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A Novel Architecture for Electromechanical Trainers Allowing Selectable Control by Either Microcontroller or PLC

Dr. Aidan F. Browne, University of North Carolina, Charlotte

Dr. Browne is an Assistant Professor in The William States Lee College of Engineering at The University of North Carolina at Charlotte. His current research areas are mechatronics, mission critical operations, instrumentation and controls. His core courses are an undergraduate three-semester embedded controller practicum and a graduate mechatronics course. He mentors a Senior Design team that competes in the NASA Robotic Mining Competition. He has worked for United Technologies (Hamilton Sundstrand) and General Dynamics on numerous projects including International Space Station Life Support, Joint Strike Fighter Propulsion Control Systems and U.S. Army Biodefense. He received his B.S. from Vanderbilt University and his M.S. and Ph.D. in Biomedical Engineering from the University of Connecticut. Dr. Browne serves as the Chair of the Engineering Technology Division of the Southeastern Section of ASEE; he also does extensive volunteer work for the FIRST Foundation (For Inspiration and Recognition of Science and Technology).

Mr. David George Vutetakis Jr, University of North Carolina, Charlotte

Mr. Vutetakis is a graduate student at The University of North Carolina at Charlotte. He is currently pursuing a Master of Science degree in the Applied Energy and Electromechanical Systems program. He received his B.S. in Electrical Engineering Technology from UNC Charlotte. His areas of interest are robotics and electromechanical systems. He is also a graduate research assistant at The University of North Carolina at Charlotte in areas such as mission critical operations and mechatronics.

A Novel Architecture for Electromechanical Trainers Allowing Selectable Control by Either Microcontroller or PLC

Abstract

Embedded microcontroller systems and programmable logic controllers (PLCs) are used extensively in industry and thus are a cornerstone in engineering education. In engineering departments, the target training hardware interfacing to these two types of devices is often duplicated in two different labs. This repetition of plant hardware can become expensive and space consuming with separate setups required for each controller. This paper discusses a novel instrumentation and control system training platform based around the use of both an embedded controller and a PLC wired to the same electromechanical plant. A supervisory controller electronically enables one of the two controllers to interface to peripheral devices and sensors. This allows an instructor to set up a trainer to be used in either a PLC class or an embedded systems class with the flick of a virtual switch. The setup could be used to control virtually any electromechanical system in an educational environment such as a small scale elevator simulator or a Cartesian robot for pick and place operation. Since the PLC and microcontroller are user operated using different programming languages, the setup provides a level of versatility through the capability to interact with two separate technologies on one independent system with no physical configuration changes necessary. This leads to lower costs by limiting the amount of hardware required while also saving space and allowing the potential for a greater diversity of training setups to be utilized in a smaller area.

Introduction

In order to effectively teach instrumentation, mechatronic and robotic courses in an Engineering or Engineering Technology curriculum, a variety of electromechanical laboratory setups are desirable. [1] Exposing students to an assortment of technologies is also desirable, to give them as broad an experience as is reasonable. Thus, setups containing different sensors, effectors and actuators and indicators are needed. Quite often, the cost of such laboratory setups (or trainers) is high, thereby challenging the desire to have numerous full setups.

To broaden the students' programming capabilities, many programs teach such courses across both microcontroller and Programmable Logic Controller (PLC) platforms. These costs can double when similar trainer equipment is desired to be used in both a microcontroller lab and a PLC lab.

During an exercise trying to decide how to best split funds between a PLC Laboratory and a Microcontroller Laboratory, it became quite frustrating trying to satisfy the needs of both without dumbing down the experience for either. Out of that exercise came the idea of sharing the actual electromechanical trainers between both labs, and rewiring them between uses. Although that approach would allow more equipment up front, there were concerns about the ongoing labor of continually rewiring the setups. The original equipment-sharing idea was further developed into a concept of wiring both a PLC and a microcontroller into an electromechanical setup in such a way that they could be switched

Background

Embedded controllers enable users to program open and closed loop control. This is extremely useful in the implementation of any type of electromechanical hardware that relies on user defined control schemes that may be subject to modification. Two popular methods of control systems in industry and consumer products are PLCs and microcontrollers.

PLCs are mainly used for high level sequence and process control. PLCs are generally programmed using ladder logic, which is a standardized programming methodology that involves the use of graphical representations of I/O along a bus. [2] Embedded microcontrollers are devices that require a higher level of programming expertise; users must have sufficient knowledge of various programming languages such as C programming, HDL or LabVIEW. They generally have more power to perform calculations and advanced controls.
Both of these types of hardware devices have extensive applications in industry and technology and are continuously improved to meet the increasing application demands. [3, 4] In order to produce individuals with the skills needed to make use of these products, it is highly effective to have them practice using actual hardware. The hands on approach facilitates a better understanding of their capabilities.

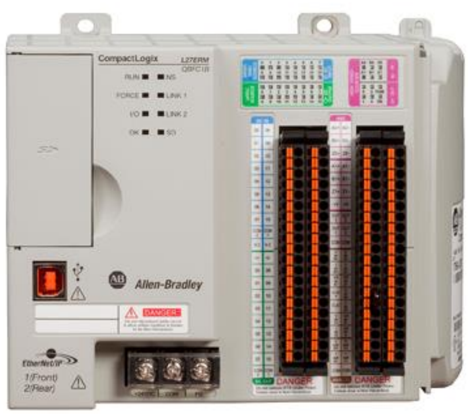

Figure 1-- Allen Bradley Compactlogix [5]

Figure 2-- National Instruments myRIO [6]

Since the two types of devices have different interfaces and compatibility, they are normally taught individually through different classes and on separate training setups. This paper presents the integration of PLC and embedded controller technology within a single laboratory setup. The integration of the two devices was done in a manner that is transparent to the user. The PLC used to implement the dual control, an Allen Bradley Compactlogix L24ER, is pictured in Figure 1; the microcontroller, a National Instruments myRIO 1900, is shown in Figure 2.

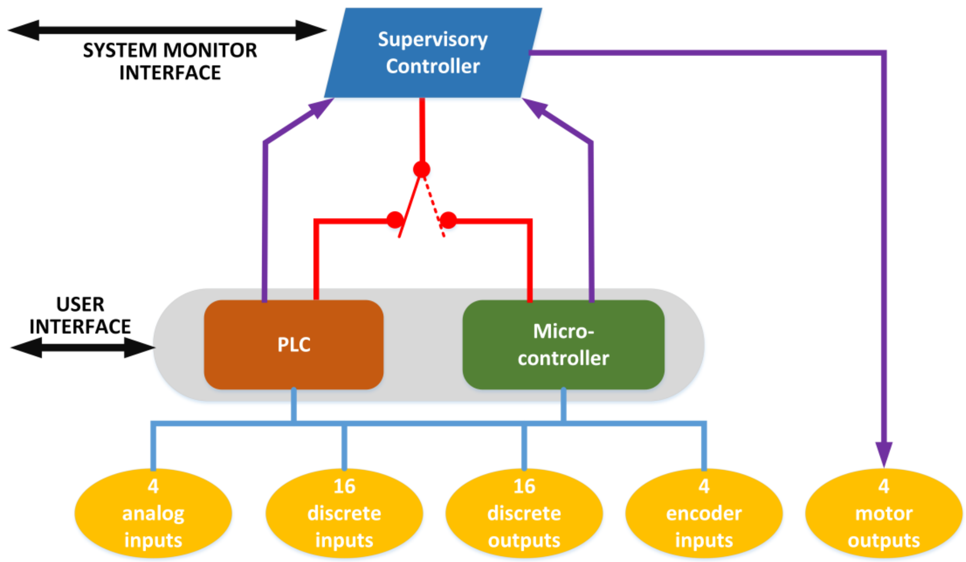

Figure 3-- Switching Architecture for PLC or Micro-controller control

Implementation

Combining the two types of controllers requires compatibility not only between controllers, but also to peripheral devices. A number of challenges were faced interfacing both the 24V-based PLC and the 3.3V-based myRIO in such a way that the interfaces would present themselves as standard to whatever analog and discrete inputs and outputs might exist in an electromechanical trainer. Each of these interface issues were solved; the details of that work are presented elsewhere. [7] Each input or output signal was wired directly to both of the controllers. The controllers were configured so that only one can be operational at a given time. Buffers were used for protection of both the peripheral devices as well as the controllers. At a high level, effectively the PLC/microcontroller pair interface externally with whatever electromechanical setup is desired, as long as it is supported by the complement of 4 analog inputs, 16 discrete inputs, 16 discrete outputs, 4 encoder inputs, and 4 motor outputs.

Figure 3 shows an equivalent block diagram of the switching architecture used to implement the combined control setup. In order to allow for external control of the setup, as well as maintaining a level of safety, a supervisory controller was used. A superuser, such as an instructor, can connect to the supervisory controller to set the mode of the control to use either the PLC or the microcontroller. The switch in the diagram represents the power switching and all the other accommodations that are necessary to switch from PLC to microcontroller mode and vice versa. Because the external interface to the supervisory controller is a command interface implemented over Ethernet, this switching can actually be automated by an external computer that is aware of which type of user would be about to connect the setup.

The second major function of the supervisory controller is to act as a safety buffer between the user programmable controllers and the motorized outputs of the attached trainer. The user is told that the pulse width modulated outputs of the PLC and microcontroller are directly wired to the motor control. In actuality, they are wired to the supervisory control, which is in turn wired to the motor controllers. This allows the supervisory control to take action to suppress the motor commands in a particular direction that may cause damage to the setup. The safety sensors wire directly to the supervisory control inputs. It is configured to allow transparency to users; from their perspective, there seems to be direct control.

An example would be a limit switch positioned at the end of travel for a device under control of a user that rides on a rail. Limit switches could be positioned at each end of the rail and fed to the supervisory controller. When a particular limit switch is tripped, the supervisory control would suppress any commands that would cause the motor to cause further travel in that direction, while freely allowing motion in the opposite direction.

Example setup

In one experimental setup example, a small 3-axis Cartesian robot platform was connected to the combined controller setup. The Cartesian robot was built to act as a pick and place machine

Table 1—Example inputs and outputs

Inputs	Outputs
• 9 Encoder channels (A,B,I per axis)	• 3 Motor control (1 per axis)
• 6 Limit switches (2 per axis)	• 3 Direction signals (1 per axis)
• 2 End effector sensors (open/closed)	• 2 End effector signals (open/closed)

using a pneumatic gripper. The hardware is shown wired together in Figure 4; the XYZ stages are shown in Figure 5. The system will drive and read the stepper motors and encoders, actuate the gripper via a pneumatic solenoid valve and read the feedback sensors as listed in Table 1.

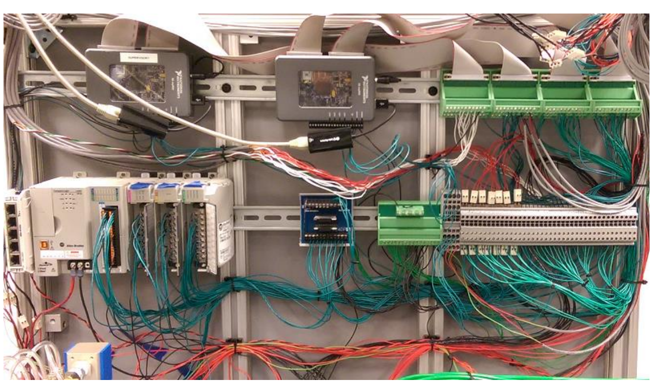

Figure 4—Wiring of implemented solution

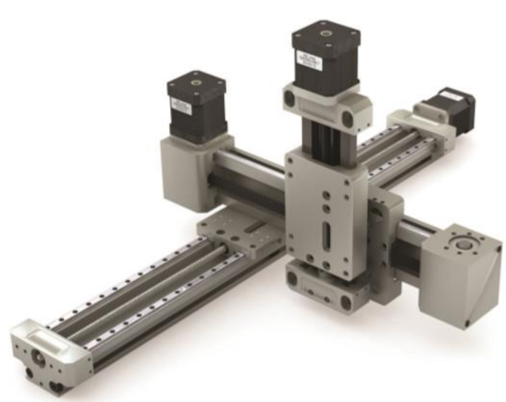

Figure 5—XYZ Stage [8]

Remote access

As the platform was developed, it became clear that the architecture and the network interface easily could be adapted to remote access and use of the trainer; Figure 6 shows the scheme for using the trainers remotely. Two Ethernet cameras were added to the setup, one showing a front view of the electromechanical trainer and one showing a rear view. A reservation interface is being developed that will allow a student to log into a central system, reserve time on a particular trainer, and indicate which experiment they wish to perform. An instructor will have indicated in advance which mode the system needs to be in when the student connects for that particular experiment. Before giving the student access to the trainer, the System Controller will send the appropriate commands to that trainers supervisory controller, which will set the appropriate parameters and return an acknowledgement. The student will then be able to connect directly to the PLC or microcontroller to complete their experiment(s). They will be able to program and control the setup, and test their progress while observing the response on one or both camera feeds.

The remote usability of the setup adds an initially unpredicted benefit: the trainers can be used around the clock, seven days a week. This allows much higher throughput of students by optimizing what is normally down-time for equipment. A second benefit is that two or more different courses that wish to use the particular trainer for experiments during a given week can all do so, without having to make any adjustments to the setup.

Having the ability to remotely access the equipment changes the nature of interaction by students. Traditionally, labs are taught in a dedicated time slot when the entire class must be present to access the equipment, and has only a small time slot usually once or twice a week for a few hours. For this reason, enough equipment must be provided to ensure all students get hands on experience. This requirement is alleviated by providing remote access to the equipment so that students can directly practice with it at any time and from any location with internet access.

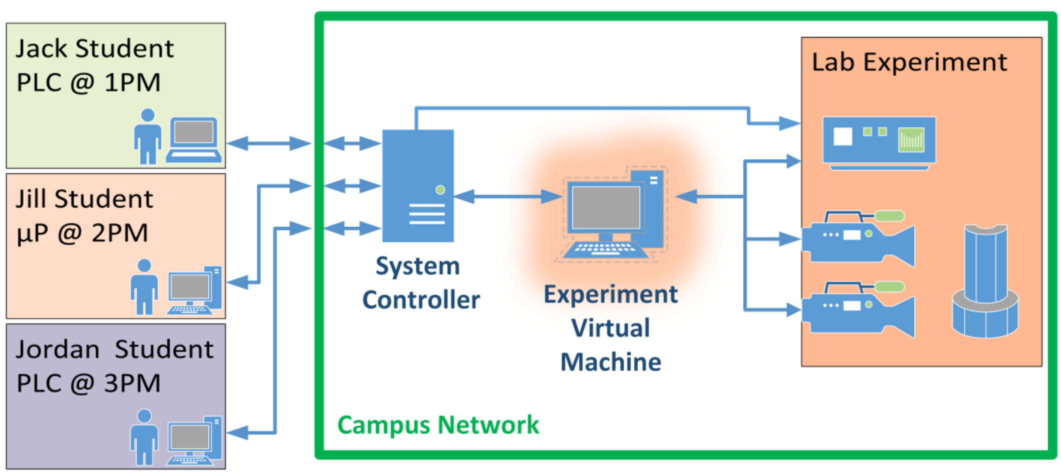

Figure 6—Remote access scheme for PLC/microcontroller setups

Educational benefits

The use of multiple control devices in one single setup also adds value from an educational point of view. When separate trainers are used for teaching microcontrollers or PLCs, the trainers themselves are often different . In such a case, students are learning to do different tasks with different equipment. However, by combining the trainers and controllers to perform the same tasks, this puts emphasis on the differences between technologies by solving the same problems on different equipment. This also adds familiarity to equipment that can translate into real world practical uses.

Conclusions

The cost of training systems often carries a high price tag when purchased as an off-the-shelf product. This cost is reflected not necessarily by the raw value of the parts, but by the integration of the plant and the controllers along with any necessary specialized software. This effect is compounded when multiple training setups are needed for differing courses. The duality of combined equipment saves money on both of these fronts, offering modular setup that can adapted for different purposes.

A novel method of integrating two different types of embedded controllers was proposed. The innovative combination allows just one electromechanical plant to be used for multiple training applications that are typically performed separately. The setups also allow trainers to interface to the controllers through a remote connection, increasing training capacity and flexibility. Use of a supervisory controller increases safety and resetability, allowing stand-alone operation that needs minimal or no physical human interaction. The reduced hardware requirements translate to lowered costs and less space. Further educational benefits can be seen by highlighting differences between different technologies used to perform similar tasks.

Future Work

As mentioned above, we are continuing to develop electromechanical trainers to be used with the dual control setup. We have also secured funding to implement the network infrastructure, System Controller, and software to create the reservation system. We are also working on the documentation that will allow us to release the design under Creative Commons Licence.

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