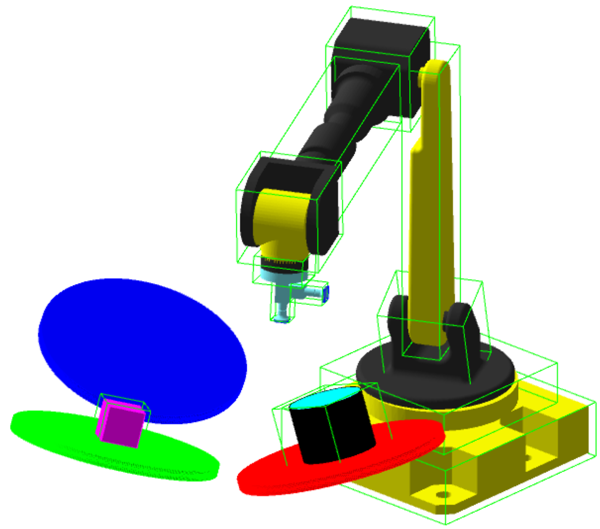

Figure 6: Workcell created to pick and place the box and cylinder on the fixtures in a cyclic manner.

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

A crooked shaped part is attached to the robot faceplate as shown in Figure 7 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.

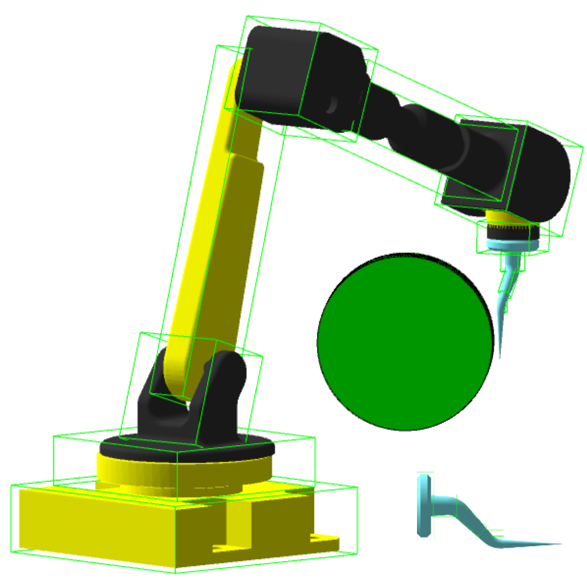

Figure 7: The robot is shown with the part that is grinded on the grinding wheel by rotating using tool frame created.

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 8. 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.

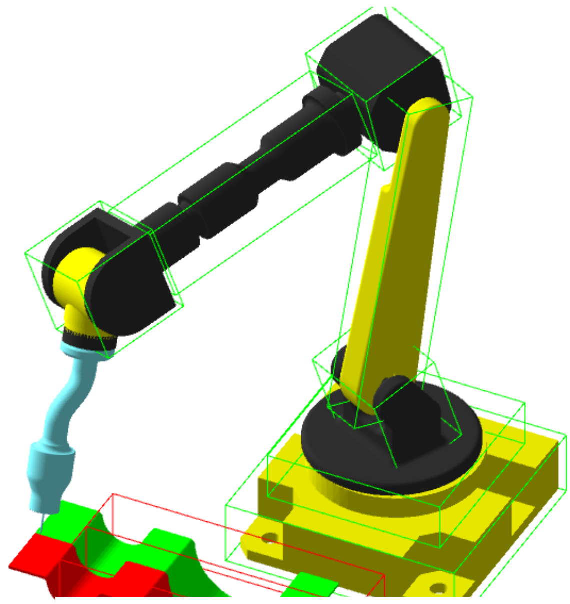

Figure 8: Welding two sheet metal parts along the path requiring linear and circular motion.

Gluing application using position registers and Offset instruction:

The robot generally performs gluing 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 9 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. Few other interesting scenarios 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. High level of details on the technical features, programming approaches and implementation scenarios can be found in our previous publications [11, 13, 14, 16, 23]

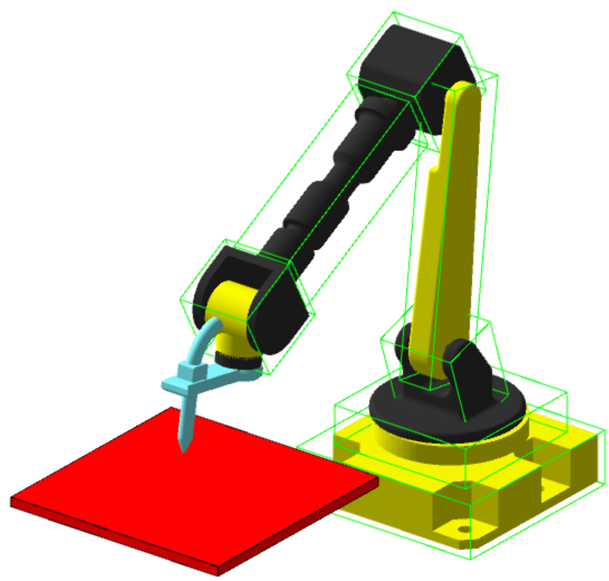

Figure 9. Applying glue on the rectangular sheet in a zigzag manner over the complete area using register and offset instructions.

Task 5: 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 led 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. The main impetus behind the workshops is to share the combined knowledge gained through curriculum development efforts and the technical information derived from lab development experiences. In addition, participants learn how FANUC Robotics training can be integrated in the curriculum of their home institutions. 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. More details on the structure of the conducted at Michigan Tech and Bay de Noc workshops can be found in our previous publications [3, 19] 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 [26, 27].

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

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. The “RobotRun” software developed will be freely available for adaptation, which will allow robotics to be taught even when the purchase of industrial robots is not feasible. Faculty development will include extensive training and industrial certification in robotics and automation. Partnership with FANUC will create 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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