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PROVIDING EXPERIENTIAL LEARNING OPPORTUNITIES IN MECHATRONICS: TELEOPERATED ROBOTIC WORKCELL RESEARCH AND DEVELOPMENT

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Abstract

The emerging technology field of Mechatronics focuses on developing and implementing advanced automation for industrial applications. Thus, Mechatronics encompasses advanced fields, including robotics, Artificial Intelligence (AI), and cybersecurity. Though the demand for Mechatronics expertise is growing, available experiential workforce development opportunities in Mechatronics are limited. This project will research and develop educational materials and tools and provide project participants with experiential opportunities through an online Mechatronics Education Portal (MEP), experiential Mechatronics Practice (MP) initiatives, and a Mechatronics Industry Pathways Rotation. The MEP and MP modules are focused on the five Mechatronics pillars of Robotics, Mechanics, Electronics/Controls, Cybersecurity, and Artificial Intelligence. This project leverages partnerships among Michigan Technological University, West Shore Community College, Gogebic Community College, three nonprofit organizations, and nine regional industry collaborators. The main project objectives are to improve interdisciplinary Mechatronics training through experiential learning opportunities; develop a flexible and comprehensive program to promote a diverse and inclusive STEM workforce: and facilitate sustainable collaboration amongst project partners centered on Mechatronic workforce preparation and placement. As part of the project research and development of the Mechatronics Educational Portal, the Teleoperated Robotics Workcell (TRW) allowing for remote robot manipulation and programming is being developed. The TRW consists of a Fanuc collaborative robot, three cameras for real-time feedback to the user and a computer server to host the developed software. The interface for the client will consist of the virtual teach pendant with an overlaid display screen of the real teach pendant and two display windows showing the robot from different angles transmitted by the cameras installed in the physical robotic workcell. The TRW will enable remote access to the robot by users from anywhere in the world via the internet in a safe environment. In this paper, the authors provide details of the research and development stages of the TRW.

Keywords: *Robotic, mechatronics, Fanuc, STEM, workforce.*

1. Project goal and objectives

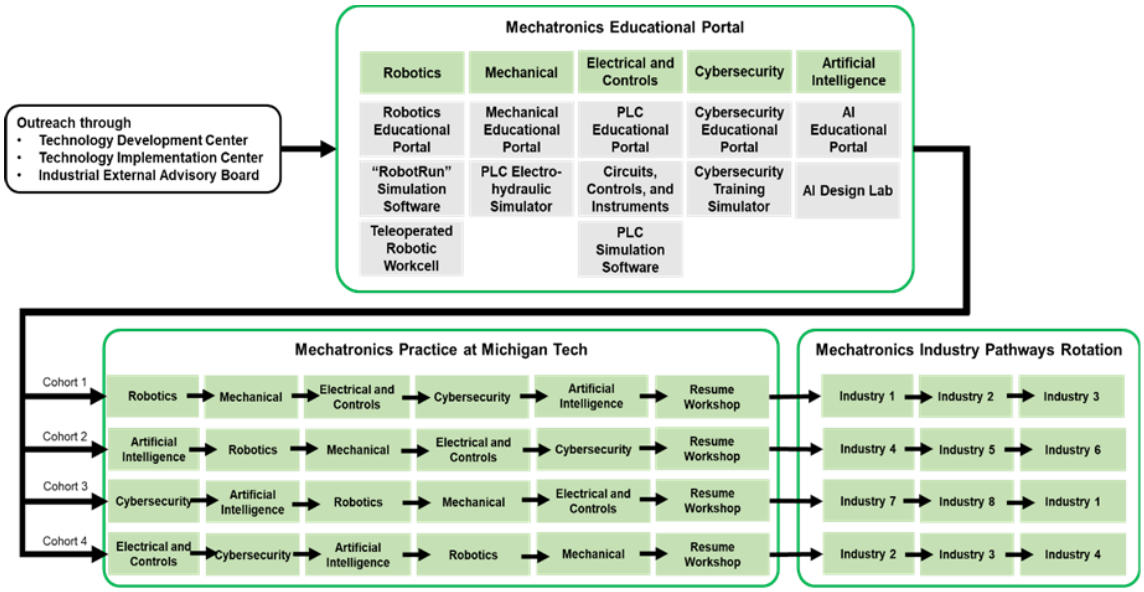
This project, sponsored by ExLENT NSF program, aims to provide experiential learning opportunities in Mechatronics to promote a diverse STEM workforce in emerging technology fields, including robotics, mechatronics, and advanced manufacturing. The project is aligned with the regional economy in the Upper Peninsula and Northern Michigan; resources will be broadly applicable and disseminated widely. In pursuit of this goal, project objectives are to:

- Promote a diverse and inclusive STEM workforce through flexible and accessible training programs;
- Improve existing mechatronics education and training by cohesively teaching advanced emerging technology fields in an interdisciplinary fashion for foundational and applied Mechatronics;
- Develop a pipeline centered around mechatronics workforce preparation and placement through a sustainable partnership amongst industry, community colleges, and four-year universities;
- Provide experiential learning opportunities in Mechatronics through state-of-the-art training facilities;
- Demonstrate a career-oriented outlook in Mechatronics through real-world experiences in advanced industry facilities.

2. Experiential learning opportunities

This project seeks to address the educational needs in Mechatronics through experiential learning opportunities. Focused on the Beginnings Track, this project will develop a STEM pipeline between 2-year and 4-year institutions while engaging industry partners to offer experiential opportunities in Mechatronics. Students will participate in online Mechatronics modules through this pipeline to build foundational knowledge in Mechatronics-related STEM topics. Students will then experience Mechatronics labs at Michigan Tech to engage in experiential learning. Participants will end their enrollment in the program through rotational site visits at advanced industrial in the region to provide an industry-oriented outlook for Mechatronics. The following figure depicts the structure of the proposed project plan. Outreach and recruitment will be conducted to ensure the participation of diverse and inclusive cohorts within the ExLENT program.

Figure 1. Experiential Learning Process Flow.



2.1. Mechatronics educational portal

Based on the solid foundation of an already established robotics and controls curriculum at Michigan Tech (Sergeyev et al., 2015), the authors intend to develop and launch a standalone Mechatronics Educational Portal (MEP). The proposed MEP will be freely available to individuals possessing some existing STEM competencies, including stackable certificates in STEM or those enrolled in associate's degree programs. The MEP will stand on the five pillars of a mechatronics foundation: robotics, mechanical, controls, cybersecurity, and artificial intelligence. Each pillar will include theoretical modules on the subject matter and relevant simulation and/or virtual training tools to enable laboratory exercises.

The Robotics Educational portal (REP) will be comprised of the "RobotRun" robotic simulation software (Hooker et al., 2017), robotic tutorials, and online lectures developed via this project. The robotic tutorials will be established with the assumption that the user has limited initial robotics knowledge. Online lectures will complement the tutorials, and industry-like scenarios will be incorporated into the "RobotRun" software (Sergeyev, Alarajie & Kuhl, 2018). The portal will include self-assessment tools. The Teleoperated Robotic Workcell (TRW) will enable remote training on industrial robots by providing the remote access to the robot by users from anywhere in the world via the internet in a safe environment.

The Mechanical portion of this program will include both theoretical and hands-on effort. The theoretical effort will be comprised of the Mechanical Educational Portal (MechEP) and Electrohydraulic System Simulator carried out through a virtual environment. The hands-on effort will be comprised of basic hand calculations, laboratory demonstrations, and experiments at Michigan Tech.

Programmable Logic Controllers Educational Portal (PLCEP) is comprised of a set of open-source and online learning modules designed to give students interactive, hands-on experience with programming PLCs on a standard desktop or laptop computer. The learning modules will include multimedia materials that introduce the content. Utilizing the Advanced Circuit Controls and Instrumentation (ACCI) module, the individuals will be trained in designing, analyzing, and enhancing advanced circuits and control systems are in high demand in the industry. The main mechatronics objectives are the interdisciplinary skills to

manipulate a complex control system and measure variables with instruments. A combination of worksheets, presentations, simulation manuals, and hands-on projects will be developed as open-access learning modules. PLC Simulation Software (Sergeyev, Alaraje, Kuhl, Kalenauskas & Li, 2014) is the integral part of the PLCEP and provides the users with the opportunity to simulate advanced mechatronics systems commonly present in today's manufacturing processes.

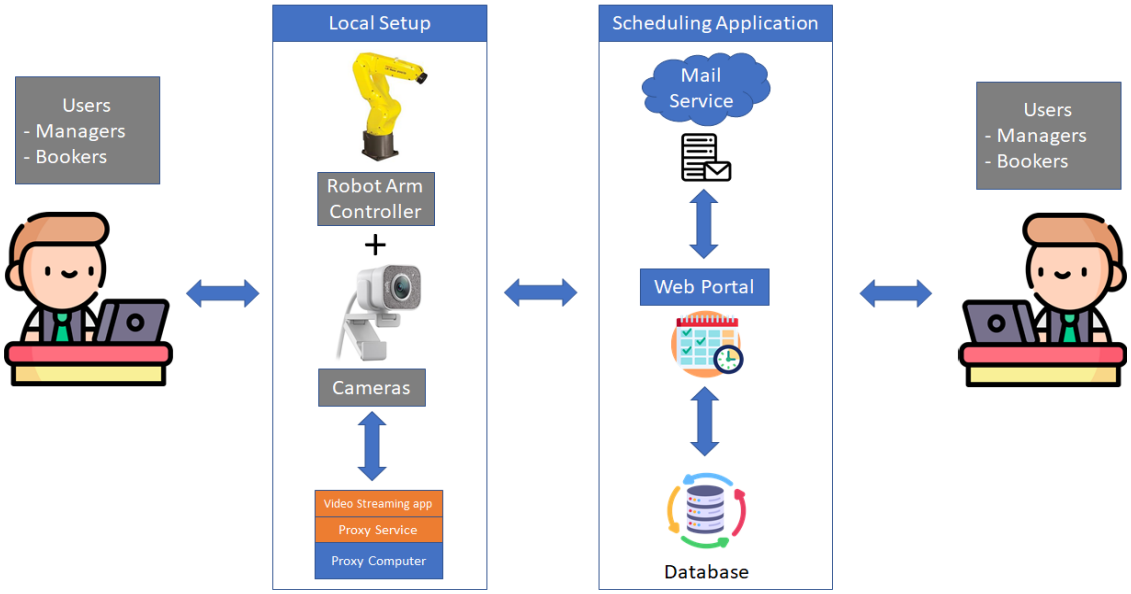
Cyberattacks are becoming more common, sophisticated, and damaging as Mechatronics technologies become more interconnected. A pressing issue is a need for a well-trained and well-prepared cybersecurity workforce. Developed via this project, a Cybersecurity Educational Portal (CEP) will provide hierarchical knowledge of cybersecurity threats to Industrial Control Systems (ICS) and the security controls to mitigate those threats. A Cybersecurity Training Simulator (CTS) will be developed as an online lab platform to provide students with simulated demonstrations and practice in best practices for cybersecurity. Both the CEP and CTS will be tailored to participants without a deep background in cybersecurity or ICS.

AI is an essential tool for modern industrial processes including electrical, mechanical, computer, robotic, control engineering, and cybersecurity areas. While Industry 4.0 brings new technologies, the industry faces challenges of a shortfall of skilled workers in AI, particularly to service advanced Mechatronics technologies. An AI Educational Portal (AIEP) and AI Design Lab (AIDL) three-module approach is proposed to address this issue. The modules are: fundamental concepts; software implementation with Python programming; and advanced applications such as production analytics and vision-based robotics. The modules include tutorials, recorded online lectures, and virtual practice implementation.

3. Teleoperated robotic workcell

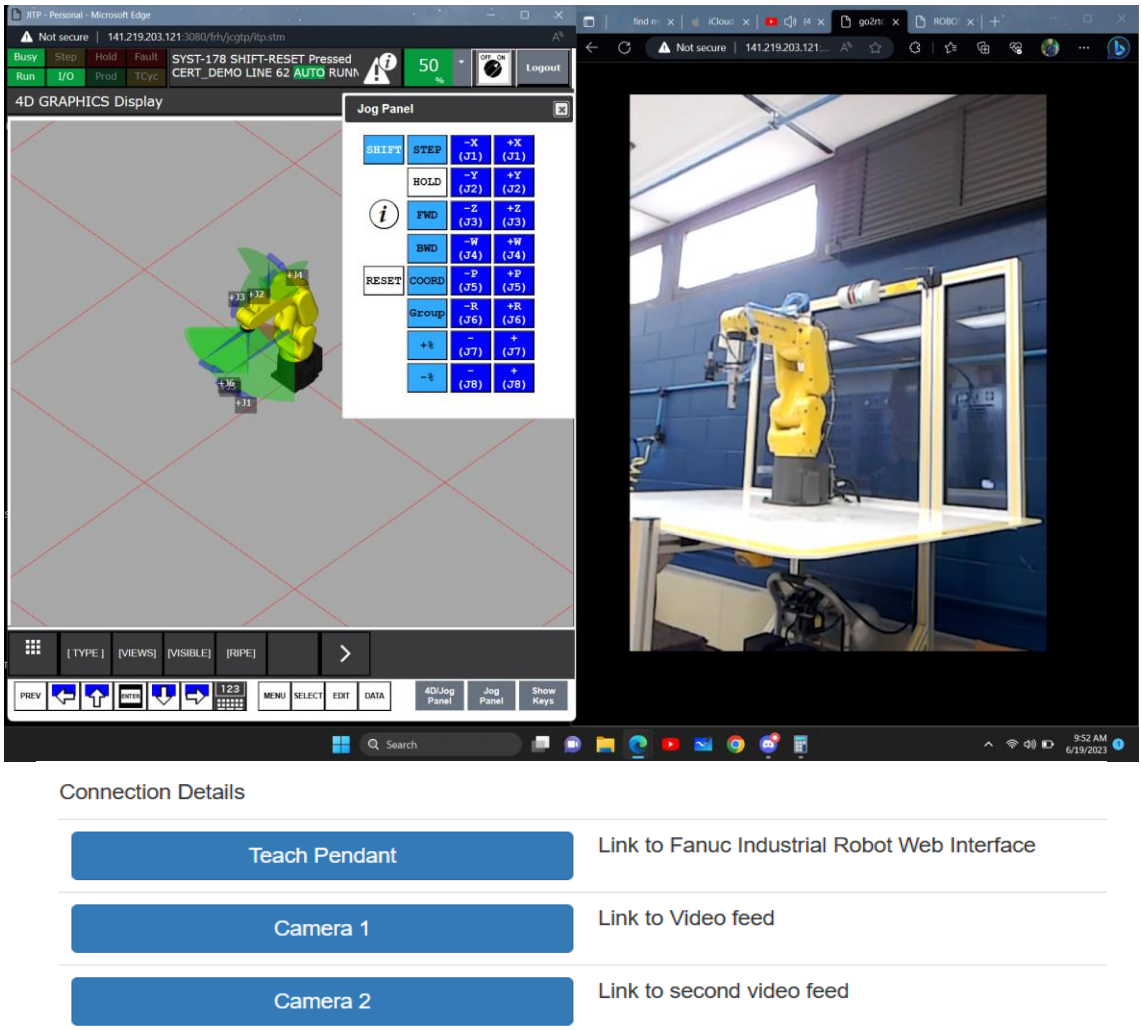
The TRW is designed to provide training opportunities to college students, industry representatives, and displaced workers wishing to retool their skills and become more competitive in the job market.

Figure 2. Teleoperated Robotic Workcell Overview.



The TRW enables remote access to the robot by a user anywhere in the world as long as an internet connection is available. The user can jog, program, and do any operations on the robot that the student can do if physically present in the lab. The developed system consists of a Fanuc robot with an added remote i-Pendant feature and R30iD controller, multiple webcams for providing a video feed to the user, and a web-based portal for remote access. The portal has admin and user features allowing complete control over scheduling and training sessions. The admin section of the portal allows the manager to enable specific time slots for the users to request training on the teleoperated Fanuc robot. The user section of the portal is used to request time and receive training. During the training, the user utilizes a web-based interface to control and program the FANUC robot and receives a real-time video feed of the robot's motion from two webcams, providing a close-up and overall view of the robot. In this paper, the authors provide the details of the system, including hardware and software options.

Figure 3. The Developed Teleoperated Robotics Workcell with Controls.



3.1. TRW hardware

The Fenceless Fanuc LR-Mate R30iD robot has a safety scanner preventing the user from approaching the robot during operation. The cell also features robotic vision systems and interchangeable end-effectors.

The proxy computer that connects to the Fanuc robot via an Ethernet connection uses at least two webcams to allow remote users to see the robot and has a second Ethernet connection to the Internet with a fixed, globally accessible IP address. The computer runs a "proxy" service that allows users to access the robot's teach pendant via their web browser during their approved, previously scheduled timeslot.

Multiple Webcams for video streaming. The cameras are situated to provide a multi-angle view of the robotic workcell. The computer runs a service that allows external users to see the robot's webcam video feeds. The two weblinks provided at the start of the session will lead to the FANUC robot homepage, which is a PC version of the teach pendant, and the second web link will lead to the webcam link of the FANUC robot. The user can enable the split screen to stream the video link and operate the robot via the virtual pendant. The robot homepage provides a medium to browse through teach pendant menus, and the jog panel/4D jog panel offers a medium to move the robot with the help of x, y, z, w, p, and r buttons. The video stream helps the user switch between the two webcam feeds as per their preference to interact with objects and environment

3.2. Booking process

Booking starts with a robot manager creating time ranges in the system from which end users can book. End users can then access the system and book sessions within those time ranges. Once the sessions are booked, they are reviewed by the robot manager and either accepted or declined. Whatever the review decision, an email is sent to the email provided during the booking process. If approved, a link is sent to the end user to access their booked session when the time comes.

3.3. Remote operation

After the user has scheduled a time slot and has it approved by the scheduling manager, they will begin a session where they can control the robot remotely at the scheduled time. The end user can view the video streams, interact with the robot's teach pendant, and control the robot. Only the authorized end-user should be allowed to control the robot during the scheduled session.

The end user will need a Windows machine running Microsoft's Edge browser in Internet Explorer compatibility mode. A large monitor or multiple screens may also be beneficial to view various video feeds and the teach pendant simultaneously. The system requires a reliable 100Mbps or similar internet connection for smooth operation. If the user's IP address changes while using the system, their connection may be temporarily interrupted. The system will re-establish the connection to resume operating the robot.

4. Conclusion

The paper describes a successful collaboration effort between several universities improve interdisciplinary Mechatronics training through experiential learning opportunities The research, develop, and implement a State-of-the-Art Teleoperated Robotic Workcell (TRW) as part of the ExLENT project to enable enhanced remote training for industrial robots is described in details. The system is designed to provide training opportunities to college students, industry representatives, and displaced workers wishing to retool their skills and become more competitive in the job market. The TRW enables remote access to the robot by a user anywhere in the world as long as an internet connection is available.

Acknowledgments

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