Industry 4.0 Edge Computing Demonstration Projects for Manufacturing Technology Education

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An Industry 4.0 Integrated Learning Approach for Manufacturing Technology Education

Abstract

Advanced Manufacturing International (AMI), a non-profit that provides professional development for small through medium manufacturers, partnered with LECS Energy Inc. to develop the Learning Integrated Manufacturing System (LIMS) as an Industry 4.0 (I4.0) applicable Industry Internet of Things (IIOT) edge platform. The LIMS appliance provides an affordable easy connection to manufacturing processing systems and subsystems to facilitate the maximum use of Industry 4.0 driven technologies installed in a manufacturing facility. This targeted manufacturing market and cost also make the LIMS platform an excellent learning tool within two-year and four-year Engineering and Engineering Technology programs focused on creating the future of work technical workforce to support the Industry 4.0 technology environment. A LIMS platform was distributed to each of the five state colleges with 2-year Engineering Technology programs in Florida. This paper reports on the results of the Informed Engineering Design approach the colleges utilized to build their unique “hands-on” applications. The paper’s focus is directed on the challenges and results from an urban and a rural college. It will also report on student learning outcomes related to IIOT as well as project opportunities to easily capture data from different independent sources and perform a variety of analyses on the data outputs relating to seemingly unconnected/unrelated data sources in a single process analysis.

Motivational Rational

The preparation of the I4.0 technical workforce as instigated and developed by the industry itself provides valuable insight into targeted skills industry expects their Engineering Technology professionals to possess. The LIMS accomplishes this assignment by incorporating its complete rules engine, over 50 Input/Output Interfaces, as well as analytics and statistics engines for the turn-key subsystem and system applications, that can be implemented in a small or medium manufacturing environment that may not include in-house edge-computing experienced IT support personnel. The LIMS platform also provides tested control examples and system applications that promote quick adoption and adaptation for real-world industry implementations.

The Florida Advanced Technological Education Center of Excellence (FLATE) with support from America Works, (an initiative of the National Institute of Standards and Technology (NIST), the NIST Manufacturing Extension Partnership (MEP) national network, FloridaMakes, (the NIST MEP Center in Florida), and the National Science Foundation (NSF-ATE), has launched a demonstrate project that features the LIMS’s appliance as a learning tool and demonstration device for edge computing.

Introduction

The continuous and rapid development of an Industry 4.0 (I4.0) technology-based workforce environment spotlights an Engineering Technology (ET) professional situation with an important scenario question as presented in Figure 1. Although this illustration emphasizes the edge access common to this new I4.0 landscape, most of that connection is not apparent when the technician is observed in this working environment.

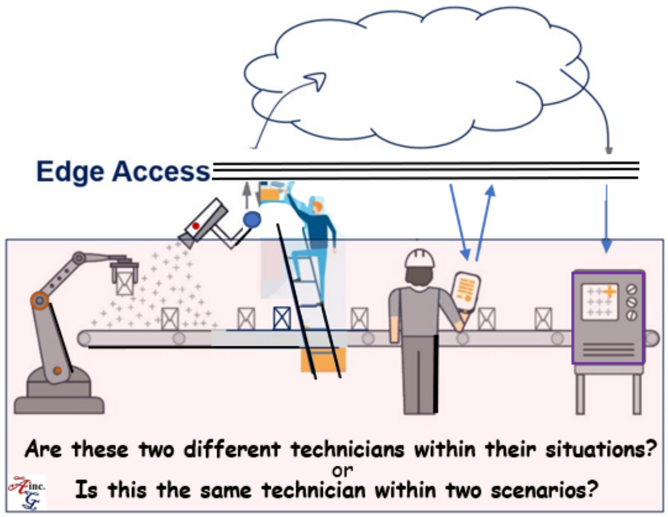

Figure 1: ET Technician in I4.0 Technology driven work environment.

The reason for this transparency is the insertion of multiple Input/output ports always included in I4.0 technology equipment. With this attribute information from equipment sensors is efficiency transferred to an edge computer and equipment operation instructions are effectively returned to the equipment final control elements.

The complete Learning Integrated Manufacturing System (LIMS), Figure 2, with over 50 Input/Output Interfaces, is an example and open access to its complete rules engine, as well as analytics and statistics engines for turn-key subsystem and system applications makes this industry focused interface an excellent tool for “hands-on” Informed Engineering Design learning approach in ET 2-year degree programs.

Figure 2: The Learning Integrated Manufacturing System (not connected).

Integrated Manufacturing System Applications in Florida’s A.S. ET Degree program

The Engineering Technology 2-year degree for technician preparation in Florida’s manufacturing environment was designed as well as implemented with resources provided by the NSF-ATE program to the Florida Advanced Technological Education Center (FLATE) and is now maintained statewide in 20 colleges by the Florida Department of Education. With equipment, faculty professional development, and project support funding provided by NIST-MEP, LIMS learning environments were developed at four State Colleges in Florida. Two of those projects, an urban and rural example, are reviewed below with the urban community college presented first.

Palm Beach State College

The PBSC project coupled the LIMS with a 3D printer (the Creality CR-10) to measure environmental temperature, bed temperature and humidity, and showcase the capabilities of an integrated process system. This student organized, executed, and completed project also featured a demonstration video and a report that included the

Figure 3: Connected System (from left to right- polymer, printer, display).

project’s design, challenges/issues, and recommendations. The design criteria included: LIMS to printer input and output connections, acquisition of data from the Creality CR-10, implementation of a predetermined Design of Experiments to print coupons at pre-determined environmental/ambient temperature, bed temperature, and humidity.

The environmental/ambient temperature is to be maintained constant through the experiment. The bed temperature and humidity are process variables that include process high and low limit values. The primary LIMS conducted product quality related action involves the measurement of the 3D printed coupons for tensile strengths using a G.U.N.T. machine.

The project generated a set of challenges that were triggered by the student traveling through their learning path and fundamental restrictions associated with the project’s 3D printer. From the student perspective, their lack of IT experience generated delays in the project's timeline. However, the LIMS support team provided valuable IT assistance when they were made aware of the issues. Student unfamiliarity with machine learning and reporting triggered additional issues. The ability to set data points within the system was challenging and possessed a steep learning curve. The equipment also contributed its share of constraints. These pre-project existing challenges were driven by Creality CR-10's restricted access to proprietary information that legally restricted connection/integration with the 3D printer's operational technology. However, again with the aid of the LIMS team, the student did obtain non-ideal legal access to and control of the printer to execute and complete this project's production target.

The students provided two Recommendations and/or Next Steps to facilitate the next team of student's interaction with this integrated learning environment. The first was the creation of a "shortcut" manual that include the important components of Information Technology and Operation Technology for this system. The manual would also include the basic 6-sigma standard environment working rules. Second, since collection and analysis of data is a challenge, the process of learning the Design of Experiment Methodology should take place before student involvement in the project. This will provide a heads-up help with getting their LIMS application project organized.

Polk State College

The PSC project coupled the LIMS with an energy harvesting system that included solar panels, batteries, inverter, and a sensor suite. The project showcases the capabilities of an integrated process system and was also student organized, executed, and completed with a demonstration video and final report. The system was tested with several loads: a conveyor belt; an electronic soldering station; and a water (vapor

Figure 4: Connected System (from top down- circuit box, LIMS box, batter pack).

condensation) generation system. The LIMS employed: voltage and current sensors to monitor the power consumption of low power resistive-load devices; temperature, humidity and ultrasonic proximity sensors to measure the amount of water produced over time at different temperatures and humidity levels.

The project's design criteria included implementation and testing in 3 phases: power generation and load testing; sensor installation and testing; and integration of LIMS system. The power generation was accomplished by connecting 7 solar panels in series to produce a total of 84 Volts DC that was fed to the inverter's input. The inverter was configured to operate off-grid and produce a 120 Volts AC output connected to the AC disconnect box, as well as a 50 Volt DC output that charged the battery bank. The disconnect box fed the power distribution box which fed the load and 24-volt sources that powered the LIMS box and all the sensors. Although the connection of the sensors to the LIMS box is straightforward, care must be taken to ensure that the sensors were wired correctly using the appropriate load resistor.

Once the sensors were connected, the LIMS "engine" was configured and data was successfully collected reflecting the use of voltage, current and temperature from the load. (a soldering station). The information from the load reflected the power being consumed and the operating temperature of the soldering station. The system was also connected to a conveyor belt mobile station that will be used to train students on the monitoring of dynamic systems that require sensing operations to control the short transport of physical loads over a limited spatial dimension using inductive, capacitive and ultrasonic sensors. Lastly, the system was configured to collect water production data from an atmospheric water generator.

This project also generated a set of challenges that were triggered by the students traveling through their learning path and fundamental restrictions associated with the sensors. The main student issues were related to the LIMS's WIFI and router connections. The CAT5 cable connections made it challenging to correctly configure the sensors according to their design specifications. As with the PBSC, the equipment generated project limitations. The lack of information on the temperature/humidity sensors prevented the LIMS configuration to collect consistent data that reflected a continuous reading of temperature and humidity when the system was used to monitor the water generation system.

The students provided Recommendations and/or Next Steps to facilitate the next team's interaction with this integrated learning environment. When a router is used as the LIMS box to computer interface, disconnect the router from the Internet before attempting to establish router communication with the LIMS. Once the connection is established, different connection topologies could be attempted. The sensor configurations should be tested with an isolated circuit using current loop and load resistor theory to make sure that voltage driven (typically 0-10 volts DC) and current sensors (typically 4-20 mA) are correctly configured before attempting connection to the LIMS system.

Conclusions

This NIST Manufacturing Extension Partnership (MEP) National Network supported project generated student projects that emphasized the important role that the Industrial

Internet of Things (IIOT) will have on technicians. Five colleges participated in the project with each creating their own LIMS edge access platform. The two examples explored in this paper reflect the level of complexity common to the individual (3 D printing; energy harvesting; part stamping; controlling process fluid pH; and monitoring tool condition) systems created. The colleges represented in this project ranged in enrollment and COVID enforced constraints, however, review of college final project reports indicated several common points. First, since all the systems were totally in the student's domain, course scheduling was not a factor. Second, access to the "parts and pieces" needed for the projects was not impacted by COVID delays or unavailability. Third, the challenges for each team generated during system creation fell into the same two categories. One common challenge was the specific Information Technology components required to meet all Operation Technologies of the project systems. The second challenge was the shortage or lack of information about the sensors and final control elements to be used in the LIMS interface. Finally, keeping in mind that all of the students in the participating colleges are enrolled in the same ET two year program with its own local employer emphasis, there was no indication of any distinction among the larger/smaller or urban/rural student performance. The obstacles encountered in these projects were primarily equipment driven and, although different equipment combinations for each project, common to all the colleges.