Development and Implementation of Teleoperated Robotic Workcell to Enable Remote Robotic Training for Students and Industry Representatives.

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Abstract

Online education is on the rise in the US and abroad and provides a convenient form of knowledge transfer to people who cannot be full- and or even part-time students at community colleges or universities. This factor impacts industry representatives, displaced workers, and low-income learners. Usually, online education consists of online lectures and/or tutorials designed so users can comprehend the studied subject. The missing piece of online education is the lack of hands-on activities. To address this issue, Michigan Tech and West Shore Community College collaborate on researching, developing, and implementing a State-of-the-Art Teleoperated Robotic Workcell (TRW) to enable enhanced remote training for industrial robots. 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.

Introduction

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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 [4]. 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

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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. The advanced features of the designed system and their utilization are explained next.

System Overview

The developed system, shown in Figure 1, includes various hardware and software components.

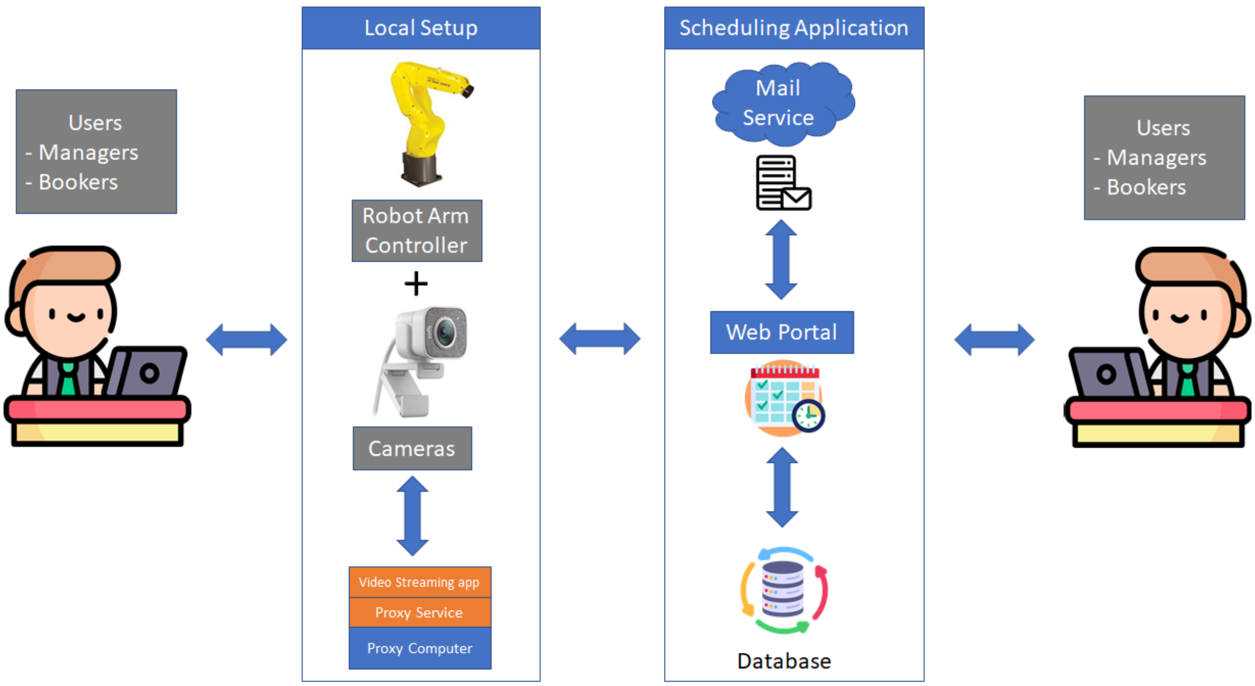

Figure 1: The Developed Teleoperated Robotics Workcell – Major Workflow

The solution is guided by two major workflows: A Booking Process and a Remote Operation Process.

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.

Remote Operation:

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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.

The **Hardware Options**, shown in Figure 2, include:

1. The Fenceless Fanuc LR-Mate R30iD [3] 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.

2. 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.

3. 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.

4. Virtual representation of the Fanuc robot performing production. The virtual model synchronously moves with the physical robot.

The **Software Options** include the web-based portal allowing users to interact with the robot remotely. The portal also hosts a scheduling application for the manager and a booking function for the user. The web portal acts as a relay between the Mail service and the Data Base (see Figure 1 for details)

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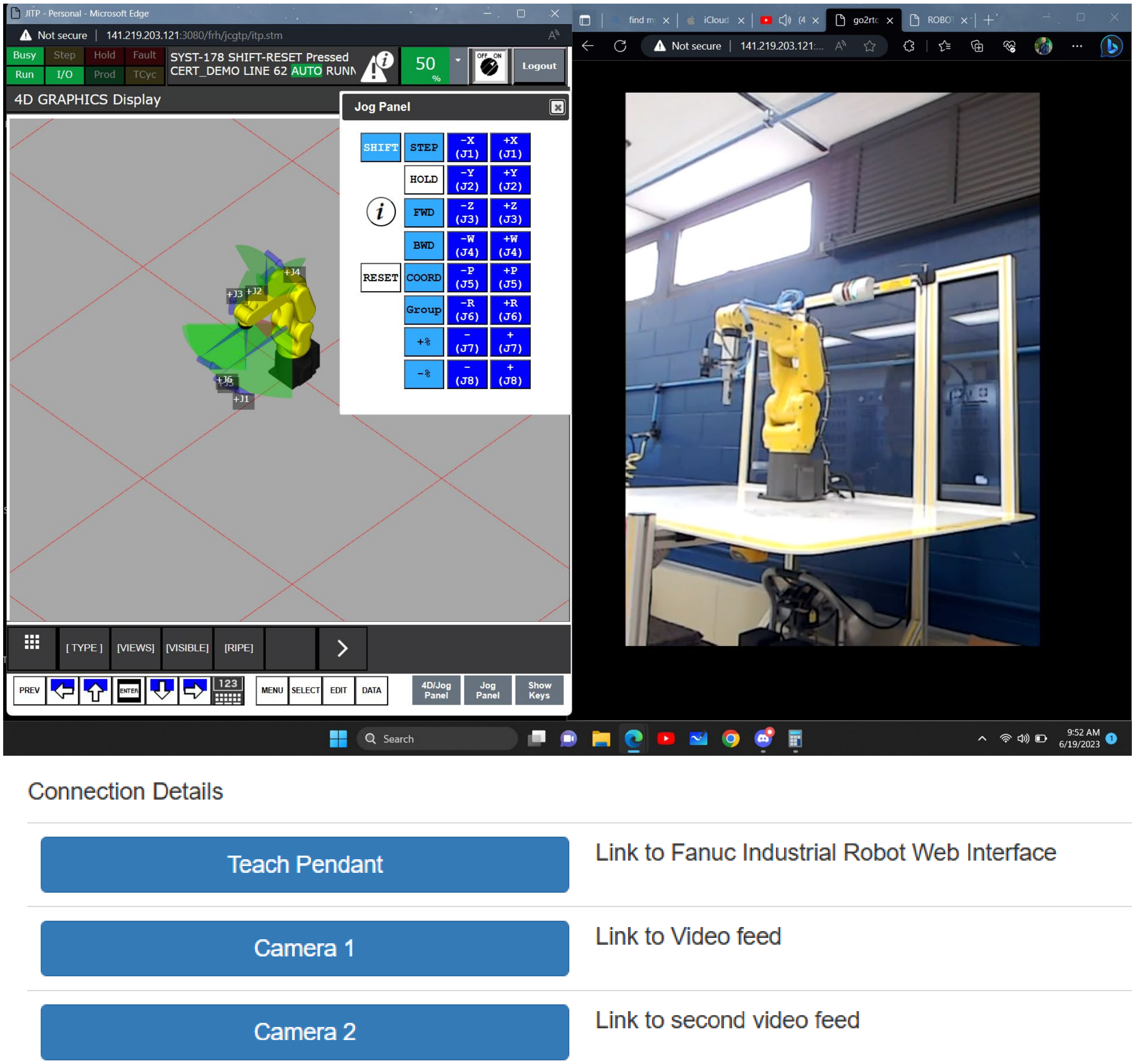

Figure 2: The Developed Teleoperated Robotics Workcell with Controls

The specifications for the systems have been grouped into modules: Booking Management, Booking Time Range Management, and User Management.

Booking Management:

The system should allow bookers to create a booking in available time ranges, validate booking request details before submission, and enable robot managers to approve or reject booking requests, to change their review decision on bookings.

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The system will send emails upon booking a request, approval, denial, and any update to a request.

Time Range Management:

The system will allow robot managers to create available time ranges for users to book, edit, or expire existing time ranges. The system will limit time slots to a configurable number of hours.

Proxy Control Windows Service

The service will create and delete proxy ports based on approved bookings.

User Management:

The system will have only one admin User who can change the password.

The user can control the physical robot directly from the portal's web page connecting to the proxy computer via the Internet. To achieve this, the user connects to the Robot Controller web page, shown in Figure 3, and selects the Jogging iPendant (JITP) option. The JITP is a handheld device designed by Fanuc for controlling and jogging their industrial robots. It provides a convenient and intuitive interface for operators to interact with the robot and perform various tasks. The iPendant typically includes buttons or a dial to adjust the jogging speed. Users can increase or decrease the speed depending on their requirements, allowing for fine-tuning or faster robot movements. Fanuc robots often support multiple coordinate systems, and the Jogging iPendant enables users to switch between them. The coordinate system selection feature lets the operator control the robot's movement based on different reference frames, such as the robot's base, tool, or user-defined coordinates. The iPendant's screen displays relevant information about the robot's status, such as current position, jogging speed, and operational modes. It may also provide menus and options for configuring settings, accessing programming interfaces, or monitoring robot performance.

The Jogging iPendant is designed to be compatible with Fanuc robots and their corresponding robot controllers. It integrates seamlessly with the robot control system, allowing operators to control the robot's movements accurately and efficiently.

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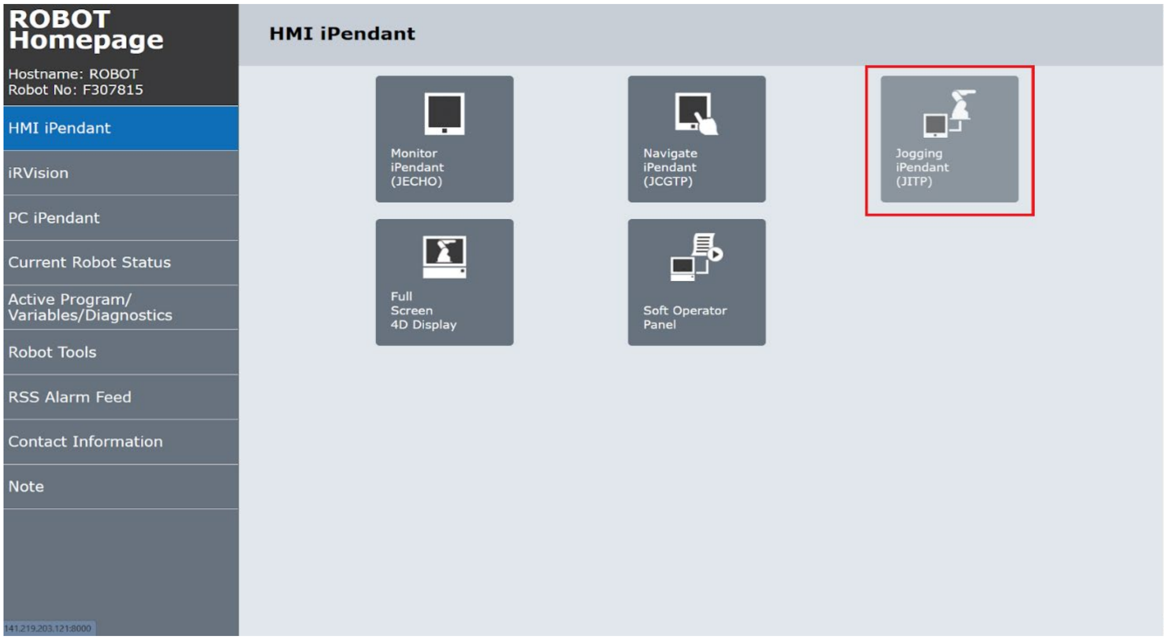

Figure 3: Jogging iPendant for remote robot control.

Enabling Experiential Learning Opportunities

Experiential learning is crucial in electrical engineering technology for several reasons. Experiential learning allows students to apply theoretical knowledge gained in classrooms to real-world scenarios. It bridges the gap between theory and practice, providing a more holistic understanding of electrical engineering concepts. Electrical engineering involves practical skills such as circuit design, troubleshooting, and equipment operation. Experiential learning provides students with hands-on opportunities to develop these skills, making them better prepared for the challenges they may face in their careers. Real-world projects and experiments often present unexpected challenges. Experiential learning encourages students to develop problem-solving abilities by requiring them to troubleshoot and find solutions on the spot, mimicking the challenges they will face in their professional roles. Many electrical engineering projects in the professional world involve collaboration with diverse teams. Experiential learning often involves group projects, allowing students to develop teamwork and communication skills, which are essential in the workplace. The field of electrical engineering technology is dynamic and continuously evolving. Experiential learning helps students stay updated with the latest technological advancements by engaging them in hands-on experiences with cutting-edge equipment and tools. Experiential learning experiences often mirror real-world work environments. This helps students develop professionalism, work ethics, and a sense of responsibility, preparing them for the expectations of the workplace. Through hands-on projects, students are encouraged to think critically and innovatively. Experiential learning experiences foster creativity and the ability to think beyond textbooks, essential qualities for engineers

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working on novel solutions and technologies. Employers in the electrical engineering field seek candidates with practical skills and experience. Experiential learning provides students with industry-relevant experiences, making them more competitive in the job market upon graduation. Experiential learning better prepares students for the demands of their future careers. It gives them a taste of the challenges and rewards of working in electrical engineering, allowing them to make informed decisions about their career paths. Learning by doing enhances the retention of knowledge. Students are more likely to remember and understand concepts when actively engaging with them in a practical setting, compared to passive learning through lectures alone.

In summary, experiential learning is essential in electrical engineering technology education as it not only reinforces theoretical knowledge but also equips students with the practical skills, problem-solving abilities, and professional attributes necessary for success in their future careers.

Considering the nature and functionality of the developed system, it provides a great way to enable additional experiential learning opportunities for learners who may not have direct access to the expensive robotic hardware.

Conclusion

The paper describes a successful collaboration effort between Michigan Tech and West Shore Community College to research, develop, and implement a State-of-the-Art Teleoperated Robotic Workcell (TRW) to enable enhanced remote training for industrial robots. 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. It also allows additional experiential learning opportunities for learners who may not have direct access to expensive robotic hardware. Utilizing the developed system, the user can jog, program, and do any operations on the robot that the student can do if physically present in the lab. The authors intend to enhance the functions further and expand on the capabilities of the developed teleoperated robotic platform.

References

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Biographical Information:

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BESTER MANGISONI is a graduate student pursuing a Master in Data Science at Michigan Technological University. He is also Fulbright Scholar from Malawi, and he works as a Senior Software Developer for the Malawi Revenue Authority (MRA). He is a passionate programmer with four years of experience with MRAs domestic systems and intends to advance his skills in the field of Data Science in the areas of Machine Learning, Data Mining, Data Visualization, and more.

GURVEETSING AJMANI is a graduate Mechatronics Engineering student in the Applied Computing department at Michigan Technological University. His expertise spans a wide array of technical disciplines, including PLC programming, Fanuc Robots and ROBOGUIDE, Python, MATLAB, and more. Gurveetsing is on a mission to leverage his skills for the betterment of the field, particularly in the fascinating domains of intra-logistics, machine manufacturing, and process automation.

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