Robotics Retrofit: Renovating Outdated Robotics Platforms to Meet Current Curriculum Requirements Driven by Industry Demand

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Abstract

Many engineering technology programs are implementing robotics and automation platforms into their undergraduate curriculum. Finding affordable solutions for these subjects can prove to be difficult; small-to-midsize institutions may not have the funding available to outfit a laboratory with robotics systems that cost $20k or more per station. Following feedback from our industry advisory board (IAB) members, as well as industry partners, a need was determined to find a way to incorporate these topics into the curriculum with our already limited resources. Faculty members presented a solution by retrofitting several outdated robots, currently in our possession, with newer technologies. These 30+ year-old robots had been slated for disposal due to age, but after some exploration, it was determined that they could be salvaged and updated. The project entailed reverse engineering motor driver circuits, developing new hardware control systems, and programming the user interface. The result is a complete set of robots that operate via National Instruments hardware (USB DAQmx) and the associated software (LabVIEW) eliminating the need for the original teaching pendants and cassette tapes from the 1980s. These systems can now be utilized in current robotics and automation curriculum throughout the engineering technology programs to meet industry demand.

Introduction

Central Washington University offers three types of engineering technology undergraduate degrees: Electrical Engineering Technology (EET), Industrial Engineering Technology (IET), and Mechanical Engineering Technology (MET). These specialized programs provide students with a combination of engineering theory and application based instruction to prepare graduates for careers in industry. Each of the programs also utilize an Industry Advisory Board (IAB) comprised of industry experts to assist in curriculum steering and program development. Several faculty members within the programs, along with assistance from IAB members recognized an educational gap between the students entering undergraduate degrees interested in robotics (based off of their robotics experiences in high school), and the demand from industry looking for graduates with knowledge in automation and industrial distribution. Conversations between the EET program faculty and the IAB, lead to planning of a Robotics and Automation minor where students interested in robotics can learn the hands-on skills and practical knowledge for successful careers in automation. The minor was designed to fit in conjunction with any of the engineering technology majors offered at CWU.

As development began for the Robotics and Automation minor, the program faculty focused on how to implement hands-on topics into the curriculum. There has been a multitude of research showing the benefits of hands-on learning [1] [2] [3] and its ability to provide a bridge from abstract topics to real-world application, with many engineering and technology programs implementing these methods [4] [5]. Each engineering technology program at CWU recognizes the benefits of these methods, and thus utilizes them throughout their respective curriculum. The topics of robotics and mechatronics along with their applications in automation and industrial distribution provide a multitude of options for hands-on learning. Program faculty quickly realized that the central problem with developing curriculum incorporating this type of teaching approach would be funding of equipment and resources.

This paper outlines the experiences of the CWU engineering technology programs' process of finding a hands-on robotics platform to match the needs of both students and industry.

Scope of the Problem

Presenting students with an industry-applicable and budget-friendly platform for the robotics and automation curriculum became a surprisingly difficult challenge to overcome. It seems that most readily-available robotics platforms fall into what the EET faculty determined as two categories: robotics toys, and industrial robotics. Examples of the former category would be LEGO Mindstorms and VEX robotics, which are fabulous platforms, but do not necessarily fit into industrial robotics curriculum. The latter category includes Universal Robots, Fanuc Robots, and Mitsubishi Robots, which are fantastic solutions for industrial robotics, but can also be quite expensive and out of reach of most budgets. Essentially, lite industrial robotics for education seemed to be a small market with no evident solutions to the problem.

Another limiting aspect regarding the implementation of modern industrial robots into education is the inability to access internal components. These "black-box" robots are purposefully designed for automation facilities where exposure of internal components would be limiting within some factory conditions and possibly hazardous. In an educational setting however, having the ability to see and analyze the motors, gears, linkages, and electrical components, under safety-guided rigor can be a handy pedagogical tool.

It should be clarified here that this search to find a robotics platform was not intended to encompass the entire robotics and automation curriculum, but rather to bridge the two aforementioned categories. LEGO Mindstorms and VEX platforms have been implemented into introductory robotics courses. In addition, a single Mitsubishi industrial robot expands the curriculum's industrial side, however it was still determined there was a need to have a platform that could fit nicely in between these existing systems.

As the program faculty began to receive quotes for industrial robot systems, it was also decided to explore options of obtaining older robot platforms that could be retrofitted to newer technologies. Through this exploration, it was found that the computer science department at CWU had some old robots from the 1980s that turned out to be good candidates for retrofit. The authors do recognize that not all educational programs will have immediate access to older robotics platforms, but with some research into avenues of obtaining outdated robots, a relatively cost-effective solution may be found.

Once the outdated robots were acquired, the next major challenge became the technical difficulties associated with retrofitting the systems. Again, with some research and creative problem solving, these robots were able to be retrofitted from parallel port communication, via teaching pendants, to USB communication. In addition, utilizing the LabVIEW environment to program the system allows for the possibility of a customized and/or modular user interface.

Robotics Retrofit Process

The ATLAS robotics platform acquired by the EET program was developed and produced by L.J. Electronics in the early 1980s. Figure 1 shows a promotional picture for the ATLAS robot controlled by an EMMA microcomputer, also sold by L.J. electronics. The original hardware was built into an aluminum frame with unipolar stepper motors for the movement, and a current-chopper stepper driver for pulse delivery. The original controller/CPU for the system was a Rockwell 6502 8-bit processor, paired with a 6522 Versatile Interface Adapter, which was used for the parallel interface port on the front panel of the base, as well as reading the end stops and controlling the motor driver circuits.

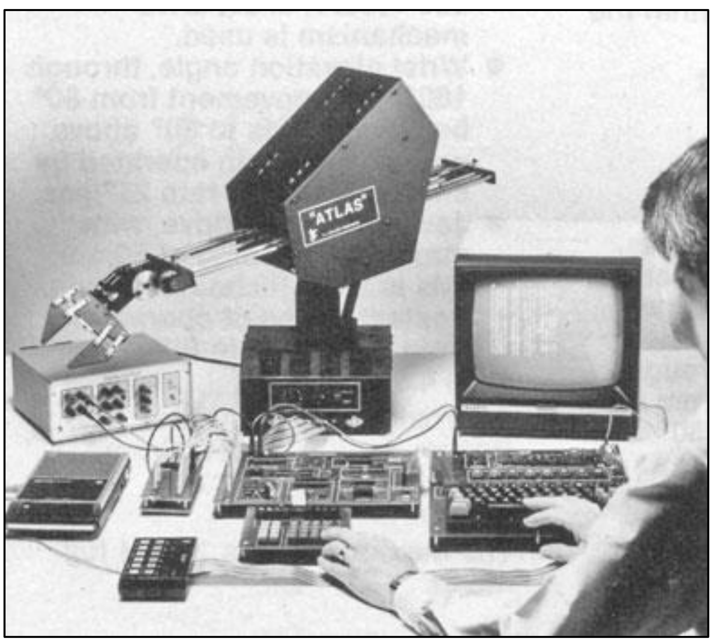

Figure 1: L.J. Electronics ATLAS Robot controlled via an EMMA Microcomputer [6]

After examining a disassembled ATLAS unit and consulting the *ATLAS-II Robotic System Technical Manual* [7], the primary functions of the controller were able to be redesigned to drive the motors via a National Instruments (NI) cDAQ-9174 with a NI 9403 digital I/O module, programmed with LabVIEW. Later on in the project planning process, the decision was made to move to a more cost effective solution, and away from the cDAQ series of chassis and modules. With cost constraints in mind, the faculty settled on a USB-6001 DAQ [8] from NI, which encompassed the needs specified in the re-design with 13 digital I/O ports, 8 analog inputs, and 2 analog outputs. An additional reason for selecting the 6001 is that LabVIEW 2017 was performing inconsistently with digital waveform output, so the analog outputs were needed for the robot to perform consistently.

The new control system for the ATLAS consists of the NI USB DAQ, and a custom demultiplexer board. A demultiplexer circuit using 7400 series digital logic ICs' is needed to drive the six motors on the system. This circuit uses a 74138 demultiplexer [9] to enable specific 7408 AND gate [10] groupings, which allow them to pass the step signal through to the motors. The 7400 series ICs were chosen because of their low propagation delay, and active-high functionality, reducing the number of ICs needed for the board. Figure 2 shows the circuit schematic for the demultiplexer board. The first unit was wired by hand using standard prototyping equipment. The remaining circuits were made via the EET program's printed circuit board (PCB) manufacturing system.

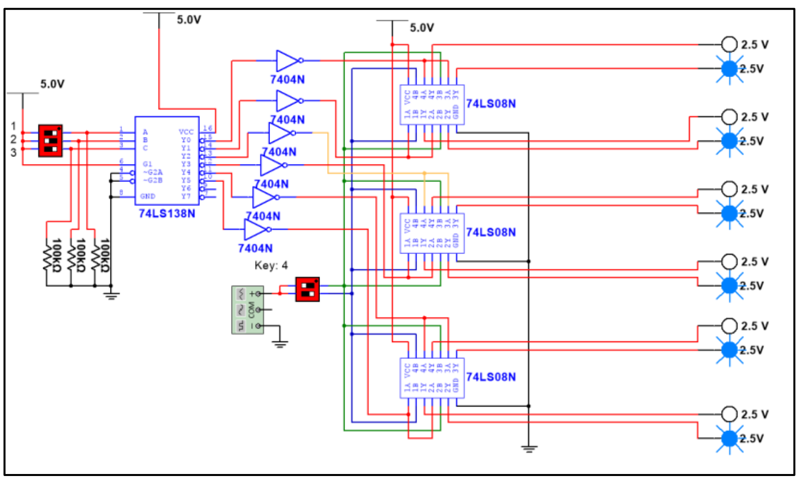

Figure 2: Custom Demultiplexer Schematic for ATLAS Control System

As mentioned earlier, LabVIEW is the primary programming environment, and one of the factors in the hardware selection process. Using LabVIEW, a set of virtual instruments (VIs) were developed to control key parts of the system. One VI drives the motors a designated number of steps. Another allows for user input, converting it to the proper number of steps used by the aforementioned VI. Motor axis control selection and actuated end stops are controlled by another set of VIs. These modules are then incorporated into a more complex routine that makes up the full program. Figure 3 shows an example of a LabVIEW VI user interface where certain aspects of the ATLAS system can be controlled and monitored. Figure 4 shows the LabVIEW programming code that runs in the background of the user interface.

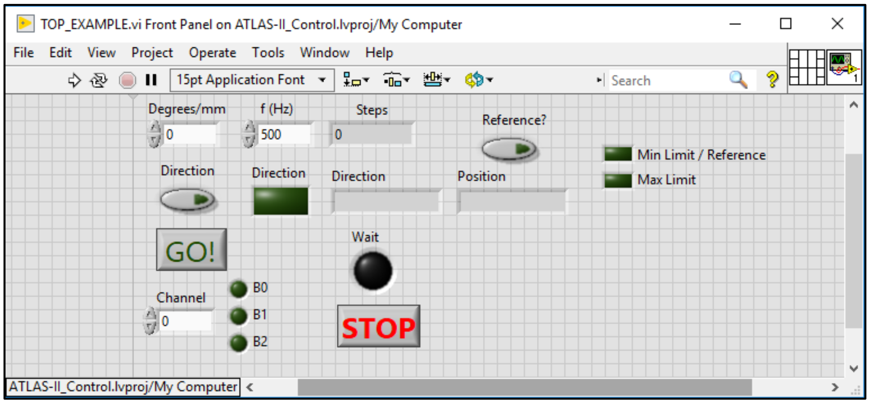

Figure 3: ATLAS basic control functions LabVIEW front panel

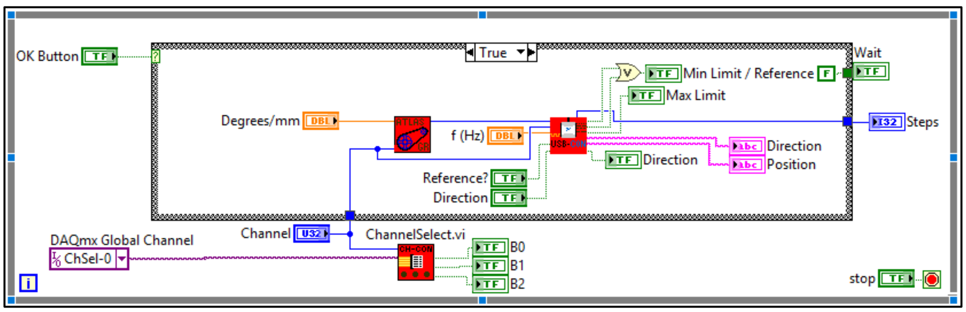

Figure 4: ATLAS basic control functions LabVIEW block diagram

The LabVIEW modules were intentionally made as a primitive, low-level implementation. The goal with the Atlas Project is not to have everything neatly packaged to the same extent as LEGO Mindstorms, or the VEX systems. This system provides the students with a hands-on and approachable robotic platform that can be taught, understood, and modified.

Conclusion and Future Work

The retrofitting process is completed and curriculum is in beginning stages of being implemented in the classroom. Figure 5 shows a completed robot, displaying the custom controller board and NI USB DAQ module. Figure 6 shows an original ATLAS robot next to one of the retrofitted robots. The plan moving forward is to leave the access panels on the robots open for students to be able to inspect and analyze the internal components of the system. Standard operating procedures and proper safety protocols are implemented at all times to ensure student safety. The ability to utilize these robots in engineering curriculum and removing the “black box” aspect of lite industrial robotics provides a wealth of educational opportunities for students. Program faculty can now include hands-on lessons on robot hardware including mechanical linkages, motors, controllers and sensors. LabVIEW software is now solidified as a consistent programming language throughout multiple hardware platforms in the programs, along with other text-based languages. Students learn graphical programming (LabVIEW and Mindstorms) and correlations to these text-based languages within the robotics and automation curriculum.

Figure 5: Retrofitted ATLAS Robot

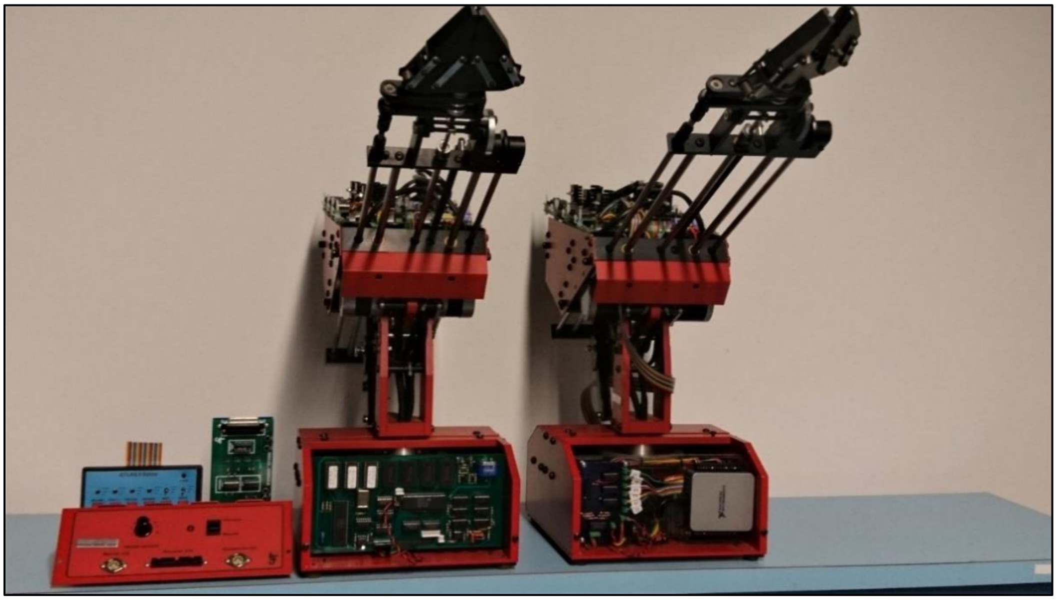

Figure 6: Original Robot (left) and Retrofitted Robot (right)

Further analysis of educational value will be completed as this project moves forward. Currently the outline of topics for the robotics and automation curriculum includes several hands-on assignments with LEGO Mindstorms and VEX robots, then the introduction of these ATLAS robots for several assignments, followed by hands-on assignments with an automation system and the Mitsubishi industrial robot. Program faculty believe that these ATLAS robots can provide a unique solution to the problems determined by the IAB. The entire project was completed at a fraction of the cost of purchasing new industrial robots and creates a common backbone throughout the curriculum. By sharing this story, the authors' goal is to spur interest for other institutions that may find value in retrofitting outdated robots to newer technologies as part of their robotics/mechatronics curriculum.

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