Promoting Robotics Education: Curriculum and State-of-the-Art Robotics Laboratory Development

by

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Abstract: *To effectively meet the next generation's workforce needs, the electrical and computer engineering technology undergraduate curriculum must be up-to-date and relevant. It must effectively teach the rapidly changing technology widely used in industry. In order to meet these needs, and further enhance the educational programs in the School of Technology (SoT), we are developing a series of courses and adding an up-to-date robotics laboratory in the Electrical Engineering Technology (EET) program in the SoT. The demand for electrical and computer engineering technologists who are equipped with skills in robotic automation continues to rise. In addition to broadening the skill set of our SoT graduates, the EET program is collaborating with Fanuc Robotics to offer a professional certificate in robotic automation. This certificate represents a good model of collaboration between industry and academia. The EET program utilizes Fanuc Robotics Certified Education Robot Training program (CERT), which is available to qualified universities with the goal and commitment to the development of the engineering knowledge base and attracting young people to the robotic automation field. The SoT purchased two industrial robots utilizing the significant educational discount available through the Fanuc CERT program. This paper describes the development of a series of robotics courses and promotion of a professional certificate in robotic automation at the electrical engineering technology program. The development includes course material in industrial Robotics and establishing a robotic automation lab in partnership with the Fanuc Robotics CERT program.*

I. Introduction

Recent advances in robotics have revolutionized our personal and business lives. Today, commercial and industrial robots are in widespread use, performing jobs more cheaply and in some cases with greater accuracy and reliability than humans. They are also employed for jobs which are too dirty, dangerous, or dull to be suitable for humans. Robots are widely used in manufacturing, assembly and

packing, transport, earth and space exploration, surgery, weaponry, laboratory research, safety, and the mass production of consumer and industrial goods. Robots play significant roles in our personal lives as well by serving humans and performing everyday tasks such as cleaning, cooking, and repairing. Intense involvement of these artificial helpers in everyday life requires human specialists with up-to-date knowledge to maintain and monitor existing robots, as well as to develop new, smarter, safer, and more advanced machines. To meet this need, educational institutions must adequately respond to the high demand for specialists in the field of robotics by developing and offering appropriate courses and/or certifying workers involved in the industry of robotics and automation.

The EET program in the SoT is stepping up to this challenge by updating the curriculum with two new highly marketable and industry-oriented courses to promote new concepts and skills in industrial robotics and automation.

II. Motivation

During the last decade, popular interest in educational exploitation of robotics has increased significantly [1,3]. Robotics in education is seen as an interdisciplinary, project-based learning activity drawing mostly on math, science, and technology and offering major new benefits in education at all levels [2]. Robotics implements 21st century technologies and can foster problem-solving skills, communication skills, teamwork skills, independence, imagination, and creativity [4]. Taking into consideration that students have a better understanding when they express themselves through invention and creation [5], robotics activities are considered to be a valuable learning tool that can contribute to the enhancement of learning and to the development of students' thinking [2].

Some specialized robotics jobs require new skills, such as those of robot installer and robot integrator. While universities have long included robotics research in their curricular offerings and tech schools have taught industrial robotic arm control, new college programs in applied mobile robots are under development at universities in both the United States and Europe, with help from Microsoft, FANUC Robotics America Inc., MobileRobots Inc., and other companies encouraging the growth of robotics. Robotics is a naturally compelling subject for engineering, engineering technology, and computer science undergraduates, but never more so than when coupled with hands-on lab work. Robots have recently become a popular tool used to raise interest in computing among middle and high school students.

Undergraduate study in robotics is fairly common, although few universities offer specific robotics degrees. For instance, Worcester Polytechnic Institute (WPI) offers a Bachelor of Science in Robotics Engineering. 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. Academic programs in the SoT are designed to prepare technical and/or management-oriented professionals for employment in industry, education, government, and business. The educational programs include significant hands-on laboratory components to prepare students for practical design and production work. For the past few years, the SoT has experienced rapid growth as an educational

unit and as an interdisciplinary research team. From an educational perspective, this has been driven by the high industrial and government demand for technically skilled graduates.

To effectively meet the next generation's workforce needs, the undergraduate curriculum in electrical and computer engineering technology must be up-to-date and relevant. It must effectively teach the rapidly changing technology widely used in industry. In order to meet these needs, and to further enhance the educational programs in the SoT, the authors are developing and implementing a series of courses as well as adding an up-to-date robotics laboratory in the EET program in the SoT. In addition to broadening the skill set of our SoT graduates, our efforts are interdisciplinary and will generate a high impact on the university as a whole. The demand for electrical and computer engineering technologists who are equipped with skills in robotic automation continues to rise. The EET program is collaborating with Fanuc Robotics to offer a professional certificate in robotic automation. This certificate represents a good model of collaboration between industry and academia. The EET program utilizes the Fanuc Robotics Certified Education Robot Training program (CERT) which is available to qualified universities with a goal and commitment to the development of the engineering knowledge base and attracting young people to the robotic automation field.

The authors intend to integrate advanced concepts in robotics into the curriculum by:

1. Developing a series of robotics- and automation-related courses, available to both students within the SoT and those from other departments. Eventually, these courses will be offered online to further broaden impact.
2. Building a robotics laboratory equipped with state-of-the-art training tools that will provide students with extensive hands-on experience on the equipment currently used in industry.
3. Offering the Fanuc Robotics industrial certificate in robotics and automation.

III. Project Impact and Learning Outcomes

The project described in this paper will generate significant impacts that are summarized as follows:

- First, the development of the robotics curriculum will strengthen the robotics area and improve the quality of STEM education for undergraduate students by creating innovative learning materials and teaching strategies and implementing advanced, industry-approved hands-on expertise greatly valued by employers. The developed courses will cover all the theoretical and practical aspects of the knowledge database required for technologists involved in the robotics industry. Students involved in the program will be prepared for rewarding careers in robot technology, computer controlled machine programming, robotic sales, and more. Graduates will be prepared to use their skills to program, assemble, troubleshoot, coordinate, or design robots for use in industry.
- Second, professional development of faculty members will be advanced through extensive training and industrial certification in the field of robotics and automation. Training and certification will be provided by the industrial partners. This partnership will create an important link between academia and industry.

- Third, the appealing nature of robotics will enable us to use this project and its related facilities for outreach to broaden interest in science, technology, and engineering among local middle school and high school students. Inviting students and K-12 teachers to participate in the organized educational workshops will introduce them to current advances in technology and in the field of robotics in particular. This will help to create an important and often missing bridge between academia and K-12 education. Finally, the developed robotics courses and the state-of-art robotics laboratory equipped with the current industrial equipment will advance undergraduate research within the SoT, fostering enhanced robotics-related senior design projects and allowing students to participate in national and international robotics competitions.

There are rigid requirements in place to obtain a certificate in robotics. Each participating student must complete series of tasks including: the theoretical portion of the industrial robotics course, multiple simulation projects, laboratory assignments, and web-based quizzes. Upon successful completion of web-based quizzes for each topic of the course material, the involved student will need to successfully pass a comprehensive HandlingTool Operations and Programming exam.

Upon successful completion all of the requirements the students will have the knowledge to:

- Discuss the CERT Cart Safety.
- Explain the different frames of the robot operation.
- Describe different inputs and outputs and how to configure them.
- Apply various program instructions and macro commands.
- Modify the program at different levels.
- Set up a robot for production using the teaching pendant.
- Manipulate files: copy and delete programs, backup all or selected files to a preferred device.
- Load program from the backup device and how to do an Image Backup and Restore.
- Simulate operation of the robot via ROBOGUIDE simulation software.
- Manipulate the robotic arm and successfully complete the assigned tasks.

IV. Proposed Courses

Several courses will be developed and implemented to promote and enhance robotics education in the EET program of the SoT. The outline of the courses is provided below, with the short description in each case.

1. Introduction to Robotics: What the Robot is; Mechanics, Analysis, Control; Basics of Programming.

The course will introduce the science and technology of mechanical manipulations and robotics systems control and cover a broad range of robotics topics, including: what is a robot?; where do robots come from?; sensors, effectors, actuators; robot learning; robotics today; and emerging directions. The course will be suitable for students working towards their bachelor's degree as well as students interested in obtaining an industrial certificate in robotics. It will be designed to serve as an overview of the interdisciplinary technology of autonomous mobile robots, including sensing, control, decision making,

and applications. The course will also address the major aspects of designing, fabricating, and enabling robotic systems. Design aspects include determining specifications for a robot, determining its configuration, and utilizing sensors and actuators. Considerable attention will be dedicated to safety procedures in operating robotics platforms. A significant part of this course will be devoted to introducing the basics of programming industrial robots using the ROBOGUIDE software package. Within the shell of this powerful simulation tool, the student will learn the structure of the programming language commonly used in the field of robotics, get familiar with the HandlingTool software installed on the physical controller of LR Mate Fanuc robotics' mini robot, and learn to perform off-line programming. Upon receiving sufficient off-line programming training and passing a safety-related test, the students will be able to implement their knowledge and perform laboratory experiments programming and operating a state-of-art LR Mate Fanuc robotics' educational mini robot platform. Lab work will be structured in teams of two-to-three students in order to foster collaboration and ease some of the challenges and frustrations inherent in working with physical hardware. Computational aspects will also be emphasized throughout the course using MATLAB programming language. The course "Introduction to Robotics: What the Robot is, Mechanics, Analysis, Control and Basics of Programming" is a three credit-hour course and constitutes of two hours of recitations and three hours of lab weekly. The course will be open for sophomore students and the pre-requisite is "Circuits I, II", "Electrical Machinery" and "Programming Languages". The course will integrate ROBOGUIDE simulation software and MATLAB programming language, and the lab will use LR Mate Fanuc Robotics' mini robot.

2. Industrial Robotics

The course "Industrial Robotics" will reflect the new generation of robotics developments and systematize the current expertise of industrial robotics and its forthcoming capabilities. It will include a discussion of scholarly and practical robotic topics ranging from kinematics and programming to practical application areas and economic concerns. This course will be specifically developed with the intent of being very practical and will offer easily applied guidance to personnel involved in manufacturing with the current robotics systems on site or who may exploit robotic systems in the near future. The stand-out topics that will be covered in this course include: the development of industrial robotics; an overview of mechanical design, control, programming, and intelligence; organizational and economic aspects; robotics in progress; robotics in operation; and various applications. Robotics terminology commonly used in industry will also be covered. Due to the very practical content, this course will be a part of Fanuc Robotics industrial certification in robotics and automation. The hands-on experience is an essential part of this course and will occupy 70% of its time. The lab exercise will be devoted to practical aspects of programming FANUC Robotics minirobots. The course "Industrial Robotics" will be designed as a week-long course, totaling 35 hours. The first 10 hours will be devoted to the theory of robots and will cover important safety considerations related to manipulating the robot. The remaining 25 hours will be used to provide extensive hands-on experience working in the lab. The course will culminate in a two-hour exam in which the participants will have to demonstrate an understanding of theoretical background as well as the ability to program the robot for a task given by

the instructor. Upon successful completion of the course, the participants will receive the FANUC robotics certificate issued by the FANUC certified faculty of the EET program in the SoT. Due to the nature of the course, it will be offered on demand and may be conducted during winter and spring breaks or anytime in the summer. This flexibility will help to attract students not only from the university, but also participants from industry and students from other institutions.

V. Partnership with industry

The EET program in the SoT has established collaboration with FANUC Robotics America Inc., the leading company specializing in the development and production of innovative and intelligent robotic solutions. FANUC Robotics deeply supports the educational mission of the SoT and the university as a whole, providing a significant educational discount on educational minirobots. In fact, the EET program has purchased two LR Mate Training Carts MH1 & Certification Package totaling 63,754 dollars. However, the company list price for the same product and services is 648,080 dollars. Given that, the FANUC robotics has already provided an educational "Gift in Kind" valued at 584,326.

FANUC Robotics Certified Education Robot Training Program

The mission of the FANUC Robotics Certified Education Robot Training (CERT) Program is to create Certified Education Robot Training that promotes an understanding of FANUC Robotics' robotic 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 program certifies instructors at educational institutions to train their students to program FANUC robots. To accompany the CERT program, FANUC robotics provides to the SoT a new innovative educational tooling package that includes an industrial robot, integrated vision system, and ROBOGUIDE simulation software. With this package, students will learn the fundamentals through advanced engineering and manufacturing concepts. Students will utilize the same robots and software that are most widely used in industry.

The FANUC Robotics Certification and the right to purchase the unique HandlingTool Operations and Training materials at the academic partner price requires extensive professional development of the faculty involved in the training effort. At least one instructor candidate must complete multiple on-line training sessions as well as on-site training. On-line training involves attending and passing the following on-line courses: The Robot Operations, HandlingTool Operations and Programming, On-Line HandlingPRO, On-Line Advanced HandlingTool Operations and Programming Certification. Upon successful completion of web-based courses, the involved faculty will need to attend and successfully pass a live HandlingTool Operations and Programming class as a student at FANUC's facility. The candidate also needs to provide an outline of the FANUC-related course materials. After all the requirements are completed, the faculty becomes certified by FANUC as an instructor to teach robotics-related courses and to issue the FANUC Robotics certificate. One of the authors has already completed all the required training, successfully past on-line and on-site examinations, and become certified by the

FANUC instructor. The first-pilot course in robotics is currently offered in spring 2010 semester to the students of the university.

LR Mate Education Training Cart MH1 from FANUC Robotics.

The FANUC Robotics LR Mate Education Training Cart MH1 shown in Figure 1 incorporates FANUC Robotics' latest generation electric, servo-driven minirobot, housed in a self-contained, portable enclosure. Portability of the entire assembly is a plus and makes the system mobile, allowing training or demonstration to be performed where needed. The LR Mate Education Training Cart MH1 can be used to teach students how to program a real robot, in real time, in a safe, controlled environment, using FANUC's HandlingTool software supplied by the FANUC robotics. The LR Mate Education Training Cart MH1 can also be used to demonstrate robot operations during department visits and at open house events, as well as for student recruiting. The self-contained Lexan enclosure provides safety while training. With its compact size and 110 volt power requirements, it can be easily set up to provide hands-on access to a real industrial robot, with minimal risk of the injuries a robot can bring to its work envelope.

The FANUC Robotics LR Mate Education mini robot provides multiple benefits: industry-standard components that allow teaching principles of automation, compact and portable design, affordability, safe construction, and an integrated vision system commonly used in the industry. The extremely powerful software solution, ROBOGUIDE developed by FANUC Robotics will allow students to program the robot off-line and simulate its future tasks. HandlingTool software also developed and installed by FANUC Robotics on the controller allows users to learn real-time singularity avoidance and collision protection. The FANUC Robotics LR Mate Education mini robot is a highly upgradable system, and the current educational training package provided by the company will allow demonstrating the basic functions such as vision, collision guard, path tracing, insert, and straight-line accuracy, as well as creating more advanced hands-on laboratories.

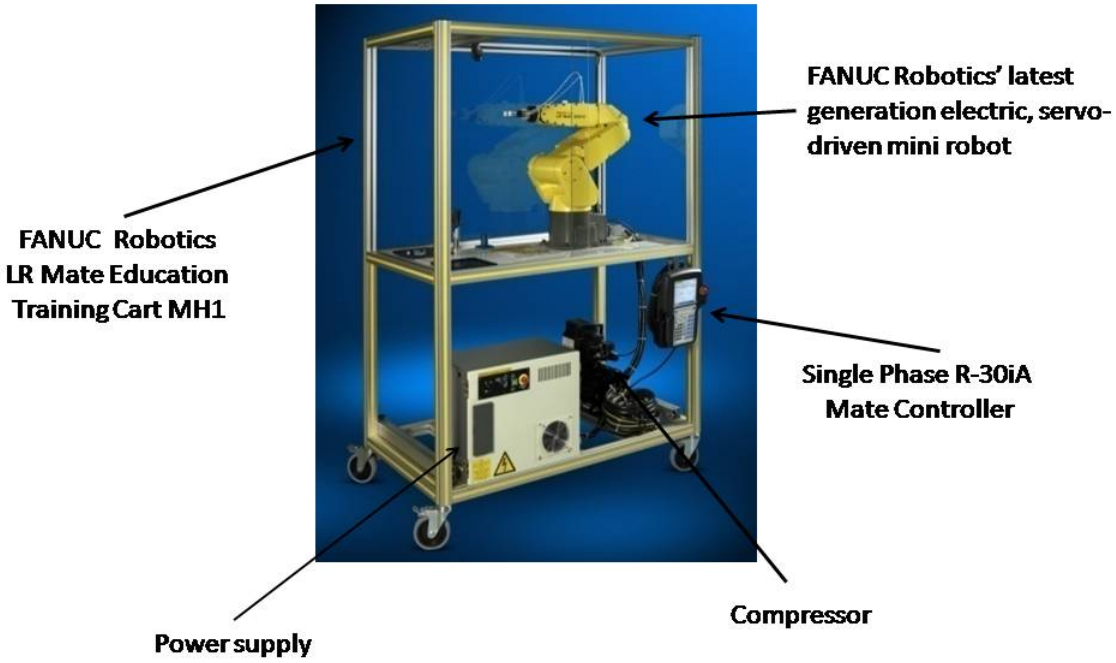

Figure 1: The FANUC Robotics LR Mate Education Training Cart MH1; incorporating FANUC Robotics' latest generation electric, servo-driven mini robot and housed in a self-contained, portable enclosure. The figure also shows the location of the power supply, the compressor, and the single phase LR Mate controller.

VI. Facilities – New Robotics Laboratory

The SoT at the University offers high-quality, up-to-date academic programs that endeavor to meet the immediate and future needs of industry. The University's strategic plan calls for us to be nationally recognized for programs that advance technological education through excellence in learning, discovery, and engagement. While we are a technology program, we go beyond most other technology programs by offering 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.

The EET program at SoT has identified present needs for a new state-of-the-art robotics laboratory that will support the two new courses "Introduction to Robotics" and "Industrial Robotics" and provide students with training that meets industrial standards and provides state-of-the-art, hands-on training. Upon completion, the laboratory will be equipped with six workstations and support class sizes of 30 students. Figure 2 shows a single workstation and consists of an LR Mate FANUC Robotics educational

mini robot platform, a single phase R-30iA Mate controller, and a high-end computer with installed ROBOUGIDE software package to be used for off-line training, programming, and modeling.

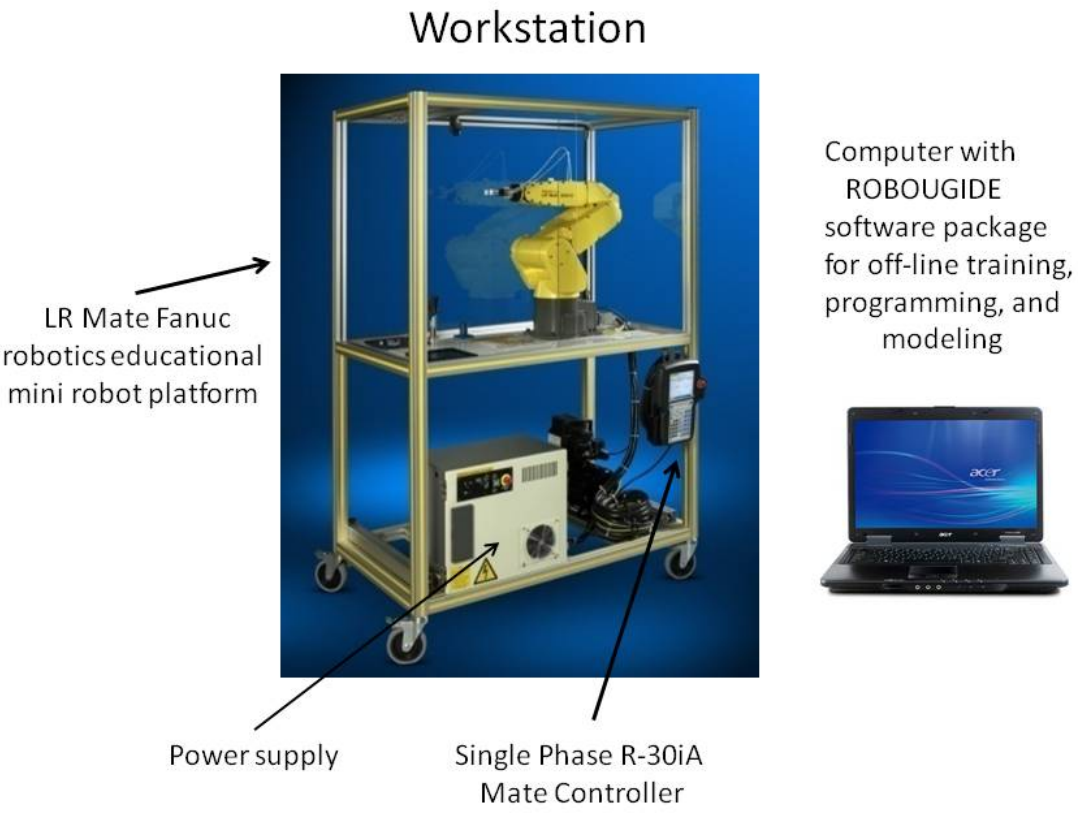

Figure 2: A single laboratory workstation consisting of an LR Mate FANUC Robotics educational mini robot platform, a single phase R-30iA Mate controller, and a high-end computer with installed ROBOGUIDE software package.

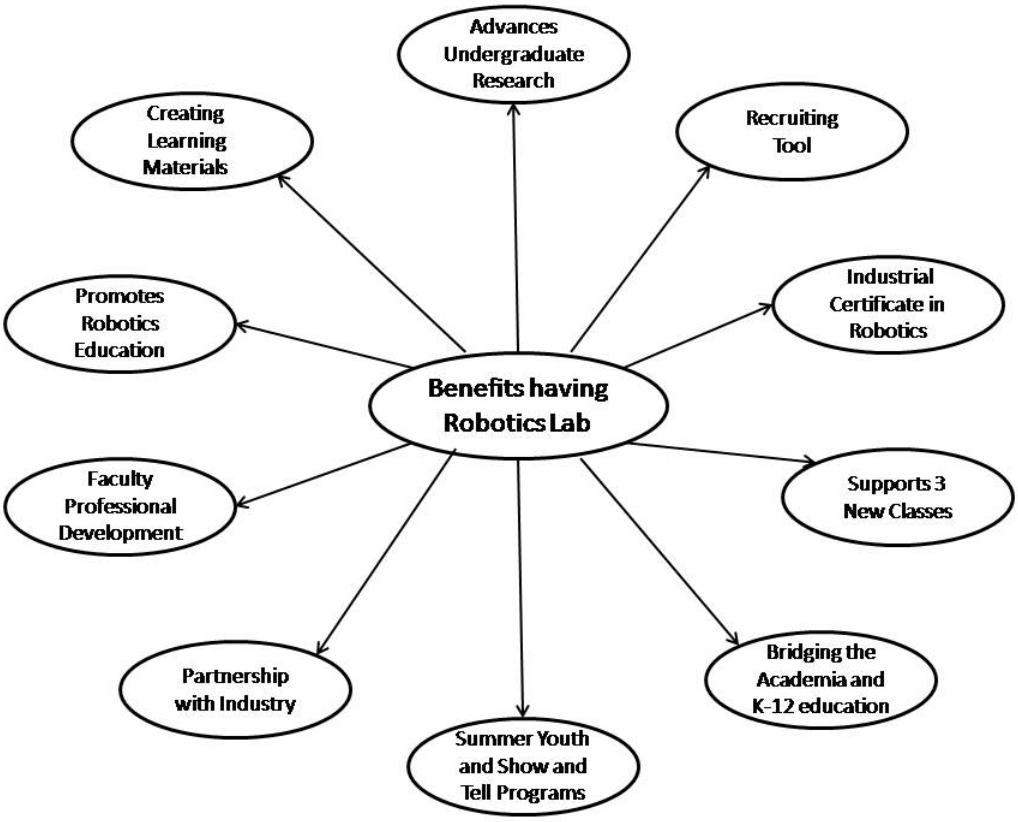

Figure 3: Chart showing the benefits of having developed robotics laboratory for the SoT and the University as a whole.

VII. Conclusion

Academic programs in the SoT in the University are designed to prepare technical and/or management-oriented professionals for employment in industry, education, government, and business. The development of new robotics-related courses and a robotics laboratory will promote robotics education and create significant impact on education in the SoT and the University as whole. The benefits derived from the project described in this paper are represented in Figure 3. By strengthening the robotics area, the proposed program will improve the quality of STEM education for undergraduate students by creating innovative learning materials and teaching strategies and by implementing advanced, hands-on expertise valuable to industry. The robotics laboratory will support two newly developed courses. The professional development of involved faculty members will be advanced through extensive training and industrial certification in the field of robotics and automation provided by FANUC Robotics America Inc. This partnership creates an important link between academia and industry. The appealing nature of the field of robotics will be used in our outreach efforts to trigger an interest among the students of the local middle and high schools. Inviting students and K-12 teachers to the organized educational workshops will introduce the current advances in technology and in the field of robotics in particular, to

the participants. This will help to create an important and often missing bridge between academia and K-12 education, and ultimately impact the future student body. The proposed robotics courses will advance undergraduate research within SoT, fostering enhanced robotics-related senior design projects and allowing students to participate in national and international robotics competitions. Such an approach to the education of engineering technology students meets the expectations of ABET accreditation standards by connecting students to the solution of real problems.

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Biography

Dr. Sergeyev is currently an Assistant Professor in the Electrical Engineering Technology program in the School of Technology at Michigan Technological University. Dr. Sergeyev is earned his bachelor degree in electrical engineering in Moscow University of Electronics and Automation in 1995. He obtained the Master degree in Physics from Michigan Technological University in 2004 and the PhD degree in Electrical Engineering from Michigan Technological University in 2007. Dr. Sergeyev research interests include high energy lasers propagation through the turbulent atmosphere, developing advanced control algorithms for wavefront sensing and mitigating effects of the turbulent atmosphere, digital inline holography, digital signal processing, and laser spectroscopy. He is also involved in developing new eye-tracking experimental techniques for extracting 3-D shape of the object from the movement of human eyes. Dr. Sergeyev is he is a member of American Society for Engineering Education (ASEE) and actively involved in promoting engineering education.

Dr. Alaraje's research interests focuses on processor architecture, System-on-Chip design methodology, Field-Programmable Logic Array (FPGA) architecture and design methodology, Engineering Technology Education, and hardware description language modeling. Dr. Alaraje is currently the Electrical Engineering Technology program chair as well as a faculty member at Michigan Technological University, he taught and developed courses in Computer Engineering technology area at University of Cincinnati, and Michigan Technological University. Dr. Alaraje is a Fulbright scholar; he is a member of American Society for Engineering Education (ASEE), a member of ASEE Electrical and Computer Engineering Division, a member of ASEE Engineering Technology Division, a member of Institute of Electrical & Electronic Engineers (IEEE), and a member of Electrical and Computer Engineering Technology Department Heads Association (ECETDHA).