6-23-2024

# Automating an Industrial Dishwashing System Using Hardware-in-the-Loop PLC Simulation with Factory I/O

Paniz Khanmohammadi Hazaveh
*Michigan Technological University*, pkhanmoh@mtu.edu

Nathir Rawashdeh
*Michigan Technological University*, narawash@mtu.edu

Dunsten M. X. Dsouza
*Michigan Technological University*

Joshua Olusola
*Michigan Technological University*

Joshua Albrecht
*Michigan Technological University*

*See next page for additional authors*



Follow this and additional works at: https://digitalcommons.mtu.edu/michigantech-p2

Part of the Mechanical Engineering Commons, and the Other Physical Sciences and Mathematics Commons

## Authors

Paniz Khanmohammadi Hazaveh, Nathir Rawashdeh, Dunsten M. X. Dsouza, Joshua Olusola, Joshua Albrecht, and Eric Houck

The Future of Engineering Education
2024 Annual Conference & Exposition
Oregon Convention Center
Portland, OR . June 23 - 26, 2024
Paper ID #41193

# Automating an Industrial Dishwashing System Using Hardware-in-the-Loop PLC Simulation with Factory I/O

**Paniz Khanmohammadi Hazaveh, Michigan Technological University**

Dr. Hazaveh received her PhD in Electrical and Computer Engineering from the Michigan Technological University in 2018 with a focus on Single Electron Transistors. She is the program director for BS in EET and Mechatronics and an associate teaching professor in the Department of applied Computing at Michigan Tech.

**Dr. Nathir Rawashdeh, Michigan Technological University**

Nathir Rawashdeh has been a faculty member in the Department of Applied Computing at Michigan Tech, since 2019. Prior, he was an Associate Professor in the Mechatronics Engineering Department at the German Jordanian University, where he spent 10 years. His industrial experience includes 5 years in software development. He was a senior software engineer in the Laser Color Science and Imaging Department, at Lexmark International, Inc. in Lexington, Kentucky, and with MathWorks, Inc. in Natick-Massachusetts working on software quality engineering for embedded DSP programming using MATLAB and Simulink. His research focus is on unmanned vehicle perception, image analysis, control systems, and mechatronics. Dr. Rawashdeh is a Senior Member of the IEEE. He has worked on projects funded by the NSF, Ford, and the European Commission.

**Dunsten Michael Xavier Dsouza**
**Joshua Olusola**
**Josh Albrecht, Michigan Technological University**
**Eric Houck**

# Automating an Industrial Dishwashing System using Hardware-in-the-Loop PLC Simulation with Factory I/O

**Dunsten Dsouza, Joshua Olusola, Josh Albrecht, Eric Houck,**
**Paniz Hazaveh, Nathir Rawashdeh**
*Department of Applied Computing, College of Computing, Michigan Technological University*

## Abstract

While industrial automation is growing in many industries, the hospitality industry has not seen much technological innovation recently. This leaves a wealth of potential for the implementation of automated solutions, especially at large-scale operations, like university dining halls or cruise ship restaurants. This paper details a student project developed in the advanced programmable logic controllers class. It is part of the master program in mechatronics. Students work in groups in a creative setting, where they learn to integrate various automation technologies and learn to write scientific publications. The project implements the automation of a student dining hall dishwashing system using the Hardware-in-the-Loop HiL method. HiL is a powerful way to mitigate risks or accidents in a real-world scenario, leading to costly damages. For testing, we have used the Factory IO simulation software. It provides a realistic simulation environment for virtual plants with low real-time latency. An Allen-Bradley CompactLogix controller provided control of the simulated environment through communication over Ethernet/IP protocol. System control was established through PLC ladder logic from RSLogix 5000. A custom human-machine interface was designed using FactoryTalk View Studio to monitor and control the system's operation. Finally, with the advent of Industry 4.0 and IIOT, a SCADA system was integrated into the system using Node-Red and MQTT to create live dashboards for monitoring and control of the HiL system. From a pedagogical perspective, the technical HiL solution development traverses a process of brainstorming, then modelling the virtual factory including sensors and actuators, then integrating a PLC and human machine interface (HMI) hardware with input-output mapping over the ethernet cable connection. Finally, the physical PLC and HMI, i.e. the hardware, are programmed to control the simulated factory floor. This allows the iterative development and verification of code on the hardware before, in a real scenario, installing the hardware on the real factory floor. The focus there would be on commissioning the hardware and primarily troubleshooting electrical connections rather than code.

## Keywords

SCADA, Programmable Logic Controllers (PLC), HMI, Hardware-in-the-Loop (HIL), MQTT.

## Introduction

Automation and robotics are rapidly exploding in popularity around the world. The reasons for this are manifold, but the ability of automation to replace repetitive tasks is crucial for both worker well-being and the economic competitiveness of plants. The Wadsworth Dining Hall at Michigan Tech currently uses student workers to manually wash the dishes for thousands of students every day. This requires manual labor, is inefficient, and provides a perfect project for an automation solution at an engineering-focused school. Our goal is to propose a system to automate the dishwashing system with as little human intervention as possible. Since fully automating an entire cafeteria's washing system is a major project that could take months of work, we found an exciting software concept with the potential to revolutionize the early stages of plant development. This software, Factory I/O, allows students and engineers to rapidly prototype and test factory layouts, comparing different setups to ensure successful operation before components are even purchased. A secondary aspect of this project is exploring the educational potential of this software, which we hope is demonstrated by our work. We chose this software solution in part for its amazing ability to realistically present a 3D bird's eye view of the process layout and performance. It connects with PLC controllers from an assortment of manufacturers, with virtual I/Os (inputs/outputs) acting as physical I/Os within the PLC architecture and logic. This allows engineers to rapidly program and test PLC ladder logic with plant layouts prior to constructing and operating a physical system. Additionally, it is a brilliant educational tool for students to apply their recently acquired knowledge to a "real" factory. For example, using Factory I/O, one could commission and integrate PLC hardware, virtual sensors, actuators, and vision to queue and sort products before sending them to a 6-axis robot for a packing application. All this occurs entirely through simulations behind a computer monitor.

## Literature Review

Recently, industrial automation has brought about innovations across several industries. The use of automation has helped provide custom solutions to industrial challenges around repetitive tasks. Michigan Technological University (MTU) has observed this shift and decided to become an active player in the movement by promoting its Mechatronics program. The precedent for our project comes from the automation projects of previous students. Namely, [1],[2],[3], and [4] have developed a measuring gripper system, force gripper system, pneumatic robot system, and solar panel control, respectively. For instance, to integrate industrial sensors and quality control systems, Erik et al. utilized an automation control of a pneumatic gripper for the measurement of workpiece thickness [2]. Our project will build upon this history of Mechatronics projects from MTU. One industry that is yet to adequately explore automation is the catering industry. One application of automation in the catering industry, especially for fixed locations such as restaurants, hotels, or dining halls, is large-scale dishwashing [5]. While automated dishwashing and drying machines are well studied and commercially available (see [5], [6], [7]), the systems themselves must be manually fed and sorted by workers. Fukuzawa et al. use a six-axis robot arm and robotic vision for sorting applications of an automated dishwashing line [5]. Wang et al. describe the design and function of a pneumatic bellows style gripper for manipulating dishware both clean and dirty [7]. Industrial robots play a significant role in pick and place applications for automated systems. Zongguang et al. use a pneumatic operated four-axis robotic arm to operate a two-jaw parallel gripper for pick and place applications [3]. With the use of Unitronics PLC and HMI, the robotic arm was programmed to pick and place objects with high precision. Hardware-in-the-Loop (HIL) simulation has been a generally utilised tool for developing and testing complex control systems, which control machines, factories, etc. Tebani et al. utilised FlexSim for a 3D simulation environment to model a manufacturing system [8]. The HiL was done by connecting a physical controller, a PLC (Programmable Logic Controller) to the FlexSim. This platform provides feedback from the sensor signals, in a similar way as if we were to connect real hardware to a factory, as an industrial manufacturing line. [8] also established a connection between the simulator and the PLC, using the OPC (OLE for Process Control) server interface and a JAVA platform. Applications of automation require an interface for proper monitoring and controlling of the automated process. With the development of the human-machine interface HMI and supervisory control and data acquisition SCADA platforms, automated processes can be easily visualised and controlled. [9] illustrates an application of SCADA using LabView to control a 3D automated environment on Factory I/O. Kovalev et al. have designed a cloud-based data collection system from a CNC machine using the OPC UA protocol with visualization on the Front End for Node-RED (FRED) platform [10]. Their system uses an OPC UA cloud server to send data from the CNC machine to a Node-RED MQTT broker. FRED then allows them to visualise this cloud data on a custom graphical interface. This has provided us with a high-level starting point, as we plan to use a very similar SCADA system utilising Node-RED and MQTT in conjunction with the SCADA Ignition platform. In deciding the proper communication protocol, we found that [11, 12] specifies a guide for evaluating communication performance to help choose the best network protocol for a control system. Some performance categories identified by [11] for choosing the best protocol are maximum overshoot, response time, stack delay, bus cycle time, and jitter. Though Ethernet/IP delivers heavy control overshoot and the worst communication delay of the three, with a maximum delay of over 4 ms in all directions, we have chosen to use it for our purposes. Since Ethernet/IP was developed by Rockwell, it integrates seamlessly with the Rockwell PLC hardware available in our current setup. Additionally, the protocol's performance will have minimal impact on our non-critical operation.

This paper is the result of an advanced PLC class project for master students in mechatronics. In the course, this assignment is designed to allow groups of students to think creatively, and gain experience in authoring research publications. The rate of papers that are published is about 40%, as previous publications show [1, 2, 3, 13, 14]. Typically, each paper is written by a group of 4 or 5 students. Since this is a new experience for most students, the assignment is divided into three stages. First, a project proposal is due a few weeks into the course (week 3 of 15). In this stage, students form groups, brain storm a project, then write a proposal in the form of a publishable paper using a conference template. In it, they have to perform a literature review, develop a system architecture, and elaborate on each team member's contribution. The second component is due towards the end of the semester (week 14/15). Here the students complete the project and write the paper describing following the conference template. The final part, is due in the last week of the course and entails creating a presentation using the university template, as well as recording a demonstration video, with the intention of sharing it on social media. Naturally, the instructor has to work with students after the course ends to manage all the conference presentation procedures. This type of assignment entails a large amount of effort on part of the students and the instructor. Nonetheless, the reward is proportionally large as well. It makes the course more creative and exposes students to academic research and publishing.

## System Overview

The project architecture consists of five major integrated software and hardware components: Factory I/O; Programmable Logic Controller (PLC); SCADA (MQTT with Node-Red); Local FactoryTalk HMI; Amatrol hardware control box. Factory I/O simulation software formed the crux of the project, allowing us to model the operational facility for the Wadsworth dining hall dishwashing line. This software enabled us to incorporate virtual sensors and actuators (such as retroreflective sensors and conveyor belts) and visualize the control concept for these field devices. The entire automated dishwashing setup is depicted in Fig. 1. The dishes enter on the left and are relayed per conveyor to two robotic washing stations. After they are washed, the move towards a three-way split conveyor toward the First-in First-out (FIFO) storage rack shown in the right in Fig. 1. Establishing communication between Factory I/O on a PC and the PLC hardware was carried out using Ethernet/IP communication protocol over an Ethernet cable. This allows digital and analogue input/output signals to be transferred between the master PLC and the simulation environment. Each input/output is provided with a tag, which links to the tag of the same name on the PLC once attached to a driver interface as shown in Fig. 2.

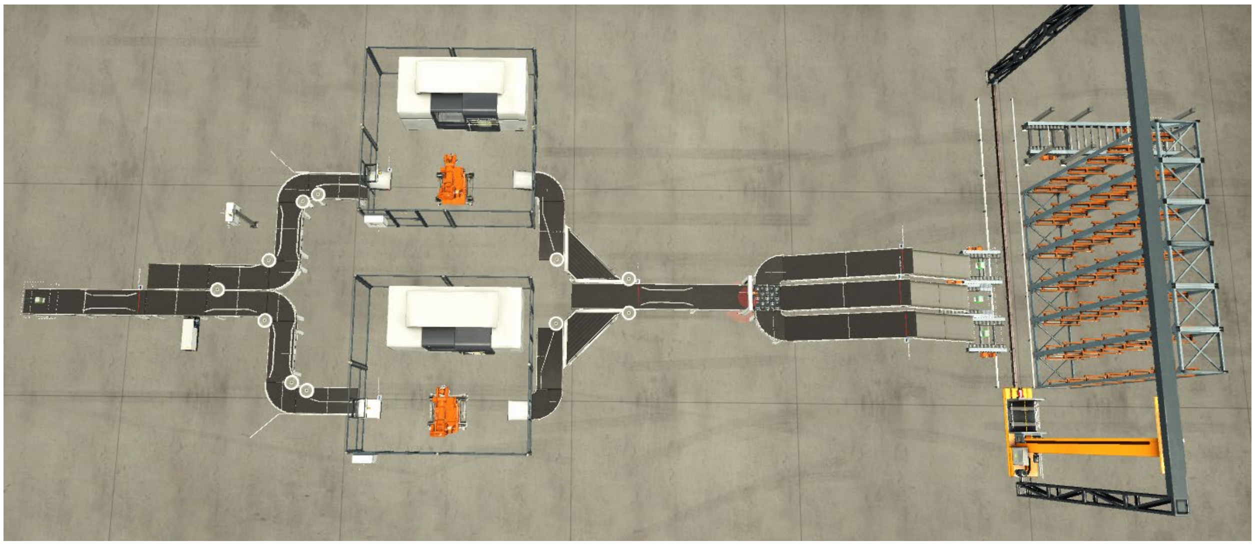

Figure 1. Full dishwashing system overview in Factory I/O

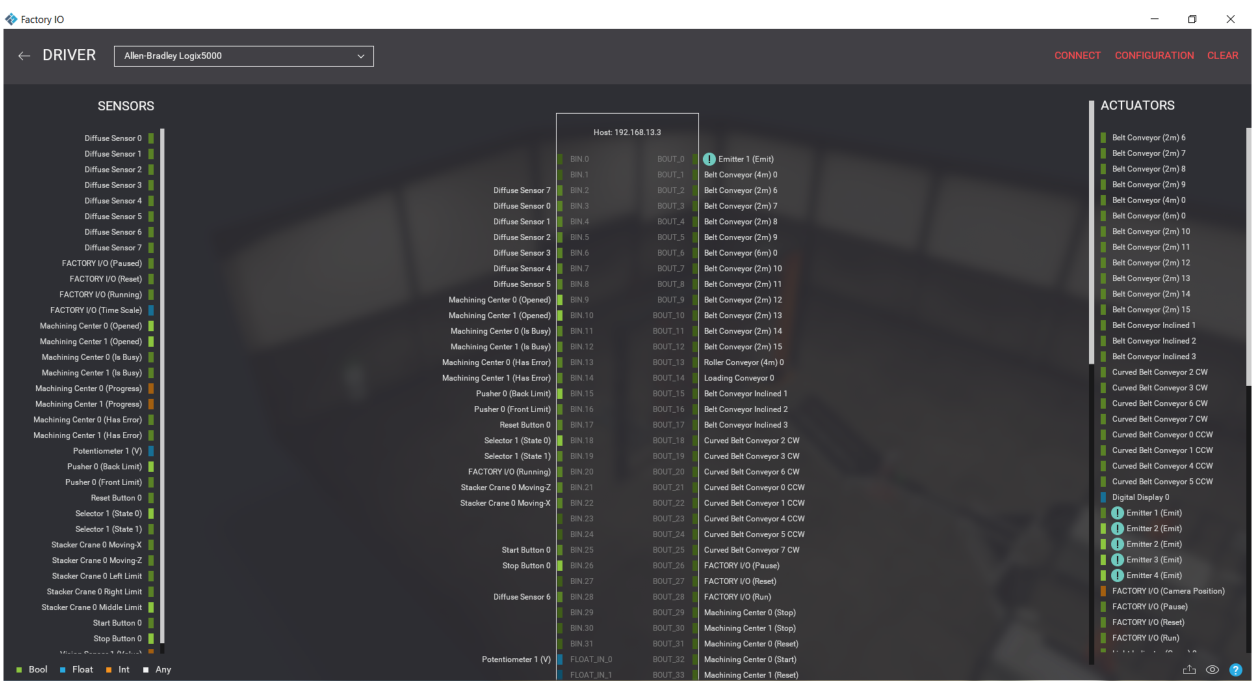


Figure 2. PLC driver interface within Factory I/O simulation environment

For the PLC, we used a Rockwell Allen-Bradley CompactLogix 5000xx. This PLC was used for two primary purposes. The first is as an external logical controller to run the simulation environment and physical field devices. Using an Amatrol PLC control box connected to the same CompactLogix 1769-L23E PLC via several I/O modules, basic control applications (like start/stop and process indication) were initialized and monitored using pushbuttons and light indicators available on the Skill Boss. We were thus able to manipulate the Factory I/O environment through the physical world. Secondly, the PLC was critical in building a local display interface (HMI) to provide local operator control and visualization (Fig. 3).

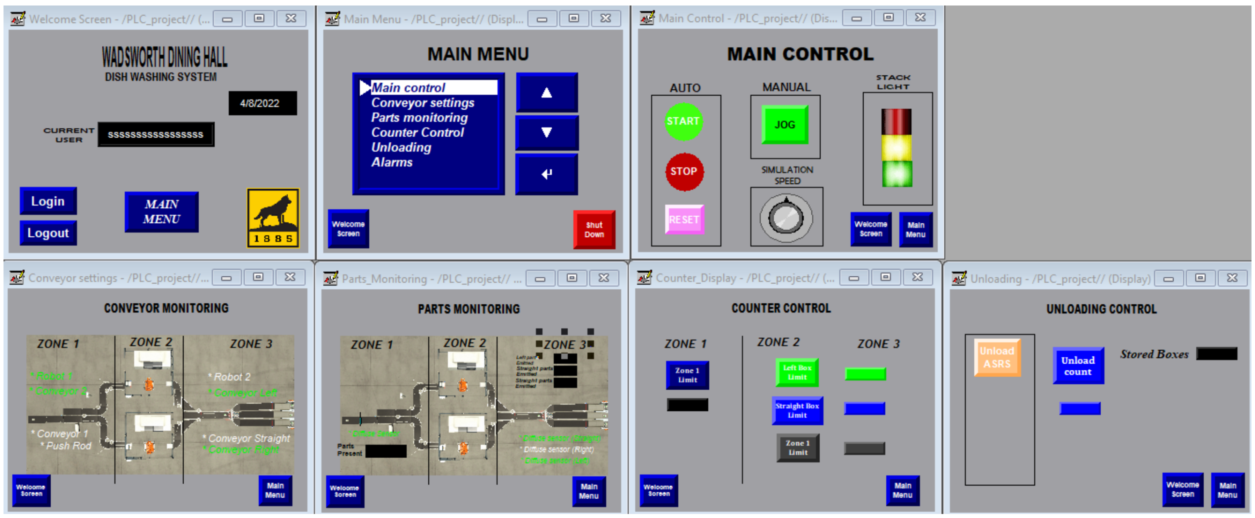


Figure 3. Custom HMI interface with security credentials

A graphical user interface is an integral part of process control. This interface can be performed at both the local and remote levels. With the use of an HMI, the system can be controlled and monitored locally. The proprietary software of Rockwell Automation for HMI applications, FactoryTalk View Studio - Machine Edition, was utilised in designing a graphical user interface for the virtual factory. This design applied hand-off-auto for basic controls, runtime security for access control, alarm logging, and I/O monitoring for supervising the conditions of inputs (such as diffuse sensors) and output devices (such as conveyors, pushrods, and robots).

*Hand-Off-Auto (HOA)*

The hand-off-auto is an industrial electronics concept used to control a system in both automatic and manual modes. In the case of this virtual factory, the HOA is used to initialise the automated line when the “auto start” is pressed and shut down the entire process when the “stop” button is pressed. Once the “jog” button is pressed, the system runs on manual mode and the conveyors are jogged without the sequence operation of all the input sensors. HOA was implemented in the HMI application with the use of momentary push buttons to provide basic control of the virtual factory.

*Runtime Security*

This provides the means to control access to certain HMI displays at various levels. The HMI application was designed to have three different access levels known as user groups: the operators, the observers, and the administrator.

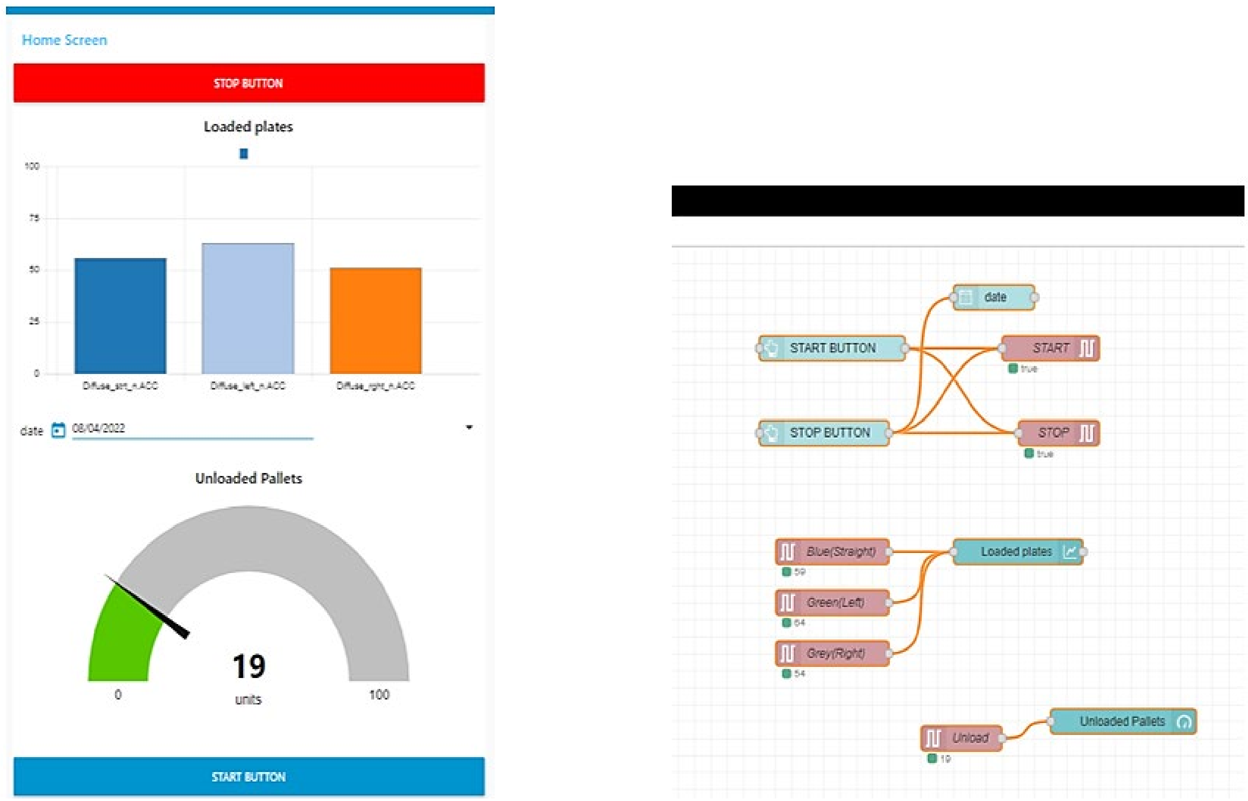


Figure 4. Node-Red connections with the control dashboard

*Alarm Logging*

Alarm events commonly occur during an operation of a machine or control process. These alarms are triggered by critical events to provide awareness to users. The HMI was designed not only to trigger alarms in the occurrence of certain events but also to log the alarms with timestamps when they are triggered.

*I/O Monitoring*

One relevant application of the human-machine interface is its ability to provide real-time the states of input and output devices in a system. With the use of multistate indicators, display screens with visual representations of the control process display the conditions of conveyors, diffuse sensors, pushrods, and robots. These aid troubleshooting and provides a visual understanding of the system.

*Node-Red using the MQTT platform*

We have also developed a supervisory control and data acquisition (SCADA) system to control the factory remotely. We have used an application called MQTT, a publish-subscribe network protocol that transfers messages between PLC and a monitoring system over TCP/IP. We have also used a Node-Red platform, a flow-based development tool for visual programming developed initially by IBM for wiring together hardware devices, APIs, and online services as part of the Internet of Things. To take this further, we used TCP/IP input nodes to transfer the data to the output nodes like Gauges, Bar graphs, and Pie Charts.This was performed to get a live dashboard running from the data we receive through the diffuse sensors. As the whole system is dynamic, it makes sense to use this platform for process monitoring and controls. In Fig. 4, the numbers injecting the dashboard nodes change as the accumulated value in the counter changes. The Node-Red UI can also inject data to the PLC by forcing a value from the outside. There are two input nodes - start and stop buttons, to control the process from the dashboard. Lastly, we will use the “Mosquito” - an MQTT Broker. This will help us create a platform to publish the data to the subscribers (The devices who would like to view the dashboard and control the system remotely). The Mosquito platform will let you access the dashboard if the username and the password entered are correct. Also, it has the feature to allow access to the devices you want by entering their IP addresses.

## Dishwashing System Description

To achieve the objective of automating the dishwashing process, we first considered the current manual operation at Wadsworth Hall. Fig. 5 shows the setup to sort, clean, dry, and stack the dishes. First, students place used dishes onto a shelf, sorted by glasses, silverware, and plates/bowls. These dishes are then manually rinsed and moved to the washing machine along rollers. These dishes are then hand-placed into conveyor-feed dishwashing and drying machine. After coming out fully clean and dried, they are hand-sorted into the appropriate containers and are returned to the dining hall. The current operation delineates several operations that must be taken into consideration. This sequence is characterized in Table 1.


Figure 5. Current dish loading setup at Wadsworth dining hall

Table 1. Automated dishwashing operation sequence

| Sequence number | Operation | Factory I/O Tool |
|---|---|---|
| 1 | The loading area for used plates | Emitter on conveyor |
| 2 | Plate transport | Conveyor belts |
| 3 | Plate cleaning machine | Machining Center with a 6-axis robot |
| 4 | Plate drying machine | Drying rack connected via stacker crane |
| 5 | Sorting | Vision sensor with pop-up wheel sorter |
| 6 | Dish collection | Remover from stackable container |

## Control Procedure

To automate the dish-washing process, six main processes were employed. First, dishes are dropped off at the proper location, indicated by the green “emitter” arrow. Dishes continue down the line to a pusher, which sends every other dish to the second dishwasher, evenly splitting the dishes between the two machines. Next, conveyors are used to transporting dishes throughout the plant. After being washed, dishes are merged back into one line and subsequently sorted into three groups, one for each dish type (plate, bowl, utensils). Note that the dish types are simulated with generic blue, green, or gray objects, given a lack of choices within Factory I/O. These dishes are collected into a stackable container before an Automated Storage and Retrieval System (ASRS) places these sorted bins into a drying rack where they await pick-up requests from the operator.

To control the dish placement, an in-built “emitter” device is used. This device randomizes the placement type and timing of dishes to create a semblance of actual dish drop-off. Conveyors then move the dishes through a diffuse sensor to a pusher device. The diffuse sensor has two objectives: to count the number of dishes entering the system to help determine when the washing queue has become congested and to split dishes into one of two possible dishwashing queues. Given that each CNC “dishwasher” is only capable of processing one dish every 30 seconds (a known Factory I/O limitation), a second dishwashing line was added. The pusher uses the input from the diffuse sensor and precise timing to push every second dish into the second dishwashing line, reducing congestion in each queue. These devices are shown in Fig. 7. After being separated into the two washing queues, the dishes are pushed by the conveyors into the washing stations, modeled by CNC machining centers due to a lack of available components in Factory I/O. Dishes are placed individually into the washing station by a 6-axis industrial manipulator, which waits until the dishes are clean before removing and placing them on another conveyor. The cleaned dishes coming out of the washing stations are counted by a diffuse sensor before continuing down the line to be sorted into palletised containers. This setup is shown in Fig. 8.

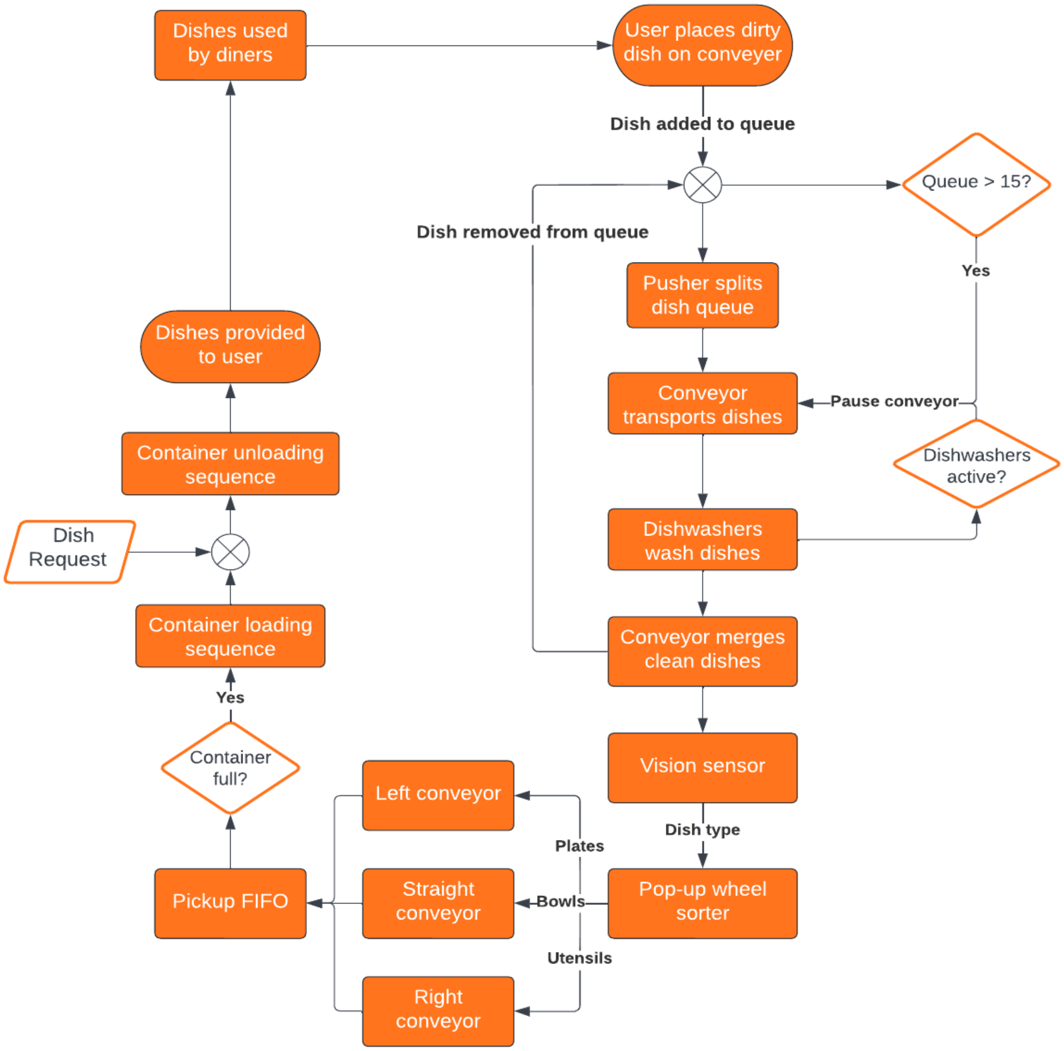


Figure 6. Dishwashing process flowchart

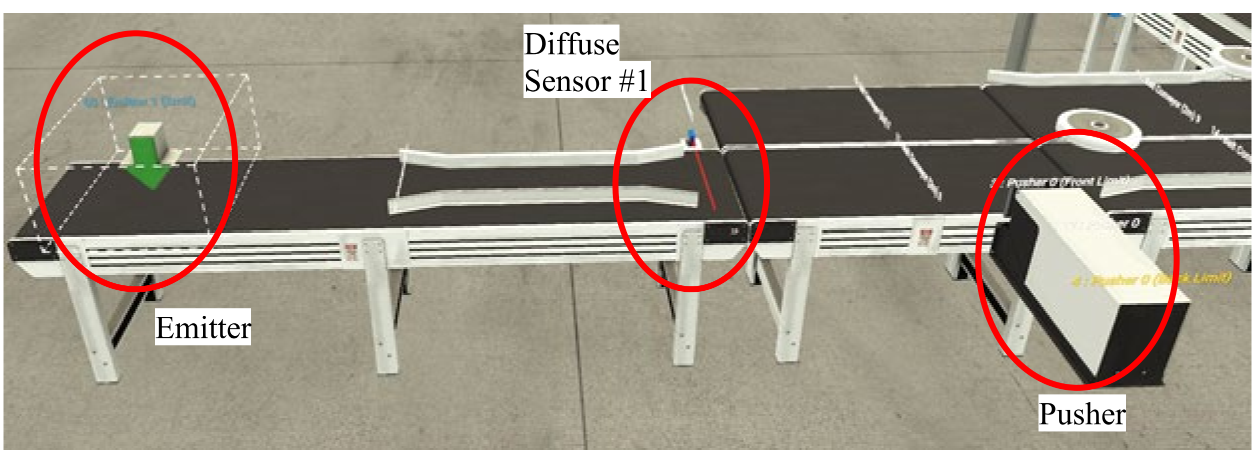


Figure 7. Dish placement and queue separation in Factory I/O

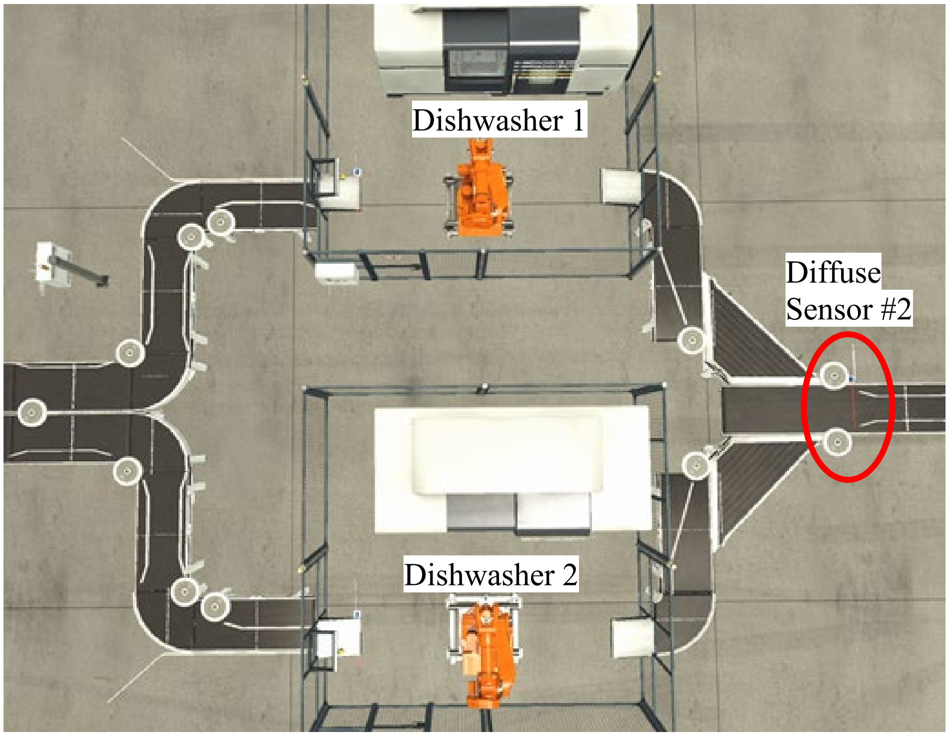


Figure 8. Machining centers for dishwashing in Factory I/O

The next step is to sort and direct dishes toward their appropriate pallet. The vision sensor shown in Fig. 9 detects dish type, producing a numeric output. This output is checked against a list, and the pop-up wheel sorter sends the dish down to the corresponding conveyor. Diffuse sensors at the end of each conveyor count the number of dishes entering each container, to signal when each is full.

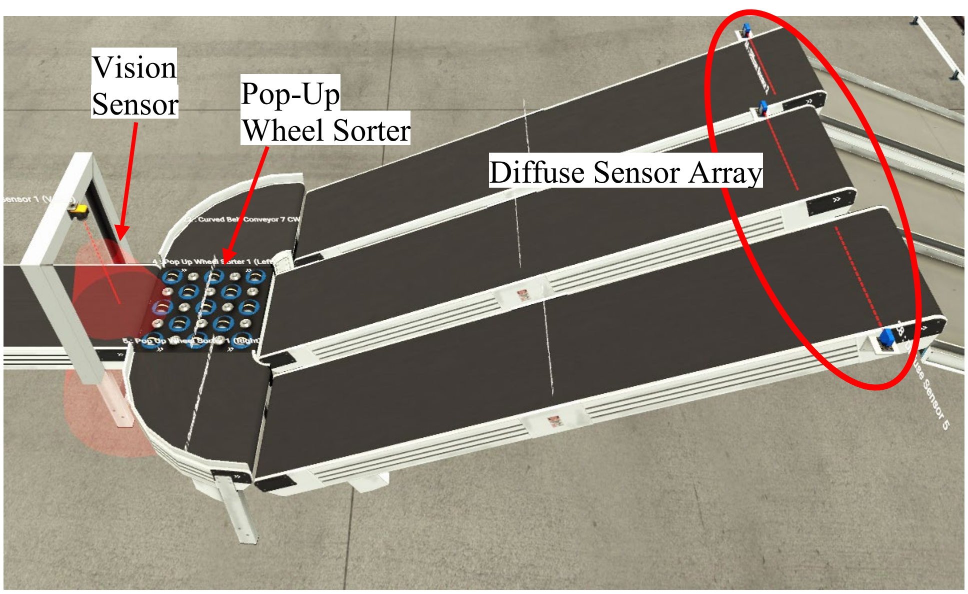


Figure 9. Sample dish sorting layout in Factory I/O using vision and pop-up wheel sorter

Once filled with the appropriate number of dishes the containers are stacked in a drying rack using a stacker crane, shown in Fig. 10. This drying rack is a type of automated storage and retrieval system (ASRS). Containers of clean dishes are assigned a location in the rack, where they are loaded to by the stacker crane using a programmed pick-up sequence. When dishes are to be unloaded from the drying rack, the operator flips a switch to begin a programmed unloading sequence, which uses the stored locations of the containers in the drying rack to retrieve the dry dishes before unloading them to the operator.

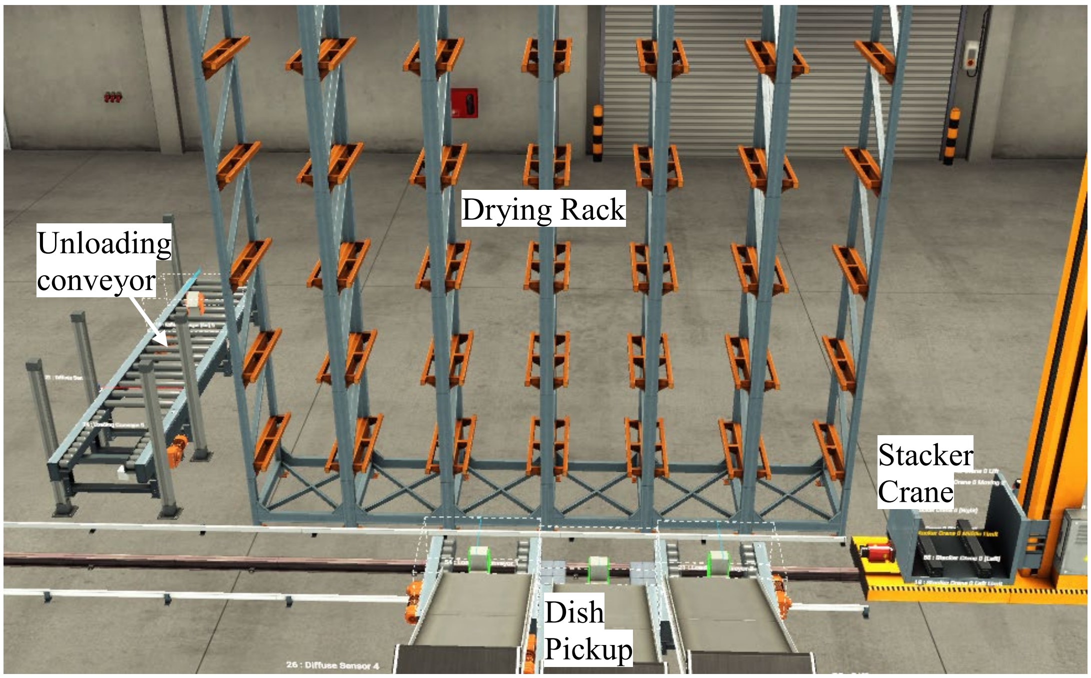


Figure 10. ASRS drying rack with stacker crane in Factory I/O

Finally, a virtual control panel was implemented for various high-level control applications. This control panel contains buttons, light indicators, a mode switch, a potentiometer, and an LCD display for various applications (Fig. 11). For example, the green button starts operation, the red button stops the system, and a potentiometer adjusts the simulation speed. Additional capabilities can be added to the panel as needed.

## Simulation Results

The main objective of this project was to determine if a fully automated dishwashing system would be feasible in replacing manual dishwashing operations in large-scale establishments. We have fulfilled that objective. The final system design effectively simulated an automated dishwashing implementation for large-scale applications, as demonstrated in Fig. 12. Designed and built-in RSLogix5000, the control system paired with the simulation software demonstrates a control philosophy that can be adopted for the automation of an industrial dishwashing process.

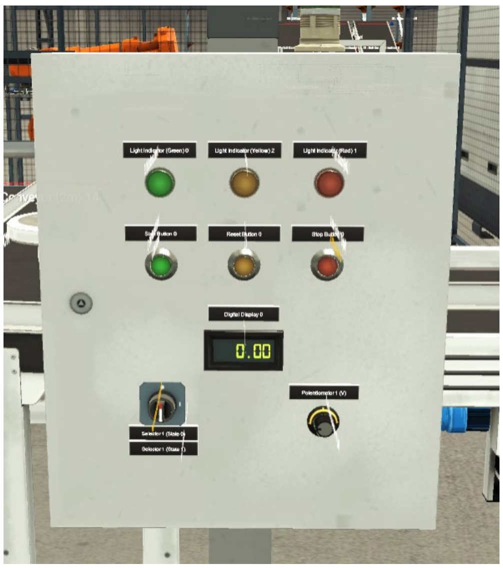


Figure 11. Virtual control panel

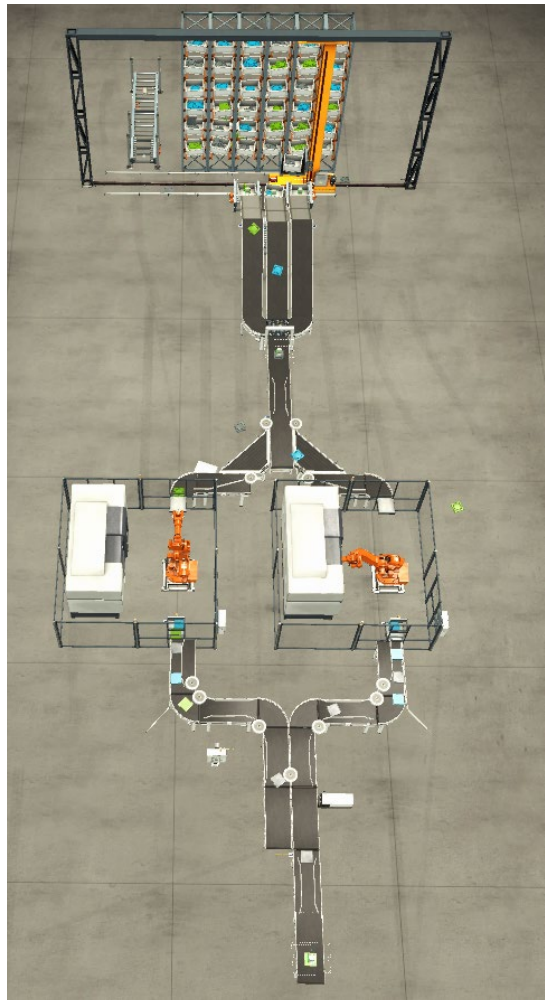

Figure 12. Rack fully filled with dishes

The flexibility of the setup allows it to handle higher and lower throughputs depending on the total demand. Testing was mostly carried out at a speed of 4 dishes/min. If the input exceeds this threshold, the dishes are queued along the conveyor to wait for either dishwasher to vacate. The operating speed of the washing system is mainly limited by the speed and availability of Factory I/O components, an issue that will arise with any industrial simulation using this software. Given the program's nature, custom components or external libraries are not permitted, greatly constraining the project. Once all the spots in the drying rack are filled, the HMI notifies the operator that the storage is full and that dishes must be unloaded to proceed. However, the size of the drying rack available for this setup is fully scalable to meet the capacity needs of any large-scale dishwashing setup.

## Conclusion

With a fully functioning Factory I/O model and a robust control system integrating PLC, HMI, and SCADA interface, the automated dishwashing system was successfully developed. Countless iterations of the Factory I/O model have left the system with the ability to accept dishes at random, clean them, and sort them without losses, jams, or breaks. Future iterations of this project should look to simplify the washing process, which would be solved simply with a dedicated dishwasher available in Factory I/O. This would remove the need for a 6-axis robot to load and unload dishes, making the implementation of an automated washing system simpler and more economical. These simple improvements would give this system the potential to replace manual dishwashing setups across various industries, including universities, military bases, or convention centers, providing food services to large numbers of people. Completing this entire project in Factory I/O afforded us the opportunity to test and troubleshoot lots of high-level machinery without the risk of damaging equipment or injuring anyone. The HiL approach was a cost-effective, simplistic, and timely approach to system design, requiring only a PLC and laptop as hardware. **(video link)**

## References


[1] Erik Kocher, Chukwuemeka George Ochieze, Ahmat Oumar, Travis Winter, Aleksandre Sergeyev, Mark Gauthier, Nathir Rawashdeh, "A Smart Parallel Gripper Industrial Automation System for Measurement of Gripped Workpiece Thickness", Proceedings of the 2022 Conf. for Industry and Education Collab., ASEE, 9-11 Feb 2022, Tempe, AZ.

[2] Brian Piechocki, Chelsey Spitzner, Namratha Karanam, Travis Winter, Aleksandr Sergeyev, Mark Gauthier, Nathir Rawashdeh, "Operation of a Controllable Force-sensing Industrial Pneumatic Parallel Gripper System", Proceedings of the 2022 Conference for Industry and Education Collaboration, ASEE, 9-11 Feb 2022, Tempe, AZ.

[3] Zongguang Liu, Chrispin Johnston, Aleksi Leino,Travis Winter, Aleksandr Sergeyev, Mark Gauthier, Nathir Rawashdeh, "An Industrial Pneumatic and Servo Four-axis Robotic Gripper System: Description and Unitronics Ladder Logic Programming", Proceedings of the 2022 Conference for Industry and Education Collaboration, ASEE, 9-11 Feb 2022, Tempe, AZ.

[4] Al Atwa, Abdullah, Ian Bumgardner, Mohammed Bushlaibi, Steven Castello, Joshua Erickson, Aleksandr Sergeyev, and Mohsen Azizi. "Capstone Project: PLC Control System with Integrated PID Controller for Control System Optimization," Proceedings of the 2014 IAJC-ISAM International Conference, ISBN 978-1-60643-379-9.

[5] Y. Fukuzawa, Z. Wang, Y. Mori and S. Kawamura, "A Robotic System Capable of Recognition, Grasping, and Suction for Dishwashing Automation," 2021 27th International Conference on Mechatronics and Machine Vision in Practice (M2VIP), 2021, pp. 369-374, doi: 10.1109/M2VIP49856.2021.9665169.

[6] Bai Yan and Zha Hongwei, "Application of Siemens S7 - 200 series PLC on full-automatic dishwasher," World Automation Congress 2012, 2012, pp. 1-4.

[7] Z. Wang et al., "A Soft Robotic Hand Based on Bellows Actuators for Dishwashing Automation," in IEEE Robotics and Automation Letters, vol. 6, no. 2, pp. 2139-2146, April 2021, doi: 10.1109/LRA.2021.3061063.

[8] Tebani K. et al., “Hardware-In-the-Loop Simulation for Validating PLC Programs.” [Online]. Available: https://www.researchgate.net/publication/303874724

[9] H. H. Hadi and M. Y. Sallom, "Pneumatic Control System of Automatic Production Line Using SCADA Implement PLC," 2019 4th Scientific International Conference Najaf (SICN), 2019, pp. 37-42, doi: 10.1109/SICN47020.2019.9019356.

[10] Kovalev, I., et al. (2020), "Development of a data collection system for a CNC system using cloud FRED technology and OPC UA specification," MATEC Web Conf.
[11] X. Wu, L. Xie, “Performance evaluation of industrial Ethernet protocols for networked control application,” Control Engineering Practice, Volume 84, 2019, Pages 208-217.
[12] L. Salameen, A. Estatieh, S. Darbisi, T. A. Tutunji and N. A. Rawashdeh, "Interfacing Computing Platforms for Dynamic Control and Identification of an Industrial KUKA Robot Arm," 2020 21st International Conference on Research and Education in Mechatronics (REM), 2020, pp. 1-5, doi: 10.1109/REM49740.2020.9313878.
[13] Valaboju, C., Amuda, M., NCh, S. C., Gopireddy, S. R., Hazaveh, P. K., & Rawashdeh, N. A. (2023, March). A Supervisory Control System for a Mechatronics Assembly Station. In 2023 15th International Conference on Computer and Automation Engineering (ICCAE) (pp. 503-507). IEEE.
[14] Nandre, C., Yazbec, E., Urunkar, P., Motey, S., Hazaveh, P., & Rawashdeh, N. A. (2023, March). Robot Vision-based Waste Recycling Sorting with PLC as Centralized Controller. In 2023 15th International Conference on Computer and Automation Engineering (ICCAE) (pp. 381-384). IEEE.

**Dunsten Dsouza**

Mr. Desouza received the MS in Mechatronics at Michigan Technological University in 2023, after which he joind Tesla as a controls engineer. He did his undergraduate in Mechanical Engineering and graduated in the year 2019. He has a work experience of 2 years of working for an automotive firm in India - Mahindra & Mahindra as a manufacturing engineer. His interests include Robotics, Automation, Controls, and Manufacturing.

**Joshua Olusola**

Mr. Olusola received the MS in Mechatronics from Michigan Technological University in 2023, and joined Tesla after graduation. He graduated with a Bachelor’s in Mechanical Engineering at the University of Ibadan in 2019. His interests include industrial automation, power engineering, and image processing. He currently instructs a Mechatronics class of high school students teaching Automation and Robotics.

**Eric Houck**

Mr. Houk received the MS in Mechatronics from Michigan Technological University in 2023. He completed his bachelor’s in mechanical engineering in 2020. Outside of academics, Eric works as a graduate assistant coach for Michigan Tech’s Nordic Ski Team, working with both domestic and international athletes. After gaining valuable industry experience at Systems Control in 2020, and Plexus Corp in 2021, Eric will go on to work in the semiconductor industry at ASML following his graduation in 2022.

**Josh Albrecht**

Mr. Albrecht was a Mechatronics MS student at Michigan Tech, after receiving a bachelor's degree in Mechanical Engineering from MTU in 2020. In addition to building automation projects, he teaches a Mechatronics class for local high school students. As a former member of the Michigan Tech Nordic ski team, Josh also occasionally provides racing services for the team. His experience includes waste torrefaction research at MTU's APS Labs in 2019 and a mechanical design internship at 3M in 2021.

**Paniz Hazaveh**

Dr. Hazaveh received her PhD in Electrical and Computer Engineering from Michigan Technological University in 2018 with a focus on Single Electron Transistors. She is currently an associate teaching professional in the department of Applied Computing. She has been the director of the undergraduate programs in Mechatronics and Electrical Technology at MTU since 2023. Her teaching expertise are circuits, electronics, and control systems.

**Nathir Rawashdeh**

Dr. Rawashdeh is an assistant professor at the department of applied computing at Michigan Tech, since August 2019. He instructs introductory and advanced programmable logic controller courses. Prior to this appointment, he was an associate professor in the Mechatronics Engineering Department at the German Jordanian University, where he spent 10 years. His industrial experience includes 5 years with Lexmark International, Inc. Lexington-Kentucky and MathWorks, Inc. in Natick-Massachusetts. Dr. Rawashdeh is a Senior Member of the IEEE. and has experience with European-funded research capacity building projects. His research interests include mobile robots, autonomous driving, image processing and sensor fusion.